FOOD TECHNOLOGY-I

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Lesson 1

INTRODUCTION TO FOOD PROCESSING IN INDIA

1.1 Introduction

India has emerged a leading producer of certain food products such as buffalo meat, black tea, milk, and fruit and vegetables. The country is in possession of premium food products such as Basmati rice, Darjeeling tea and Alphonso managoes to offer to the world.

1.2 Factors Influencing the Consumers to seek Processed Foods

Some of the factors which have led to the growth of processed foods in India are:

a) Emerging urban and rural middle class population with requisite purchasing power.
b) Socio-cultural changes, strongly influenced by the communication media.
c) Changing demographic pattern.
d) Increase in working women population.
e) Consumer competitiveness with alternate and substitute products, and
f) Entry of modern and self-service market outlets.

1.3 Constraints in Food Processing Sector

Despite being one of the largest producers of food items, only 2.0% of the total produce is processed as against an average of 40.0% in many developing and 70.0% in most developed countries. Moreover, because of the bottlenecks present in the supply chain, about 30.0% of the harvested produce is spoilt during distribution to the consumers.

The factors that have impeded the growth are summarized below:

a) Non-availability of the right quality of processable raw materials.
b) Seasonal excesses and scarcities of raw material causing wide fluctuations in the prices.
c) High taxation.
d) Complicated administrative and legislative processes.
e) Streamlining of food laws.
f) Lack of interface between research institutions and the farmers and also between research institutions and the processors.
g) Indifference about the quality systems in the food processing sector.
h) Lack of awareness of intellectual property rights, and
i) Unpreparedness of the industry to meet the challenges posed by WTO agreement.

1.4 Status of Food Processing Industry in India

The food industry has a turnover of Rs. 2,50,000 crores and accounts for 26.0% of GDP and provides 61% of employment. The processing of fruits and vegetables is as low as 2.0%, ~ 35.0% in milk, 21.0% in meat and 6.0% in poultry products. By international comparison, these levels are very low i.e. the processing of agriculture produce is ~ 40.0% in China, 30.0% in Thailand, 70.0% in Brazil, 78.0% in Philippines and 80.0% in Malaysia. The value addition to food production is only 20.0% in India as against 23.0% in China, 40.0% in Phillippines and nearly 200% in UK. The annual wastage is estimated to be valued at ~ US $ 13 billion. A study by the Confederation of Indian Industries and Mc Kinsey and Co. has predicted that the consumption of items preferred by the lower and middle classes such as packaged attas, milk and bakery products and poultry items will grow by over 15.0% a year. The current status of food processing industry is depicted in Table 1.

Table 1.1 Status of food production in India

Food item	Year	Quantity produced per annum	Growth rate (%)	Ranking in world
Fruits	2009-10	63.50 million tonnes	10.0 %	3rd
Mango	2010-11	16.18 million tonnes		1st
Banana	2007-08	10.4 million tonnes		1st
Vegetables	2009-10	126.0 million tonnes	13.28%	2nd
Food grains	2010-11	235.0 million tonnes	6.2%	3rd
Rice	2010	94.5 million tonnes		2nd
Wheat	2010	84.0 million tonnes		2nd
Coarse cereals	2007-08	40.73 million tonnes		
Pulses	2009-10	14.59 million tonnes		
Oilseeds	2009-10	24.90 million tonnes		
Maize	2010	30.00 million tonnes		
Sugar cane	2010	340.00 million tonnes		
Bakery products	1999	30 lakh tonnes	8.0%	Biscuit – 2nd
Chocolate products	2000	22,000 tonnes	10-12%	
Milk	2011	120 million tonnes		1st
Black tea	2010	1.07 million tonnes	2.51%	1st
Breweries	1996	5.0 million hectolitres		
Spices	2000	2.7 million tonnes		1st
Cashew	2010	6.3 lakh tonnes		1st
Mushroom	2000	1.0 lakh tonnes		
Fish	2008-09	7.6 million tonnes		3rd
Eggs	2006-07	50.7 billion numbers		
Broilers	2005-06	450 million		
Chicken meat	2006-07	2.0 million metric tonnes		
Meat and meat products	2008-09	6.50 million tonnes	4.0%	

1.4.1 Fruit and vegetable processing

Mango, banana, citrus, guava and apple account for 75.0-80.0% of fruit production. The installed capacity of fruit and vegetable processing industry is about 2.1 million tonnes in 2006. The processing of fruit and vegetables is about 2.2% of total production in India. The fruit and vegetable processing industry has registered an average annual growth rate of 30.0% in 2008-09. India's share in the world production is about 10.0% in fruits and about 13.28% in vegetables. Some recent products introduced include vegetable curries in retortable pouches, canned mushroom and mushroom products, dried fruit and vegetables and fruit juice concentrates.

Contract farming in wheat is practiced in Madhya Pradesh by HLL and by Pepsi Foods Ltd. in Punjab for tomatoes, potatoes, food grains, spices and oilseeds are examples of contract farming in India that has promoted cultivation of processable variety of farm produce.

1.4.2 Plantation

Tea, coffee, cashew, cocoa, etc. are major plantation crops in the country. India's principal plantation crops accounted for about 5.0-6.0% of India's aggregate export earnings. India is the world's leading producer and exporter of cashew kernels and accounts for ~ 31.0% of the world production of raw cashew and nearly 48% of the world's export of cashew kernels in the year 2007-08.

1.4.3 Food grains

Grain processing is the biggest component in the food sector, sharing over 40.0% of the total value. There is predominance of primary processing sector, sharing 96.0% of the total value; with secondary and tertiary sector contributing about 4.0% of the total value addition.

In 1999-2000, there were 91,000 rice hullers, and 2,60,000 small flour mills engaged in primary milling. There were ~ 43,000 modernized rice mills/huller-cum-shellers. An estimated 820 large flour mills in the country converts ~ 10.5 million tonnes of wheat into wheat products. There are over 10,000 pulse mills, milling about 75.0% of pulse production of 14 million tonnes in the country.

Indian Basmati rice commands a premium in the international market. There is some headway in preparing value added foods viz., breakfast cereals and rice analogue from broken rice.

1.4.4 Spices

India is known as the 'Home of Spices'. India is the largest producer of spices accounting for 61.0% of the world production and 39.0% of world export. About 63 spices are grown in the country. Among the various spices cultivated in India, pepper the 'King of spices' earns the major export share.

1.4.5 Milk and dairy products

India has one of the highest livestock population in the world, accounting for 50.0% of the buffaloes and 20.0% of the world's cattle population. The cooperative movement has played a significant role in improving the milk production through 'Technology Mission' and 'Operation Flood' programmes. Consumption of liquid milk accounts for ~ 46.0% of the total milk produced; remaining 54.0% is utilized for conversion to milk products. Of this, the share of the organized sector is about 10.0%.

Dairy products are worth US $ 10.5 billion, and the segment is growing at 6.5% during 2007. Milk is the most lucrative product, with annual production of about 108 million tonnes in 2009. The per capita milk consumption in 2005-06 was 229 g /day. The organized sector produces ghee, butter, cheese, ice cream, milk powder, malted milk food, condensed milk, infant foods, etc. Today, the industry has also introduced a number of new products such as sodium-caseinate, lactose, dairy whiteners, cheeses such as Mozzarella, Swiss, Gouda, etc. Other products include Table Margarine, Low-fat spread, long-life milk, etc. The cheese slices segment has grown sharply in recent years. The cheese market is expected to sustain a 15.0% annual rate of growth in the next few years. Some new entrants in the Indian market include Kook Koko Chocolate milk, Prolife Probiotic Wellness Ice cream, Sugar-free Probiotic Diabetic Delight, etc. launched by Amul.

The ice cream market is estimated to be worth Rs. 500 crores. Competing in the ice cream market at present are an estimated 150 players in the organized sector (60.0% market share) and over 2000 units in the non-organized sector (40.0% share). The ice cream segment is growing at the rate of about 10.0% annually.

Indian probiotic dairy market stands at US $ 25.2 million. The exports of dairy products have been growing at the rate of 25.0% per annum in quantity terms and 28.0% in value terms since 2001.

1.4.6 Meat and poultry

The processing level of buffalo meat is estimated at about 21.0%. Only about 1.0% of total meat is converted into value-added products like sausages, ham, bacon, kababs, meat balls, etc. The processing of meat is licenced under Meat Food Products Order, 1973. The slaughter rate for cattle as a whole is 20.0%, for buffalo it is 41.0%, pigs 99.0%, sheep 30.0% and goats 40.0%. The country has 3600 slaughter houses, 9 modern abattoirs and 171 meta processing units. The growth rate of meat is estimated to be about 10.0%.

India ranked fifth in world egg production in 2009 and produced 30,000 million every year. Egg production has shown an average annual growth rate of 16.0% while that of broilers is at the rate of 27.0% per annum. There are eight modern integrated poultry processing plants functioning in the country. Such egg products plants are producing whole egg yolk and /or albumen powders.

1.4.7 Marine products

The fish production in 2005-06 was 3.01 and 3.50 million tonnes for marine and Inland fishes, totaling 6.50 million tonnes per annum. Processing of marine products into canned and frozen forms is carried out for export market. There are 372 freezing units and 504 frozen storage facilities. Besides this, there are 11 surimi units, 473 pre-processing centres and 236 other storages. Export products include conventional block frozen products, IQF products, minced fish products such as fish sausage, cakes, cutlets, pastes, surimi, texturized products, dry fish, etc.

Domestic per capita consumption of fish is only 5 kg/annum vis-à-vis a world average of 12 kg/annum. Sixty per cent of the production of fish in India is from marine source. There are 23 canning units with a capacity of

84.5 tonnes and 24 fish meal units with a capacity of 419 tonnes. Processing of produce into canned and frozen forms is carried out almost entirely for the export market.

1.4.8 Bakery products

The two major bakery industries, namely bread and biscuits account for ~ 82.0% of the total bakery products. There are about 60,000 bakeries. Bread and biscuit production per annum is about 4.0 million tonnes. Out of total bread production, 40.0% is produced by organized sector; remaining 60.0% in unorganized sector. For biscuits, the share of unorganized sector is about 80.0%.

1.4.9 Mushrooms

Currently, in India very few companies are engaged in the processing of mushrooms and that too are limited to the pickling and canning processes. In recent years, the gourmet appeal of mushrooms is gaining popularity and the consumer's demand for varieties has led to the processing of mushrooms to chutneys, pickles, soups, flavour, etc. Mushrooms are now available in fresh, frozen, canned and dried forms. The mushrooms processed include white button (85.0% of total), oyster and paddy straw ones.

1.4.10 Consumer industries

The product groups included in this category include confectionery, chocolates and cocoa products, soya-based products, ready-to-eat (RTE) foods, mineral water, high protein foods, etc.

1.4.10.1 Soft drinks

Indian soft drink market is worth US $ 480 million a year, guzzling 4 billion bottles. Currently, it is estimated that 85.0% of consumers prefer the non-carbonated drinks. India is witnessing a shift in the consumer trend from synthetic drinks to fruit-based products in some segment of the people. The aerated soft drinks industry comprises of over 100 plants. It has attracted one of the highest foreign direct investment in the country.

1.4.10.2 Chocolate products

India's per capita consumption is extremely low at just 200 g. Major chunk of Indian chocolate market is ruled by Cadbury capturing > 70.0% of market share. Nestle, the Swiss leaders in packaged foods has share of 25.0% which is the only other major competitor for Cadbury. There are 20 units engaged in the manufacture of cocoa products like chocolates, drinking chocolate, cocoa butter substitutes, cocoa based malted milk foods with an annual production of approximately 34,000 tonnes in 2008.

1.4.10.3 Confectionery products

These products grew at the compound rate of 6.0-7.0% in recent years.

1.4.10.4 Soybean processing

The soybean processing and utilization centre at Bhopal has developed 15 soy products matching with Indian food recipes and habits. There are 19 soybean processing equipment and pilot scale production facilities for full-fat and partially defatted soyflours, soymilk, Tofu and soy-fortified biscuits. About 5.0% of total soybean production goes for direct food and feed uses, 10.0% for seed and 85.0% is processed for oil and protein.

1.4.10.5 Mineral water

The market for mineral water is growing at the rate of 25.0-30.0% per annum. The Bailey's mineral water, launched in 1993, has registered a growth of 100.0% in 1999.

1.4.11 Alcoholic beverages

The liquor made in India is categorized as beer, country liquor and Indian made foreign liquor (IMFL). The Indian beer market is growing at the rate of 15.0% per annum. India is the third largest market for alcoholic beverages in the world. The wine market is estimated to be growing at ~ 25.0% annually.

1.4.12 Fast growing delicacies

The growth of the instant food industry in India is like the pace of its target group – 'fast'. In RTE products sector, the total installed capacity in the organized sector is 33,400 tonnes for manufacture of pasta products like noodles, macaroni, vermicelli, etc. Besides, there are 10 units for cornflakes, oat flakes and pearl barley.

1.5 Steps Taken by Government for Upliftment of Food Processing Industry

The Government of India has set up a separate Ministry of Food Processing Industry (MFPI) for better control, growth and upfilment fo the indian food industry. Financial outlay has been made for setting up infrastructural facilities including cold chain facilities for the food processing sector. MFPI has set up Joint Sector Food Parks. A Food Park in Orissa, mainly concentrates on processed fish, a coconut complex in Andaman and Nicobar Islands and a general Food park in Goa. Exclusive commodity boards have been established for the promotion of milk, tea, coffee, cashew and spices. The Govt. of India has planned to build over 60 Value Added Centres (VAC) for perishables, spread over the whole subcontinent of India. The VAC will reduce post-harvest losses with 10-25% and will cut expenses in the supply chain.

Agricultural and Processed Food Products' Export Development Authority (APEDA) is setting up cold chains at about 62 centers in different states. It aims to promote and nurture the agro-processing industry to enhance the export of processed foods.

1.6 Exports

India's major exports are fruit pulps, pickles, chutneys, canned fruits and vegetables, concentrated pulps and juices, dehydrated vegetables and frozen fruit and vegetables. The share of export in processed fruit and vegetables increased to 14.0% vis-à-vis for fresh fruit and vegetables, whose share remained at 10.0%.

1.7 Smart Packaging

It is possible to extend the storage and shelf life of post-harvest fruits by 200-400% by use of appropriate plastic packaging. The market for packaged soups is growing at a phenomenal rate of 20.0% per annum. Packaged Atta industry grew to Rs. 15,000 crores by 2005.

1.8 Quality Approach

Since international market has become demanding in terms of quality, safety and delivery, installation of quality systems in food industry would provide a competitive edge to food supplies in the international market.

Four systems viz., ISO 9000, ISO 14000, ISO22000, and 'Hazard Analysis Critical Control Point' (HACCP) are vital for management of quality and safety of food to assure customers around the world. The concept of 'Good Manufacturing Practices' (GMP) and 'Good Hygienic Practices" (GHP) also needs to be inculcated in the minds of the processing units.

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Lesson 2

STATUS OF FOOD INDUSTRY IN INDIA AND ABROAD

2.1 Introduction

The status of several food industries of India have been covered in Lesson 1. In this lesson the food processing industry in few countries abroad will be discussed for comparison with our own food processing industry. India is viewed as a very large market for processed food products by the International processing marketers of food items in the world.

2.2 Comparison of Indian Food Industry with Other Nations

Despite being one of the largest producers of food items, only 2.0% of the total produce is processed in India as against an average of 40.0% in many developing and 70.0% in most developed countries of the World. The value addition to food production is only 7.0% in India as against 23.0% in China, 40.0% in Philippines and nearly 200.0% in UK.

The percentage of processed food in Gross Domestic Product (GDP) of few countries is presented in Table 2.1.

Table 2.1 Percentage of Processed food in GDP of some countries

Country	Processed food (%) in GDP	% Processed food in total manufacturing
Japan (Total food and beverages)	2.6	11.0
USA	4.4	11.7
Canada	5.2	12.3
Brazil	20.4	19.7
China	25.4	7.3
Australia	6.1	19.4
Germany	6.1	8.7
France	7.5	14.1
Thailand	23.8	13.9
India	9.0	11.9

2.3 Food Industry in the United States of America

The American food industry generates approximately 1.0 trillion US dollars a year in sales. In 2000, United States firm accounted for 40.0% of the World's top 50 food processors and the United States is the World's largest exporter and importer of processed foods and drink. Exports at US $30 billion in 2000 stagnated and fell off in the second half of the 1990s, whereas imports at US $37 billion in 2000 increased considerably in the same period. The principal exports are meat products, (deleted miscellaneous foods), grain mill, fats/oils, fruit and vegetables etc. By order of importance the five principal importers of US processed foods and drink are Japan, Canada, Mexico, Thailand, South Korea and Hong Kong. Imports, in their turn, come primarily from Canada, Mexico, Thailand, France and Italy. Three tendencies of trade in processed foods are noted *viz.*, the importance of regional blocks, the westernization of diets in the developed Asian economies, and the competitiveness of high-quality European products.

The top American food company in 2005 was Tyson Foods, originally a chicken processor that branched out into beef, pork and a wide range of prepared food products. Tyson's 2005 food sales (from 2004) reached nearly 24 billion US dollars. Close behind Tyson Foods stood American food icon Kraft Foods, many of whose brands are true household names in the US: Chips Ahoy cookies, Louis Rich meats, Maxwell House coffee, Cracker Barrel cheese, Oscar Mayer meats, Planters nuts, Oreos, Nabisco, Velveeta spread, Jell-O, Kool-Aid, Sanka coffee, Shake 'N Bake, Ritz crackers, Minute Rice, Miracle Whip, etc. PepsiCo, with brands like Pepsi, Aunt Jemima pancakes, Lipton Iced Tea, Frito-Lay snacks, Mountain Dew, Tropicana orange juice, and Rice-A-Roni, nosed up an aggressive third on the list, exceeding 20 billion US dollars in sales.

2.4 Food Industry in Brazil

The Brazilian food processing industry was valued at US $ 173 billion in 2009. The food market in Brazil is expected to increase by 4.0-4.5 % in the next five years.

The meat and by-products sectors are the most lucrative processing industry in 2009, accounting to US $ 34.4 billion in sales. Coffee, tea and cereals ranked second accounting for US $ 19.5 billion. The sugar industry ranked third, with a significant increase compared to 2008.

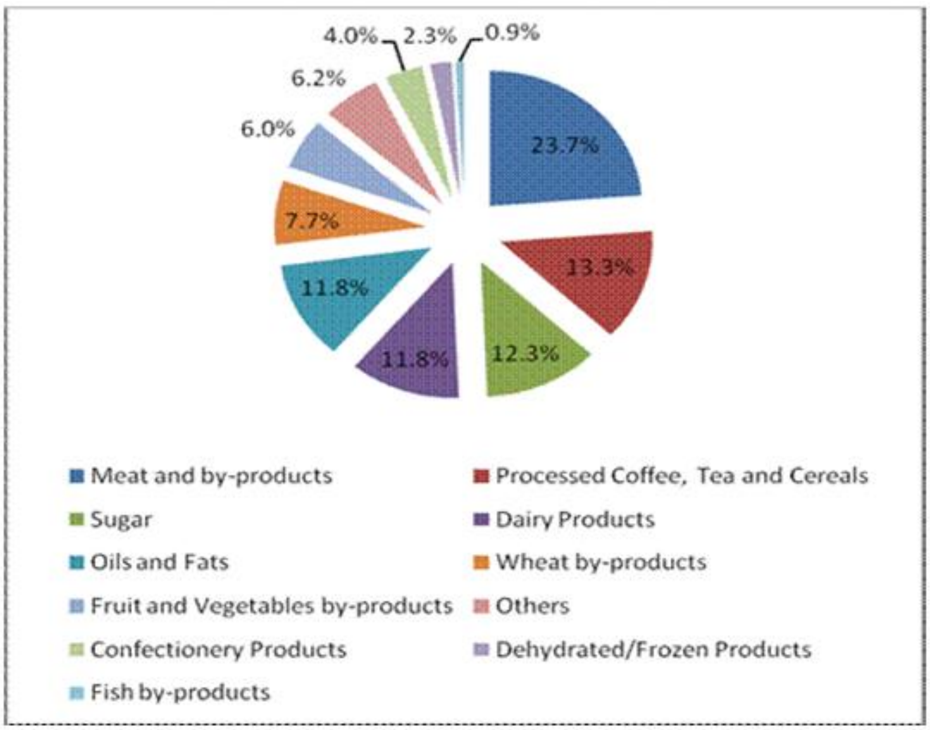

Fig. 2.1. Share of food items in sales of the Brazilian food industry
Source: Brazilian Food Processor's Association, 2009

2.5 Food Industry in China

The food processing industry has played an important part in its economic development. In 2007, China's food sales revenue exceeded RMB (Renminbi) three trillion ($ 384 billion), 70 times the 1978 pre-reform level. China's food industry grew at 9 % in 2008. In addition, the value of foreign trade in 2008 reached $ 1,218 trillion, up 27 % from $ 956 trillion in 2007.

In 2007, the number of large food processing companies grew to nearly 30,000 with fixed assets totaling RMB (deleted Renminbi) 344.8 billion ($44.2 billion) with total food export and imports of $32.3 billion and $30.6

billion, respectively. China has up to 500,000 food processing firms, which includes small industries. Despite 30 years of development, its ratio of processed output value to agricultural production value is only 1:2; lower than 3:1 observed for developed countries.

Recently China has developed a strong domestic demand for dairy products, which is attracting more of the world's dairy firms. In 2004, China imported 388 MT of dairy products. China targets at developing its produce of corn, wheat, dairy products, food additives and seasonings. Moreover the demand for imported poultry, cereals, fish; tree nuts and soybeans will continue to be on the rise with new growth for baking ingredients and fruit flavorings.

2.6 Future Scope of Food Industry

In the field of processed foods, the bigger opportunities lie in soft drinks, liquid milk and dairy products, confectionery, packaged wheat flour, biscuits, processed meat and poultry tea and coffee than that of jams, sauces, etc.

Biotechnology (providing genetically modified foods) in the Indian context could create wealth for the nation, improve health care system, increase agricultural output and provide cleaner technologies for sustainable development. Organic farming will go a long way in delivering safe produce to the consumers.

The future lies in delivering quality products at a quick pace. This requires high-tech machines and expertise. Adoption of foreign technology will make the products competitive in the international market. There is a strong justification to make the use of organic waste as energy source, an integral part of food processing. This would reduce the dependence of food industry on conventional energy supply and reduce pollution.

2.7 Conclusion

India has all the makings of an agricultural super power. From the stage of struggling to take care of the basic food needs of its ever expanding population during the independence, it has made some headway in visualizing the tremendous potential for commercial and export-oriented agro-business. Development of food processing industries requires cooperation and collaboration of the government, R & D Institutions, farmers, industrial and financial bodies.

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Lesson 3

MAGNITUDE AND INTERDEPENDENCE OF DAIRY AND FOOD INDUSTRY -I

3.1 Introduction

Food industry has represented major commercial users of dairy products and ingredients ever since time immemorial, when milk became accepted as an important functional ingredient. Some of the important food industry which relies a lot on dairy ingredients includes Bakery, Meat and Poultry, Chocolate, Malted powder, etc. Likewise industries like Ice cream, Mozzarella/pizza cheese, Dairy analogues (cheese, whipped toppings, ice cream, paneer, etc.) also relies on food ingredients and products. Thus, there is a tremendous interdependence of dairy with food industry.

As an agro-based industry, the future of dairy industry lies in the food industry. The dairy products are not only used for their significant effect on the physical and chemical properties of baked products, but also because of their nutritional contribution to these items. The classical examples of interdependence of dairy with other food products are shown in Table 3.1. However, dairy products are one of the most costly raw materials utilized in the food industry.

The profusion of dairy products now being offered to the food industry as a consequence of adoption of newer techniques such as membrane filtration, ion-exchange, immobilized enzyme, etc. may cause dilemma to the food industry.

Table 3.1 Examples of interdependence of dairy with other food

Sr.No.	Classic example of synergy between dairy and food	Benefits
(a)	Fruit/nut/chocolate flavourings, colourings, stabilizers, emulsifiers in ice cream mix	Fruit, nut, chocolate contributes to varied flavours and texture for the consumers to enjoy. Stabilizers and emulsifiers help to build body, smoothen texture and aid in air incorporation in ice cream
(b)	Blend of cow/buffalo milk with vegetable milk viz. soymilk, groundnut milk, rice milk,	Allows complementing amino acid and fatty acids of two sources in one product; reducing cost,

	oat milk, etc. and products made thereof (i.e. flavoured milk, fermented milk products, ice cream-like products, paneer-like products, etc.)	healthier product
(c)	Mozzarella cheese/Pizza cheese with pizza	Enjoyed as fast food; flavour and nutrition from cheese used as topping on pizza; shred, stretch, melt, oil-off important properties of cheese for use on pizza
(d)	Malted milk powder/foods	Easy to digest, more nutritious and palatable (malt provides flavor and color), cost effective
(e)	Milk/White chocolate; Use of Milk Crumb in chocolate manufacture	Milk solids affects desirable appearance, taste and influences texture of chocolate
(f)	Milk solids in Bakery products viz., Milk Bread, Cheese crackers, Cheese cake, etc.	Milk solids improves appearance, taste and nutritional property of bread
(g)	WPC or WPI in formulation of egg-less cake	Enables obtaining spongy 'eggless' (vegetarian) cake
(h)	Dairy ingredients/products in meat and poultry products	Affects appearance, taste and texture favourably in cooked dishes
(i)	Milk analogues, Imitation whipped cream, Imitation whiteners, Cheese analogues, etc.	Healthier product with low-fat, cholesterol-free image; cost-effective; high shelf life

3.2 Relation Between Dairy and Baking Industry

Technological properties of milk constituents in relation to baking properties

The milk constituents have certain functionalities either by themselves or in combination with other ingredients which may be usefully exploited in baked products.

3.2.1 Milk fat

Although more expensive than other edible fats, it is a much appreciated ingredient of flour confectionery products because of its superior taste and flavour.

The important characteristics which distinguish milk fat from other edible fats are:

- Has an intrinsically attractive flavor, which is pleasing to human palate.
- Higher proportion of short chain fatty acids contribute to ease of digestibility.
- Has fat soluble vitamins such as A, D, E and K.

When used in baking it serves much the same purpose as do other fats, namely to lubricate and weaken the gluten structure and thereby shorten and tenderize the product. The crystalline nature of milk fat assists in the formation of the initial foam structure of batters. After baking, when the product 'sets', the fat partlyrecrystallizes and assists in maintaining the moist texture by binding the water.

3.2.2 Milk proteins

The characteristics of milk proteins which are advantageously exploited in the preparation of baked goods are:

a) Stabilization of food during preparation, conservation and storage, which is brought about by prevention/lessening of water separation, fat separation and escape of gas.

b) Improvement and/or maintenance of consistency and structure of food.

c) Many of the flavours and aromas which develop during baking result from thermal degradation of protein and amino acids.

Some of the utility of dairy ingredients in baked goods is depicted in Table 3.2. The type of cheeses recommended in bakery product is furnished in Table 3.3.

3.3.3 Lactose

Lactose is commercially produced from whey, the by-product of cheese, casein, chhana and paneer. Some important properties of lactose for baking purpose are:

a) It enhances the flavor of products such as vanilla, chocolate, spice, etc. and maintains the flavor, color and aroma of baked goods by retarding the losses during processing and baking.

b) Owing to its sweetness, it may replace 10-50% of the sugar in some bakery items and forms a convenient bulking agent.

c) It binds water to give a tender, moister and better eating quality product.

d) Its emulsifying property enables replacing and/or increasing the efficiency of shortening.

e) It gives tenderizing effect and strengthens the cell walls.

f) Being non-fermentable by yeast during processing, it is made available for Maillard reaction and caramelization to occur at the high temperatures prevailing in the oven, resulting in golden brown crust color.

3.3.4 Minerals

Minerals are of some significance as nutritional adjuncts in bread and other bakery products and comprise a part of milk's buffer system. Ions such as calcium and phosphorus bring about changes in casein and are used to modify skim milk for special bakery blends.

The influence of some important dairy ingredients on the quality of baked goods is shown in Table 3.2. The type of cheese suitable for baked goods in furnished in Table 3.3.

Table 3.2 Milk solids as value-added ingredient in baked goods

SN	Type of dairy ingredient	Raw materials	Influence exerted in baked goods
1.	Fluid milk	Milk/Skim milk	Important moistening agent. Improves dough or batter handling properties,flavour, crust colour, nutritional value. Applications 'Milk bread', 'Skimmed milk bread'
2.	Condensed milk	Condensed skim milk	Problem with uneconomic shipping, storage and spoilage
		Concentrated whey	Its high lactose content is desirable where high crust colour is desired.
		Condensed butter milk	Valued ingredient in specialty bakery products requiring short texture, without excessive dryness. Used as flavouringagent in 'Rye-bread'
3.	Milk powders	WMP	Limited usage due to high cost. Gives rich character in

			milk bread.
		NFDM	High heat powder desirable where freeze-thaw stability desired and high carbohydrate system; other applications low heat powder desirable. Heat treated NFDM improves crust colour, loaf volume and nutritional quality.
		Dried cream	Used in cream cakes. Both sweet and sour cream are spray dried to obtain this.
		Whey powder	'Breading' or 'Crumb coatings' used on fried products contains whey as a critical ingredient. Heat treated whey has improved functionality in baked goods.
		Butter milk powder	Butter milk solids @ 3% of flour weight desirable for bread
4.	High protein powders	Caseinates	Enhanced protein content of foods, improved functional properties
		Whey protein concentrates	Enhanced protein content of foods, improved functional properties
5.	Fat sources	Butter	Important for flavor and texture. Used in butter sponges, savouries, biscuit, short bread
		AMF/Butter oil	AMF sometimes denatured by vanillin or carotene
		Fractionated butter fat	Avoids use of hydrogenation which has unhealthy image. Applied in puff, pastry, short cakes and croissants.
		Fat blends	Helps in cost reduction, more healthy fats (i.e. more polyunsaturated fats, low cholesterol). Utilized in puff-pastry butter.

WMP – Whole milk powder, NFDM – Non-fat dried milk, AMF – Anhydrous milk fat.

Table 3.3 Type of cheeses recommended for a bakery product

Sr.No.	Cheese variety	Recommended bakery items
1.	Mature Cheddar cheese	Cheese biscuits and straws, Cheese sticks, Speciality breads, Hamburger, Buns, Muffins
2.	Dried Cheddar cheese	Snack foods, Dry prepared mixes
3.	Cottage cheese	Sour dough formulation, muffins, Devils food cake, Yellow layer cake, Lemon pudding, Thick sauces for casseroles
4.	White cheese (FromageBlanc)	Cheese cakes
5.	Mozzarella cheese	Pizza, Cheeseburger, Tacos
6.	Romano, Parmesan, Provolone	Pizza
7.	Quarg cheese	Cakes, Cheese-cream baked goods, Fillings, Some confectioneries

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Lesson 4

MAGNITUDE AND INTERDEPENDENCE OF DAIRY AND FOOD INDUSTRY-II

4.1 Introduction

In the previous lesson the need for studying interdependence of dairy with food industry was emphasized and the dependence of dairy with baking industry was dealt. In this lesson, the dependence of chocolate and meat industry with dairy industry will be discussed.

4.2 Milk Solids in Chocolate

4.2.1 Milk solids

Roller dried Whole milk powder (WMP) is preferred over spray-dried ones. Roller dried powders tend to have a somewhat spicy and salty taste whereas spray dried ones have a distinct milky flavour. The high content of free surface fat (> 95% vs. < 10% in spray-dried powder) results in favourable rheological properties during the manufacturing steps of mixing and conching. The energy consumption is reduced and amount of cocoa butter can be reduced (by about 2-3% of cocoa butter) under constant rheological conditions. The impact of free milk fat resulted in lower viscosity, quicker melting, reduced hardness, and obtaining smaller particles through refining process.

Na-caseinate can be used to replace dried milk in chocolate. Incorporation of buttermilk powder can exert some emulsifying action. Use of whey products may offer benefits by reducing the sugar content and chocolate liquor enhance flavor and may afford resistance to fat bloom (i.e. grayish haze on chocolate as a result of greater fat crystal size).

4.2.2 Milk crumb

For milk chocolate, one of the biggest flavour differences that may occur is due to the chocolates made from milk powder (Continental Europe) and the 'Milk crumb' (UK and parts of America). Crumb is made by the evaporation and drying of milk components together with sugar and cocoa liquor (Table 4.1). **Deleted one sentence.** As cocoa contains natural antioxidants, it improved keeping properties of dehydrated form over extended periods without refrigeration. The drying process develops distinct cooked and caramelized flavour too. The already developed caramelized flavour and the removal of undesirable flavour elements during the evaporation and drying stages in crumb manufacture reduced the conching time considerably. Conching is a process in chocolate making wherein the mixture of ground cocoa mass, sugar (with or without milk solids) and cocoa butter is subjected to mechanical treatment using rollers with heating to obtain a flowable, homogneous chocolate mass.

Table 4.1. Typical crumb recipe

Ingredients	Percentage of total product
Moisture	1
Sucrose	53
Milk solids	32
Cocoa liquor	14

To make chocolate using Milk Crumb, only cocoa butter needs to be added externally.

The advantages of using Milk crumb in Milk chocolate manufacture are darker colour, higher flavour intensity, smoother texture and better mouth feel.

4.2.3 Butter oil

It is cheaper than cocoa butter. It can be used to replace 1-5% of the total fat. Excess replacement softens the chocolate and has adverse effect on the gloss, hardening and demoulding.

4.3 Dairy Ingredients in Meat Products

Meat and dairy products have several things in common. Both are appreciated from organoleptic and nutritional points of view. They have been regarded as two of the main protein sources for humans. In a modern diet, meat contributes about 35% of the protein intake, and milk about 25%.

Meat is very important for the intake of iron and certain vitamins viz., thiamine and riboflavin, while dairy foods are critical for the intake of calcium and vitamins.

Milk ingredients especially milk proteins can play an important role in the stabilization of meat products. In many countries, milk protein (caseinate) is legally allowed in meat, poultry and seafood products. In US, caseinate is approved for use in sausages; skim milk powder and whey powder is permitted in such allied foods.

The functional properties of milk proteins in meat products include stabilizing, emulsifying, immobilizing water, control texture and consistency and improve color and organoleptic properties. Caseinates behave better than whey proteins; caseinates does not show any heat gelation and denaturation and thus contributes to high viscosity in solution.

Milk proteins are used to overcome stability problems. It emulsifies free fat in meat emulsions and saves salt-soluble part of myofibrillar proteins (SSP) for water binding. Since large numbers of small fat globules are created in the presence of milk protein, the expelled water during heating of meat is reduced, thereby preventing shrinkage.

Milk proteins can be applied in three ways: (a) as a powder at the beginning of the comminuting process, (b) as a jelly (milk protein is dissolved in water in a bowl chopper or colloid mill), usually containing 10-15% milk protein in water, and (c) as a pre-emulsion prepared from milk protein-fat-water.

Use of milk protein as an ingredient in coarse and non-comminuted meat such as pumped ham leads to improvement in the water binding property. Lactose helps in masking the flavour imparted by use of phosphates and bitter aftertaste, besides imparting low sweetness profile. It also has reducing action and improves stability of meat products. Hence lactose is desirable in liver products, cooked hams, and cooked sausages. Calcium reduced Skimmed Milk Powder (SMP) has found application in meat products since calcium negatively influences the binding properties of meat proteins.

4.4 Products Made From a Blend of Milk and Vegetable Milks

Soymilk and ‘Paneer like’ products have been made from a blend of cow/buffalo milk and soy milk in various proportions, desirable being 70:30 or still lesser quantity of soymilk in the milk blend. Such product is advantageous in being cheaper, complementing the fat (unsaturated from soybean) and amino acid profile, reducing the cholesterol and lactose content, and developing new products. Such soymilk from blend of milk and soymilk can be suitably flavoured to yield more acceptable products. Table 5.4 gives the examples of products made from blend of cow/buffalo milk with soymilk and the benefits obtained thereof.

Table 4.4 Examples of food products made from a blend of soymilk and cow/buffalo milks

Product	**Effects**
Ice cream	Formulation composed of soy milk (8% TS), SMP, Cream (60% fat), sugar and stabilizer. **Deleted soybean variety name.** Low-cost acceptable product with high protein content (5.09 vs. 3.34% in control) was obtained, except for slight beany flavour, chalky taste and low overrun.
Shrikhand	Blending milk with soy milk (40:60, w/w) yielded chakka suitable for Shrikhand making. The protein content of Shrikhand with such soymilk supplementation was 8.8% on dry matter basis.
Paneer/chhana-like product	Cow/toned milk: soy milk (30:70, w/w) had no adverse effect on quality of chhana analogue with respect to flavour and hardness; the yield was increased. The fat content of paneer-like product tended to decrease with increase in level of soy milk in the blend.

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Lesson 5

RECENT DEVELOPMENTS AND FUTURE GROWTH IN THE FOOD INDUSTRY

5.1 Introduction

Though we rank second in world scenario in terms of total production of fruits and vegetables, India needs to further improve its food processing strategies in order to reduce the extent of spoilage, go for large scale food processing to make processing viable and cost-effective and even compete with foreign goods available in India.

5.2 Recent Developments in Food Industry

The food industry has always strived to be in consonance with the latest developments that have taken place in the food processing. Some of the aspects that have improved by adopting the latest technologies include freshness, value addition, preservation of nutrient profile, varied flavor and textures, shelf life, etc.

The recent developments that have been adopted by the food industry include:

(a) Minimal processing of fruits and vegetables using non-thermal processing methods like High Pressure Processing, Pulsed electric field processing, etc.

(b) Membrane processing viz., Ultrafiltration (UF), Reverse Osmosis (RO), Nanofiltration (NF), Microfiltration (MF), etc.

UF and RO can be used to concentrate milk, whey, fruit juices, etc. NF can be used to demineralize whey to produce demineralized whey powder. MF has been used in preparing ‘Extended Shelf Life Milk.

(c) Osmotic dehydration

This is used to reduce the water content of fruit tissues, thus enhancing the shelf life of product.

(d) Freeze concentration and freeze drying of foods

Freeze concentration can be used to concentrate fruit juice solids without impairing its flavor, color and nutritive value. Freeze drying is specifically used for heat sensitive foods like fruit juices, starter cultures.

(e) Use of Extrusion cookers

Extrusion cookers are being used to prepare an assorted range of snack foods using multigrain.

(f) Use of biotechnology

'Golden rice' made using genetic technology is an example of value-added rice rich in β-carotene (thus vitamin A) and iron. Recombinant chymosin is a classic example of rennet used for coagulating milk in cheese making.

(g) Fermentation of foods, especially probiotic and synbiotic food products

Fermented milk products containing live probiotic organisms (viz., *Lb. acidophilus*, *B. bifidum*) in high numbers (i.e. > 10^8/g) is referred to as 'Probiotic food', while inclusion of a prebiotic (food for probiotics) like fructo-oligosaccharides, inulin, etc. makes the product 'Synbiotic'.

(h) Functional foods by use of phytonutrients

These are foods containing valued ingredients from plant sources (viz., epigallo catechin gallate, β-carotene, glucan (a soluble dietary fiber), etc. that can exert beneficial therapeutic effects in humans.

(i) Irradiation of foods

This is a non-thermal preservation method specifically used for sprout inhibition of potatoes, deinfestation of spices, increase shelf life of sea foods and even fruit and vegetables. Dosage of irradiation below 7 KGy (Kilogray) is considered safe.

(j) Use of microwaves for drying

This is a very rapid drying technique using energy from microwaves.

5.3 The Major Indian and Overseas Players in Food Processing Industry

The Companies that have established their brands in India and some of their recently launched food products are as follows:

SN	Name of the Company	Recent food product
1.	ITC Limited	Multigrain (Barley, Oat, Raagi, Jowar, Corn, Wheat) biscuit with enriched vitamins and proteins
2.	Parle Products Pvt. Ltd.	Hide and Seek Milano – exotic cookie in four flavours Chocolate chip,

		Butter nut, Butterscotch, Butternut
3.	Agro Tech Foods	Peanut butter, Act II Microwave Popcorn
4.	Amul	Long shelf life Amul Taaza UHT milk, Gulabjamun mix powder
5.	Perfetti India Ltd.	Happy dent Protex sugar-free Chewing gum
6.	Cadbury India Ltd.	Truffle – soft centre moulded chocolate bars.
7.	PepsiCo India Holdings	Baked variants 'Aliva' brand – Multigrain waves, Milk Minis, Crispy Thinz
8.	Nestle India Pvt. Ltd.	Sweet lassi, Actiplus Probiotic Dahi
9.	Britannia Industries Ltd.	Milk based health drinks – Actimind and Tiger Zor flavored milk
10.	Hindustan Lever Limited	Blend of fruit juice and soya milk, Bakery – Chapi and Cream Rolls
11.	Parag Milk Foods	'Go Dahi' – Frozen Yoghurt
12.	MTR foods limited	Frozen foods range – Spring rolls, Parathas, Dosas, Samosas
13.	Godrej industries Limited	Xs range of fruit juices – Sweet Orange, Mango, Litchi, Pineapple
14.	Gits Food Products Pvt. Ltd	Dairy Whitener, Gulabjamun mix powder
15.	Dabur India Ltd.	Fruit flavored Chyawanprash – Orange and Mango

5.4 New Product Development

Some of the recent product launched in India is presented in Table 5.1.

Table 5.1 Recent products launched in India by renowned companies

Product	**Company**
Lonong and Devil Curry flavoured special noodles	Nestle
Peanut butter for export	Pepsi Foods Ltd.
Ethnic convenience foods – natural food with claim “As good as Mother makes it”	Pure and Natural Foods Pvt. Ltd., Mysore
Ready to Serve Dal targeted at busy executive class of consumers	Tetra Pak India Ltd., Pune
Ready-to-Eat Chappati, packaged as Annapurna Chappati	Hindustan Lever Ltd., Mumbai

5.5 Infrastructure Development in Food Processing Industry

The MOFPI has taken lot of steps by launching several schemes to improve the growth of Indian food processing industries. Some of these schemes are as detailed below.

5.5.1 Food parks

Food Parks have been set up in different parts of the country so that small and medium entrepreneurs can invest in capital intensive activities. In Food parks, common facilities like cold storage, food testing and analytical lab, effluent treatment plants, common processing facilities, packaging centre, power supply, water supply, seminar/conference/training facilities, etc. has been assisted with an outlay of ` 1.04 billion. The number of Food Parks sanctioned in the 8^{th}, 9^{th} and 10^{th} Plan were 2, 39 and 10 respectively; 22 Food Parks have been operational till 2005.

5.5.2 Packaging centers

The Scheme provides facilities for packaging, which may help in enhancement of shelf life of food products and make them internationally acceptable. An assistance of `1450 million has been sanctioned to one packing centre in Jammu and Kashmir.

5.5.3 Integrated cold chain facility

The Scheme intends to improve the viability of cold storages and enhance cold storage capacity. The Tenth Plan has sanctioned an assistance of ` 4010 million to three cold storages in Gujarat, three in Maharashtra, one each in Uttar Pradesh, Kerala, Manipur, Meghalaya, Andhra Pradesh, Haryana, Delhi and Goa. Previously, 9^{th} Plan had established 53 cold storages all over India.

5.5.4 Irradiation facility

This has been provided to enhance the shelf life of food product through irradiation techniques by preventing infestations like in flour, sprouting and change in chemical composition of the product (e.g. in potato). So far four irradiation projects – two in Maharashtra and one each in West Bengal and Haryana have been sanctioned with an assistance of ` 78.9 million.

5.5.5 Modernized abattoirs

The Scheme aims to make possible scientific and hygienic slaughter, causing least pain to the cattle and ensuring better byproduct utilization. One case of MCD, Delhi has been approved for grant of ` 40 million.

5.6 Avenues for Further Upliftment of Food Processing Industry

The contract farming should be encouraged to ensure the availability of right type of raw materials to the industry. Development of captive orchards should be encouraged by liberalizing the State Land Laws and treating horticulture at par with plantation crops with attendant incentives.

Development of appropriate genetic varieties would not only increase the yield, but also enable growing of that food which can best be preserved to meet the needs of the growing population. In this regard, the steps taken by certain companies particularly in the matter of tomatoes, sunflower and gherkins are very encouraging.

5.7 Future of the Food Industry

The Indian Food Processing Industry has seen significant growth and changes over the past few years, driven by changing trends in the market, consumer segments and regulations. These trends such as changing demographics, growing population and rapid urabanization are expected to continue in the future and therefore will shape the demand for value added products and thus for food processing industry in India. The Government of India is attracting more Foreign Direct Investments (FDI) too.

The market forces are compelling the Indian Agriculture producers to increase the quality of their farm produce while continuing to maintain their cost competitiveness in order to be able to compete effectively in the global food market. Even in the domestic market, the rising per capita income and changing demographic profiles of the population has ensured the growing demand for processed and convenience foods. Increasing consumer awareness about health and hygiene has shifted the focus of the market to 'safe' foods. In the field of processed foods, bigger opportunities lie in soft drinks, liquid milk and dairy products, confectionery, packaged wheat flour, biscuits, processed meat and poultry, tea and coffee than that of jams, sauces, etc.

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Module 2. Post-harvest management of fruits and vegetables

Lesson 6

POST HARVEST MANAGEMENT OF FRUITS AND VEGETABLES

6.1 Introduction

Fruits and vegetables, fresh or processed, form an important component of our diet and there is an ever-increasing demand for these. India being the top producer of both fruits and vegetables in the world, more emphasis is needed to minimize past harvest losses. At present about 70-80% of our production goes waste mainly during transportation and storage. A clear understanding of biochemical and physiological changes in fruits and vegetables during post harvest operations will enable persons involved in handling, transportation and storage operation to regulate certain critical parameters.

6.2 Harvesting or Maturity Indices of Fruits and Vegetables

The stage at which the fruits and vegetables should be harvested is very important in determining the market life, storage, transport, eating and processing quality. Harvesting indices are defined in terms of either their "physiological maturity" or their "commercial maturity". The former refers to a particular stage in the life of a plant organ and the latter is concerned with the time of harvest as related to a particular end-use that can be translated into market requirements. Physiological maturity refers to a stage in the development of the fruit or vegetable when maximum growth and maturation has occurred. It is usually associated with full-ripening in a fruit. It is followed by senescence. Clear distinction between the three stages of development of a plant organ is not always easy, since the transition between the stages is often quite slow and indistinct. Commercial maturity is the stage of a plant organ required by market. The marketing of fresh fruits and vegetables is aimed eventually at appealing to the consumers. There are two methods for determining the harvesting maturity as given in Table 6.1. They are (a) destructive and non-destructive methods and (b) physiological methods. Harvesting maturity should meet the following criteria:

a. Should be at a stage which will allow it to be at its peak condition when it reaches the consumer.
b. Should be at a maturity that allows it to develop as acceptable flavour or appearance.
c. Should be at a size required by the market.
d. Should not be toxic.
e. Should have an adequate shelf-life.

Fruits are harvested at slightly immature or mature greens stages and yet their physiological activities continue. Harvesting of fruits and vegetables at appropriate maturity level is important and one of the basis of close observations, maturity indices is fixed for various commodities. These maturity indices are based on physico-chemical characteristics, like their weight, fullness of finger, total soluble solids, sugar to acid ratio and certain arbitrary units like colour, heat units, and period after blooming. Commonly following criteria have been utilized for fixing maturity standards:

- Computation of days from bloom to harvest
- Measurement of heat units

- Visual means- skin colour, persistence or drying of parts of plant, fullness of fruit
- Physical methods- ease of separation, pressure test, density, grading etc.
- Chemical methods- total solids, sugars, acid, sugar-to-acid ratio, starch content etc.
- Physiological methods- respiration methods etc.

6.3 Factors Affecting the Postharvest Quality of Fruits and Vegetables

Two types of factors are involved in the postharvest quality of fruits and vegetables. They are biological or internal factors and environmental or external factors.

6.3.1 Biological factors

a. Respiration rate

Even after harvesting fruits and vegetables behave as living commodity (entity) and continues to respire. However, the rate and pattern of respiration depends upon several factors like physiological maturity, injury, storage atmosphere. Respiration is the process by which stored organic materials (carbohydrates, proteins and fats) are broken down into simple end products with a release of energy. Oxygen (O_2) is used in this process and carbon dioxide (CO_2) is produced (Eq.6.1). The loss of stored food reserves in the commodity during respiration hastens senescence as the reserves that provide energy to maintain the commodity's living status are exhausted. The energy released as heat, which is known as vital heat, affects post harvest technology considerations such as estimations of refrigeration and ventilation requirements.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 673 \text{ K.cal} \qquad \text{(Eq. 6.1)}$$

Respiration rate is expressed as ml of O_2 consumed or ml of CO_2 evolved per kg of fruit per hour. Gas analyzers are placed to measure the level of gases. Respiration rate indicates the storage life of the commodity. A high rate of respiration usually associated with a short life. It would also indicate the rate at which the fruit is deteriorating in quality and in food value. Moreover, respiration is a rather complex process that is affected by a number of factors. Knowledge of these factors is of immense importance from the handling and storage point of view. Fruits, on the basis of their respiration pattern during ripening, can be classified as either climacteric or non-climacteric. Non-climacteric fruits are not capable of continuing their ripening process once removed from the plant e.g. dates, grapes, pineapple, lemon, lime, pomegranate, etc. while climacteric fruits can be harvested mature and ripened off the plant e.g. apple, papaya, banana, mango, guava, sapota (chikoo), etc. Respiration pattern of climacteric and non-climacteric fruits is given in Fig.6.1 and a generalized respiration rate of a climacteric fruit during different stages of growth is given in Fig.6.2.

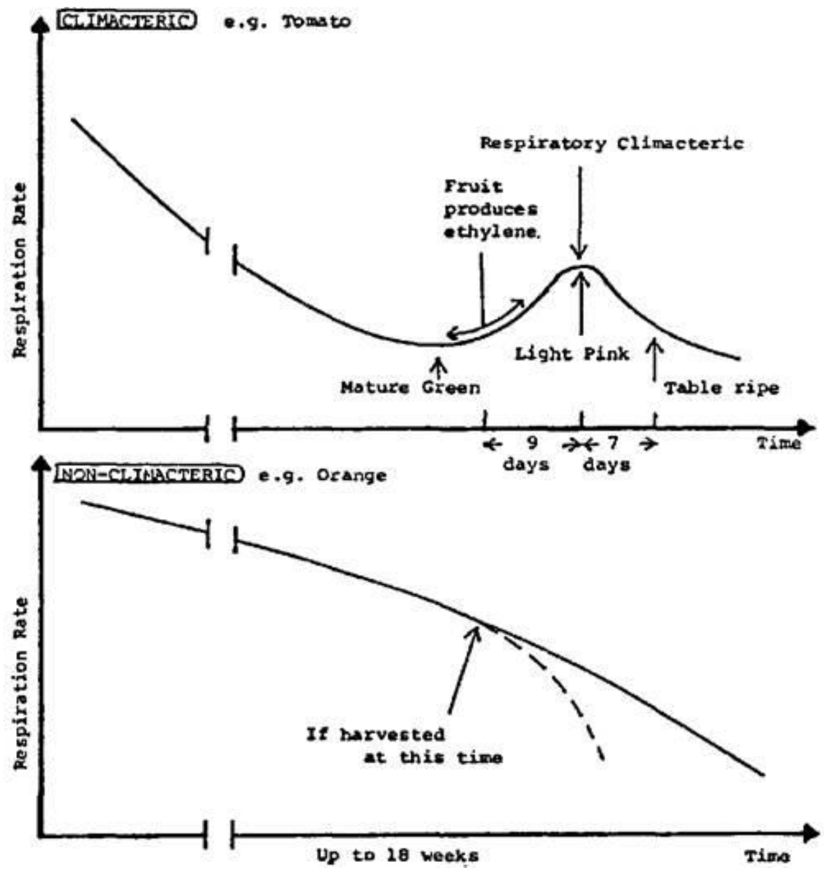

Fig. 6.1 Respiration pattern in climacteric (e.g. tomato) and non-climacteric (orange) fruits

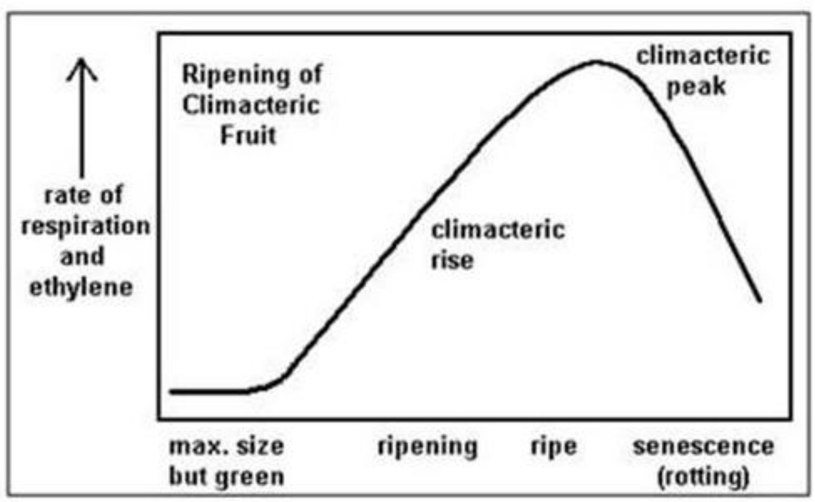

Fig. 6.2 Respiration rate of a climacteric fruit during different stages of growth

Most of the physico-chemical changes occurring in harvested fruit are related to oxidative metabolism including respiration. There are three phases of respiration:

I. Breakdown of storage macromolecules like polysaccharides, fats or proteins

Breakdown process is carried out by enzymes such as carbohydrases (pectic enzymes, celluloses, hemicelluloses, and amylases), proteinases and lipases. In many cases it is also apparent that metabolism of organic acids can account for a significant proportion of respiration.

II. ***Oxidation of sugars to pyruvic acid***

Respiratory pathways namely utilized glycolytic and oxidative Pentose-Phosphate pathways by fruits are common to all plant (OPP) tissues.

III. ***Aerobic transformation***

Pyruvate and other organic acids are aerobically transformed into carbon dioxide, water and energy. This involves TCA cycle and electron transport chain.

b. Ethylene production

Ethylene, the simplest of the organic compounds affecting the physiological processes of plants, is a natural product of plant metabolism and is produced by all tissues of higher plants and by some microorganisms. As a plant hormone, ethylene regulates many aspects of growth, development and senescence and is physiologically active in trace amounts (less than 0.1 ppm). Ethylene biosynthesis starts with the amino acid methionine, which is energized by ATP to produce S-adenosyl methionine (SAM). The key enzyme in the pathway, ACC synthase, converts SAM to 1-aminocyclopropane-1-carboxylic acid (ACC), which is converted to ethylene by the action of ACC oxidase. Ethylene production rates, which depend on the fruit, generally increase with maturity at harvest, physical injuries, disease incidence, increased temperatures up to 30°C, and water stress. On the other hand, ethylene production rates by fresh fruits are reduced by storage at low temperature and by reduced O_2 (< 8%) and elevated CO_2 (> 1%) levels in the storage environment around the commodity.

c. Transpiration or water loss

Water loss is the main cause of deterioration because it results not only in indirect quantitative losses (loss of salable weight) but also in losses in appearance (wilting and shriveling), textural quality (softening, flaccidity, limpness and loss of crispness and juiciness), and nutritional quality. The outer protective coverings (dermal system) govern the regulation of water loss by the commodity. Transpiration (evaporation of water from the plant tissues) is a physical process that can be controlled by applying treatments to the commodity (e.g. waxes and other surface coatings or wrapping with plastic films) or manipulation of the environment (e.g. maintenance of high relative humidity and control of air circulation).

d. Physiological disorders

Physiological disorders that occur in fruits and vegetables are chilling injury, freezing injury, heat injury, disorders due to pre-harvest nutrient imbalances, breakdown of fruits and vegetables due to very low (< 1%) oxygen and elevated (> 20%) carbon dioxide concentrations. Freezing point of fruits and vegetables is slightly below the freezing point of water, for example apple has freezing point of – 1.5^0C. Freezing point may vary among cultivars or even depends of crop production practices. The varied amount of soluble solids is also one of the reasons for variation in freezing point. Freezing injury occurs when fruits and vegetables are held below the freezing temperatures of cell sap, they get damaged, which is referred as "freezing injury".

Chilling injury occurs when fruits and vegetables are held at temperatures above their freezing point and below 15□ C depending on the commodity. Chilling injury is more common in fruits which are of tropical or sub-tropical in origin. These include mango, papaya, banana, citrus, tomato, pineapple, guava, cucumber, eggplant and pepper. Chilling injury is manifested in a variety of symptoms, which include surface and internal discoloration (internal/external), surface pitting, appearance of water-soaked areas, necrotic (black spots) areas, uneven ripening or failure to ripen, off-flavour development, and accelerated incidence of surface molds and decay. Fruits suffered with chilling injury sometimes fail to ripen when bring back at ambient conditions. Chilling injury is generally noticed after transferring to non-chilling temperature.

Heat injury results from exposure to direct sunlight or to excessively high temperatures. Symptoms include surface scalding, uneven ripening and excessive softening and desiccation.

e. ***Physical damage***

Physical damage causes greatest amount of loss to fresh horticultural crops. Certain most prevalent physical damages include surface injuries, impact bursting and vibration bruising, during harvesting, transportation and storage. Mechanical injuries are not only unsightly but also accelerate water loss, stimulate higher respiration and ethylene production rates and favor decay incidence. They also render produce more susceptible to microbial invasion. Physical damage also leads to tissue discolouration.

f. ***Pathological breakdown***

Decay is one of the most common or apparent causes of deterioration. However, attack by many microorganisms usually follows mechanical injury or physiological breakdown of the commodity, which allow entry to the microorganism. In a few cases, pathogens may infect healthy tissues and become the primary cause of deterioration.

6.3.2 Environmental factors

a. ***Temperature***

Temperature is the most important environmental factor that influences the deterioration rate of harvested fruits and vegetables, for each increase of 10□ C above the optimum temperature, the rate of deterioration increases by two- or three-fold. The term Q_{10} if often used to denote the ratio of reaction rates with 10□ C rise in temperature (Eq. 6.2). Temperature also influences how ethylene, reduced oxygen and elevated carbon dioxide levels affect the commodity. The growth rate of pathogens is greatly influenced by temperature and some pathogens are sensitive to low temperatures. Thus, cooling of commodities below 5□ C immediately after harvest can greatly reduce bacterial and mold rot incidences.

$$Q_{10} = \frac{\text{Reaction rate at given temperature} + 10°\text{C}}{\text{Reaction rate at given temperature}} \qquad \text{(E.q. 6.2)}$$

b. Relative humidity (RH)

The rate of water loss from fruits depends upon the vapour pressure difference between the commodity and the surrounding ambient air, which is influenced by temperature and relative humidity.

c. Air movement

Air circulation rate and velocity can influence the uniformity of temperature and RH in a given environment and consequently rate of the water loss from the commodity.

d. Atmospheric composition

Reduction of oxygen and elevation of carbon dioxide, whether intentional such as in modified or controlled atmosphere storage or unintentional, can have a beneficial or harmful effect on deterioration. The magnitude of these effects depends upon commodity, variety, physiological age, O_2 and CO_2 level, temperature and duration of storage.

e. Ethylene

The significance of ethylene has already been dealt in previous sub-section. A concentration as low as 50 parts per billion (ppb) ethylene for example leads to kiwifruit softening at 0 C. Use of ethylene to ripen citrus fruits can accelerate their senescence and increase their susceptibility to decay-causing pathogens.

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Lesson 7

POST HARVEST PROCESSING-I

7.1 Storage of Fruits and Vegetables

Storage of fruits and vegetables is practiced for various reasons. It is part of orderly marketing where the storage period is usually short, to allow for accumulation of sufficient produce by the grower or group of growers to send to market. Certain fruits and vegetables are stored for longer periods of time to extend the duration of their availability. In some cases fruit and vegetables destined to be processed are first stored to even out the supply to the factory. Often the objective is to provide a constant supply of raw material for the factory for as long a time as possible. Often this type of storage is different from storage of fruits and vegetables destined for fresh market. Many types of storage systems are available for fruits and vegetables. Some of the important ones are given below.

7.1.1 Evaporative cooling and storage

In tropical countries like India deterioration in quality of fruits takes place immediately after harvest due to lack of on farm storage. To overcome this problem low cost, environmental friendly zero energy chambers also called as evaporative coolers have been developed. When water evaporates from the liquid to the vapour phase, it requires energy. This principle is used to cool stores or chambers by passing the air that is introduced into the store first through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. These can be easily constructed at small and marginal farmers' field and are helpful to keep temperature 15-30 C lower than atmospheric temperature. These can be used for short-term storage of fruits and vegetables at the farmers' field.

7.1.2 Controlled and modified atmosphere storage

Normal atmospheric air contains about 78.08% of nitrogen (N_2), 21% of oxygen (O_2), 0.04% of carbon dioxide (CO_2) and remaining other gases. A reduction in the concentration of O_2 and/or an increase in CO_2 concentration of the storage atmosphere surrounding fresh fruits and vegetables reduce the rate of respiration and also inhibits microbial and insect growth. The terms "controlled atmosphere" (CA) and "modified atmosphere" (MA) mean that the atmospheric composition surrounding a perishable product is different from that of normal air. Concept of controlled atmosphere storage (CAS) of fruits and vegetables was given by J.Be'rard of France in 1821. However, commercial use of CAS grew out of the research of Kidd and West in 1917 on respiratory behaviour of fruits under modified atmospheres. It was applied commercially for the first time in 1927 for storage of fruits and vegetables. In-transit use of CA and MA has been developed much later, during 60's only. Both CA and MA commonly involve manipulation of CO_2, O_2 and N_2 levels.

The principle of CA or MA involves the complete or partial removal of air from the storage are and its replacement with a single gas or mixture of gases by either passive or active methods. Passive modification is a slow process. It requires reactions between the fruit or vegetable and its surrounding gases to take place, and the package to play the role of a regulator. On the contrary, active modification is faster and can be achieved by gas flushing, vacuum application or by using gas scavengers / emitters. Passive MA relies on the selective permeability of the packaging materials to different gases and on product respiration and is traditionally used with fresh and minimally processed fruits and vegetables. Gas-flush MA involves the establishment of a specific gas composition within the package in a single stage during the packaging operation, by flushing with the selected gas mixture before sealing. Depending on the desired residual O_2, a vacuum operation may be needed prior to gas flushing. The gas mixture used is dependent on the type of fruit or vegetable. MA differs from CA only in how precisely gas partial pressures are controlled; CA is more precise than MA. When combined with chilling, CA or MA are increasingly important methods of maintaining high quality in processed foods during an extended shelf life. The following are some types of atmosphere-modification techniques:

a. Atmosphere Generation

Oxygen partial pressures can be reduced by purging with nitrogen, burning, using catalytic converters, or using silicone membranes. Water, lime, and molecular sieves have all been shown to be effective scrubbers for removal of CO_2. Pressurized cylinders or dry ice can be used for addition of CO_2 into the holding chamber. Carbon monoxide can also be added from pressurized cylinders.

b. *Hypobaric (Low-Pressure) Systems*

Hypobaric storage is a type of CA storage in which a product is held under a partial vacuum. By reducing the normal atmospheric pressure in the ambient environment around the commodity, the effective partial pressures of individual ambient gases are also lowered. For example, a one-fifth reduction in the total pressure of normal air would result in an effective oxygen partial pressure (oxygen tension) equivalent to 4% O_2. In addition to lowering the partial pressure systems allow gases to escape more rapidly. This is due to the fact that the diffusion coefficients of various gases, including ethylene and other volatiles are inversely proportional to atmospheric pressures.

c. Commodity-Modified Atmospheres

In this particular approach an actively respiring and metabolizing product reduces the O_2 an increases the CO_2 in the ambient air within a chamber in which various barriers and restrictions to gas exchange exist. Ethylene and CO_2 scrubbers are used when either of these components is considered harmful to the commodity. When a plant material is put in a CA/ MA chamber, composition of cellular environment also changes due to Devaux effect. Devaux effect defines that due to difference in concentration gradient of gases on the two sides of membrane, diffusion of gases from the higher concentration side to the lower concentration side take place till equilibrium is attained. It is caused by difference in concentration gradient of gases on the two sides of membrane. Diffusion of gases from higher concentration side to the lower concentration side takes place till equilibrium is attained. CO_2 from the tissues of plant and O_2 from the external environment to the tissues occur. Rate of diffusion of CO_2 is much faster than that of O_2. Commodity modified atmosphere can be attained by using various techniques such as wax coating, by putting plastic covers with diffusion windows, manipulation of shipping containers or vehicles, applying polythene liners in shipping containers, packaging in film wraps and using air-tight cold storage rooms. The barriers can be created by commodity itself, or using package or storage rooms.

7.1.3 Benefits of CA storage

- Very low levels of O_2 (<2%) and high CO_2 level (≥60%) can control insects.
- A considerable decrease in respiration rate, in climacteric maximum, accompanied by an expansion of both pre-climacteric and post-climacteric period.
- Reduction in effect of C_2H_4 due to its interaction with O_2 and hence delay in development and appearance of the symptoms of senescence.
- Increased flesh firmness due to inhibition of enzymes responsible for damage of cellular membrane, at high CO_2 level.
- High turgidity and hence more juicy & crisp fruits.,
- Superior sensory and nutritional quality.
- A limited degradation of chlorophyll resulting in greater colour stability.
- Some physiological disorders, such as chilling injury, spot, decay, browning, water core and scald are greatly reduced.
- Mould growth is low due to less O_2 and high CO_2.
- Longer storage life.

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Lesson 8

POST HARVEST PROCESSING-II

8.1 Introduction

Fruits and vegetables are important constituents of our diet and they serve as a vehicle of nutrients like vitamins, minerals, sugars and fiber. However, being harvested from farm or field they are prone to contain dirt, soil, bacterial contamination, extraneous matter making them unfit for direct consumption by consumers. Hence, processing interventions are necessary to make fruits and vegetables free from all the above mentioned materials. Also, their processing is required to increase their shelf life as well as to prepare a number of value added products from them. Fruits and vegetables are processed by various methods like low temperature, thermal treatment, concentration, freezing and irradiation. But prior to subjecting fruits and vegetables to such treatments, all fruits and vegetables undergo some preliminary operations. Each processing method is based on certain principles and each has its own advantages and disadvantages.

8.2 Post Harvest Preliminary Processing Operations

The preliminary processing operations of fruits and vegetables are sorting, grading, washing, peeling, sizing, blanching, etc. The importance of each operation is discussed below.

8.2.1 Sorting and grading

Sorting and grading are terms which are frequently used interchangeably in the food processing industry, but strictly speaking they are distinct operations. Sorting is a separation based on a individual physical properties of raw materials such as weight, size, shape, density, photometric property, etc. while grading is classification on the basis of quality incorporating commercial value, end use and official standards. The selection of fruits and vegetables is important from processing point of view for the manufacture a particular end product. The fruit should be ripe, but firm and evenly matured while vegetable should be tender and reasonably free from soil, dirt, etc. They should be free from blemishes, insect damage and malformation. Over ripe fruit is generally infected with microorganisms and would yield a poor quality finished product. After this preliminary sorting, the fruits and vegetables are graded. This is necessary to obtain a pack of uniform quality as regards size, colour, etc. It is done manually or with the help of grading machines.

8.2.2 Washing

The graded fruits and vegetables are washed with water in different ways, such as soaking and subsequent washing in running water or sprayed with water or dry air to remove surface adhering material. A thorough wash is very essential for improved microbiological quality of final product. Vegetables may preferably be soaked in a dilute solution (0.1%) of potassium permanganate or sodium hypochlorite solution to disinfect them. Agitation of the washing water is effected generally by means of compressed air or a force pump or propeller-type equipment. Among all, spray washing is the most efficient method.

8.2.3 Size reduction

Fruits and vegetables are processed either as whole or into small pieces by size reduction. Size reduction involves peeling, coring and sizing. Peeling is done to remove unwanted or inedible material and to improve the appearance of the final product using a peeler (Fig. 8.1) while coring is done to remove central inedible portion using a corer (Fig. 8.2). There are five main methods of peeling. They are flash peeling (e.g. for root crops), knife peeling (e.g. for citrus fruits), abrasion peeling (e.g. for potato), caustic peeling (e.g. for guava, orange segments) and flame peeling (e.g. onion and garlic). Some of these are given below:

a. Hand peeling

Many of the fruits and vegetables are peeled and cut by hand with the help of special knives.

b. Peeling by heat

Some fruits and vegetables, particularly certain varieties of peaches and potatoes, are scalded in steam or boiling water to soften and loosen the skin, which is subsequently removed easily by hand. It usually involves exposing the fruit or vegetable to a temperature of $40^\circ C$ for 10-60 seconds where by the skin bursts and retracts facilitating its easy removal by means of pressure sprays. To achieve good results, the fruits and vegetables should be of uniform size and maturity. Using this method, there is practically no loss of flavour and the product is of uniform colour, free from any blemishes.

c. Lye peeling

Fruits and vegetables such as peaches, apricots, sweet orange, carrots, sweet potatoes, etc. are generally peeled by dipping them in boiling caustic soda or lye solution of 1 to 2 percent strength, for short periods, ranging from 0.5 to 2 minutes depending on the maturity of the fruit or vegetable. The hot lye loosens the skin from the flesh underneath. The peel is then removed easily by hand. Any traces of alkali is removed by washing the fruit or vegetable thoroughly in running cold water or preferably by dipping it for a few seconds in a very weak solution of hydrochloric or citric acid.

d. Flame peeling

It is used only for garlic and onion which have a papery outer covering. This is just burnt off.

Fig. 8.1 Fruit peeler

Fig. 8.2 Pineapple corer and its use

8.2.4 Blanching

Blanching refers to the mild heat treatment given to fresh produce such as vegetables to inactivate enzymes. Polyphenol Peroxidase (PPO) is most important groups of enzymes causing browning, off-flavour development in fruits and vegetables. PPO cause oxidation of phenolic compound namely Catechin, Gallic acid, Chlorogenic acid and Caffeic acids. Besides PPO certain peroxidase and pectic enzymes are also require inactivation. Pectic enzymes such as Pectin methyl esterase (PME) and Polygalacturonase (PG) are highly meat resistance and if failed to inactivate may lead to loss of cloud in citrus juices and serum separation in fruits and vegetables products, respectively. Their inactivation is the index of blanching. Blanching also improves colour, flavour and nutritional quality. Usually it is done with boiling water or steam for short periods, followed by cooling. In small scale industries, the fruit or vegetable to be blanched is placed in a wire of perforated basket, which is first dipped in hot water (88-99□ C) for about 2-5 minutes. Microwave treatment is also used for blanching. Blanching requirement varies with different fruit or vegetable and depends upon relative enzyme concentration and maturity of commodity.

8.2.5 Ripening

Ripening before processing may be required for certain fruits such as avocado, banana, kiwifruit, mango, nectarine, papaya, peach, pear, plum, melons, etc. that are picked immature. Ethylene treatment can be used to obtain faster and more uniform ripening. The optimum temperature range for ripening is 15-25□ C and within this range, the higher the temperature the faster the ripening. Relative humidity should be maintained between 90 and 95% during ripening. About 10 ppm ethylene in enclosed chamber is sufficient to initiate ripening. Ethylene is produced by the reaction between calcium carbide with moisture, mainly those involved in trade of fruits to hasten the ripening process. However, indiscriminate application may pose serious health hazards.

Commercially ethephon is used for the pre-harvest ripening of top fruits, soft fruits, tomatoes and coffee. It is also used to facilitate the harvest of fruit and berry crops (by loosening the fruits) and to accelerate post-harvest ripening. It is essentially a plant growth regulator with systemic properties. It penetrates into the tissues and is translocated. It decomposes into ethylene which is the active metabolite.

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Module 3. Processing of Fruits and Vegetables

Lesson 9

CANNING AND OTHER METHODS OF THERMAL PROCESSING

9.1 Introduction

In continuation of the previous lesson, the reader would now be introduced to some of the other post harvest processing operations of fruits and vegetables such as canning, osmotic dehydration, etc.

9.2 Canning

The process of sealing fruits and vegetables or any other foodstuffs hermetically (air tight) in containers and sterilizing them by heat for long storage is known as canning. In 1904, Nicholas Appert of France invented this process and he is called as "Father of Canning". The process of canning is also known as Appertization. Fruits and vegetables are canned in the season when the raw material is available in plenty. The canned products are sold in off-season and give better returns to the grower. The process flow diagram for canning is given in Fig. 9.1. Most of the preliminary operations of canning such as selection of the raw material, washing, sorting and grading, blanching have already been discussed in previous lesson and hence not repeated.

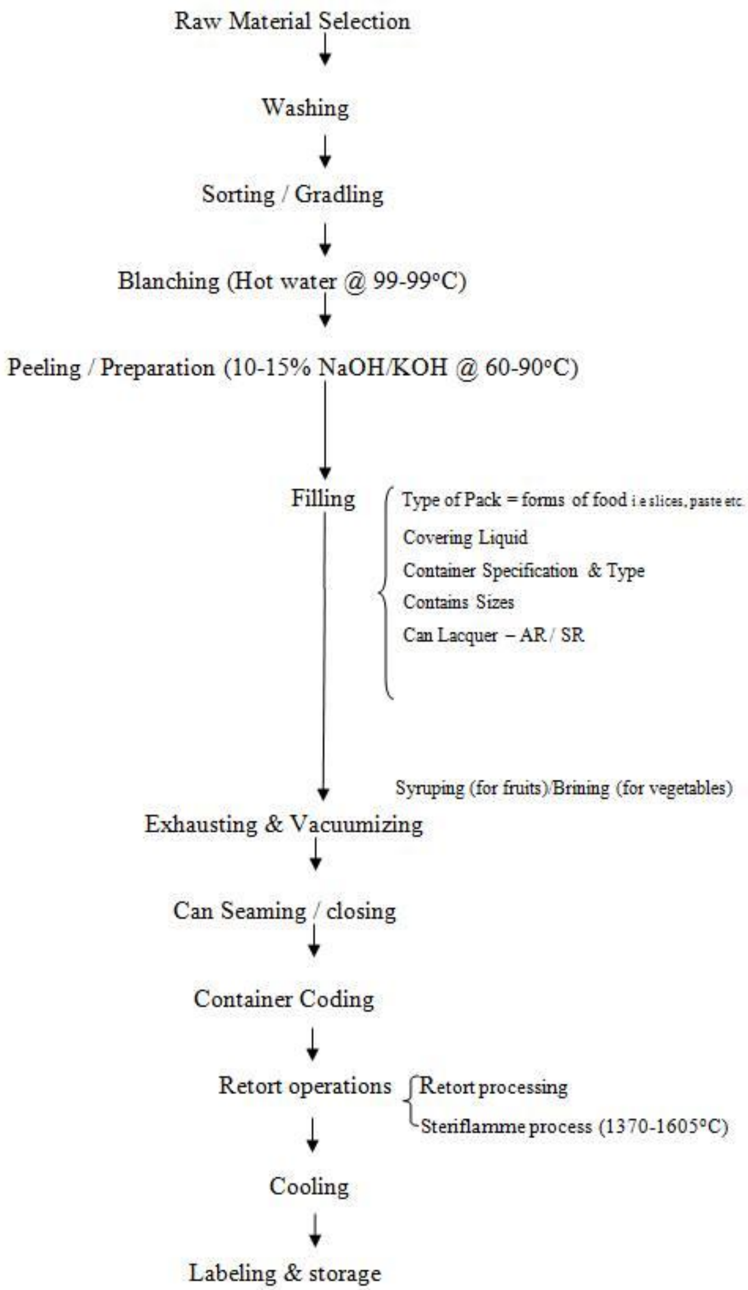

Fig. 9.1 Flow diagram for the canning process of fruits and vegetables

9.2.1 Can filling

Can filling is the process of aseptically filling whole or sized fruit or vegetables into the containers. The cans are washed with water or subjected to steam jet to remove any adhering dust or foreign matter. Tin cans made of thin steel plate of low carbon content, lightly coated on either side with tin metal to a thickness of about 0.25 mm are usually used in canning. The thickness of coating varies from 0.31 mm to 1.54 mm. The following are the different types of base plates used for can manufacture:

- Type L: It is a high purity steel with low metalloid and residual content. This kind of base plate is used for highly acidic foods.

- Type MR: It is a low metalloid steel with no severe restriction on residual content. It is used for moderate acid foods.
- Type MC: It is similar to MR type but has high phosphorus content to give mechanical strength or stiffness. It is usually used for low acid foods.

9.2.1.1 Lacquering

It is difficult to coat steel plate uniformly with tin during the process of manufacture. Small microscopic spaces are always left uncoated, although the coating may appear perfect to the naked eye. The content of the can may react with the exposed parts of container and cause discolouration of the product or corrosion of the tin plate. When the corrosion is severe, the steel is attacked and black stains of iron sulphide are produced. Hence, it is necessary to coat the inside of the can with some material like lacquer, which would prevent discolouration, but would not impart its own flavor or injure the wholesomeness of the contents. The process of coating of inner side of the can to prevent discolouration of the product is called as lacquering. Lacquers include oleo-resinous material, synthetic resins, phenolic resins, epoxy resins and vinyl resins. There are two types of lacquers: (a) acid resistant and (b) sulphur resistant. The acid-resistant lacquer is ordinary gold coloured enamel and the cans treated with it are called as A.R-enamel cans. The sulphur-resistant lacquer is also of golden colour and the cans coated with it are called C-enamel cans or S.R. cans. Acid-resistant cans are used for packing of fruits of the acid group with soluble colouring matter such as raspberry, strawberry, red plum, coloured grapes, etc. Sulphur-resistant cans are used for non-acid products like peas, corn, beans, etc.

9.2.2 Syruping and brining

In canning, syrups are added to fruits whereas brine (salt solution) is added to the vegetables. Purpose of adding syrups or brine is to improve the flavor, fill the space between the pieces of canned product and aid in the heat transfer during sterilization. Cane sugar, glucose syrup, invert sugar and high fructose corn syrups are used for canning. Brine containing 1 to 2 percent of common salt is generally used for vegetables. Strength of syrup is measured by using hydrometer or a refractometer while strength of brine is measured by salometer or salinometer. The syrup or brine should be added to the can at a temperature of about 90 C, leaving suitable headspace in the can.

9.2.3 Exhausting

Exhausting usually means heating the can and can contents before sealing. Sometimes it is may also refer to the treatment of the container under a mechanically produced vacuum. But in either case it is done to remove air from the can interior and prevent corrosion. It also prevents undue strains upon the can during sterilization and prevents overfilling of can contents. Removing of air also helps in better retention of vitamins especially of vitamin C. The other advantages of the exhaust process are prevention of bulging of the can when stored at high altitudes or in hot climates. In heat exhaust method, the cans are generally passed through a tank of hot water at about 92-97 C or on a moving belt through a covered steam box. The time of exhaust varies between 5 to 25 minutes. After exhausting cans are immediately sealed with the help of double rolling operation of seamer.

9.2.4 Processing of the cans

The term “processing” as used in canning technology, means heating of canned foods (fruits, vegetables and other food stuffs) to inactivate bacteria. This is also called as “retorting”. Processing consists of determining just the temperature and the extent of cooking that would suffice to eliminate all possibilities of bacterial growth. In retort, saturated steam is supplied to heat the product. Time-temperature combination of processing depends upon the type and physical state of the product, the heat resistance of microorganisms or enzymes likely to be present in the food, the heating conditions, pH of the food, and size of the can to get complete sterility. In low acid foods (pH > 4.5), *Clostridium botulinum* is the most dangerous heat resistant spore forming pathogen likely to be present. Under anaerobic conditions inside a sealed can it can grow to produce a powerful exotoxin, botulin, which is sufficiently potent to be 65% fatal to humans. Because of the extreme hazard from botulin, the destruction of this microorganism is therefore a minimum requirement of heat processing (i.e. in canning and sterilization). Normally foods receive more than this minimum treatment as other more heat-resistant spoilage bacteria may also be present. In more acidic foods (pH 4.5 – 3.7), other microorganisms (e.g. yeast and fungi) or heat-resistant enzymes are used to establish processing times and temperatures. In acidic foods (pH < 3.7), enzyme inactivation is the main reason for processing and hence, heating conditions are less severe. The preservative effect of heat processing is due to the denaturation of proteins, which destroys enzyme activity and enzyme-controlled metabolism in microorganisms.

The rate of destruction is a first-order reaction; that is when food is heated to a temperature that is high enough to destroy contaminating microorganisms, the same percentage die in a given time interval regardless of the number present initially. This is known as the logarithmic order of death and is described by *thermal death rate* curve (Fig. 9.2). The time needed to destroy 90% of the microorganisms (to reduce their numbers by a factor of 10) is referred to as the decimal reduction time or ***D-value***. D-values differ for different microbial species (Table 9.1) and a higher D-value indicates greater resistance. The thermal destruction of microorganisms is temperature dependent and cells die more rapidly at higher temperature. By collating D-values at different temperatures, a *thermal death time* (TDT) curve is constructed (Fig. 9.3).

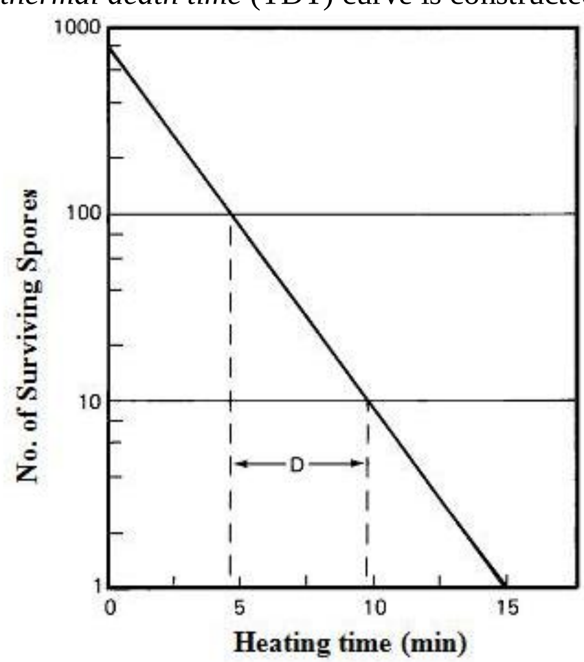

Fig. 9.2 Thermal Death Rate curve

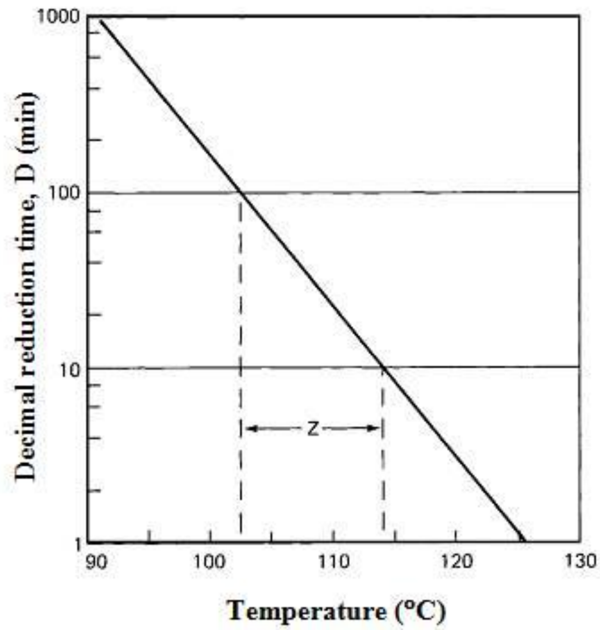

Fig. 9.3 Thermal Death Time curve

The thermal death time or ***F-value*** is used as a basis for comparing heat sterilization procedures. F-value is the time required to achieve a specified reduction in microbial numbers at a given temperature and it represents the total time-temperature combination received by a food. The slope of the TDT curve is termed the ***z-value*** and is defined as the number of degrees Celsius required to bring about a 10-fold change in decimal reduction time. F-value is quoted with suffixes indicating the retort temperature and the z value of the target microorganism. For example, a process operating at 110° C based on a microorganism with a z-value of 10° C would be expressed as F^{10}_{110}. Hence, D-value and z-value are used to characterize the heat resistance of a microorganism and its temperature dependence, respectively while F-value is used for comparing sterilizing procedures.

Table 9.1 Heat resistance of some spore-forming bacteria used as a basis for heat sterilization of low-acid foods

Microorganism	z-value (^{0}C)	D_{121} value (min)	Typical foods
Thermophilic (35-55° C)			
Bacillus stearothermophilus	9 – 10	3.0 – 4.0	Vegetables, milk
Clostridium thermosaccharolyticum	7.2 – 10	3.0 – 4.0	Vegetables
Mesophilic (10-40° C)			
Clostridium sporogenes	9.9 – 11.1	0.7 – 1.5	Meats
Bacillus subtilis	4.1 – 7.2	0.3 – 0.76	Milk products
Clostridium botulinum toxins A and B	5.5	0.1 – 0.3	Low-acid foods
Bacillus coagulans	6 – 9	0.01 – 0.07	Milk
Bacillus cereus	36	3.9	Milk
Psychrophilic (-5 to -1.5^{0}C)	10	3.0 (60^{0}C)	Low-acid foods

9.2.4.1 Rate of heat penetration in processing

Heat is transferred from steam or pressurized water through the container and into the fruit or vegetable or any other canned food. The heat transfer patterns in canned foods are given in Fig. 9.4. The rate of heat penetration is measured by placing a thermocouple at the thermal centre of a container (the point of slowest heating) to record temperatures in the food during processing (Fig. 9.5). It is assumed that all other points in the container receive more heat and are therefore adequately processed. The zone of slowest heating in a container is called as ***cold point***, which is most difficult to sterilize. In cylindrical containers the thermal centre is at the geometric centre for conductive heating foods and approximately one third up from base of the container for convective heating foods (Fig.9.6).

The important factors that influence the rate of heat penetration into a food are given below:

- **Type of product** – Liquid or particulate foods (for example peas in brine) in which natural convection currents are established heat transfers faster than in solid food in which heat is transferred by conduction (for example pastes or purees). The low thermal conductivity of foods is a major limitation to heat transfer in conduction.
- **Size of the container** – Heat penetration to the centre is faster in small containers than in large containers.
- **Agitation of the container** – End-over-end agitation and to a lesser extent, axial agitation increases the effectiveness of natural convection currents and thereby increases the rate of heat penetration in viscous or semi-solid foods (for example beans in tomato sauce).
- **Temperature of the retort** – A higher temperature difference between the food and the heating medium causes faster heat penetration.
- **Shape of the container** – Tall containers promote convection currents in convective heating.
- **Type of container** – Heat penetration is faster through metal than through glass or plastics owing to differences in their thermal conductivity.

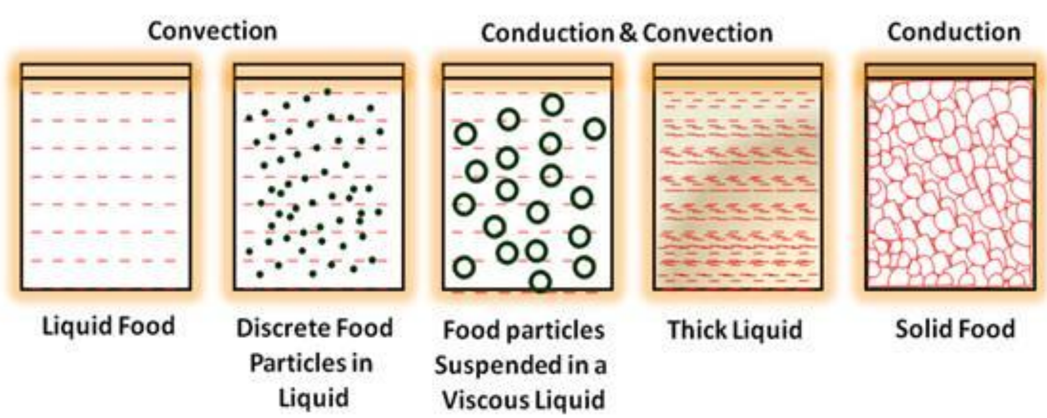

Fig. 9.4 Heat transfer pattern in canned foods

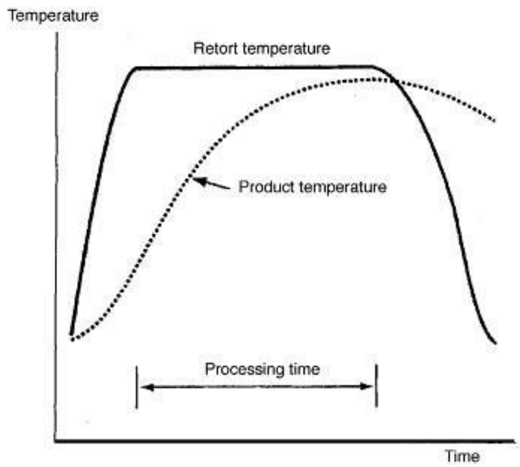

Fig. 9.5 Heat penetration into a can of conductive heating food

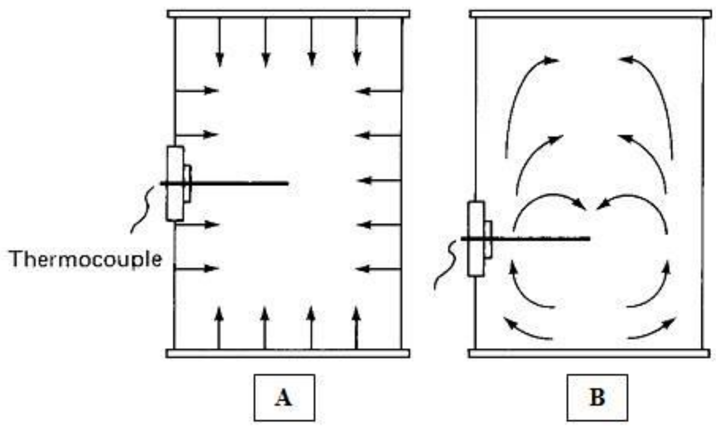

Fig. 9.6 Heat transfer into containers by conduction (A) and convection (B)

9.2.5 Cooling

Immediately after processing, cans are cooled to room temperature in cold water bath or water tank. Once cooling is carried out, the outer surface is dried and labeled.

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Lesson 10

FREEZING: PRINCIPLE, METHODS AND APPLICATIONS

10.1 Introduction to Freezing

Freezing preservation is one of the most beneficial preservation methods. It involves, conversion of liquid content of food into ice crystals, which lowers down water activity and microbial growth is arrested due to cold shock. Pure water is frozen at 0^0C but since fruits and vegetables contain number of dissolved solids like sugars, acids, they freeze at below 0^0C.

10.2 Process of Freezing

During freezing the commodity cools down below their freezing point but don't freeze this phenomenon is called as ***super cooling***. It is shown by AB phase of curve (Fig. 10.1). At super cooled storage nuclei formation (***nucleation***) which is the first and most important step in ice-crystal formation in in freezing process. Here the temperature of water will be lower than 0^0C but it will remain in liquid form. At this stage, further lowering of temperature result in the formation of ice crystals. The second step is called ***crystal growth stage***. The release of heat of crystallization further enhances temperature (BC). Since food molecules contain substantial amount of soSlute hence, a progressive freezing occurs as depicted in Fig. 10.1. Various water molecules gathers around nuclei and due to subsequent addition, crystal growth occurs. Nucleation may be either due to chance orientation of molecule or due to induction of nuclei from outside, but in fruits & vegetable mostly chance nucleation occur. In next step, crystal growth around these nuclei occurs and as a result of ice-crystal formation, heat of crystallization is generated, which cause increase in temperature of commodity. This T_{es} is shown by BC lines. So, time taken by freezing curve from initial cooling to E point of curve is known as ***thermal arrest time***. It determines how quick or slow freezing process is. After this point more ice crystal formation takes place and temperature lowers down.

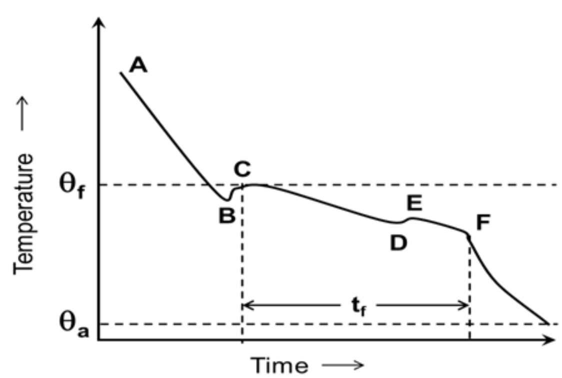

Fig. 10.1 Schematic diagram of freezing process

10.3 Advantages of Freezing

- No nutrient loss
- Retain freshness of commodity.
- Retain colour and flavor constituents.
- No microbial contamination.
- No respiration, hence longer shelf-life.

10.4 Effect of Freezing

Freezing process is divided into two broad categories *viz*. slow freezing and quick freezing.

a. ***Slow freezing***: when thermal arrest time is more than 30 min.
b. ***Quick freezing***: Thermal arrest time is less than 30 min.

In slow freezing, less number of nuclei is formed and as a result of slow freezing more concentrated solution is left in inter-cellular spaces which causes osmotic effect and liquid comes out from cells. This affects turgidity of cell and they collapse and on thawing cannot regain their original shape. Also, crystals forms are larger in size and pierce the cell membrane, puncture it and damage the cells. Whereas in quick freezing large numbers of nuclei are formed, hence having large numbers of crystals of smaller size evenly distributed within the cell and in the intercellular space. Since process is very quick, hence no concentration effect occur and commodities retain their original shape.

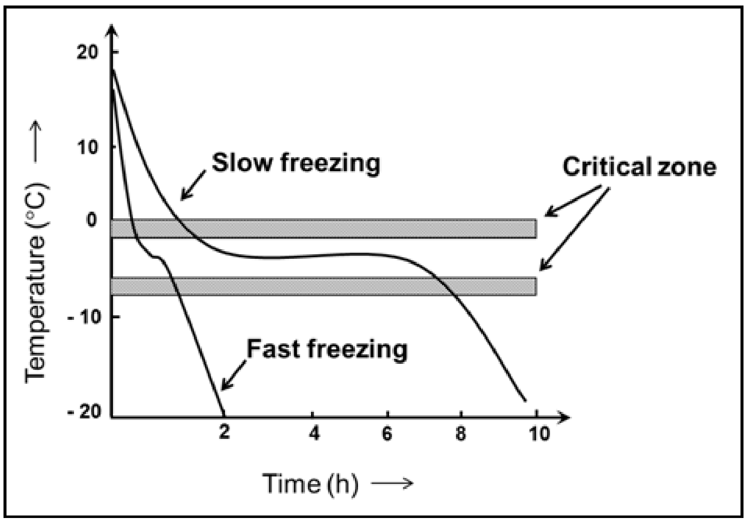

Fig. 10.2 Schematic diagram of temperature changes of food through the critical zone during freezing process

10.5 Freezing Methods

Mode of heat transfer in freezing food product is convection. Following points should be considered while selecting a freezing method:

a) Product dimension
b) Shape
c) Specific heat
d) Thickness of pieces

e) Freezing rate
f) Packaging
g) Food product components.

10.5.1 Air freezing

This is an oldest method of freezing and utilizes cool air having a temperature of -18 to -40°C as freezing method. Different types of air freezing are:

a) Tunnel freezing
b) Fluidized bed Freezing
c) Air blast freezing

Air-blast freezers recirculate air over foods at between -30°C and-50°C at a velocity of 1.5-6.0 ms^{-1}. The high air velocity reduces the thickness of boundary air films. Air flow is either parallel or perpendicular to the food and is ducted to pass evenly over all food pieces.

Air freezing may result in

- Excessive drying
- Costly
- More efficient & more rapid heat transfer
- Less product dehydration & less frequent requirement of frosting.
- Short freezing time so less moisture loss.

10.5.2 Plate freezing

Packaged or fresh commodities are placed over the surface of plate cooled by refrigerant in a cylindrical scraped – surface heat exchanges. Double plates are specially used in retail storage. Plate freezing is a slow freezing process and packages must be of uniform thickness.

10.5.3 Liquid immersion freezing

Certain liquids are used as refrigerant which are known as cryogens. Example: Liquid Nitrogen, Liquid NO_2, Liquid Ammonia, etc.

10.5.4 Cryogenic freezing

Freezers of this type use a change of state in the refrigerant (or cryogenic) to absorb heat from the freezing food. The heat provides the latent heat of vaporization or sublimation of the cryogen. The cryogen is in intimate contact with the food and rapidly removes heat from all surfaces to produce high heat transfer coefficients and rapid freezing. The two most common refrigerants are liquid nitrogen and solid carbon dioxide. The main advantages of cryogenic freezing are as follows:

- Short freezing time due to high heat transfer
- Reduction in flavor loss
- Reduction in drip loss
- Reduction in oxidative changes
- Improved texture of the product

- Suitable for freeze sensitive products

The main disadvantage of cryogenic freezing is relatively high cost of cryogens.

10.6 Changes Associated With Ice Formation

10.6.1 Volume changes

The volume of ice is 9% greater than pure water when water is transformed into ice at 0°C, and hence upon freezing there is expansion of foods. However, few exceptions also exist. For example, highly concentrated sucrose solution. The degree of expansion depends upon (a) composition, (b) fraction of water that fails to freeze, and (c) temperature range.

- ***Moisture*** High moisture contents in foods produce greater changes in volume.
- ***Cell arrangement in fruits and vegetables*** Fruits and vegetables have intercellular air spaces which absorb internal increases in volume without large changes in their overall size.
- ***Concentration of solutes*** High concentrations reduce the freezing point and foods do not freeze or expand at commercial freezing temperatures.
- ***Freezer temperature*** It determines the amount of ice and hence the degree of expansion.
- ***Temperature range*** Observed changes depend upon the temperature range to which food product is exposed.

  a. Cooling of the specimen: contraction
  b. Ice formation: Expansion
  c. Cooling of ice-crystals: contraction
  d. Solute crystallization: contraction

- ***Crystallized components***: These include ice, fats and solutes, contract when they are cooled and this reduces the volume of food.

10.6.2 Concentration of non-aqueous system

During freezing water freezes first. So nearly all the dissolved substances are therefore concentrated in the diminished quantity of water. So in some manner it is similar to dehydration. Unfrozen phases have changed physico-chemical properties like pH, titrable acidity, ionic strength, viscosity, freezing point, or potential. Dissolved gases will be removed/expelled from the space. Water structure & water-solute interaction may be drastically increased, macromolecules will come together and many detrimental reactions may occur. As freezing progresses, concentration of a particular solute increases and eventually reaches or exceeds their respective saturation concentration crystallization.

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Lesson 11

DRYING: PRINCIPLE, METHODS AND APPLICATIONS

11.1 Introduction

Drying and dehydration of fruits and vegetables is an age old method to preserve these products. Removal of the water (75-90%) present in fresh commodity results in reduction in the water activity and ultimately resistance against most of the deteriorative agents. The removal of water is carried out by the application of heat and this heat is usually supplied in the form of solar energy or artificially generated hot air. Removal of moisture and exposure of heat often results in poor textural attributes, loss in nutritive value (vitamins), discolouration and loss of flavouring components. Although both drying and dehydration are interchangeably used, drying is referred to removal of water to an equilibrium moisture content while dehydration is removal of water to an almost bone dry condition.

A number of processing steps are carefully designed to check all these adverse effects of drying. Some of the new technologies have been introduced in recent years to produce a wholesome and nutritive product. Partial dewatering by osmosis and impregnation soaking process before drying saves energy during drying and improves quality of dried product. Osmotic dehydration is gaining popularity, as the dehydrated product is more stable during storage due to low water activity by solute gain and water loss. The low water activity resulted in fewer rates of chemical reactions avoiding deterioration of the food. Osmotic dehydration in many cases is employed to increase sugar to acid ratio of acidic fruits, thereby to improve the taste, texture and appearance of dried product. The processing steps involve in drying of fruits and vegetables are summarized here.

11.2 Why Drying of Foods?

- Water activity is defined as the ratio of vapour pressure of food to that of the vapour pressure of pure water at a constant temperature. Reduction in water activity (a_w) so control/check over chemical and microbiological changes (deterioration).
- Reduction in weight, size and volume of food material. Hence bulk transportation becomes easier and cheaper.
- Packaging requirements are simple and cheap.
- Facilitate further processing. Example: grain drying for flour.

11.2.1 Water content in foods

Water is present in food as free or/and bound water. **Free water** is defined as water within a food that behaves as pure water. Unbound water is removed during the constant rate period of drying, when the nature of food does not have a great effect on the drying process.

Bound water can be defined as water that exhibits a lower vapour pressure, lower mobility and greatly reduced freezing point. So, bound water molecules have different kinetic and thermodynamic properties than ordinary water molecules. The a_w as affected by the extent of bound water is given in Table 11.1:

Table 11.1 Water activity as affected by the extent of bound water

Extent of bound water	Water activity (a_w)
Tightly bound water	< 0.3
Moderately bound water	0.3 to 0.7
Loosely bound water	> 0.7
Free water	~ 1.0

11.3 Mechanism of Drying

When hot air is blow over a wet food, heat is transferred to the surface and latent heat of vaporization causes water to evaporate. Water vapours diffuse through a boundary film of air and is carried away by the moving air. This create a region of lower water vapour pressure gradient is established from the moist interior of the food to the dry air. The gradient provides the "**driving force**" for water removal from the food.

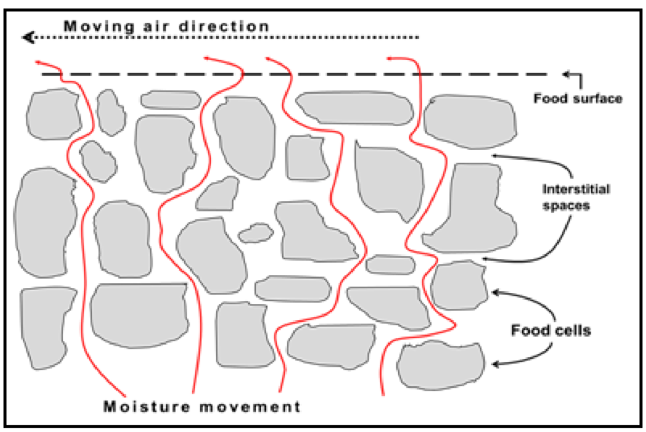

Fig 11.1 Schematic diagram of movement of moisture in the interstitial spaces of food cells during drying in fruits and vegetables

1. Liquid movement by capillary force.
2. Diffusion of liquids, caused by concentration gradient.
3. Diffusion of liquids, which are absorbed in layers at the surfaces of solid components of the food.

4. Water vapour diffusion in air spaces within the food caused by vapour pressure gradients.

11.3.1 Phases of drying

1. Initial warm up period
2. Constant drying rate period
3. Falling drying rate period

In hygroscopic food material more than one falling rate period occurs. In the first period plane of evaporation moves inside the food and water diffuses through the dry solids to the drying air. It ends when plane of evaporation reaches to the centre of food and the partial pressure of water falls below the saturated water vapourpressure. Second falling rate period occurs when the partial pressure of water is below the saturated vapour pressure and the drying is by desorption. Falling rate period is the longest period during drying of food product. **Equilibrium moisture content** (EMC) occurs when dry spots develop at the surface so less area exposed to dry air and evaporation decreases.

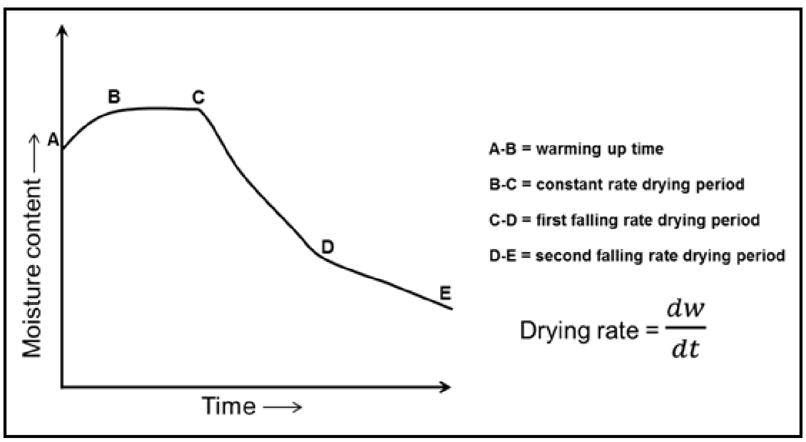

Fig 11.2 Schematic diagram of change in moisture content with time (drying rate)

There are 4 resistances to heat transfer in drying:

1. Resistance to external heat transfer
2. Resistance to internal heat transfer
3. Resistance to external mass transfer
4. Resistance to internal mass transfer

11.4 Drying Time

Drying time is the total time required for removal of water from food material. Drying time ***during constant rate period*** is inversely proportional to wet bulb depression while drying rate is directly proportional to wet bulb depression.

$$\text{Drying time (t)} = \frac{(w_i - w_t) \times \rho_s \times L \times d}{h \times (T_a - T_w)}$$

where, w_i = initial moisture content, w_t = moisture content at time t, ρ_s = bulk density of solid, L = latent heat of vapour, d = thickness of material, h = surface heat transfer coefficient, T_a = dry bulb temperature of hot air, T_w = wet bulb temperature of air, $(T_a\text{-}T_w)$ = Wet bulb depression

If velocity of air is increased, *h* and hence drying rate will increase and drying time is decreased.

Total drying time is the time required to attain critical moisture content ($w_t = w_C$)

Drying time ***during falling rate period*** is decided by predominantly by diffusion and to some extent by capillary action.

$$\text{Drying time (t) due to diffusion} = \frac{4\,d^2}{\pi^2\,D}\, ln\left(\frac{8}{\pi^2}\left(\frac{w_c - w_e}{w - w_e}\right)\right)$$

where, D = liquid diffusivity

w_e = equilibrium moisture content

$$\text{Drying time (t) due to capillary} = \frac{\rho \times d \times L \times (w_c - w_e)}{h \times (T_a - T_w)} \times ln\left(\frac{w_c - w_e}{w - w_e}\right)$$

if, $w_i < w_c$ it is falling rate

$w_i > w_c$ it is constant rate

11.5 Factors Affecting Drying Rate

The factors that affect drying rate are external and internal factors.

The external factors are:

- Dry bulb temperature
- Relative humidity
- Air velocity
- Surface heat transfer coefficient

Internal factors are:

- Surface to volume ratio
- Surface temperature
- Rate of moisture loss
- Composition i.e. moisture, fat

11.6 Effects of Drying on Foods

11.6.1 Shrinkage

During drying as moisture is removed and food material becomes smaller in size. This also affects bulk density (weight per unit volume) of food material. Slow drying results in development of internal stress. These rupture compress and permanently distort the relatively rigid cells, to give the food a shrink / shrivelled appearance. Such food material on rehydration absorbs water more slowly. Gelatinization of starch, denaturation of proteins, and crystallization of cellulose also affect rehydration characteristics. Rapid drying improves textural characteristics such as wettability, sinkability, dispersibility and solubility.

11.6.2 Case hardening

Formation of impervious layer over the surface of a dried food product characterized by inner soft and outer hard layer resulting in inadequate drying. It always occurs in food products rich in solutes and when initial drying temperature is very high. During the initial high temperature solute particles comes out and deposit at the surface resulting of building up of an impermeable layer which prevents further moisture removal. It can be prevented by using lower drying temperature.

11.6.3 Browning

Browning refers to change in the colour of food material to light to dark brown colour. This change in colour may occur by any of the three methods given below.

- Residual enzymatic browning: the residual enzymes especially in vegetables such as polyphenol oxidases cause oxidation that result in the change of colour.
- Maillard's reaction: it is the reaction between the amino group of proteins and reducing sugars of carbohydrates in presence of heat. This type of browning is most common in dried foods.
- Caramelization: it is the conversion of sugars only into dark coloured compounds in presence of heat.

11.7 Types of Drying

a. Hot Air drying: It includes spray drying, tray drying, fluidized bed drying, etc. In spray drying a fine dispersion of pre-concentrated food (40-60% moisture) is "atomized" to form fine droplets and then sprayed into a co-or counter-current flow of heated air at 150-300 C in a large drying chamber. Tray driers consist of an insulated cabinet fitted with shallow mesh or perforated trays, each of which contains a thin (2-6 cm deep) layer of food. Hot air is blown at 0.5-5.0 m/s through a system of ducts and baffles to promote uniform distribution over and/or through each tray.

b. Microwave drying: It involves use of microwaves.

c. Freeze drying: It is also known as "lyophilization" and is usually used for drying heat sensitive food material by freezing the material and then reducing the surrounding pressure to allow the frozen water to sublimate directly from the solid phase (ice) to gas phase (water vapour).

f. Osmotic drying: This is explained in section 11.8

11.8 Osmotic Dehydration

Osmotic dehydration, also called as dewatering and impregnation soaking (DIS) process, was pioneered by James D. Ponting in 1966. It is a water removal process that involves the soaking of foods – mostly fruits and vegetables in hypertonic salt or sugar or in a combined solution, to reduce the water content while increasing the soluble solid content. Osmotic dehydration is undertaken to reduce the product water activity in minimal processing, which is carried out either at atmospheric pressure or at vacuum conditions. The raw material is placed in concentrated solutions of soluble solids with higher osmotic pressure and lower water activity. Water moves through the selective permeable membrane with much greater ease than in the dissolved substances.

11.8.1 Mechanism of osmotic dehydration

In osmotic dehydration process, a solid product of high moisture content is immersed in a concentrated solution (mainly of sugar or salt), which initiates three types of counter-current mass transfer. The diagrammatic presentation of osmotic dehydration is given in Fig. 11.3.

- Water outflow from the product to the surroundings solution as a result of osmosis through a semi-permeable membrane.
- Solute transfer, from the solution to the product.
- Leaching out of the water-soluble component along with water from the product to the solution.

The last two mass transfers occur mainly because of diffusion. This counter current mass flow is due to the water and solute activity gradients across the cell's membrane. This process continues till the osmotic potential on two processes reaches equilibrium. In an ideal osmotic solution a semi-permeable membrane would be permeated by the solvent molecules but not by the solute molecules. In fruits and vegetables, the cell wall membranes are living biological units and selective permeable, which can stretch and expand under the influence of growth and turgor pressure generated inside the cells. These cellular membranes, which are composed mainly of parenchymatous cells, freely allow the solvent molecules to pass through, but they also allow, to a lesser degree, the passage of some of the solute molecules. Such membranes are called as differentially permeable, rather than semi-permeable. Osmotic dehydration may result in 40-50% decrease in initial volume, if properly performed.

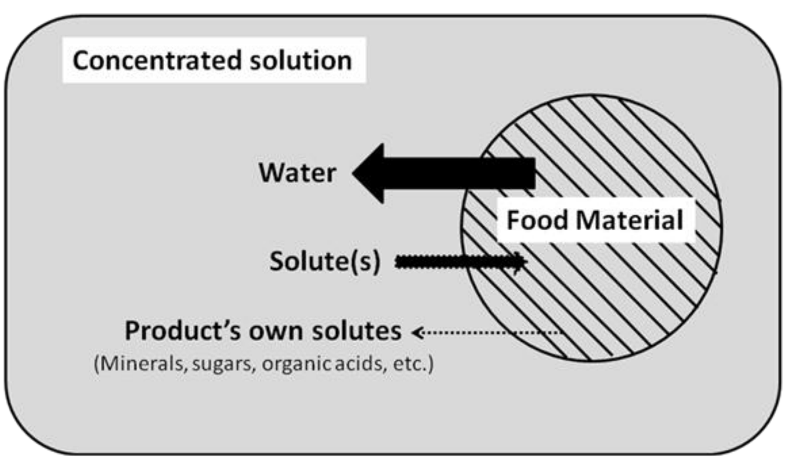

Fig.11.3 Diagrammatic presentation of Osmotic Dehydration

11.8.2 Osmotic agents and their requirements

Osmotic agent must have lower water activity (a_w), good solubility, constant concentration during processing, and it should be cheap. However, non-toxicity, inertness to food constituent and good sensory attributes is other added attraction, while selecting any osmotic agent. These are number of compounds available, satisfying above mentioned criteria, like, sucrose, glucose syrups, invert sugar, corn syrups, honey, and humectants such as sorbitol and glycerol. The kind of sugar utilized strongly affects the kinetics of water removal, and by increasing the molecular weight of osmotic substance, larger water removal could be achieved with little uptake of solutes. Low molecular weight substances (glucose, fructose, sorbitol etc.) favour the sugar uptake because of the high velocity of penetration of the molecules so that solid enrichment instead of dehydration is the main effect of the process. Sodium chloride (NaCl) is an excellent osmotic agent for vegetables and other animal derived products, but its use with fruits is restricted because of alteration in taste and bleaching of colour. Addition of NaCl to osmotic solution increased the driving force for drying owing to the a_w lowering capacity of salt. Synergistic effects between sugar and salt have also been observed. The use of blends comprising two or more solutes seems to be an attractive alternative.

11.8.3 Factors affecting osmotic dehydration

In any type of food product, many mechanisms can be acting at the same time, the relative contribution of which depends upon the following:

1. Nature of the product
2. Processing temperature
3. Operating conditions such as osmosis, diffusion, flux interactions and shrinkage.

11.9 Manufacturing Steps Involved In Drying of Fruits And Vegetables

11.9.1 Selection of raw material

The major cost involve in drying operation is the price of raw material. Hence good quality raw material is of prime importance. Immature or over mature fruits and vegetables often result in poor quality product. For example over mature green peas result in less sweet and starchy dried product with poor rehydration characteristics. Similarly high specific gravity fully mature potatoes with low reducing sugar content are desirable because they are large, mealy and less prone to browning or yellowing during dehydration.

11.9.2 Washing

Before further processing raw materials should be thoroughly washed to remove the adhering dirt, dust and other foreign particles. On commercial scale raw material is dumped in large tanks for some time and then sprayed with a jet of water. Alternatively, it may cleaned in a stream of running water. Water for this purpose must be of potable quality. To remove the traces of pesticides, colouring material commonly used nowadays to impart shining; some of the chemicals like dilute acids may also be added in washing water. Addition of sanitizers like chlorine based compounds is permitted to certain level for washing purpose. These sanitizers improve the microbiological quality of the finished product.

11.9.3 Peeling, trimming and sizing

Fruits and vegetables are either dried as whole or undergo size reduction before drying. A number of peeling processes are available on commercial level. Trimming is done to remove unwanted parts. Sizing is done to develop uniform product and it also facilitates subsequent unit operation. Increase in surface area causes faster drying.

11.9.4 Pre-treatments

In order to improve the quality of finished product fruits and vegetables they are invariable subjected to many pre-treatments. Some of the pre-treatments are summarized here.

11.9.4.1 Checking

Checking is an operation in which fruits specially raisins, prunes are dipped for a brief period in hot solution of alkali. This cause removal of waxy layer and it also improve the drying rate.

11.9.4.2 Blanching

Blanching is mild heat treatment given to some fruits and majority of vegetables primarily to inactivate the naturally occurring enzymes. These enzymes belong toperoxidase group like polyphenol peroxidases that catalyze the oxidation of phenolic substances, resulting in production of brown coloured compounds. The cell wall degrading enzymes, catalase (off-flavour), and ascorbic acid oxidase also get inactivated during blanching process. Blanching improves the colour of dried products, it aids to rapid reconstitution of dried product, it also increase drying rate, it also expels dissolved oxygen and it also improve bacteriological quality of the finished product.

11.9.4.3 Sulphiting

Sulphur dioxide and sulphites (usually sodium metasulphite or potassium metabisulphite) are well known anti-browning agents. The sulphur dioxide gas competes withperoxidases for the active sites and prevents the oxidation of phenolic substances. In many products that contain anthocyanin as major pigment, the colour of the product turned blue when exposed to acidic conditions. In such fruits or vegetables sulphur dioxide treatment may prove beneficial. The blanched or checked fruits or vegetables are exposed to fumes of sulphur dioxide by burning sulphur powder in an enclosed chamber. This is most widely used method of sulphuring. However, they can be dipped in solution of some sulphur salt. Proper penetration of sulphur dioxide is important to prevent internal darkening during drying. In fuming process, the sulphur dioxide absorption is faster as compared dipping. However the absorption is more uniform in later.

11.9.5 Drying

Drying of the fruits and vegetables is usually carried out in cabinet dryer. The material is loaded over perforated aluminium trays and dried using hot air. The temperature, velocity and the humidity of the air are important for drying process. It usually varies from commodity to commodity. A lower drying temperature is generally used for fruits, as there may be chances of case hardening. The temperature varies from 55-80^{o}C. To create perforation initially temperature is maintained towards higher side and them it is reduced. Some vegetables those are light, cylindrical or spherical like peas are dried in fluidized bed dryer. This improves the rehydration characteristic and the nutritive value of the product, as it take lesser time and more uniform drying.

11.10 Some Common Processes Used for Drying of Fruits and Vegetables

11.10.1 Drying of some vegetables

11.10.1.1 Drying of Onion

Onion is bulbous crop characterized by pungent flavour, attractive colour and high amount of reducing sugar. It an important seasoning item for traditional Indian cuisines. The demand for onion has increased considerably over the years because of its unique flavour profile and well established medicinal and therapeutic properties. To meet the demand of consumers, the onions are processed in various convenient forms as paste, dried slices powder, etc. The flow diagram represents the various unit operations involved in drying of onion.

Medium to large sized onion bulbs

(High solids, higher amount of pungency and pigments)

↓

Peeling

↓

Slicing 5 mm thickness

↓

↓

Dipping into 5% salt solution for 30 min or warm water (70°C) for 1 min. with stirring

at regular interval and then dipped in starch solution for 30 min at room temperature

↓

Drying in cabinet dryers at 60°C for 10 h
(final moisture about 4-4.5%)

↓

Blending in grinder

↓

Sieving with 30 mesh size

↓

Packaging in 400 gauge low density polyethylene

↓

Storage at low temperature 7°C at 80% RH

11.10.1.2 Drying of Cauliflower

Cauliflower contains protective nutrients and small quantities of major nutrients. The storage life of cauliflower is 2 to 4 weeks at 0^{o}C. However, the preservation of cauliflower is possible by canning, freezing, drying and pickling.

During drying or canning, white cauliflower is turned to pink or brown discolouration, which seriously affects the acceptability. The pigmentation of cauliflower is attributed mainly due to the presence of leucoanthocyanidins. The discolouration can be checked by addition of 0.05% citric acid and 0.03% ascorbic acid. Blanching treatment of cauliflower containing 0.075% sodium metabisulphite and 0.25% sodium sulfite followed by dipping in 20% glycerol or sugar syrup resulted in a superior dried product of pale white colour with superior rehydration characteristics.

Cauliflower heads

↓

Washing thoroughly

↓

Cutting into small pieces

↓

Blanching in boiling water for 6 min

↓

Dipping into 2.5% starch solution containing 0.75% sodium metabisulphite and 0.25% sodium sulfite for 15 min

↓

Straining

↓

Drying in a cabinet dryer at 70 $\pm$ 1°C till 4% final moisture

↓

Packaging in polyethylene bags
With air tight sealing

↓

Storage at 15 to 25°C

11.10.2 Drying of fruits

Perceived as a "value-added" ingredient, dried fruit adds flavour, colour, texture and diversity with little alteration to an existing formula. The growing interest in dried fruits and the change to a more healthy way of eating has also moved dried fruits considerably closer to the mainstream.

Found primarily in the baking industry, dried fruits is coming into its own in various food products, including entrées, side dishes and condiments. Compotes, chutneys, rice and grain dishes, stuffings, sauces, breads, muffins, cookies, deserts, cereals and snacks are all food categories encompassing dried fruit.

Since some dried fruits is sugar infused (osmotic drying), food processors can decrease the amount of sugar in formula – this is especially the case in baked products. Processors are making adjustments in moisture content of the dried fruits so that a varied range is available for different applications. An added bonus is dried fruits' shelf stability (a shelf life of at least 12 months). Dried fruit is more widely available in different forms, including whole dried, cut, diced and powders.

11.10.2.1 Drying of Apple

Uniform size apples, discard undersize apples (< 2.5'' diameter)

↓

Washing or spray of dilute acid (remove pesticide residues) followed by second washing with clean water

↓

Peeling and coring

↓

Slicing or Dicing (0.5'' slice or 0.25''dice)

↓

Sulfuring (immersing in 0.5% sodium bisulphate solution or by burning sulfur for 2-3 hours, gas concentration must be 2%)

↓

Dehydration (Two stage, first drying at 80°C & 25% RH and second at 70°C & 10% RH

↓

Cooling and grading

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Module 4. Fruits and vegetables juice processing

Lesson 12

GENERAL STEPS IN JUICE PROCESSING

12.1 Fruit Juice Processing

Juice and juice products represent a very important segment of the total processed fruit industry. Juice products are being marketed as refrigerated, shelf-stable, and frozen, in a variety of packages with increased emphasis on functionality, health attributes, new flavors or blends, and in some cases fortified with vitamins and minerals. High-quality juice operations are dependent upon a source of high-quality raw material.

Most fruit juices are excellent sources of vitamin C, several are good sources of carotene and many contain moderate amounts of pyridoxine, inositol, folic acid and biotin. Fruit juice is regarded as source of energy due to their rich carbohydrate content. The organic acids present in the fruit juice plays a significant role in the maintenance of the acid-base balance in the body.

The process starts with sound fruit, freshly harvested from the field or taken from refrigerated or frozen storage. Thorough washing is usually necessary to remove dirt and foreign objects and may be followed by a sanitation step to decrease the load of contaminants. Sorting to remove decayed and moldy fruit is necessary to make sure that the final juice will not have a high microbial load, undesirable flavors, or mycotoxin contamination. For most fruits, preparation steps such as pitting and grinding is required prior to juice extraction. Heating and addition of enzymes might also be included before the mash is transferred to the extraction stage. Juice extraction can be performed by pressing or by enzymatic treatment followed by decanting. The extracted juice will then be treated according to the characteristics of the final product.

For cloudy juices, further clarification might not be necessary or may involve a coarse filtration or a controlled centrifugation to remove large insoluble particles. For clear juices, complete de-pectinization by addition of enzymes, fine filtration, or high speed centrifugation is required to achieve visual clarity. The next step is usually a heat treatment or equivalent non-thermal process to achieve a safe and stable juice and final packaging if single-strength juice is being produced. For a concentrate, the juice is fed to an evaporator to remove water until the desired concentration level is obtained. Other processes used for water removal include reverse osmosis and freeze concentration, which are best suited for heat-sensitive juices. The concentrate is then ready for final processing, packaging, and storage.

The generalized flow chart for preparing fruit juice is shown in Figure 12.1.

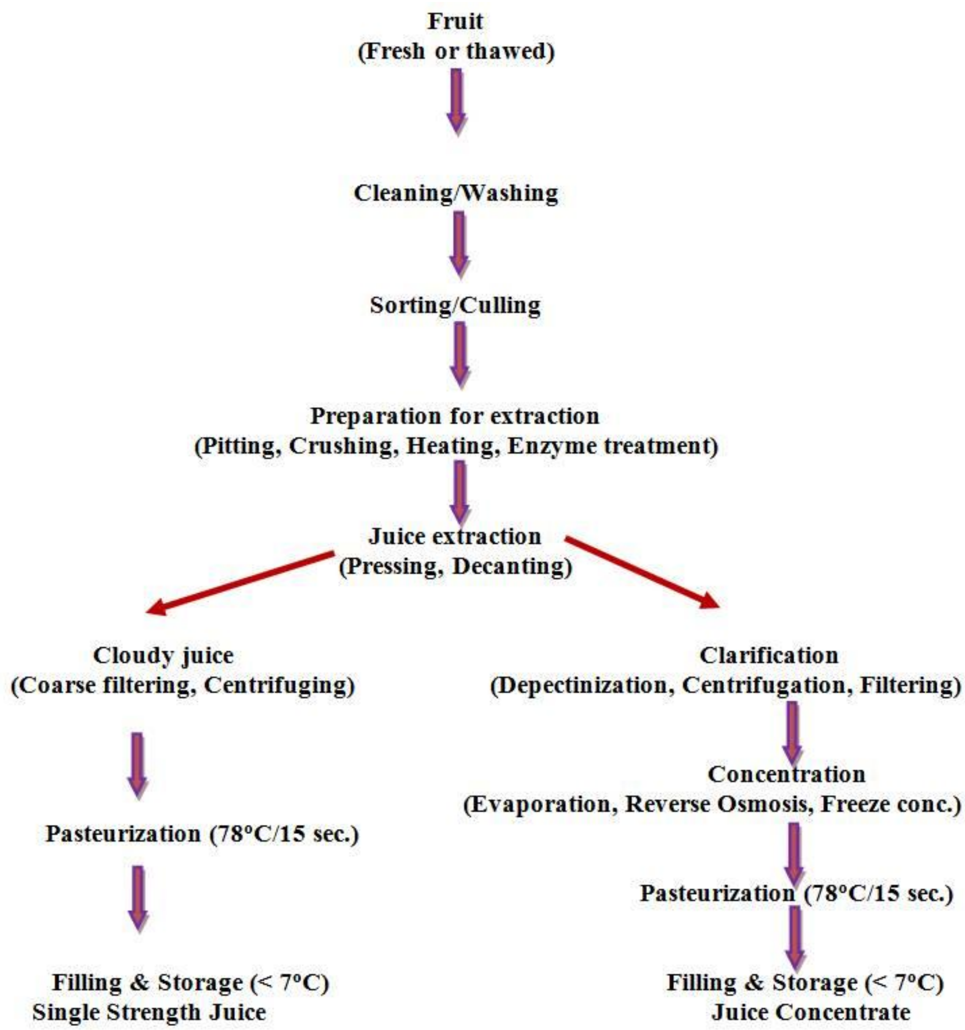

Fig.12.1 Generalized flow chart for fruit juice production

12.2 Significance of Few Important Steps in Fruit Juice Production

12.2.1 Straining/Filtration/Clarification

- Extracted fruit juice contains varying amount of suspended solids – broken fruit tissue, seed, skin & various gums, pectic substances and proteins in colloidal suspension.
- Coarse particles removed by straining (non-corrodible metallic screens) or sedimentation.
- If clear juice required (grape, apple, lime juice cordial) complete removal of all suspensions effected through filtration or clarification with the help of fining agents and enzymes.
- Fining agents (i) Enzymes (pectolytic, starch liquefying, proteolytic), (ii) Mechanical finings (Infusorial earth), (iii) Chemical finings (Gelatin, albumin, casein).
- Apple juice – 0.5-1.5 oz. of tannin and 1.5-6.0 oz. of gelatin per 100 gal. of juice – fining purpose.

12.2.2 Disintegration

Juicing process starts with crushing, a step to break down the cell tissue. This may be accomplished using various type of mills viz., hammer mill, grinding disk mill, grating mill, crushers, stoned fruit mill or even turbo extractors.

12.2.3 Hot break process

In order to maximize juice yield and color-flavour extraction, a hot break process is often used.

12.2.4 Mash enzyme treatment

This step might not be used for the production of high quality, single-strength, cloudy and clear

juices, where the preservation of the fresh flavor is imperative. Depectinization is designed to reduce the viscosity and slipperiness of the pulp and thus permit the effective use of decanters and presses with proper press aids as needed. It is especially useful in processing mature and stored fruit that results in low juice yield.

12.2.5 Fruit juice extraction process

Hydraulic rack and frame press is the most common batch press system used in small scale operations. Other type of extractors include horizontal piston press, bladder press, belt press, screw press or even decanter centrifuge.

12.2.6 Deaeration

Pure orange juice which is extremely susceptible to the adverse action of the residual air, is subjected, immediately after extraction, to a high vacuum whereby most of the air as well as other gases are removed.

12.3 Role of Enzymes in Fruit Juice Extraction

The use of enzymes in juice industry has contributed in increasing the yield and production of various types of juices. The addition of pectinases aims in particular to degrade the pectic substances, in the cell wall and middle lamella of the cells of plants, aiming to minimise the impacts of these compounds on the characteristics of the final product, such as colour, turbidity and viscosity.

Enzymes are also able to remove bitterness of citrus juice, extract pigments, among other applications, and have also had great interest in the juice industry.

12.3.1 Pectinase, cellulase and hemicellulase

Pectinases, cellulases and hemicellulases are used for clarification of fruit juices, juice extraction, improvement of cloud stability of vegetable and fruit juices and nectars, liquefaction and maceration of fruits and vegetables, reduction of cooking time of pulses and improvement of rehydration characteristics of dried vegetables.

These enzymes degrade structural polysaccharides that interfere with juice extraction, filtration, clarification and concentration. These enzymes are termed ‘macerating or mash enzymes’ that finds application in extraction of juice from citrus fruits and from tropical fruits such as mango, banana and papaya and pineapple. For Apple and Pears, pectic enzymes are used to facilitate pressing or juice extraction, to aid in separation of flocculent precipitate by sedimentation, filtration or centrifugation.

Combination of pectinolytic enzymes are added to fruit and pressed fruit juice to reduce juice viscosity. Such viscosity reduction makes juice filtration, clarification and concentration more efficient. In concentrated fruit systems, it improves the efficiency of spray drying.

Aspergillus niger and *A. oryzae* produces mixture of pectinolytic enzymes.

12.3.1.1 Pectinases

The two well recognized types of pectolytic enzymes are pectinesterase and polygalacturonase, the actions of which is shown below:

$$\text{Pectin} \xrightarrow{\text{pectinesterase}} \text{Methanol + Polygalacturonic acid}$$

$$\text{Polygalacturonic acid} \xrightarrow{\text{Polygalacturonase}} \text{Galacturonic acid}$$

Most commercial pectinase enzymes are mixtures of these and probably other enzymes. Commercial pectolytic enzyme preparations containing predominantly polygalacturonase (PG) and pectin and pectate lyase (PLs) are utilized.

Liquefaction is accomplished using both pectolytic and cellulolytic enzymes in combination, taking advantage of observed synergistic effects.

Pectins are colloidal in nature, making solutions viscous and holding other materials in suspension. Pectinesterase removes methyl groups from the pectin molecules exposing carboxyl groups which in the presence of bi- or multivalent cations, such as calcium, form insoluble salts which can readily be removed. At the same time, polygalacturonase degrades macromolecular pectin, causing reduction in viscosity and destroying the protective colloidal action so that suspended materials will settle out.

Extensive use of pectolytic enzymes is made in processing fruit juices. Addition of pectic enzymes to grapes or other fruits during crushing or grinding results in increased yields of juice on pressing. Wine from grapes so treated will usually clear faster when fermentation is complete, and have better color.

Pectic enzymes are necessary for making high density fruit juice concentrates or purees. If apple juice is concentrated to 72^{o}Brix without removal of the naturally occurring pectin, a gel will result rather than the desired liquid concentrate. In most cases, juices are depectinized and filtered before concentration, but in others the pectinase is allowed to act while the juice is being concentrated.

12.3.1.2 Cellulases

Commercial cellulase products capable of hydrolyzing nonpectin polysaccharides such as cellulose, glucans, and xylans are used to fractionate the cell walls and liquefy the remaining solids.

12.3.1.3 Naringinase and Limoninase

Naringinase and Limoninase have been used to hydrolyze naringin and limonin – the bitter compounds that are found in grapefruit juice.

12.3.1.4 Amylase and Arabinase

Starch and araban imparts a cloudy appearance called ‘haze’, when released into the juice from certain fruits. Hazes due to starch are common in juice from early season apples and can be degraded by amylases.

Although araban is not a problem in extracted juice, it produces a permanent haze in concentrated juices, where it has limited solubility. Arabinase can be used to hydrolyze araban so that haze does not develop during storage of juice concentrates.

12.4 Clear Fruit Juice

Juices extracted from ripe fruit contain a significant amount of pectin. Pectin imparts a cloudy appearance to the juice and results in an appearance and mouth feel that many consumers do not find appealing. Pectinases are naturally occurring enzymes that act on pectin yielding a crystal clear juice with the appearance, stability, mouth-feel, taste, and texture characteristics preferred by consumers. While pectinases naturally occur in most fruits used to make juice, the manufacturer often adds more to produce clear juice in a reasonable amount of time.

Most consumers prefer clear fruit juices. The cloud, such as in fresh Cider, is usually material held in suspension by pectin and filtration is difficult. The safest way to accomplish pectin removal without affecting color or flavor is to treat the juice with a pectic enzyme. Juice for jelly manufacture is frequently depectinized since more uniform jelly can be achieved when a standard amount of pectin is added in controlled amounts. The variable quality and quantity of the natural pectin in the juice does not interfere when it is treated with pectinase enzyme.

12.5 Benefits in the use of enzymes

- Increased juice yield
- Improved efficiency of juice filtration
- Improved juice stability and concentration
- Enhanced juice clarity
- Reduced juice bitterness

12.6 FSSAI specifications for various fruit juices

Table 12.1 FSSAII specifications for various fruit juices

No.	Juice type	TSS (%), Min.	Acidity expressed as citric acid (%), Max.	Nutritive Sweetener(g/kg), Max.
1.	Apple Juice	10	3.5 (as malic acid)	-
2.	Orange Juice			
	a) Freshly expressed	10	3.5	50
	b) Reconstituted from concentrate	10	3.5	-
3.	Grape Fruit Juice	9	-	50
4.	Lemon juice	6	4.0 Min.	200
5.	Lime juice	-	5.0 Min.	200
6.	Grape Juice			
	a) Freshly expressed	15	3.5	
	b) Reconstituted from concentrate	15	3.5	-

7.	Pineapple Juice a) Freshly expressed b) Reconstituted from concentrate	 10 10	 3.5 3.5	 50 -
8.	Black Currant	11	3.5	200
9.	Mango, Guava or any other pulp fruit	15	3.5	GMP
10.	Other fruit juices of single species (not very acidic)	10	3.5	50
11.	Other fruit juices of single species (very acidic)	10	3.5	200
12.	Other fruit juices of single species or combination thereof (not very acidic)	10	3.5	50
13.	Other fruit juices of single species or combination thereof (very acidic)	10	3.5	200

12.7 Problems encountered during fruit juice processing

Some of the problems that may be faced in preparation of fruit juices are:

- Browning of juice due to action of enzyme Poly phenol oxidase inherent in fruit (i.e. Apples).
- Foaming of fruit juice that may lead to oxidation of vitmin C and pose problem during filling of juice in packages.
- Bitterness of juice due to action of enzyme limonin and naringinase (e.g. in Orange).
- Cloudy juices due to pectinaceous substance (apple juice) or even bitartrates (i.e. argol precipitation) (i.e. in grape juice).

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Lesson 13

EQUIPMENTS AND METHODS OF EXTRACTION, CLARIFICATION AND PRESERVATION

13.1 Introduction

In order to prepare fruits and vegetable juices at commercial level, several equipments are needed. Some of the important equipments required for processing of specific fruit and vegetables are discussed herein.

13.2 Pome Fruit and Small Fruit Processing

Generally, most pome fruit (e.g. Apple, Pear, Quince) and small stone fruit (e.g. Plum, Olive, Peach, Cherry) can be used for juice extraction. No peeling is needed. Small stone fruit such as apricots and plums might have to be destoned (pitted) depending on the grinding–extraction equipment selection. Cherries, although containing a pit, may be pressed with the pit intact. Breakage of the pit will release benzaldehyde, the familiar aroma of maraschino-type cherries.

13.3 Disintegration

The juicing process starts with the crushing step to break down the cell tissue. Grain sizes of 5 - 8 mm diameter are recommended for presses, while grain sizes of 3 - 5 mm are desirable for decanters.

13.3.1 Hammer mills

These are devices used to crush the whole fruit in preparation for pressing. Hammer mills consist of heavy stainless steel bars spinning from a common axis under high-speed rotation. The fruit is disintegrated until it passes out through a screen of a specific size mounted in the bottom of the mill. With firm fruit, a small screen size should be used, and the mash will be of a finer particle size. Mash from firm fruit will press more easily, and the smaller particle size will allow greater yields.

13.3.2 Grinding mills

They offer an alternative method to disintegrate fruit. The fruit was drawn past fixed knives mounted on a rotating cylinder. Control of the grind was accomplished by adjusting the depth of the knives and, thus, the size of the cut from the fruit.

13.3.3 Grinding disk mills

They offer more flexibility and improved performance. In the Bucher-Guyer unit, the fruit is transported by a feed screw to the grinding area. The screw pressurizes the fruit against a rotating disk equipped with grinding knives in a star pattern, and the milled fruit exits via an adjustable discharge slot. The process can be controlled by adjusting the feeder speed, the rotating speed of the grinding disk, the width of the product discharge slot (up to 10 mm), or by changing the knife size. Better yield is obtained by requisite adjustment corresponding to the fruit ripeness at the time of operation.

13.3.4 Grating mills

These mills are used in small juice operations to produce uniformly sized fruit pieces. Fruit is fed to a rotating–grating disk with fixed aperture, and the shredded fruit is discharged at the bottom. Fruit must be relatively firm with small seeds or pitted.

13.3.5 Stemmer/crushers

These crushers are used in grape juice processing to remove residual stems, leaves, and petioles from grapes and to perform the initial crush of the fruit. These units are designed around a perforated rotating drum, with holes ~ 2.5 cm in diameter. While traversing the rotating drum, the grapes are caught by the perforated drum and knocked from the stems. Individual grapes are broken open or crushed in the process and dropped through the drum. Stems, leaves, etc. continue on to the center of the drum and are discharged at the end for waste. Grapes are generally put through the crusher in order to gently express the juice and free up the flesh, yet still not break the seeds. Breakage of the seeds releases increased amounts of phenolics, adding to the astringency of the juice.

13.3.6 Stoned fruit mills

Such mills are used for plums and apricots to crush the fruit without breaking the stones to avoid juice flavor changes and storage instability. Hard rubber-lobed wheels rotate simultaneously, forcing the fruit down and separating most of the flesh from the intact stone.

13.3.7 Turbo extractors

These are used for extraction of juice and puree from fruits and vegetables. The cold extractor unit has a feeding section with a variable speed screw and a cutting head; a softening section consisting of a stator and rotor (roto-pulse); and an extraction area equipped with a rotor with paddles and a perforated cylindrical screen that continuously turns the product by centrifugal force (Figure 13.1). The extractor can be adjusted by changing the feeding speed, the rotor speed, the gap between the rotor and the screen, and the screen size. The fruit can be protected from oxidation by the injection of nitrogen gas or antioxidant solution to the cutting area through built-in openings.

Fig. 13.1 Turbo extractor

13.4 Hot Break Process

In order to maximize juice yield and color-flavor extraction, a hot break process is often used. The most common use is in grape juice processing, but other fruits such as cherries, plums, and berries may also benefit. Increased interest in highly colored juices, rich in phenolic compounds with associated health benefits, is driving the development of better techniques to preserve the functional components while maximizing the extraction. Typically crushed fruit or mash passes through a large bore, tubular heat exchanger where it is heated to 50 to 60^{o}C. This stage, known as the *hot break process,* is designed to extract a large amount of color and assist in maximizing the yield. To the hot fruit, a pectolytic enzyme is added, and in case of red grape juice processing, kraft (wood pulp) paper is also added prior to pressing to serve as a press aid.

The addition of press aid to the mash provides coarseness and channels for the juice to exit. Alternative press aids include rice hulls, bleached kraft-fiber sheets or rolled stock, and ground wood pulp. If the juice is going to be extracted by decanting or centrifugation, then there is no need for press aids.

13.5 Mash Enzyme Treatment

This step might not be used for the production of high quality, single-strength, cloudy and clear juices, where the preservation of the fresh flavor is imperative. Soluble pectin found in fresh juice as a result of the activity of pectolytic enzymes that are located in the fruit cell wall. The soluble pectin is the cause for difficulty in juice extraction due to increased juice viscosity and the lubrication it affords the press cake. Typically, the fruit mash is heated to 45 to 50^{o}C followed by the addition of pectolytic enzymes. Reaction time can take up to 1 - 2 h.

De-pectinization is designed to reduce the viscosity and slipperiness of the pulp and thus permit the effective use of decanters and presses with proper press aids. It is especially useful in processing mature and stored fruit that results in low juice yield. Several depectinizing tanks are employed so that a continuous flow may be maintained to the presses or decanters. Treatment of the mash with enzymes is expected to increase the yield, reduce the processing time, and improve the extraction of valued components of the fruit.

13.6 Fruit Juice Extraction Equipments

13.6.1 Rack and frame hydraulic press

The hydraulic rack and frame press is a very common batch press system found in small juice operations (Figure 13.2). Heavy cotton or nylon cloths are filled with a set amount of mash and then folded to produce what is called a *cheese*. The individual cheese is stacked and separated by a wooden, stainless steel, or plastic spacer platen. The combined stack is then compressed using a hydraulic ram, during which the juice is expressed. The process delivers good yield but is labor intensive.

Fig. 13.2 Hydraulic Rack and Frame Press

13.6.2 Horizontal piston press

One of the most successful press systems in the fruit juice market is the Bucher horizontal piston press, Switzerland. This press is capable of pressing berries, stone fruit, and vegetables. It operates in batch mode with loads of up to 14 t/filling. Flexible drainage elements covered with a nylon filter cloth carry the expressed juice out to a manifold.

The Bucher-Guyer Press is a highly automated pressing system used in a batch pressing operation. Generally, this system consists of a rotatable basket or cylinder with a hydraulic ram used for juice expression. Within the cylinder are fabric-covered flexible rubber rods with longitudinal grooves in them, that allow the juice to transport easily to the discharge port.

13.6.3 Bladder press

The Willmes Press is a commonly used system for grape juice pressing. It is a pneumatic-based system that consists of a perforated, rotatable, horizontal cylinder with an inflatable rubber tube (air bag) in the center. The cylinder is filled with grape mash through a door on the cylinder wall, which is rotated to the top position. After filling, the press is rotated to ensure even filling. During this rotation, the air bag is filled, creating the mash compression action. The bag is then collapsed, and the cylinder is rotated. The rotation and pneumatic compression of the mash is repeated many times with increasing air pressure.

13.6.4 Belt press

The continuous belt press is effective for grape and apple juice processing. In belt presses, a layer of mash is pumped onto the belt entering the machine. Press aid may be added for improved yield and reduced suspended solids. The belt is either folded over or another belt is layered on top of the one carrying the mash. A series of pressurized rollers compress the enveloped mash. Expressed juice is caught in drip pans. The cake is discharged from the last pressure roller.

13.6.5 Screw press

A typical screw press consists of a reinforced, stainless steel cylindrical screen enclosing a large bore screw with narrow clearance between the screw and the screen (Figure 13.3). Breaker bars are located between the screw intervals in order to disrupt the compressing mash. Back pressure is provided at the end of the chamber and is usually adjustable. Capacities for screw presses with diameters of 30.5 and 41.0 cm are 5,080 and 15,240 kg/h, respectively.

Fig. 13.3 Conical Screw Press

13.6.6 Decanter centrifuge

In addition to sieving technology, the separation of juice from the mash can be performed by sedimentation through increased gravity in a decanter. Centrifugal force is used to accelerate the settling of higher density insoluble particles present in the juice. Enzyme-treated mash is best suited for juicing by decanters, as the reduced viscosity and higher temperatures result in faster and more effective separation. The photograph of such decanter is furnished in Figure 13.4.

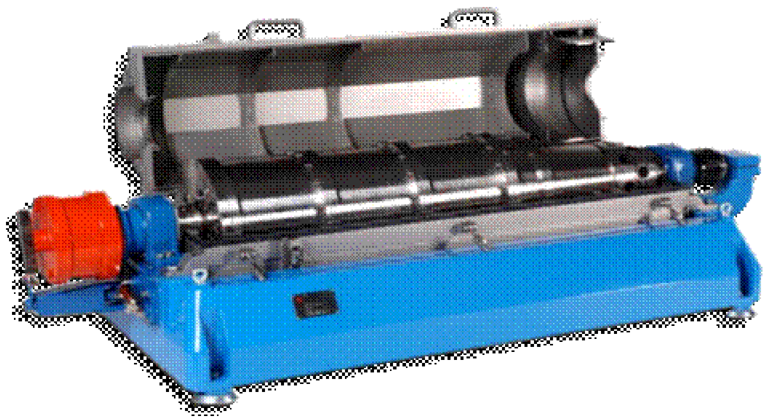

Fig. 13.4 Decanter centrifuge

13.6.7 Pulper cum finisher

The separation of liquid and solids is accomplished by means of paddles rotating concentrically within a cylindrical screen. The liquid and desired amount of solids passes through the screen. The balance of the solids (pomace) is discharged through a large non-plugging port. The dryness of the pomace with a given screen can be controlled by paddle speed, pitch, clearance, or feed rate. Production throughput is dependent on the type of product being prepared, screen hole size and open area, paddle speed and pitch. An inlet impellor for breaking or macerating is available as an optional accessory.

Diverse type of materials viz. apricots, tomatoes, pumpkin, pears, apple, plums, berries, prunes and figs can be satisfactorily reduced to pulp, free of seeds, skins and fiber. Products such as citrus juices, jam, soup, peanut butter, jelly and fruit nectar can be finished to uniform clarification consistency. The picture of such machine is shown in Figure 13.5.

Fig. 13.5 Pulper cum Finisher

13.7 Mechanical Separation

For clarification of juice, after the enzyme (Pectinase) treatment, the sedimentable particulates are separated by mechanical means. The equipments used for such process are as follows:

13.7.1 Decanters and finishers

A high-solids stream can be partially clarified using decanters and finishers. Both pieces of equipment operate on the same principle with a spinning central cone, drum, and set of paddles pushing the juice through a screen of some type. The unit is typically mounted horizontally, and throughput is relatively high. Total suspended solids may be reduced to $< 1\%$ during operation, depending upon the characteristics of the feed stream and operating conditions of the separator.

13.7.2 Centrifugation

It is used for removal of juice-insoluble solids. A centrifuge places the juice under high gravimetric force induced by centrifugal action. This is effective in producing a juice that is opaque but free of visible solids. Modern centrifuges are highly automated and run continuously with timed solids ejection. Centrifuges with a high force of gravity are capable of producing clear juice under optimized conditions. Centrifuge must be operated in a manner to minimize the introduction of oxygen in the product. Possible remedies include the use of inert gas.

13.7.3 Pressure filtration devices

13.7.3.1 Filter press

The cost is typically lower than other types of pressure filters. The system can be dismantled easily for inspection and cleaning. Filter cakes can be easily washed from the system once disassembling has progressed. In the filter press, the amount of unfiltered liquid is relatively low once the shutdown process is terminated.

13.7.3.2 Cylindrical element filter

In this system, tubular elements are suspended vertically in a closed tank system. Juice enters from the base of the system and filters through the elements, and the filtrate exits from the top of the system. Wash down and automation of this system are relatively straightforward.

13.7.3.3 Vertical leaf filter

It is a low-cost system because of the inherent simplicity of its design. It offers an easy cake removal system and can be automated. A modified version of the leaf filter is the horizontal tank vertical leaf filter that accommodates a very large area of filtration surface, up to 2000 ft^2 (180 m^2). Filter leaves can easily be removed, inspected, and repaired.

13.7.3.4 Rotating leaf filter

In this filter, the filtration elements are circular leaves suspended on a central axis. The leaves are rotated only during cleaning and discharging, which allows for an automated and rapid cake removal and clean-up system.

13.7.3.5 Horizontal rotating leaf filter

It is essentially identical to the vertical rotating leaf system, except that it is available in much smaller models.

13.8 Clarification of Fruit Juice

Consumers have a strong preference for clear juices. In order to have attractive appearance of finished fruit juice, especially for beverages like fruit juice cordial, clarification of juice is highly essential. Such clarification can be done by the help of centrifugation and use of pectinase followed by decantation. Filter aids such as Infusorial earth, bentonite helps in achieving better clarification of fruit juices. Ultrafiltration (UF) and microfiltration (MF) have been used commercially for the clarification of fruit juices. After extraction, the fruit juice after depectinization is fed to UF unit for clarification. If the juice contains strong colour, microfiltration can be suitable for avoiding colour losses.

Pre-centrifugation (10,000g for 15 min) of juice (especially cherry juice) before clarification is recommended.

13.9 Preservation of Fruit Juices

Traditionally, the shelf-life stability of juices has been achieved by thermal processing. Low temperature long time (LTLT – 63-65^{o}C/30 min) and high temperature short time (HTST – 72-90^{o}C/15-30 sec.) treatments are the most commonly used techniques for juice pasteurization. However, thermal pasteurization tends to reduce the product quality and freshness. Therefore, some non-thermal pasteurization methods have been proposed during the last couple of decades, including high hydrostatic pressure (HHP – pressures up to 1000 MPa with or without heat), pulsed electric field (PEF), etc. These emerging techniques seem to have the potential to provide “fresh-like” and safe fruit juices with prolonged shelf-life.

Apart from thermal pasteurization, some chemical preservatives are also widely used for the extension of the shelf-life of fruit juices and beverages. Two of the most commonly used preservatives are potassium sorbate and sodium benzoate. However, consumer demand for natural origin, safe and environmental friendly food preservatives has been increasing since 1990s. Natural antimicrobials such as bacteriocins, organic acids, essential oils and phenolic compounds have shown considerable promise for use in some food products. Natural antimicrobials such as *bacteriocins*, *lactoperoxidase*, herb leaves and oils, spices, chitozan and organic acids have shown feasibility for use in some food products. Some of them have been considered as Generally Recognized As Safe (GRAS) additives in foods. Bacteriocins are series of antimicrobial peptides which are readily degraded by proteolytic enzymes in the human body. Among them, nisin is the most commonly used food preservative that has been used to preserve fruit and vegetable juices.

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Lesson 14

PROCESSING OF SELECTED FRUIT JUICES-I

14.1 Introduction

Fruit are one of the most popular natural food that is highly nutritious and enticing. People are now craving for fruit juices/beverages in 'ready-to-drink' form. The shelf life of fruit is limited; they tend to decay with progress of ripening. Concentration of fruit juice, freezing, individual quick freezing, osmotic dehydration, dehydration to obtain fruit powders are some to the methods being used to counteract the limited shelf life of fruit. The fruit as slices/chunks/candied or even as juice/pulps/concentrates are used in food industry viz. ice cream, fruit yoghurt, fruit cakes, fruit bread, etc.

14.1.1 Classification of fruit juices

Food Safety and Standards Act (FSSAI) has laid down specifications for various types of fruit juice beverages including nectars (Figures 14.1 and 14.2).

Table 14.1 FSSAI specifications for various types of fruit beverages.

No.	Name of the product	Fruit juice/puree in the final product (%), Min.	Total Soluble Solids %, Min.	Acidity expressed as citric acid, Max
1.	Squash	25	40	3.5
2.	Crush	25	55	3.5
3.	Fruit Syrup/Fruit Sherbats	25	65	3.5
4.	Cordial	25	30	3.5

Table 14.2 FSSAI specifications for nectars.

Type of Nectars	**TSS (%), Min.**	**Fruit Juice Content (%), Min.**	**Acidity expressed as citric acid (%), Max.**
Orange Nectar	15	40	1.5
Grape Fruit Nectar	15	20	1.5
Pineapple Nectar	15	40	1.5
Mango Nectar	15	20	1.5
Guava Nectar	15	20	1.5
Peach Nectar	15	20	1.5
Pear Nectar	15	20	1.5
Apricot Nectar	15	20	1.5
Non-pulpy Black Currant Nectar	15	20	1.5
Other Fruit Nectars	15	20	1.5
Other Fruit Nectars of High Acidity/Pulpy / Strong flavour	15	20	1.5
Mixed Fruit Nectar	15	20	1.5

In this lesson we will be discussing Orange, Grapefruit, Lemon and lime juices.

14.2 Grapefruit – Botanical name - *Citrus paradise*

Two main varieties include :

1. White grapefruit – ‘Duncan’ and ‘Marsh’. The seedless Marsh is the most popular. The Duncan variety has best flavor.
2. Pink or pigmented grapefruit – ‘Red blush’ and ‘Star Ruby’ – both contains red pigment lycopene.

14.3 Lemon – Botanical name – *Citrus limon* (L).

Two varieties are very popular viz., ‘Eureka’ lemon and ‘Lisbon’ lemon.

Mesero lemon of Italy is best processing lemon in the world.

14.4 Lime – Three types – small fruited one is Citrus aurantifolia, large-fruited one is Citrus latifolia and Sweet lime is *Citrus limettoides*.

Indian lime is sweeter than other limes and popular in India and Pakistan.

Lime is greener in color than lemons, both on the exterior and interior of the fruit.

14.5 Production of Citrus juices

Washing and Grading of fruit

↓

Extraction of juice using Food Machine Corporation, USA (FMC) or Brown Extractors

↓

Large Reamers (Grapefruit), small Reamers (Lemon/Lime)

Pulp removal in two stages (Pulp content ~ 20% by volume)
Screening or Finishing
Or
Ultrafiltration to provide clarified product
Pass through Centrifuge – reduce juice pulp by < 3.0%

↓

Pass juice through Evaporator

↓

Oil Extraction
Desludger (8000-10000 rpm)
Separates slurry into 'oil-rich emulsion'
Removes > 90% of oil

↓

Discharge of concentrated oil emulsion

↓

Enzyme treatment, hold in tank for hours
Or
Placed in freezer, store for 30 days

↓

Use De-oiler centrifuge i.e. High speed centrifuge (Polisher)
(16000-18000 rpm, separates pure citrus oil) or partial distillation in vacuum
A Spinning Cone Column may be used

↓

Winterizing
Precipitates dissolved waxes

↓

Evaporation and Pasteurization
85-90°C for 30-40 sec (Grapefruit)
75-85°C/30 sec (Lemon)
90-98°C/60 sec (Orange)
Concentrate (60-65°Brix – Grapefruit)
Gram of equivalent citric acid/lit. of solution – for Lemon or Lime
400 + 5 GPL, ~ 57°Brix

↓

Debittering
Pass fruit juice through a debittering column
Max. 5 ppm Limonin, 600 ppm Naringin (Florida State Department of Citrus)

↓

Single strength Grapefruit juice (1.0-1.5% acid)
Orange juice (< 1.0% citric acid)
Brix/acid = 7-10 (Grapefruit), 13-18 (Orange)

↓

De-aeration
Glucose oxidase can help to reduce oxygen by oxidizing glucose to gluconic acid

Fig. 14.1 Flow chart for preparation of Grapefruit juice

The lemon oil is more valuable than that of orange oil due to high aldehyde (2-4% aldehydes viz., citral – a mixture of neral and geranial) in lemon oil.

Grapefruit oil comprises of terpene thiols and nootkatone, which gives characteristic flavor and aroma to the oil.

FMC system uses Desludger to separate slurry into ‘oil-rich emulsion’, which removes ol from the fruit peel at the juice extractor.

The extent of heat treatment given to juices is important since it should deactivate the pectinase (pectin methyl esterase). Further heating should be avoided to prevent hydrolysis of pectin and sugar, which may result in cloud loss and gelation. If pectic enzyme is inactivated, it avoids separation of two layers viz., pulpy lower one and clear upper one in extracted juice.

14.5.1 Deaeration of juice

Single strength lemon juice even when stored under low temperature undergoes significant degradation, depending on the essential oil content. If oxygen is absorbed in juice during processing, it causes decay, ascorbic acid is oxidized. d-limonene is attacked with the formation of terebenthic taste.

14.5.2 Deoiling of juice

About 5-6% of juice is transformed to vapour at 50^{o}C; there is 80% removal of essential oil plus removal of air. The non-terpenic aromatic fractions are condensed and reintroduced. The oily phase is separated by centrifugation or decantation.

14.6 Orange Juice

The scientific name of Sweet Orange is *Citrus sinensis*. Some varieties of Orange include Sathgudi, Mosambi, Malta; The exotic varieties being Jaffa, Hamlin, Pineapple, Valencia, etc.

14.6.1 BIS Standard: Orange juice shall be obtained by a mechanical process from the endocarp of ripe, sound mandarine or oranges or by reconstituting orange juice. The juice shall have characteristic bitter taste, clean aroma and flavour (free from fermented flavour). The additives permitted include peel oil, orange essence and flavour, sugar, invert sugar and/or liquid glucose. It should be free from preservatives.

Table 14.3 BIS requirements for Orange juice

Particulars	Requirement
Brix of clear sample	Min. 10.0
Acidity	0.25 – 1.0% as anhydrous citric acid
Essential oil	Max. 0.3 ml (based on weight)

14.6.2 Bitterness in juice

Limonin is the main bitter fraction of 'Navel' oranges. The non bitter monolactone of limonic acid gets rapidly converted to bitter tasting dilactone i.e. limonin at pH of about 3.0. Delayed bitterness is due to chemical change i.e. conversion of nonbitter precursor to bitter compounds by the process of extraction of the juice.

14.6.3 Other means to prevent bitterness of orange juice

- During preparation of product, excessive extraction of bitter fractions from the rag and pulp should be avoided.
- Raise the pH to > 4.0 which can prevent the formation of limonin di lactone.
- Use of pectic enzymes. The dispersed colloieds are coagulated by the enzymes and in the subsequent precipitation, they carry the bitter principles with them.
- Stirring the juice with dry polyamide powders and subsequent centrifugation. However, loss of up to 25% of ascorbic acid is reported.

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Lesson 15
PROCESSING OF SELECTED FRUIT JUICES-II

15.1 Introduction

In the last lesson (Part-1) we dealt with Citrus fruit juices viz. Orange, Lemon, Lime, Grapefruit. In this lesson we will deal with Apple, Grape, Mango(pulpy) and other juices.

15.2 Apple Beverages

Apple juice, apple cider and vinegar are made from fruit, not suitable to be marketed as fresh product. The particulars of some Apple variants are depicted in Table 15.1. The flow chart for preparation of Apple juice is furnished in Figure 15.1.

Table 15.1 Particulars of some Apple varieties

Parameters	American	Maharaji
Weight (g)	70.50	136.80
Flesh (%)	82.00	80.20
Peel and Core (%)	17.73	19.25
Seed (%)	0.29	0.49
Juice recovery (%)	85.20	76.20

Selection of apples

Fresh, sound, juicy, blended (tart & aromatic varieties)
Criteria for blending – Brix, tannin, total acidity, pH

↓

Decontaminate and Wash
Dump apples in trough of moving water
Final spray wash on roller-type conveyor

↓

Sorting/Inspection

↓

Coring and cutting into pieces

↓

Dip in Potassium metabisulphite solution (100 ppm SO_2)

↓

Crush/Grind with simultaneous addition of SO_2 (100 ppm)
1st type – grates apples to pulp
2nd type – Hammer mill

↓

Juice extraction
Hydraulic cider press, Pneumatic fruit press, Continuous screw type press,
Continuous plate type, horizontal basket press, press racks, screening centrifuge

↓ → Residue

Cider screen (100-150 mesh)

↓

Cloudy juice
Yield (80-85%)

↓

Juice clarification at 74°C

↓

Store juice at 4-5°C For 24 h → Add Gelatin & Tannin or heat juice ← Pectinase 0.5% (v/w) keep overnight

Store juice at 4-5°C For 24 h ↓ Siphon out

↓

Filtration
Diatomaceous earth or bentonite treatment using filter aid (0.5-2%)

↓

Settling (1 h)

↓

Filtration

↓

Sparkling clear juice

↓

Mild pasteurization with/without chemical preservation
HTST: 82.2-87.8°C/25-30 s between plates or tubes
Add 0.05% sorbic acid or K-sorbate or 0.1% Na-benzoate

↓

Canning/Bottling

↓

Sealing & Cooling

Fig. 15.1 Flow chart for preparation of Apple juice

15.3 Salient Features of Some Steps of Manufacture

15.3.1 Blending

A blend of tart and aromatic varieties gives more flavourful juice than single variety.

15.3.2 Crushing

The macerated apple pulp is covered with cotton press cloth and subjected to pressure in racks in a hydraulic press.

15.3.3 Repressing

The press cake may be broken up and pressed for a second time. The juice contains more or less finely divided pomace and cloths may be precoated with rice hulls.

15.3.4 Chemical preservation

Juice sold as fresh cider is generally bottled after 0.1% Na-benzoate has been added to protect product from bacterial or yeast spoilage. Sorbic acid or K-sorbate (0.05%) in combination with mild pasteurization may be employed.

15.3.5 Clarification of juice

Pectinase hydrolyses pectin, which releases particles that settles to the bottom. Tannin and gelatin are added to form a coagulum and then precipitate. Alternately, the juice may be heated to have the same effect.

Table 15.2: Composition of Apple juice

Constituents	American	Maharaji
Moisture (%)	84.50	84.02
°Brix	14.56	14.24
Reducing sugar (%)	10.60	9.94
Total sugar (%)	12,65	10.99
Acidity (as % malic acid)	0.221	0.501
pH	4.2	3.7
Specific gravity	1.052	1.051

15.4 Type of Apple Juices

15.4.1 Unclarified juice

It is sold in fresh state or preserved by 0.1% Na-benzoate for prompt consumption. The juice has coarse particles removed by screening or settling.

15.4.2 Centrifuged apple juice

The pressed, screened juice is passed through a centrifuge. The juice is slightly clearer than unclarified juice, but more opaque than filtered juice.

15.4.3 Filtered apple juice

The juice is first treated to reduce pectinaceous matter. Then juice is filtered to remove all particles, giving brilliantly clear product. Filtered juice may be produced by (a) tannin and gelatin, (ii) enzyme treated, (iii) heat treated, or (iv) treatment with bentonite.

15.4.4 Untreated juice

The filtered juice has superior flavour with excellent body, if freshly pressed and screened juice is filtered and processed rapidly. Filter aid (0.5-2.0%) is added to juice and filtered. The juice carries slight haze but has full flavour of original fruit. It develops no objectionable sedminent during storage; however, slight increase in cloudiness may occur.

15.4.5 Opalescent juice

It is made by retaining the fine pulp particles suspended in the juice. It is preferred by some over the traditional clear juice.

15.5 Grape Juice

Scientific name of grape: *Vitis vinifera*

Varieties: Concord, Bangalore blue, Beauty seedless, Himrod, Anab-e-shahi, etc. The flow chart for preparation of Grape juice is furnished in Figure 15.2. The composition of grape juice obtained from some variants is shown in Table 15.3.

Selection of grape
Fully ripe, seedless variety

↓

Organoleptic & body of juice
16°Brix considered ripe; < 0.85% tartaric acid desirable

↓

Store for 2-3 days
Mellows the flavour

↓

Discard underripe and decayed fruit

↓

De-stemming (Remove stalk)

↓

Washing

↓

Bucket or spray washing

↓

Crushing
Wooden roller/ Rotary grape crusher/ Garolla grape crusher

↓

Pump juice and pulp

↓

Preheating
Heat crushed mass to 54.4°C/10 min then to 63°C/10 min

↓

Enzyme treatment
@0.09 kg pectic enzyme/ton of grapes at 60°C for > 30 min
4.5-9 kg wood fiber as bulking agent

↓

Pressing
Hydraulic rack and frame press/Willmes press/Continuous screw press)/
Hydraulic press – raise pressure gradually to 17-20 kg/cm^2
Yield of juice 662-700 lit./ton of grapes

↓

1-2% diatomaceous earth as filtering aid

↓

Sweetening for sour variety
Sugar @ 50 g/lit. of juice

↓

Cool to 0°C

↓

Store in storage tanks

↓

Argol precipitation
Hold at cool temperature for 1-6 months

↓

Siphon off the argols

↓

Pass through continuous bowl centrifuge

↓

Pasteurize and store again
Second argol precipitation

↓

Filter in filter press using infusorial earth as filter aid

↓

Clear juice
Adjust brix and acidity

↓

Heat to 79.5-86.0°C

↓

Filling (cans/bottles), Sealing/Crown corking

↓

Processed at 75-85°C/15 min for 150 ml bottles

↓

Cool & store

Fig. 15.2 Flow chart for preparing Grape juice

15.5.1 Salient Points on Juice Recovery from Different Varieties

15.5.1.1 Beauty seedless

No difference in juice yield (79%) either by cold or hot pressing. An increase of 5.50% in yield resulted due to pectolytic enzyme treatment.

15.5.1.2 Himrod

Hot pressing gave 4.5% higher juice recovery than by cold pressing (78.8%). Enzyme treatment enabled increase in juice recovery by 7.3% vs. by cold pressing.

15.5.1.3 Anab-e-shahi

An increase in 6-12% juice yield was there due to pectolytic enzyme treatment.

Table 15.3 Composition of cold and hot pressed juices

Constituents (%)	Cold pressed juice	Hot pressed juice
Sugar	16.36	17.43
Non-sugar	13.90	14.03
Total acid	2.43	3.40
Tartaric acid	0.78	1.09

According to **US grade A Unsweetened grape juice**, it should possess

Min. 15^{o}Brix and Min. acidity – 0.60% as tartaric acid

For Concord grape

Brix at harvest: 16-19^{o}Brix

Total sugar: 14-16^{o}Brix

Table 15.4 Composition of juice of different grape varieties

Parameters	Grape variety	
	Beauty Seedless	Himrod
TSS, %	18.50	18.60
Protein (N x 6.25), %	0.81	0.70
Reducing sugar (as dextrose), %	16.60	16.50
Tannin (tannic acid, mg/100g)	51.0	62.0
pH	3.2	3.5
Acidity (% tartaric acid)	0.72	0.60
Juice recovery, %	84.5	86.1

15.4 Mango

Mango is christened as the 'King of Fruits'. Mangoes are grown in 83 countries and 63 countries produce more than 1000 metric tonnes a year. Total world production of mangoes in 2009-10 was 31.5 million tonnes. India is by far the largest producer, accounting for nearly 55% of world production, followed by Mexico, Pakistan, Indonesia, Thailand and Brazil. The mango products have a share of 43-44% in the total production of fruit and vegetable products.

Generally 20 varieties are used; for processing the important ones include: Totapuri, Alphonso, Kesar, Dashehari, Pairi, Baneshan, Neelam and Fazli. Sindhu is a seedless mango variety. There is a concern of incidence of spongy tissue in Alphonso and fruit fly and stone weevil in Totapuri. The particulars related to pulp, peel, stone, etc. of some important Mango varieties are furnished in Table 15.5. The composition of few important varieties of Mango has been shown in Figure 15.6.

Table 15.5 Particulars for some mango varieties

Variety	Av. wt. (g)	Pulp (%)	Peel (%)	Stone (%)	Fibre (%)	Color of pulp
Amrapali	140	70	14.03	15.04	-	-
Kesar	151	67	13.60	16.55	-	-
Totapuri	353	-	16.45	13.61	3.76	Light yellow
Dashehari	165	-	16.63	17.26	0.47	- do -

Table 15.6 Composition of certain Mango varieties

Variety	TSS (°B)	pH	Acidity	Reducing sugar (%)	Total sugar (%)	Vit C (mg/100g)	Carotenoids (µg/100g)
Amrapali	21.62	-	0.16	-	-	-	-
Kesar	20.62	-	0.12	-	-	-	-
Totapuri	14.60	4.15	0.30	3.49	9.28	8.53	3679
Dashehari	19.33	4.82	0.15	3.40	12.47	9.17	8043

15.5 Comparative appraisal of nutrient composition of some fruit juices

For comparison of the various compositional characteristics, the data for few fruit juices are depicted in Table 15.7.

Table 15.7 Composition of some fruit juices

Composition	Pineapple	Apple	Plum	Orange	Mango
TSS (°B)	9.00	12.00	16.00	10.00	20.00
pH	3.65	4.04	3.20	3.60	4.04
Acidity (%)	0.90	0.32	1.89	0.84	0.25
Brix/Acid	10.0	37.5	8.4	11.9	80.0
Ascorbic acid (mg/100g)	18.72	6.50	10.40	4.20	10.25
Reducing sugar (%)	2.08	2.50	4.32	2.78	4.45
Total sugar (%)	8.10	10.24	14.10	8.37	17.27
Juice/Pulp*(%)	39.8	58.1	72.0	41.9	41.44

*Basket press method

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Lesson 16

CONCENTRATION AND DRYING OF FRUIT JUICES

16.1 Introduction to Concentration of Fruit Juices

Fruit juices are watery mixtures of most unstable volatile compounds. The solid content of most liquid food is 8-16% and is expensive to pack, store for long periods or to transport to distant places. Hence, it is desirable to remove a part or all of the water from such liquids.

Fruit juice concentrates are valuable semi-finished products for use in the production of: (a) fruit juice, (b) fruit juice beverage, (c) fruit juice powder.

16.1.1 Advantages of concentration

- Provides microbiological stability
- Permits economy in packaging, transportation and distribution of the finished product.

16.1.2 Methods of concentration

The methods used for concentration include the following:

1. Evaporative concentration under vacuum
2. Membrane concentration – Ultrafiltration, Reverse osmosis, Microfiltration
3. Freeze concentration

16.1.2.1 Thermal evaporation under vacuum

This process is commonly adopted since it is economical method of fruit juice concentration. Use of multiple effect vacuum condensing plant is used for the purpose and use of high vacuum (i.e. 29 inches of Hg column) helps in evaporating water from fruit juice at much lower (i.e. 58-60^{o}C) than its boiling temperature with steam economy too.

Table 16.1 The types of evaporators used for fruit juice concentration are

Concentration method	**Specific type**
Vacuum pan – Tubular	Climbing film Falling film
Recirculation	Single stage and one pass Five stages and single pass
Plate	Three stages and single pass
Agitated film	Single stage
Centrifugal	Single stage

a) *Disadvantages of conventional vacuum concentration*

- Causes loss of much volatile flavouring compounds as well as nutritive value.
- Requires use of fining agents, enzymes and centrifugation for juice clarification
- High temperature promotes oxidation of compounds in the juice, which may result in chemical alteration of the aroma and flavor compounds.

b) *Fouling of evaporators*

When pulpy or cloudy juice is required to be concentrated, the deposition of burnt layer of organic matter on the hot surface of evaporator causes severe problem. The evaporation rate is retarded and it may become difficult to concentrate such fruit juices in a falling film and plate evaporators. In such cases use evaporators having agitators or use 'Serum concentration process' where the fruit juice is centrifuged to separate the solid phase (pulp) and the liquid phase (serum) is concentrated in an evaporator, before mixing with the pulp.

16.1.2.2 Freeze concentration

Freeze concentration (FC) of fruit juices is a cold, gentle and selective concentration procedure, in which two distinctive steps, viz., ice crystallization and ice separation from the concentrate phase are involved.

a) *First stage*

Fruit juice is supercooled below its freezing point to allow water to separate as ice crystals. This uses either (a) Direct contact crystallizer, or (b) Indirect contact crystallizer.

b) *Second stage*

The ice crystals are separated from the concentrated fruit juices. This takes help of Presses, Filtering centrifuges, Wash columns or a combination of these.

c) *Advantages of FC over evaporative methods*

- The energy needed to freeze a unit of water is much less.
- The low process temperature prevents undesirable chemical and biochemical reactions (minimum color change, non-enzymatic browning and vitamin losses).
- As vacuum is not involved, the losses of low-boiling flavor and aromatic esters are completely avoided
- The flavor profile is better.

d) *Drawbacks of Freeze concentration*

- Major problem is the loss of soluble solids of the juice in the separated ice.
- The final concentration of the concentrated juice is as low as 40-55% dry matter, due to steep increase in the viscosity of ice-concentrated mixture.

e) *Multi-stage freeze concentration*

As the juice concentrates, there is increase in viscosity which retards water crystallization. Multi-stage FC overcomes this to a great extent. In such process, the ice crystals are separated out at the end of each cycle and the remaining concentrate is fed to the succeeding crystallizing compartments. Here, the ice crystals are separated at different levels of concentration and viscosity.

16.1.2.2 Membrane processing

In the fruit juice industry, membrane technology is used mainly to clarify the juice by means of ultrafiltration and microfiltration and to concentrate it by means of nanofiltration and reverse osmosis.

a) ***Ultrafiltration (UF)***

These membrane processes can perform clarification and fractionation over and above concentrating.

i) *Advantages of UF*

- Produces juice of desirable quality at low cost of operation and with greater speed.
- In a single step, it performs juice clarification and fining.
- Lower energy consumption (i.e. 20-30 BTU/lb. of water removed vs. 300 BTU for triple effect vacuum condensing plant)
- Increased flavor and aroma retention

b) Reverse osmosis (RO)

It is basically a concentration process. Pressure is applied to fruit juice that is greater than its osmotic pressure. This pressure forces the water out of the juice.

i) Advantages of RO

- Considerable amount of aroma retention at a cost competitive with evaporation, without undue loss of solids.
- Concentration without phase change or thermal damage.

ii) Drawback of RO

It limits the upper concentration level at about 28^{o}Brix.

16.1.2.4 Combined UF and RO

Initially, the fruit juice is passed through UF system to remove suspended solids. The UF permeate is directed to an RO system to simultaneously concentrate the flavor and aroma compounds, sugars and amino acids for eventual reconstitution to single strength juice. This allows for concentration of orange juice to levels of ~ 42^{o}Brix. On commercial scale up to 45-55^{o}Brix can be achieved.

16.2 Drying of Fruit Juices

Fruits and vegetables are dried to enhance storage stability, minimize packaging requirements and reduce transport weight. Preservation of fruits and vegetables using solar drying techniques can lead to poor quality and product contamination. Energy consumption and quality of dried products are critical parameters in the selection of drying processes. New drying technologies are being considered to have minimal drying time, economy with less nutrition loss; these includes osmotic drying, vacuum drying, freeze drying, superheated steam drying, heat pump drying and spray drying.

Fruit may be dried as a whole (e.g., grapes, various berries, apricot, plum, etc.), in sliced form (e.g., banana, mango, papaya, kiwi, etc.), in puree form (e.g., mango, apricot, etc.), as leather, or as a powder by spray or drum drying. Depending on the physical form of the fruit (e.g., whole, paste, slices), different types of dryers must be used for drying.

The advantages of fruit and vegetable drying are compensated by some negative changes that occur during drying, for example 'heat damage' of heat-sensitive constituents (vitamins, enzymes, etc.); browning, shrinkage, and 'case hardening'; irreversible loss of ability to rehydrate; loss of volatile constituents; and changes in moisture distribution within the product.

16.2.1 Methods of drying fruit juices

There are several methods of drying the fruit and vegetables, solar drying being the oldest one. The type of dryers is listed below:

- Fluidized bed dryers – includes Vibrofluidized, Pulse fluidized or Spouted bed dryers.
- Spray dryers
- Contact dryers
- Foam drying
- Vacuum and freeze drying

The fluidized bed dryers give good mass transfer due to enhanced air turbulence in such dryers. The description of some important drying techniques is given below:

16.2.2.1 Spray drying

Some fruit or vegetable powders are produced from juices, concentrates, or pulps by using a spray drying technique. Dry powders can be directly used as important constituents of dry soups, yogurt, etc. The drying is achieved by spraying of the slurry into an airstream at a temperature of 138°C to 150°C and introducing cold dry air either into the outlet end of the dryer or to the dryer walls to cool them to 38°C– 50°C. The most commonly used atomizers are rotary wheel and single-fluid pressure nozzle. A wide range of fruit and vegetable powders can be dried, agglomerated, and instantized in spray drying units, specially equipped with an internal static fluidized bed, integral filter, or external vibrofluidizer. Bananas, peaches, apricots, and to a lesser extent citrus powders are examples of products dried by such techniques.

Spray drying of soluble fruit powders and convective drying of fruit and vegetables reduces the thermo-plasticity of particles and product hygroscopicity. They also eliminate the need for adding stabilizers which may adversely affect the sensory properties of the final product.

16.2.2.2 Foam drying

Foam mat and foam spray drying are two foam drying methods. Foam mat dried fruit or vegetable powders have fewer heat-induced changes in color and flavor than conventional spray dried or drum dried products. It yields product with lower density than that of a conventional dryer. The product density is about equal to the density of instantized or agglomerated powder.

A stable gas-liquid foam is a prerequisite. Glycerol monostearate, solubilized soya protein, and propylene glycol monostearate are the typical additives for the fruit and vegetable foam formulation from juice or pulp. Foam mat drying involves drying a thin layer (0.1–0.5 mm) of the stabilized foam in air at 65°C–70°C for a few minutes, as the foam structure decreases drying time to about one-third. The foam is spread on perforated floor craters as the airstream is forced through the bed. A continuous belt tray dryer or a modified spray dryer can be used. Good quality tomato, apple, grape, orange, and pineapple powders can be produced by this technique. Optimal initial concentration of feed solids is in the range of 30% for tomato and 55% for orange.

16.3 Other Methods of Fruit Dehydration

Though these methods cannot be employed for fruit juice dehydration, the fruit pieces can be subjected to following methods for dehydration as detailed below:

16.3.1 Osmotic dehydration of fruits

Osmotic dehydration is one of the processes used to reduce or avoid detrimental phenomena in fruit and vegetables without a sensorial and nutritional quality loss.Osmotic dehydration, consists of placing fruit pieces in contact with sugar syrup to remove 30-50% of water by weight, before conventional drying methods, that inhibits the action of polyphenol oxidase and prevents loss of volatile flavour constituents during dehydration. The process involves immersion of the fruit and vegetables (reduced to 3-10 mm pieces), in a concentrated solution of sugar syrup and ascorbic acid to effect partial dehydration (from ~ 6-8 to 1.0-1.5 kg moisture/kg dry matter). Most fruits are suitable for osmotic dehydration, except tomatoes and citrus fruits. The technique is currently largely used in the production of semi-candied fruits.

The factors affecting the osmotic drying process include size and shape, type of osmotic agent, concentration of the osmotic solution, temperature, food to solution ratio, duration, pressure, agitation of the osmotic medium and food pieces, Ca fortification of fruits and vegetables, etc. The osmotic agents used were a saturated glucose or sucrose solution, 60^{o}Brix glucose or isomerized glucose-fructose syrups, sucrose (70%)-glycerol (65%) 1:1 and ethanol. The temperatures of about 25 -43^{o}C have been successfully used.

The recent technologies that have been used to enhance osmotic drying include blanching, freeze-thawing, pulsed vacuum osmotic drying, ultrasound, pulsed electric fields, high pressures, supercritical $CO_{2,}$ etc.

Osmotic drying has been used as a pretreatment prior to another drying process while use of osmotic drying for production of intermediate moisture foods.

16.3.2 Freeze-drying of fruits

There are two main stages in the freeze drying process: (a) freezing of the food, when most of the water is converted into ice, and (b) sublimation, when the bulk or all of the ice is transferred into vapor under very low pressure or high vacuum. In some cases, additional final drying, in the same or other equipment, is necessary. Cabinet or tunnel batch-type dryers are typically used with pressures in the range 13.5–270 Pa. Bananas, oranges, strawberries, peaches, plums, tomato, fruit juices and flavors, asparagus, beans, cabbage, cauliflower, celery, mushrooms, onions, peas, parsley and chives are processed by freeze drying.

The advantage of freeze drying over other methods of drying is the superior quality of the product. Little or no shrinkage occurs. The dry product has a porous structure and a color almost as fresh as that of the raw material. The only disadvantage of this process is the high equipment and operational cost.

Freeze-drying includes fluidized bed processes, spray-drying, continuous processes, foam drying processes, slush freezing and the thermal shock processes.

16.4 Preservation of fruit juices

Especially for low pH fruit juices (like lime, lemon juices) mild pasteurization is sufficient to have the desired shelf life. However, for higher pH fruit juices over and above stringent pasteurization, chemical preservatives (i.e. salts of sorbic acid or benzoic acids) may be used, where permitted by laws. The main purpose is to prevent fermentation from occurring during the refrigerated or even ambient temperature storage.

Sterilization of the fruit juice by In-can (retort) or by Ultra high treatment (UHT) followed by aseptic packaging can help in extending the shelf life for months even under ambient storage conditions.

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Module 5. Jam, jelly, marmalade and glazed and crystallized fruits

Lesson 17
ROLE OF SUGAR AND OTHER INGREDIENTS IN FRUIT PRESERVATION

17.1. Introduction

The fruit are perishable in nature and so are the juices expressed out of them. Preparation of sugar preserves like Jams, Jellies, Marmalades, Conserves, etc. are one means to extend the shelf life of fruit juice at the same time enable the consumers to enjoy the body and texture of a gel – a mouthfeel that is relished by all. The high osmotic pressure of sugar creates conditions that are unfavourable for the growth and reproduction of most species of bacteria, yeasts and molds.

17.2 Preservation of Fruit Solids by Sugar

Food preservation if the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by microorganisms. A sugar concentration of about 60% in finished or processed fruit product generally increases their preservation. Preservation is not only determined by the osmotic pressure of sugar solutions, but also by water activity in the liquid phase, which can be lowered by sugar addition and by evaporation down to 0.848 aw. This value however, does not protect the products from mould and osmophilic yeasts. Maximum saccharose concentration that can be achieved in liquid phase of product is about 67.89%.

In the case of jellies and preserves, the water is withdrawn from the microorganisms toward the concentrated sugar syrup through osmotic gradient. The microorganisms become dehydrated and incapacitated, and are unable to multiply and bring about food spoilage. In jellies, jams and preserves, a concentrated sugar solution of at least 65% is necessary to perform this function. Since the sugar content naturally present in fruits and their juices is less than 65%, it is essential to add sugar to raise it to this concentration in jellies and preserves.

17.3 Fruit Products Based on Sugar Preservation

17.3.1 Preserves

They are whole fruits or large pieces of fruit in thick sugar syrup, often slightly jellied. Preserves are made from practically all fruits including peaches, pears, plums, aonla, strawberries, grapes, muscadines, quinces and tomatoes.The fruit for preserving should be in a firm-ripe rather than a soft-ripe stage. By using up to 25% of firm-ripe fruit, the tartness is increased and less pectin is required in the formula. The fruit should be uniform in size or uniform pieces so as to cook evenly. Examples include fig preserve, watermelon rind preserve, etc.

17.3.2 Jam

It is essentially a gel or semi-solid mass containing pulped or whole fruit, made by boiling the fruit pulp with sugar solution. It is made from crushed or macerated (ground) fruit and generally is less firm than jelly.
They may be made from a single fruit or mixture of fruits. It may contain small particles of fruit as against preserves, which may contain whole or large pieces of fruit.

17.3.3 Jelly

It is made from fruit juice. A perfect fruit jelly has a clear colour and a flavor characteristic of the fruit used. It is transparent and sparkles, quivers but does not flow when removed from its mould. The jelly should be tender enough to cut easily and is so firm that angles produced retain their shape.

17.3.4 Conserves

Conserves are similar to jams with chopped nuts (pecans, walnuts or others) and raisins added for texture and flavour. Conserves are mixtures of two or more fruits usually including citrus fruits. The chief ingredient in specific conserves being figs, peaches, pears, plums, oranges or carrots.

Conserves contain higher proportion of fruit than preserves or marmalades.

17.3.5 Marmalades

They have the characteristics of jellies and preserves combined. It is a semi-viscous jelly which contains the fruit pulp and may contain the peels suspended evenly throughout the jellied juice.
They are made from under ripe fruit, rich in pectin and acid, chiefly citrus fruits – alone or in combination with other fruits. Popular marmalades are combination citrus, orange-peach, orange-pear, ginger-pear, pear-pineapple and grape. The pectin and acid contents of the marmalades should be kept slightly higher than what has been recommended for jellies.

17.4 Prerequisites for Preparing Gelled Fruit Products

17.4.1 Selection of fruits

They maybe from under ripe, undersize and off-grade fruit or even from peels, cores and wind-fall fruit. The fruit should be sufficiently ripe (not overripe); mixture of under-ripe and ripe fruits is advantageous. Combining fruits rich in acid with those rich in pectin is less expensive than using acid or commercial pectin to supplement the deficiency. The juices of different fruits may be mixed.

17.4.2 Principle

The preparation is based on the gel making power of pectins which are present naturally in the products or added to them. Fruits that are low in pectin and acid components can be used to make jams and jellies, provided the pectin and acid content is adjusted to levels that make them gel.

17.4.3 Pectin in jelly formation

Protopectin is a component of the cementing material between plant cell walls; also a part of cell walls themselves. These are most abundant during the immature stage of fruit and are converted to pectin as the fruit matures. The chemical structure of pectin is shown in Figure 17.1.

When fruit are heated, the protopectin that has not turned to pectin is partially hydrolyzed or converted to pectin. To increase the amount of pectin extracted, some acid has to be added to the extraction solution and heat has to be applied.

When fruit are very ripe, other enzymes break up the pectin into pectic acid and alcohol. Pectic acid does not form a gel, except in the presence of added calcium molecules.

Jellies made with additional commercial pectin are usually bright and more transparent with no lessening of colour.

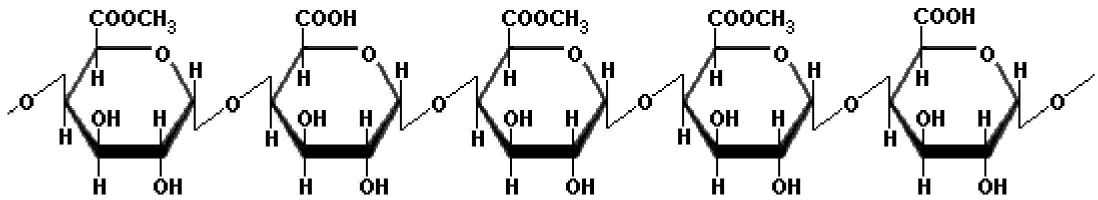

Fig. 17.1 Chemical structure of Pectin

17.5 Commercial Production of Pectin

Plant materials are used. Most frequently culled or rejected apples, apple pomace or the pulp (together with peel and core wastes) remaining after apple juice extraction are used. Lemon rejects are also a good source. Extract all pectin substances including protopectin, pectinic acid, pectic acids and pectin related compounds.

17.5.1 Pectins are classified into two groups:

(a) those with a high methoxyl content (HMP) ~ 11% methoxyl
(b) those with low methoxyl content (LMP)

HMP is extracted with higher temperature, acidic solutions. Pectins with high methoxyl content forms gels in presence of high sugar and acid concentration. Most commercial pectins are HMP.

LMP containing pectic acids are extracted with lower temperatures with less acidic solutions, but in presence of other chemical compounds. LMP are pectin derivatives which do not need sugar to gel. If used, they need to react with a calcium salt (dicalcium phosphate), which has to be added during jam making.

17.5.2 Pectin extraction method

The fresh fruit tissue or separated parts, including the peel and core are heated in 95% alcohol or 0.05N HCl (pH 2.0) for 10-20 min at 70^{o}C to inactivate pectic enzymes. After the pretreatment, the materials is ground in an electric blender and placed in water. Versene or Na-EDTA is added at 2.0%. The pH is adjusted to 6.0. The mixture is heated for about an hour at 90-95^{o}C. The slurry formed is rapidly filtered and the pectin is precipitated from the solution using acidified alcohol. The precipitate is centrifuged and repeatedly washed with 70% alcohol. Acetone is used for dehydration and the pectin produced is vacuum-dried. It may also be dried in a hot-air oven at 50^{o}C for 4 h.

17.5.3 Household extraction of pectin

A pectin solution of maximum strength can be obtained with about 30 min of boiling. When this period is divided into two, each of 15 min period of extraction, maximum amount of pectin can be extracted.

Other jellying agents include agar, arrow root, tapioca flour or cassava starch.

17.6 Other Ingredients

Successful jelly formation requires correct proportion of sugar, acid and pectin.

17.6.1 Sugar

Pectin-sugar gel formation occurs as a result of the precipitation of a part of pectin present in solution. Precipitation takes place in such a way so as to develop high binding forces at the surface. These hold the solution of other ingredients with sufficient strength to confer on the whole system the rigidity and texture associated with a jelly.

The addition of sugar is essential to produce an ideal jelly texture, appearance, flavour and yield. The sugar reduces the stability of the system by removing water from the pectin particles and affects the strength of the acidity.

The sugar content influences (a) the pH optimum or maximum acidity, and (b) maximum gel strength.

A sugar content of between 60-65% is usually preferable. The proportion of sugar added to extract should be appropriate to pectin concentration; depends on the acid present in the extract.

Smaller percentage of sugar gives lower jelly strength at all acidity levels. This may be made up by use of larger amount of pectin or acid or both.

Too little sugar added when pectin is over-concentrated results in tough jelly.

The principal cause for failure in gel formation is addition of too much sugar.

17.6.1.1 Inversion of sugar

The maximum solubility of sucrose at 86^{o}F is 68.7 %.

Inversion is desirable since (a) it lowers the concentration of sucrose, and (b) it reduces the possibility of sugar crystallization.

$$\text{Sucrose} \xrightarrow{\text{Heat + Acid}} \text{Glucose} + \text{Fructose}$$

The degree of inversion depends on:
(i) Hydrogen ion-concentration
(ii) Duration of boiling

For sufficient inversion, boil the pectin extract for 10 min at pH 3.0 or for 30 min at pH 3.5 (i.e. boil sugar with 0.05% H_2SO_4 for 15 min).

In the finished jelly, 30-50% invert sugar/glucose should be present.

If < 30% invert sugar – chances of crystallization.
If > 50% invert sugar - development of a honey-like mass.

17.7 Estimation of Pectin Strength of Fruit Extract

The following methods can be employed to determine the pectin in fruit juices:

1. Testing amount of pectin by precipitating it with alcohol or methylated spirit.
2. Finding the viscosity of pectin solution using a jelmeter. The temperature of pectin solution should be between 70-100oF. Close the bottom end and fill juice in the tube; allow dripping for 1 min. and close the bottom. The figure (i.e. 11/4, 1, ¾, ½ etchings) nearest (< or >) the level of the juice in the tube of jelmeter is noted. The data shows the cups or parts of cups of sugar to be added to each cup or part of the juice extract.
3. Making actual test jellies from the fruit extract.

17.7.1 Alcohol test

Place 1 teaspoon (5 ml) of liquid in a saucer. Allow it to thoroughly cool down. Three teaspoonfuls (15 ml) of alcohol (95%) are added and the mixture is gently shaken and allowed to stand for 3-5 minutes (Table 17.1).

Table 17.1 Alcohol test to estimate the pectin strength of fruit extract

Observation	Inference	Quantity of sugar
A firm jelly-like mass forms	Extract is rich in pectin	¾ - 1 cup of sugar to 1 cup of fruit extract.
Pectin precipitates in form of several lumps	Extract is medium in pectin	½-2/3 of a cup of sugar to 1 cup of extract.
Few small stringy lumps	Low pectin concentration	Extract should be concentrated.

17.8 Acid

For any given pectin-sugar combination under given conditions of temperature, there is a maximum hydrogen-ion-concentration or acidity which just permits the completion of jelly formation within the time limit of the system.

The acid concentration affects the final structure through the alteration of the rate of setting, but does not show an optimum when the setting time is made sufficiently long by diminishing the sugar content.

Given a certain proportion for a particular pectin level, the sugar and acidity controls the strength of the jelly formed; the sugar through its dehydration of the pectin particles, and the acid by its own destabilizing action and its effect on the speed at which sugar-pectin equilibrium is attained.

High quality product is associated with a sugar content of ~ 65% and this is related to a pH of 3.4 - 3.1. The rheology of jelly as influenced by the acidity of the system is depicted in Table 17.2.

Table 17.2 Rheology of jelly based on the acidity of system

Quantum of acid	Rheology of jelly
Small amount of acid	Weak fibrillar structure; unable to support sugar solution adequately.
At higher acidity or lower pH	Jelly is somewhat stiffer.
Acidity further increases	Acid tends to hydrolyze pectin fibrils. Fibrils lose elasticity and jelly becomes syrupy. Syneresis is likely to occur.
Less acid (sugar normal)	Add more pectin.

The final jelly should contain a minimum of 0.5% (preferably 0.75%) total acidity and not exceeding 1.0% acidity.

Weak jellies can be improved by adding a little acid.

When fruit extracts are deficient in acid, either characteristically or because they are obtained from over-ripe fruit, it is possible to improve their jellying capacity by addition of acids viz., citric, tartaric or malic acids (usually found in fruits); tartaric acid gives best results. Lemon juice may be added, or other fruit juices which are sour can be blended with them.

The acid should be added near the finishing point. If external pectin is used, acid should be added just before the jellies are poured into containers.

17.8.1 Proportion of ingredients

The desired proportion of ingredients required to obtain good jelly is as follows:

Table 17.3 Desired proportions of ingredients for jelly making

Pectin	Sugar	Fruit acid	Water
1.0	60-65	1.0	33-38

17.9 Acid

For jelly containing 1.0% pectin, the optimum pH and sugar requirement is as follows:

Table 17.4 pH of jelly mass based on the sugar content used

Optimum pH	3.0	3.2	3.4
Sugar (%)	60	65	70

17.10 Theory of Jelly Formation

17.10.1 Fibril theory

When sugar is added to pectin solution, it destabilizes the pectin-water equilibrium and pectin conglomerates forming a network of fibrils through the jelly. The network of fibrils holds the sugar solution in the inter-fibrillar spaces.

The firmness of network depends on (a) the concentration of sugar, and (b) acidity.

The fibrils of pectin become tough in presence of acids. Small amount of acid gives a weak fibrillar structure. Large amount of acid tends to hydrolyze pectin; the fibrils lose elasticity and the jelly becomes syrupy.

17.10.2 Spencer's theory

Sugar acts as a precipitating agent; the presence of acid helps it. Greater the quantity of acid, lower is the sugar requirement.

17.10.3 Olsen's theory

Sugar acts as a dehydrating agent which disturbs the equilibrium existing between water and pectin. The negative charge on pectin is reduced with help of hydrogen-ion-concentration. Pectin precipitates and coalesces in the form of a fine network of insoluble fibres, provided sugar is present in sufficient concentration. As the system reaches equilibrium, the jelly strength becomes the maximum.

17.11 Pectin – A Prized Ingredient in Jam/Jelly making

17.11.1 Raw materials for Pectin

Apple pomace and Citrus peel (Lime, lemon and orange) serves as raw material for extraction of pectin
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17.11.2 Types of Pectin

High methoxyl (HM) pectins are defined as those with a Degree of Esterification (DE) above 50, while low methoxyl (LM) pectins have a DE of less than 50. LM pectins can be acid or alkali-treated. LM pectins can be either amidated (LMA) or non-amidated (LM).

17.11.3 Pectin in jelly formation

Protopectin is a component of the cementing material between plant cell walls; also a part of cell walls themselves. These are most abundant during the immature stage of fruit and are converted to pectin as the fruit matures.

When fruit are heated, the protopectin that has not turned to pectin is partially hydrolyzed or converted to pectin. To increase the amount of pectin extracted, some acid has to be added to the extraction solution and heat has to be applied.

When fruit are very ripe, other enzymes break up the pectin into pectic acid and alcohol. Pectic acid does not form a gel, except in the presence of added calcium molecules.

Jellies made with additional commercial pectin are usually bright and more transparent with no lessening of colour.

17.5 Concentration of Pectin and Jelly characteristics

1.0% pectin	Firm and tough jelly
< 0.5% pectin	Jelly fails to set

17.11.4 Commercial production of pectin

Plant materials are used. Most frequently culled or rejected apples, apple pomace or the pulp (together with peel and core wastes) remaining after apple juice extraction are used. Lemon rejects are also a good source.
Extract all pectin substances including protopectin, pectinic acid, pectic acids and pectin related compounds.

Pectins are classified into two groups:

(a) those with a high methoxyl content (HMP) ~ 11% methoxyl content
(b) those with low methoxyl content (LMP) – lower methoxyl than mentioned above

HMP is extracted with higher temperature, acidic solutions. Pectins with high methoxyl content forms gels in presence of high sugar and acid concentration. Most commercial pectins are HMP.

LMP containing pectic acids are extracted with lower temperatures with less acidic solutions, but in presence of other chemical compounds. LMP are pectin derivatives which do not need sugar to gel. If used, they need to react with a calcium salt (dicalcium phosphate) which has to be added during jam making.

17.11.5 Pectin extraction method

The fresh fruit tissue or separated parts, including the peel and core are heated in 95% alcohol or 0.05N HCl (pH 2.0) for 10-20 min at 70^{o}C to inactivate pectic enzymes. After the pretreatment, the materials is ground in an electric blender and placed in water. Versene or Na-EDTA is added at 2.0%. The pH is adjusted to 6.0. The mixture is heated for about an hour at 90-95^{o}C. The slurry formed is rapidly filtered and the pectin is precipitated from the solution using acidified alcohol. The precipitate is centrifuged and repeatedly washed with 70% alcohol. Acetone is used for dehydration and the pectin produced is vacuum-dried. It may also be dried in a hot-air oven at 50^{o}C for 4 h.

17.11.6 Household extraction of pectin

A pectin solution of maximum strength can be obtained with about 30 min of boiling. When this period is divided into two, each of 15 min period of extraction, maximum amount of pectin can be extracted.
Other jellying agents include agar, arrow root, tapioca flour or cassava starch.

17.11.7 Manufacture of different types of Pectin

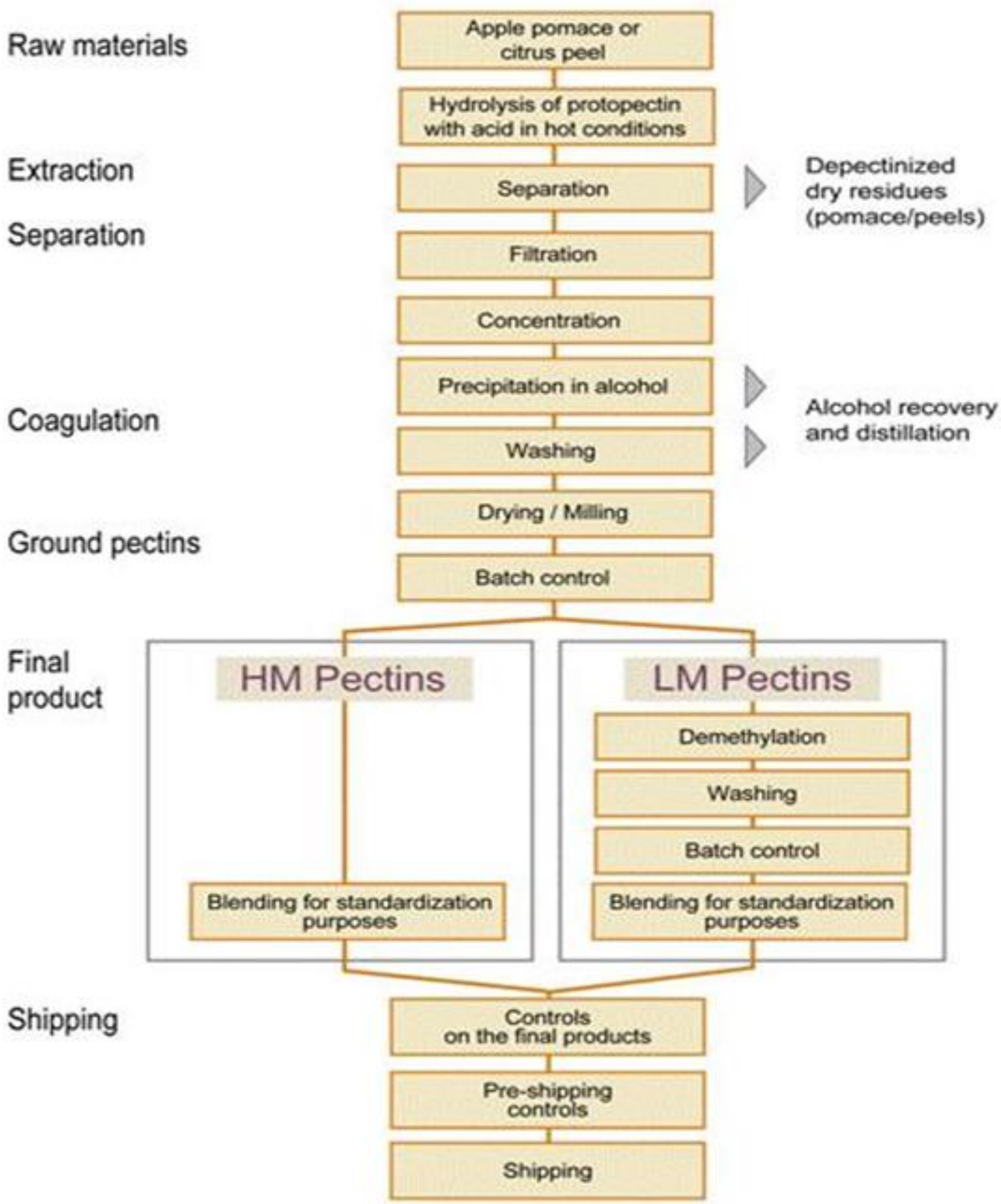

Fig. 17.2 Flow diagram for manufacture of Pectin

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Lesson 18
JAM, JELLY AND MARMALADE

18.1 Introduction

In previous lesson (No.17), the role played by several functional ingredients in preparation of sugar preserved foods like Jam, Jelly and Marmalade were discussed. In this lesson the mode of preparation of these products and means to prevent any defect in such products will be taken into account.

18.2 Fruit Jam/Fruit Cheese

As per FSSAI, Jam means the product prepared from sound, ripe, fresh, dehydrated, frozen or previously packed fruits including fruit juices, fruit pulp, fruit juice concentrate or dry fruit by boiling its pieces or pulp or puree with nutritive sweeteners namely sugar, dextrose, invert sugar or liquid glucose to a suitable consistency. It may also contain fruit pieces and any other ingredients suitable to the products. It may be prepared from any of the suitable fruits, singly or in combination. It shall have the flavour of the original fruit(s) and shall be free from burnt or objectionable flavours and crystallization.

The specific requirements for Jam are as follows:

Total soluble solids (m/m) - Min. 65.0 %

The product shall be manufactured from minimum 45.0% by weight, of original prepared, fruit, exclusive of any added sugar or optional ingredients of finished product, except for Strawberry or Raspberry fruit, where it shall contain minimum 25.0% fruit.

As per FSSAI, Fruit cheese means the product prepared from pulp/puree of sound, ripe fruit (s), whether fresh, frozen or previously preserved or dry fruits, by cooking with salt, nutritive sweeteners to attain a thick consistency so that it sets on cooling. The fruit cheese shall be neither too soft nor too hard to chew. It may be prepared from any of the suitable fruits, singly or in combination. It shall have the flavour of the original fruit(s) and shall be free from burnt of objectionable flavours and crystallization.

The specific requirements of Fruit cheese are the same as specified for Fruit Jam.

18.2.1 Salient characteristics of jam

The amount of pectin in the gel is quite small (< 1.0% of the weight of jam); sugar content is very high (60-70%). Of the remainder, the bulk is water with a small amount of fibrous matter and seeds.

For a chunky texture, some pieces of fruit are added about 5 minutes before the cooking is finished. If a stiffer or sweeter jam is desired, more thickener or pectin, honey or sugar may be added.

18.2.2 Fruit or fruit combinations

Some fruits such as lemons and bitter oranges are rich in both acid and pectin and can be easily made into jam.

Some popular combinations include: pineapple and paw paw, orange and banana, apple and plum.

18.2.3 Sugar

55 parts of sugar is required for every 45 parts of fruit. With excess sugar, the jam becomes gummy and sticky.

The finished jam should have 30-50% invert sugar / glucose to avoid crystallization of cane sugar during storage.

18.2.4 Acid

Acidity can be supplemented by use of citric, tartaric or malic acid. The pH influences inversion of sugar and setting of the jam.

For pectin jam, pH of 3.3 gives a good set. For Apple and Plum jam, the pH range of 3.2-3.5 is desirable; optimum being 3.35.

18.2.5 Preparation of Jam

The process for preparing Fruit Jam is depicted in Fig. 18.1.

Selection of fruits
Combination of high and low pectin fruit

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Washing

↓

Preparation of fruits
Stone fruits – pitted
Apple, Pear, Peach, etc. – Peeling required
Cut into pieces or thinly sliced
Add water (if required) and soften hard fruits by simmering for 30-45 min

↓

Sugar addition
Proportion varies as per species of fruit and stage of ripening
(4 cups of prepared fruit + 4 tablespoonful of lemon juice + 1-2 teaspoonful of powder pectin – Mix together and allow to stand for 1 h + 2-3 cups of sugar)

↓

Mixture boiled with constant stirring
60-80 lbs. of steam pressure for 100 lb. lot
Boiling under vacuum (65.5-76.7°C)

↓

End point
Jelly thermometer – boil at 103.3-105.5°C at sea level
Abbe Refractometer – Soluble solids of 68.5% (Reading 55-60)

↓

Cooling (to 93.3°C) in cooling pan

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Fill hot (87.8-93.3°C) in preheated glass jars or in cans

↓

Sealing

↓

Pasteurize at 82.2-85°C/30 min in water bath

↓

Cooling

↓

Store in a cool place; RH 80%

Figure 18.1 Flow chart for preparation of Jam

18.2.6 Judging the end-point or point at which boiling is stopped

18.2.6.1 Determining the boiling point with thermometer

Thermometers or thermocouples are used to indicate the temperature which should be approximately the boiling point of a 65% sugar solution (103.9-105^{o}C), when the process is complete. A 65% solids boils at 104.8^{o}C at sea level. It should be 8-9^{o}C higher than the boiling point of water at that place.

18.2.6.2 Hydrometers

They help in determining the specific gravity of material.

18.2.6.3 Refractometer

We can determine the percentage solids i.e. TSS read directly on scale. Use Abe or Zeiss type refractometers and for dark colored jams/jelly, use projection type refractometer.

18.2.6.4 Sheeting or Ladle test

a) Cold plate test

A drop of boiling liquid from the pan is placed on a plate and allowed to cool. If the jelly is about to set, it will crinkle when pushed with a finger.

b) Sheet or Flake test

Some portion of a jelly is taken in a large spoon or wooden ladle and cooled slightly. When dropped, if it falls in the form of flake or sheet, the end point is reached. If the jelly drips like syrup, it is required to further concentrate.

18.2.6.5 Weighing

The boiling pan is weighed before and after putting the fruit extract and sugar in it. The weight of finished jelly should be 1.5 times the weight of sugar used. Industry uses specific gravity method, which gives a reliable indication of the point of readiness.

18.2.7 Storage of jam

The surface of jam is susceptible to mold growth; yeast cannot grow or thrive. There is risk of mold development and fermentation, with alteration in the taste. Permitted preservatives may be used at levels sufficient to inhibit the growth of yeast and molds.

Jam should be stored in a fairly cool place or else some moisture evaporates resulting in surface graining and shrinkage of jam. It should be stored in a place having RH of ~ 80%.

18.3 Fruit Jelly

As per FSSAI, Fruit Jelly means the product prepared by boiling fruit juice or fruit(s) of sound quality, with or without water, expressing and straining the juice, adding nutritive sweeteners, and concentrating to such a consistency that gelatinization takes place on cooling. The product shall not be syrupy, sticky or gummy and shall be clear, sparkling and transparent.

The specific requirements are as shown below:

Total soluble solids (m/m) - Min. 65.0 %
The product shall be manufactured from minimum 45.0%, by weight, of original prepared fruit, exclusive of any added sugar or optional ingredients of finished product.

18.3.1 Manufacture of jelly

Fruits

Washing
Warm solution of 1.0% HCl, rinse with water

Preparation of fruit
Orange & Lemon – Remove outer yellow portion of peel
Guava, Apple – Does not require peeling
Berries – Plugs not removed
Cut fruit into thin slices

Pectin extraction
Add minimum quantity of water and boil pieces
Grapes, Berries – no water addition; crush and boil

Straining and clarification
Basket or Hydraulic press
More solid (e.g. apple) – Discharged into press-cloth and pressed

Pomace

Moistened, broken up; boiled and pressed again

Clarification
Settling tanks, flannel jelly bags, mechanical pressure filters using pulp or kieselguhr as filter medium, Mechanical centrifuges

Addition of pectin, sugar and fruit acid
Sugar sprinkled on fruit extract while heating and stirring
Add acid to adjust pH to 3.1-3.5

Cooking of jelly
Vacuum pans
Remove scum/foam on top;, 1 tsp. of oil/100 lb. of mixture controls foaming
Boil to desired consistency in 20 min.

Add flavour and color towards end of boiling

Doneness/Judge end point
Boiling point of 104-105°C at sea level (65-68% sugar)

Filling and packaging

Cooling and setting
Jelly cooled rapidly to 21°C and allowed to set quiescently

Storage at ambient temperature

Fig. 18.2 Flow chart for preparation of jelly

18.3.2 Defects in jelly

18.3.2.1 Crystals in Jelly

Sugar crystallization may result from:

(a) Too much sugar
(b) Too little acid
(c) Overcooking of jelly
(d) Too long a delay in sealing the container of jelly.

Crystals may sometimes be found in jelly because during the boiling, syrup spatters on the side of the pan and dries up. In subsequent pouring of the finished product, these crystals (act as seed material) are carried into the glasses of jelly.

18.3.2.2 Cloudy jelly

Usually occurs with the red juices. It is caused by imperfect straining. Restraining of juice without pressure brings a lower yield, but ensures a clear product.

18.3.2.3 Failure to gel

a) Causative factors

Improper balance of pectin, acid, sugar and mineral salts, which may come about in several ways:

- Fruit used may lack sufficient pectin or acid or both.
- Overcooking may destroy so much pectin that a gummy mass is formed.
- Undercooking, due to insufficient concentration.
- Too much water used for extraction of juice, so that the proportion of sugar is too great for the pectin and the long time required for evaporation may destroy some of the pectin.

18.3.2.4 Tough Jelly

The jelly becomes tough or stringy when too little sugar is used for the quantity of fruit juice used or when boiling is continued after the jellying point has been reached.

18.4 Marmalade

As per FSSAI, Marmalade means a product prepared by boiling sound fruits with peel, pulp and juice, with or without water, added nutritive sweeteners and concentrating to such a consistency that gelatinization takes place on cooling of the product. It shall not be syrupy, sticky or gummy and shall be clear and transparent. The photograph of Marmalade is furnished in Figure 18.3.

Fig. 18.3 Photograph of packaged marmalade

The specific requirements are as follows:

(i) Total soluble solids (m/m) - Min. 65.0 %
(ii) Fruit content except peel (m/m) - Min. 45.0 %
(iii) Peel in suspension - Min. 5.0 %

The container shall be well filled with the product and shall occupy not less than 90% of the net weight of the container, when packed in the rigid containers.

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Lesson 19
FRUIT PRESERVES

19.1 Introduction

Fruits are seasonal in nature. Further, it has got limited shelf life. Sugar has got the ability to increase the shelf life of fruit products through its osmotic pressure action on microorganisms. Preparation of fruit preserves is one novel method of preserving the seasonal fruit for use in non-season or to make available the ‘fruit of choice’ for the consumers to enjoy throughout the year.

19.2 Preserves

They are whole fruits or large pieces of fruit in thick sugar syrup, often slightly jellied. Preserves are made from practically all fruits including peaches, pears, plums, aonla, strawberries, grapes, muscadines, quinces and tomatoes.

The fruit for preserving should be in a firm-ripe rather than a soft-ripe stage. By using up to 25.0% of firm-ripe fruit, the tartness is increased and less pectin is required in the formula. The fruit should be uniform in size and uniform pieces so as to cook evenly.

The examples of Preserves include Fig preserve, Watermelon rind preserve, etc.

19.3 Preliminary Processing

The fruit should be washed thoroughly. If the fruit had been sprayed with insecticide to check blight, it should be washed with dilute HCl, especially is the peel is not removed from the fruit for preparation of the preserve.

The preliminary treatment varies with the variety of fruit taken. For instance, apples and pears are just peeled and pricked if they are to be kept whole, otherwise they are peeled, halved or quartered, cored and punctured. Mangoes are peeled, sliced and pricked. Peaches are destoned and lye peeled. Apricots, cherries are only pitted and destined. Oranges, lemons, grape fruits and citrus fruits are halved and the pulpy portions removed from the cut fruit. Pumpkins are sliced, peeled, pricked and placed in dilute lime water for few hours to harden the texture. Strawberries and Raspberries are used as such, without any preliminary treatment.

The fruit is first cooked slightly in water to make it soft enough to absorb sugar. Cooking of the fruit in syrup is rather a difficult process, because the syrup is to be maintained at a proper degree of consistency so that it can permeate the entire body of the fruit, without causing it either to shrink or to toughen. The fruit should be boiled initially in water before transferring it to the syrup or cooked first in a dilute syrup with low sugar concentration. Highly juicy fruits may, however, be placed directly in a thick syrup at the very outset, because the excess of juice present in the fruit would serve to dilute the syrup.

19.4 Cooking in Syrup

There are three ways of cooking the fruit in a syrup. These are: (i) Open Kettle one period process, (ii) Open kettle slow process and (iii) vacuum cooking process.

19.4.1 Open kettle one period process

The concentration of the starting sugar syrup for cooking the fruit should be low. Boiling should be continued with gentle heating until the syrup becomes sufficiently thick. Rapid boiling will make the fruit tough, especially when heating is done in large shallow pans with a small quantity of syrup. Soft fruits such as strawberries and raspberries require little boiling for softening, unlike hard fruits like apple, pear, peach, etc. which require prolonged heating. The final concentration of sugar syrup should not be less than 68^{o}Brix, which corresponds to a boiling point of 106^{o}C at sea level.

19.4.2 Open kettle slow process

The fruit is first cooked in water to make it tender. Sugar equal to half the weight of fruit is added to the boiled fruit in alternate layers in a vessel and the mass is allowed to stand for 24 h. During this period, the fruit gives out excess water, and the sugar goes into solution resulting in a syrup of ~ 38^{o}Brix. More sugar is added to raise the strength of the syrup to about 60^{o}Brix. A small quantity of citric or tartatic acid (62-125 g per 100 kg of sugar initially taken) is added to invert a portion of the cane sugar. The whole mass is then boiled for 4-5 min and kept for 24 h. On the 3rd day, the strength of syrup is raised to ~ 68^{o}Brix by adding sugar and the mass is boiled again for 4-5 min. The fruit is then left in the syrup for 3-4 days. Finally, the strength of the syrup is raised to 70^{o}Brix and the preserve, in finished condition, is then packed in containers.

19.4.3 Vacuum cooking

Preserves made by cooking under vacuum retain the flavor and colour better than those made in open kettles. In vacuum cooking process, the fruit is initially softened by boiling and then placed in the syrup, which should be about 30-35^{o}Brix. The fruit syrup blend is then transferred to a vacuum pan and concentrated under reduced pressure to ~ 70^{o}Brix. Hard fruits like apples and pears require slow boiling to facilitate penetration of sugar, while soft fruits can be boiled briskly.

19.5 Cooling and Packing

If the preserve is to be stored in bulk, it should be cooled quickly after the first boiling to avoid any discolouration of the product. The fruit is drained from the syrup and filled into dry containers. Freshly prepared boiling syrup of 68^{o}Brix is then poured into the containers such as in A 2.5 size cans, which are exhausted for 8-10 min at about 100^{o}C in steam, and then hermetically closed.

If the preserve is packed scalding hot in dry cans, subsequent sterilization of the cans may be omitted. A 2.5 size (can hold 28.5 fluid ounce i.e. 843.6ml) can may be preferably sterilized for about 25 min at 100^{o}C and cooled immediately thereafter.

19.6 Typical Examples

The examples of sugar preserves include Aonla preserve, Apple preserve, Bael preserve, Carrot preserve, Cherry preserve, etc. The process of manufacturing two such preserve is discussed herein.

19.6.1 Aonla preserve

Aonla preserve is a highly valued product in India as it is associated with valuable therapeutic properties.

Select large fruit (Benarasi variety preferred) for making the preserve. Wash the fruit in water. Prick them with a needle of bamboo/wood/stainless steel. Place the pricked fruits in 2.0% common salt solution. Raise the strength of the salt solution progressively by 2.0% on subsequent days, until the final concentration reaches about 8.0%. Wash the fruit in water and place them in freshly prepared 8.0% brine for about a week. This treatment removes most of the astringency in the fruit. Wash the fruit again. Blanch the fruit in 2.0% alum solution until they become sufficiently soft, taking care to see that the segments do not break or crack in the process. They are then passed through several stages of syrup treatment just as for apples. The final product should be packed in lacquered cans.

19.6.2 Apple preserve

Specifically two varieties namely the Sweet and the Sour ones are preferred for preparing Apple preserve and Apple candy.

Peel the apples thinly, but do not remove the stem and core. Prick the peeled fruit with a stainless steel needle or fork. Place the sweet variety of apple in 2-3% common salt solution and the sour variety in plain water to prevent browning and disintegration of the fruit during subsequent blanching. Transfer them next to dilute lime water (2 parts of lime water and 1 part of water) and leave them for 24 h. Prepare 2-3% alum solution and bring it to boil in a pan. Now transfer the apples to this boiling solution. Add a small quantity of sodium bisulphate to whiten the colour of the apple. Continue boiling until the fruit become soft. Take out the fruit and place them in cold water, discarding the blanching solution. Prepare fresh alum solution separately for each batch. The cooled apples are now ready for the syrup treatment.

Take sugar equal to half the weight of prepared apples. Usually 74-76 kg of sugar is required for every 100 kg of the whole apple, prior to peeling. Place the sugar and apples in alternate layers in a vessel and leave the mass undisturbed for 24 h. During this period, the fruit will give out sufficient water to dissolve the sugar. Ordinarily, the resulting syrup will be of 36-38^{o}Brix. Next, boil the mass for a few minutes and raise the strength of the syrup to ~ 60^{o}Brix by adding more sugar. Next, add a small quantity of citric or tartaric acid, or invert sugar or corn syrup to the extent of 25% by weight. After boiling for a few minutes, let the apples remain in the syrup for another 24 h. On the 3rd day, raise the strength of the syrup to 70^{o}Brix and let the product stand for a week. Now, the preserve is ready for packing in jars or cans.

If the preserve is to be candied, the Brix of the syrup should be raised to 75^{o}Brix and again allowed to stand for another week, before it is ready for candying.

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Lesson 20
GLAZED AND CRYSTALLIZED FRUIT

20.1 Introduction

A fruit impregnated with cane sugar and glucose, and subsequently drained and dried, is called a ***Candied fruit***. Candied fruit covered or coated with a thin transparent coating of sugar, which imparts to it a glossy appearance, is called ***Glazed fruit***. When candied fruit is coated with crystals of sugar, either by rolling it in finely powdered sugar or by allowing the sugar crystals from a dense syrup to deposit on it, it becomes what is called ***Crystallized fruit***.

20.2 Candied Fruit

The process is similar to the one employed in preparing fruit preserves, but here the fruit is impregnated with a higher percentage of sugar or glucose; the total sugar content is about 75.0%. A certain amount of invert sugar or glucose is substituted in place of cane sugar.

The fruits suitable for such preparation are those that possess pronounced flavor, such as pineapple, peach, peels of orange, lemon, grapefruit, citrus, cherry, etc. Use of slightly underripe fruit helps in preventing formation of jam-like consistency in the syruping process.

The sweeteners used maybe Confectioner's glucose (corn syrup, crystal syrup or commercial glucose), dextrose, invert sugar, etc.

20.2.1 Syruping treatment

The prepared fruit or peel is boiled in a sugar syrup of 30^{o}Brix containing 3 parts of cane sugar and 1 part of corn syrup and then left in the syrup for about 24 h. The strength of syrup is raised to 40^{o}Brix by adding a mixture of cane sugar and glucose syrup. The process is repeated and the strength of syrup is raised by 10^{o}Brix to 65^{o}Brix and then by 5^{o}Brix on alternate days, until the final concentration of sugar reaches about 75^{o}Brix, when the process is complete.

It is desirable to have cane sugar and invert sugar in the final syrup in nearly equal proportion. The acidity should be maintained at 0.1% by adding a small dose of acid daily along with added sugar, to ensure adequate inversion.

20.2.2 Draining and drying

After syrup treatment is over, the fruit is removed from the syrup and drained for about half an hour. The fruit or peel is wiped with a wet sponge. Sometimes it is dipped for a moment in boiling water to remove the adhering syrup. This is followed by slow drying in the shade, or in a drier at about 66^{o}C for 8-10 h. Candied citrus peel needs drying for 10-12 h.

20.3 Examples of Candied Fruit Products

20.3.1 Candied citrus peels

Candied citrus peels are highly popular for festive occasions like Christmas, Diwali, etc. They are manufactured and sold in large quantities in several parts of the world. They are useful as flavouring materials in cakes, puddings, etc. Citrus peels, especially orange peels, are waste products in the manufacture of orange juice, squash, segments, etc. Thick rinds of citrus fruits like orange, lemon, grape fruit, citrus, and pummelo are used for candying.

After the peels are prepared, they are covered with a cold syrup of 30^{o}Brix in a vessel and left for 48 h. On the 3rd day, the strength will be less than 30^{o}Brix, which is raised by 10^{o}Brix and the peels boiled in this syrup for about 5 min. The process is repeated until the strength reaches 60^{o}Brix. At this stage, citric or tartaric acid is added at the rate of 1.25 g for every kg of peels. Alternatively, glucose or invert syrup may be added up to a maximum of 50.0% of the cane sugar used. The strength of the syrup is then raised to 75^{o}Brix by 5^{o}Brix every succeeding day. The peels are then left in this syrup for 2-3 weeks. Finally, they are taken out from the syrup and dried on wire mesh trays at room temperature until they are no longer sticky. They may also be dried at 49^{o}C for 2-3 h in a drier.

20.3.2 Petha (Candied ash gourd)

Take fully, mature petha (Ash Gourd) and cut longitudinally into fairly large piece. Remove the fluffy portion from inside of the slices and peel each side separately. Soak the peeled slices for about 30 min in lime water, diluted with three times the quantity of water. Prick the pieces with a stainless steel needle or fork and cut the slice into pieces of suitable size. Keep the pieces in lime water again and let it stand overnight. Prepare 2-3% alum solution and bring it to boil. Boil the pieces in this solution till they become tender. Drain and cool them in running cold water. Sodium sulphite may be used while cooking the slices, to render the pieces white. Arrange the prepared slices in alternate layers with sugar (half their weight) in a vessel and allow standing for 24 h. During this period, the pieces will give out sufficient water for the sugar to dissolve. The syrup will be about 36-38^{o}Brix. Add sugar to raise the strength of syrup to 59-60^{o}Brix. Add citric/tartaric acid at the rate of 0.62 g/kg of sugar used. Alternatively, add 25% by weight of invert sugar or corn syrup to raise the syrup strength. Boil the slices in syrup for 10 min and set then aside for 24 h. Later on, increase the strength of the syrup by 5^{o}Brix on every alternate day till it reaches 70^{o}Brix. Allow the pieces to remain in this syrup for 4-6 weeks.

For candying, bring the whole mass of petha and syrup to a boil and while still hot, drain the syrup. Roll the drained pieces in finely powdered sugar and dry them on trays at room temperature.

Fig. 20.1 Dry petha from ash gourd

20.4 Glazing of Fruit

The syrup needed for glazing process is made by boiling a mixture of cane sugar and water in the proportion of 2:1, in a steam pan at 113-114°C and skimming the impurities as they surface. Heat is stopped and the syrup cooled to 93°C. Granulation of the sugar is achieved by rubbing the syrup with a wooden ladle on the side of the pan. Dried candied fruit are passed through the granulated portion of the syrup, one by one, by means of a form, and then placed on trays that are kept in a warm, dry room. To hasten the process, the fruit may be dried in a drier at 49°C for 2-3 h. When it becomes crisp, it is packed in air-tight containers.

20.5 Crystallized Fruit

In this case syrup of 70°Brix is employed. It is placed in a large deep vessel and allowed to cool to room temperature. To avoid premature granulation of sugar, a sheet of waxed paper is placed on the surface of the syrup. The candied fruit is placed on a wire mesh tray, which in turn is placed in a deep vessel. The cooled syrup is then gently poured over the fruit so as to cover it entirely. To prevent the fruit from floating, another wire-mesh tray is placed on it and a sheet of waxed paper is placed on the surface of the syrup. The whole mass is left undisturbed for 12-18 h, at the end of which a thin crust of crystallized sugar is formed. The tray containing the fruit is then removed carefully from the pan, and the surplus syrup drained off. The drained fruit are spread in a single layer on wire mesh trays and allowed to dry at room temperature or in driers at about 49°C.

Fig. 20.2 Glazed fruit

20.5.1 Improved mechanization of preparing glazed and crystallized fruit

Vacuum concentration process of Cruess is an improvement over the conventional one. The fruit and the syrup are maintained at 60°C and the concentration of sugar is raised at the rate of 1°Brix per hour; a part of the syrup is continuously withdrawn and concentrated in a Cascade or Calandria type of evaporator.

Using modified technique, the syrup strength could be raised from initial 30° to 70°Brix in 40 h. The ash gourd and apple preserves made by this method are highly satisfactory.

20.5.2 Spoilage of glazed and crystallized fruit

There is a likelihood of spoilage occurring due to fermentation, especially in the initial stages of preparation of preserves and candies when the concentration of sugar in the syrup is low. This can be controlled by boiling the product at proper intervals. If the candied and crystallized fruit are stored under humid conditions, they throw off some of their sugar owing to absorption of moisture from the air. Later on, they become mouldy, if they are packed in wet rather than dry containers. The danger of mould infestation may accrue if such fruit is not sufficiently dried.

Module 6. Tomato and tomato based products

Lesson 21

TOMATO JUICE EXTRACTION AND JUICE CHARACTERISTICS

21.1 Introduction

Tomato *(Lycopersicum esculantum)* belongs to family Solanaceae.Tomato is one of the most popular and widely grown vegetable crops in the world. It stands next only to potato in terms of production. India is fourth largest producer of tomato next only to China, USA and Turkey with an estimated production of 11.98 million tonnes in 2010. In India, Bihar is the leader in terms of area under tomato crops, but Uttar Pradesh leads is production as well as productivity. It is short duration vegetable crops which fit suitably among different dropping system. Important cultivars of tomatoes grown in India include Pusa ruby, Pant bahar, Pusa hubrid-1 & 2 and Arka Saurabh.

Tomato is a very versatile vegetable for culinary purposes. Ripe tomato fruit is consumed fresh as salads and utilized in the preparation of a large number of processed products such as puree, paste, powder, Ketchup, sauce, soup and canned whole fruit. The partially ripened fruits are processed into pickles, chutney and in the recipe of number of traditional cuisines.T he waste obtained after the juice or pulp extraction i.e. seeds and pomace is also utilized for the extraction of tomato seed oil and lycopene, respectively.

21.2 Composition of Tomato

Chemical composition of tomato depends on various factors such as variety, growing environment and package of practice. Besides it, the composition may also vary at different stage of maturity. The composition of tomato is important from the quality point of view as it affects colour, nutrient content, flavour and texture of the both raw as well processed tomato.

Table 21.1 Composition of tomato at different stages

Variable	Green (Mature)	Red	Red (Ripe)
Total Solids (%)	6.4	5.8	5.2
Titratable Acidity (%)	0.29	0.27	0.29
Ascorbic Acid (mg/100g)	14.5	23	22
Starch (%)	0.61	0.18	0.07
Reducing Sugar (%)	2.4	3.45	3.65
Pectin (%)	2.34	1.74	1.62
Lycopene (mg/100g)	8	374	412
β-Carotene (mg/100g)	50	10	0
Protein Nitrogen (mg/g dry wt.)	9.44	10.27	6.94

Chemical composition of tomatoes varies at different stage of maturity. Total solid content decreases with maturity from green (mature) to eating ripening maturity due to the conversion of insoluble components mainly starch and insoluble polysaccharides into simple sugars and soluble polysaccharides, respectively. Soluble solids in tomato mainly consisted of sugars, which play significant role in flavour development. The chlorophyll content decreases with concomitant increase in the concentration of lycopene, the major pigment in tomato. The concentration of β-carotene lowered during the maturity and its concentration is more in pink & yellow coloured varieties than red varieties.

Pectin a major cell wall constituent is important for the firmness of fresh tomato and influence the consistency of tomato products. However, the concentration of soluble pectin increased during the ripening because of the higher pectinolytic acidity. Acidity of tomato is mainly attributed to their citric and malic acid content. The average calorific value of tomato varies in the range of 23-25 Kcal/100 g, which is quite low. However, the higher amount of antioxidants like lycopene and ascorbic acid further enhance their nutritional value. They are also very good source of minerals specially magnesium and potassium which have heart healthy role. They also supply copper, iron and sulphur in diet. Oxalate is considered as anti-nutrient component in tomato which may be responsible for stones in kidney and gall bladder by complexing calcium in gastrointestinal lumen. Thus it also decreases the bioavailability of calcium in body.

21.3 Nutritional and Therapeutic Effects of Tomato & Tomato Products

Tomatoes are good source of ascorbic acid, which constitutes about 15-20 mg per 100 g of edible parties. The level of ascorbic acid increases with ripening. The concentration also depends on the cultivar and exposure to sunlight. One of the most widely researched components is lycopene, a reddish colour pigment, responsible for characteristic colour of tomatoes. Lycopene is the most effective singlet oxygen scavenger in biological system. Vitamin C, lycopene and carotenoides present in tomatoes are effective antioxidants and have been found effective in prevention of number of cancers. Lycopene also exhibits similar effectiveness in inhibiting low density lipoprotein oxidation as -carotene.

21.4 Tomato Pulp and Juice Extraction

Tomato juice and pulp are the major primary processed products of tomato which may be utilized for the production of high value added products like puree, sauce, ketchup, chutney, powder etc. All varieties of tomato are not suitable for processing point of view. The varieties which are used for juice and pulp manufacture must possess following characteristics.

1. Deep red coloured varieties are preferred as yellow coloured pigments not only mask the red colour in processed tomato products but these are also susceptible to oxidation resulting in brown colouration.
2. Firm but ripe fruits should always be used as they contain sufficient amount of pectin which is essential for the consistency of the finished products like puree, sauce, ketchup etc.
3. Green coloured and sour varieties should not be used as they will affect the flavour and colour of the resultant products.
4. Tomatoes are also susceptible to microbial decay, hence any infected or diseased fruit should never be used for the manufacture of products as they may pose health hazards.

Fig 21.1 Tomato's suitable for pulp extraction

21.4.1 Preliminary processing of tomato

After selection of suitable fruits, they are washed in running water to remove all adhering dirt, dust, foreign particles including fungal filaments and other microbes. On large scale production plant, rotary washers or trough washers flitted with moving conveyer belt and soft rubber brushes are generally employed.

21.4.2 Trimming & sizing

Tomatoes are trimmed manually with the help of knife to remove green, yellow coloured portion, decayed or infected parts and stalks. The trimming losses may vary from 4 to 17% depending on the selection of raw material. After trimming, tomatoes are cut into 4-6 small pieces of 0.4-0.6 inch and crushed for juice extraction.

21.4.3 Pulping or juice extraction

The tomato juice is probably one of the most widely used juices. Fresh raw tomato juice is most beneficial and because of its alkaline reactions if consumed alone. However, presence of sugar and starch rich foods along with tomato juice make is acidic. The juice extraction may be done either by hot pulping, or cold pulping method.

21.4.3.1 Hot pulping

Crushed tomatoes are boiled in their own juice in steam-jacketed stainless steel kettles or aluminum pans for 3 to 5 minutes to facilitate pulping. The crushed or chopped tomato pieces are heated to at least 82^{0}C for 15-20 seconds to inactivate pectic enzymes. On industrial scale heating is usually carried out in rotary coil tanks followed by passing through a plate heat exchanger (PHE) and holding tube to achieve a processing temperature of 104^{0}C to retain at least 90% of the potential serum viscosity in the original fresh tomato. At small scale crushed or whole tomatoes are pressure cooked for 2-3 minutes. Hot pulping or hot break method has following advantages:

- Serum separation tendency in the product is checked, because of more extraction of pectin present in skin and around the seeds. Heat treatment also inactivates the enzymes (pectic enzymes specially polygalacturonase) that may hydrolyze pectin and reduce the viscosity of the juice or pulp. Polygalacturonase is highly heat resistance enzyme that cause splitting of two adjacent galacturonic acid molecules and responsible for softening.
- Juice is quite viscous, heavy bodied and homogenous because of the extraction of pectin and other soluble polysaccharides.
- Thermal treatment partially sterilizes the juice or pulp; thereby it decreases the initial microbial load and product can be kept for longer period.
- Inactivation of oxidative enzymes i.e. ascorbic acid oxidase, prevent loss of vitamin C.
- More juice yield as compared to cold pulping.
- Juice or pulp obtained by hot pulping process is deep red and attractive in colour. It is because of the release of pigments located within the cell vacuoles due to heating.

21.4.3.2 Cold pulping

In cold pulping or cold break method tomatoes are scalded to facilitate the separation of skin before chopping. Tomatoes are crushed or chopped at temperature less than 66^0C and allowed to fall into a holding tank, where they remain for few minutes. During this period the native cell wall hydrolyzing enzymes of pectinolytic enzymes of the tomatoes are liberated and catalyze the various hydrolytic reactions to release the cellular components. The cold break juice is better in terms of flavour, colour and nutrients mainly vitamin C, but the juice is quite prone to spoilage and quick processing of the extracted juice is necessary. However, following defects are found to be associated with this method:

- Extraction of juice from the interior of cell requires higher pressure. Hence often juice yield become low, higher pressure cause extraction at juice around the seeds, which is more acidic and less sweet.
- Inferior colour (lighter) because of the less extraction of pigments from the skin
- Poor microbiological quality as comparison to hot break juice.
- Less nutrition due to oxidation of vitamin C resulting in loss.
- Cold extraction results in insufficient extraction of pectin and other polysaccharides that may adversely affect the viscosity or consistency.

21.4.3.3 Equipments for pulp or juice extraction

Two different types of machines are used to extract the juice or pulp from the tomatoes namely Continuous spiral press and the Cyclone or pulper.

21.4.3.3.1 Continuous spiral press

The equipment consists of a long spiral screw which presses the tomatoes against a tapered screen of fine filter of 25 mesh size. The crushed tomatoes are fed through hopper and conveyed by the rotation of screw which normally rotates at a speed of 250 rpm. The low speed further disintegrate the tomatoes and free flowing juice and small pulp particles passed through the screen whereas skin and seeds are retained. During the extraction of juice or pulp care is taken to avoid incorporation of air and minimize the oxidative damage.

21.4.3.3.2 Cyclone or pulper

Juice can also be extracted by passing the crushed or chopped tomatoes through a cyclone or pulper. The machine consists of perforated cylindrical screen with apertures on about 25 mesh size and one rotating shaft which moves at very high speed to broken down the tomatoes into very small sized particles. The free flowing juice and smaller pulp particles are passed through the screen and separated out. In this method the insoluble solids in the juice are very finely divided and remain in juice for longer period. However, the use of cyclone results in incorporation of air which accelerate the various oxidative reactions.

In any method of juice or pulp extraction not more than 60% of fruit should be recovered as juice or pulp other it may affect the flavour and appearance of the resultant juice or pulp adversely.

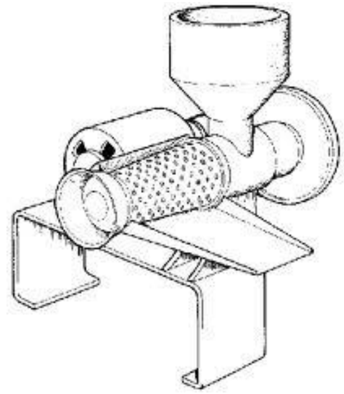

Fig. 21.2 Schematic Diagram of Tomato pulper

21.5 Processing of Juice or Pulp

As per FSSAI definitions thermally processed tomato juice means the unfermented juice obtained by mechanical process from tomatoes (*Lycopersicum esculentus*L) of proper maturity and processed by heat, in an appropriate manner, before or after being sealed in a container, so as to prevent spoilage. The juice may have been concentrated and reconstituted with water for the purpose of maintaining the essential composition and quality factors of the juice. The product may contain salt and other ingredients suitable to the product. The product shall be free from skin, seeds and other coarse parts of tomatoes. The product shall have pleasant taste and flavour characteristic of tomatoes free from off flavour and evidence of fermentation. The product shall conform to the requirements of total soluble solids (TSS) m/m free of added salt to be not less than 5.0 percent. The product may contain permitted food additives as specified by FSSAI. The juice thus obtained is filtered to remove undesired portions like skin fractions, seeds by passing through filter (metallic or polymer vibrating perforated screen with desired pore size). The filtered juice is de-aerated immediately to prevent the oxidative losses. The additives or ingredients like sugar, citric acid or salt is added to improve the flavour of the juice. On an average juice should have TSS content of 5.66 per cent at 20^0C. Juice may further be filled into bottles, cans using filling machine. The fill machines are adjusted to give minimum headspace as possible in order to check oxidative deteriorations. The cans are hot filled at about 82-88^0C followed by processing at 121^0C for not less than 0.7 minutes, followed by cooling of containers by spraying cold water jackets.

In case of pulp homogenization is suggested to retard the tendency of serum separation in juices and other processed products. Tomato juice or pulp is very much susceptible to spoilage by mould, yeast and bacteria. The pH of the tomato juice and pulp varies in the range of 4.0 to 4.4. The major risks of spoilage of from spore forming species other than *Clostridium botulinum* mainly *Bacillus coagulans* among the aerobes and *Clostridium pasteurianum* and *Clostridium thermosachharolyticum* among anaerobes. The spoilage of tomato juice is characterized by a peculiar off-taste and odour known as ‘flat sour”.

Lesson 22

TOMATO PUREE, PASTE, SAUCE AND KETCHUP

22.1 Manufacturing of Tomato Puree and Paste

The pulp which is obtained by hot or cold break method is concentrated to manufacture puree and paste. Fully mature and deep red coloured tomatoes are preferred for the manufacture of tomato puree and paste.

22.2 Tomato Puree

Tomato juice or pulp as obtained by cold or hot extraction method is concentrated to about 9.0 percent to 12.0 percent total solids to prepare tomato puree. Commercial tomato puree can be defined as concentrated tomato juice or pulp without skin or seeds, with or without added salt and containing not less than 9.0 percent salt free tomato solids, is “medium tomato puree”. Further concentration to 12.0 percent solids will yield “heavy tomato puree”.

22.3 Tomato Paste

Tomato paste can be defined as concentrated tomato juice or pulp without skin and seeds, and containing not less than 25 percent of tomato solids. If the tomato paste is further concentrated to a tomato solid levels of 33 percent or more then it is called as concentrated tomato paste. The manufacturing technology for the production of tomato puree and paste is outlined in Fig.22.1.

Tomato Juice or Pulp
(Strained)
↓
Concentration
(Open Kettle/Vacuum pan)
↓
Hot Filling into Bottles or Cans
(82-88^{0}C)
↓
Thermal Processing
↓
Cooling
↓
Storage

Fig.22.1 Process flow diagram for tomato puree or paste manufacture

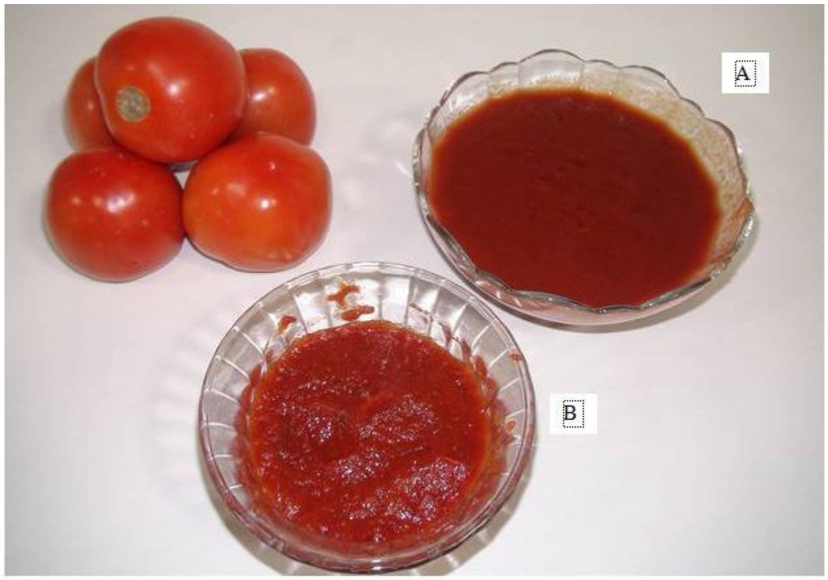

Fig. 22.2 Tomato puree (A) and Tomato paste (B)

Tomato juice or pulp is strained or filtered to remove portions of skin, seeds and large coarse pieces to get uniform juice or pulp. The juice or pulp is concentrated in open kettle or vacuum kettle to evaporate water and the process of evaporation in case of puree is continued till the volume reduced to equal or one-half of original. The end point is determined by the hand refractometer to measure the total soluble solids and expressed as degree Brix. Alternatively it can also be determined by using specific gravity bottle or by drying the juice or pulp under vacuum at 70^0C. The puree of desired total soluble solids is then filled into cans (temperature of filling 82-88^0C) and processed in boiling water for 20 min. The processed cans are cooled immediately either by dipping them in cold water or sprinkled with cold water. The cans are then stored in dry and cool place.

For the manufacture of tomato paste, tomato juice or pulp is first concentrated in open steam jacketed kettle to total solid levels in the range of 14-15 percent and subsequent concentration is carried out in vacuum pan. During cooking in open kettle common salt, basil leaf or sweet oil of basil leaf may also be added to prevent the excessive foaming, burning and sticking. In vacuum pan, the water present in pulp or juice starts evaporating at 71^0C. It assists in retention of bright red colour and flavour. The removal of air also check any oxidative reaction that may adversely affect the nutritional value i.e. vitamin C. For sterilization of the product, vacuum is removed and the temperature is raised to 100^0C and held at that temperature for about 10 min.

22.4 Technology of Tomato Ketchup and Sauce

Among the tomato products, in India tomato sauce and ketchup are very popular and are being manufactured on an increasingly large scale. It is one of the simplest ways of conserving the tomato solids. As per FSSAI standards “Tomato ketchup and sauce means the product prepared by blending tomato juice/puree/paste of appropriate concentration with nutritive sweeteners, salt, vinegar, spices and condiments and any other ingredient suitable to the product and heating to the required consistency. Tomato paste may be used after dilution with water suitable for the purpose of maintaining the essential composition of the product. The finished product should contain not less than 25.0 percent total soluble solids (salt free basis) and acidity not less than 1.0 percent as acetic acid. The product should also meet the given microbiological criteria (Table 22.1).

Table 22.1 Microbiological criteria for tomato ketchup and tomato sauce

Tomato Ketchup and Tomato Sauce	Mould count	Positive in not more than 40.0 percent of the field examined
	Yeast and spore count	Not more than 125 per 1/60 c.m.m
	Total plate count	Not more than 10000 per ml

Tomato ketchup and sauce can be made from freshly extracted juice or pulp or using tomato puree or paste. Strained tomato juice or pulp along with spices, salt, sugar and vinegar is cooked or concentrated to the extent that ketchup and sauce contains not less than 12 percent tomato solids, 25 percent total solids and minimum acidity as 1% acetic acid. The TSS content in tomato ketchup should be 25-29 for grade C, 29-33 for grade B and over 33 for grade A.

Basically there is no difference between tomato ketch-up and tomato sauce. Tomato sauce has thinner consistency and it is blended with juice or pulp from other vegetable sources including potato puree, cucumber juice or carrot pulp. In the manufacture of tomato ketchup following steps are involved:

22.4.1 Selection of raw material

Careful selection of tomato for the manufacture of tomato ketchup is very crucial step as it may affect the quality as well as shelf-life of the finished product. The criteria for selection include maturity, freedom from blemishes and defects. Ripe deep red coloured tomatoes with higher TSS and pulp provide a better quality product. Pectin content and pigmentation are two important parameters determined the finished product quality.

All green and yellow coloured portions should be removed. Chlorophyll and Xanthophyll present in immature fruits, upon heating form brown coloured compound pheophytin that may adversely affect the acceptability of the product. Flavour of the product also gets affected, if green tomatoes are used.

22.4.2 Extraction of pulp or juice

The pulp or juice could be extracted by using hot or cold pulping method. However, hot pulping method yields pulp with higher proportion of total solids, lycopene; pectin content and of good microbiological quality. The freshly extracted pulp or juice as well as preserved pulp or puree or paste may be used as starting material. Use of puree or paste of suitable total solid level produce ketchup of uniform quality and also ensure consistency from batch to batch.

22.4.3 Juice standardization

Freshly squeezed juice is a thin, watery fluid and its specific gravity varies with the kind of tomato and duration of boiling. Its T.S.S. should not be below 5.66^{o} Brix. In case of tomato puree or paste these are diluted to desired total solid level before ketchup preparation. After standardization of juice or pulp total solid the ketchup or sauce is manufactured by the process as outlined in Fig. 22.2.

Tomato Juice or Pulp
(Strained)

↓

Addition of 1/3rd Sugar & Spice Bag
(Open Kettle/Vacuum pan)

↓

Cooking & Concentration

↓ ← **Addition of remaining Sugar & Salt**

Concentration

↓

End Point (by Refractometer)

↓ ← **Addition of vinegar and Preservative**

Bottle Filling

↓

Thermal Treatment/Pasteurization
(at 85-88^{0}C for 30 minutes)

↓

Cooling & Storage

Fig.22.3 Process flow diagram for tomato ketchup or sauce manufacture

Fig 22.4 Tomato ketchup and tomato sauce

22.4.4 Addition of ingredients

22.4.4.1 Spices

The spices should be of good quality and they should be added in the proper proportions to give an agreeable taste and flavour to the product. No single spice dominates the natural flavour of the tomato. The spices which are preferred in ketchup manufacture include red chili, black pepper, nutmeg, clove, cinnamon, cardamom, mace and cumin. Beside these spices seasonings like onion, ginger and garlic may also be used in ketchup recipe. While adding spice certain precautions are recommended to produce excellent quality ketchup or sauce.

- Red chili powder, spices, onion and ginger should be tied loosely in bag for better diffusion of flavoring principles in ketchup.
- The head portion of clove should always be removed before its grinding as it may lead to black neck defect in ketchup.
- Normally garlic is not preferred seasoning in ketchup or sauce manufacture as its flavour may predominate over other spices.
- Essence of clove, cinnamon and cardamom is preferred in place of using coarsely ground powder because of the convenience of use and better flavour note in finished product.

The spices may be used in the following way during the manufacture of ketchup or sauce.

22.4.4.1.1 Bag method

The coarsely ground spices are tied loosely in a muslin cloth bag and the bag placed in the tomato juice during boiling. The bag is pressed intermittently to release the flavouring component during processing. The proportion these spices should be standardized in such a way that they should not affect the colour of the resultant product and does not impart bitterness. This bag can be used for second batch also. This method has following drawbacks:

- By chance opening of bag may spoil the whole batch. Even if we want to remove these, spice particles by passing it through sieve, it may darken the product.
- Incomplete extraction of flavouring component, so, flavour of ketchup may vary from batch to batch.
- Some of the volatile constituents may get lost during boiling.

Still bag method yield ketchup of superior quality and it is most preferred for ketchup or sauce preparation at small scale or batch methods. The spice bag may also be used for subsequent batches and used spices may also be in pickle preparation.

22.4.4.1.2 Use of essential oils

An essential oil is a concentrated hydrophobic liquid containing volatile aroma compounds from spices. They are extracted by the process of distillation or solvent extraction. The Essential oils of spices contain only the volatile substance of the spice and devoid of tannins, hence the colour and flavour of ketchup is not affected.

These can be easily blended and precision in terms of percentage can be made. However, they lack the true aroma of the whole spice. The actual amount of essential oil for raw spice is mentioned below.

Table 22.2 Essential oil content in different spices

S. No.	Spice (100 kg)	Equivalent Weight of Essential Oil (kg)
1	Cinnamon	0.5
2	Clove	1.5
3	Mace	3.5
4	Pepper	1.0
5	Cardamom	3.0

22.4.4.1.3 Use of oleoresins

Oleoresins are pure and natural extracts of spices, obtained by solvent extraction. These concentrated extracts contain all the flavour components, be it volatile oils or non-volatile resinous fractions. These are the resins of active flavouring component in some solvent. The active flavouring molecule is extracted with a suitable solvent and it can provide the full flavour profile of the raw spice with quick release of the flavour. Application of oleoresins is advantageous in commercial production of ketchup or sauce. The only limitation while using oleoresin is the cost of production. Oleoresins are added few minutes before the final boiling during the manufacture of ketchup or sauce.

22.4.4.1.4 Use of extracts

Spice extract is prepared on large scale by steeping or boiling spices in vinegar. The aroma component of the spices gets extracted in vinegar and vinegary extract may be used in place of whole spice. It assists in maintaining the same taste and aroma and also standardizes the proportion of spices in the recipe. Nowadays, it is one of the most widely accepted methods of spice addition.

22.4.4.2 Sugar

Sugar is mainly used to adjust the sugar-to-acid ratio of the ketchup or sauce. Sugar may be added in the form of granular sugar, corn syrup and other syrups are used. However, granular sugar is most preferred one. About 1/3rd of sugar is added in the initial stage of boiling. This help in preserving the natural colour of the product. Rest of the sugar is added minute before final concentration is reached. Initial addition of sugar will adversely affect the colour of the product as cooking of the product with higher amount of sugar under acidic conditions flavour brown coloured “Furfural”, Commercial level, sugar level varies between 10-26%. Higher amount of sugar may impart higher sweetness which is not liked by consumers.

22.4.4.3 Common salt

Salt bleaches the colour of the tomato and also dissolve to some extent copper from the processing equipment. It is, therefore, desirable to add towards the end point of the process. Range of common salt varies between 1.5 – 3.5%, salt is added to enhance flavour of the product and exert preservative action to a lesser extent. Salt of very high purity is preferred for the ketchup manufacture. Salt also counteract the highly acidic flavour of the tomato pulp.

22.4.4.4 Vinegar

Well matured salt-vinegar, cider vinegar or malt vinegar may be used as acidulant in the product. However, these vinegars are not colourless; hence they may affect the colour of the finished product. Vinegar contains not less than 5 percent acetic acid. On industrial scale commercially available glacial acetic acid is preferred because of the following reasons.

- Lower cost as compared to malt, or cider or salt vinegar
- Glacial acetic acid is 100% acetic acid; hence it will have lesser effect of heating.

Vinegar is always added towards the end of the process in ketchup or sauce manufacture. Since it is a volatile product most of the acid will lose during cooking. Ketchup contains 1.25-1.50 percent acetic acid. Vinegar contributes towards the flavour as well as microbial stability of the ketchup.

22.4.4.5 Thickening agent

Insufficient quantity of pectin in tomato juice, puree or paste invariably results in serum separation in ketchup during storage. Ketchup prepared by cold pulping process contains very less amount of pectin due to incomplete solubilization and extraction of pectin. Likewise using variety with low pectin content may also necessitate addition of certain thickening agents. Hence, pectin (0.1 – 0.2%), corn starch (1%) and other hydrocolloids may be added to control this problem. Xanthan gum is an ideal thickener for this type of products because of its acid stability and pseudoplastic flow properties it imparts. The glass or sheen, which xanthan gum imparts to these sauces or ketchup is another appealing factor for the consumer. Pectin may also be added @ 0.1-0.2 percent by weight of finished product in clear juice or pulp to check the problem of serum separation and to also increase viscosity.

Table 22.3 Recipe for Tomato Ketchup

S. No.	Ingredient	Amount
1	Tomato pulp	1 kg
2	Sugar	70 gm
3	Salt	10 gm
4	Chopped onion	1.5 gm
5	Chopped garlic	1.5 gm
6	Red chili powder	0.5 gm

7	Cumin, Cardamom	0.40 gm each
8	Clove (headless)	1.5 gm
9	Cinnamon	1.5 gm
10	Vinegar	10 ml

22.4.5 Cooking & concentration

The tomatoes juice along with other ingredients is cooked and concentrated to get the desirable flavour, uniform taste and fine thickness or body. The cooking of ingredients may be carried out in open jacketed kettle or vacuum concentrator. The cooking continues till the concentration reached 25 percent TSS. However, concentration of 28-30 percent total solid is ideal as further increase may adversely affect the flavour of the product. However, to improve the stability of ketchup slightly higher amount of sugar, salt and vinegar is added.

22.4.6 Bottling & Packaging

The ketchup after attaining the desired total solid level and consistency is finally passed through a finisher to remove any tomato fibre, seeds and any other suspended solids. The Ketchup or sauce after cooking should be bottled hot at 85-88°C to prevent browning and loss of vitamin during subsequent storage and distribution. Hot filling of bottle also assist in creation of vacuum in the headspace during the cooling of ketchup. The crown cork used for ketchup bottle should be lined with polyvinyl chloride (PVC) to prevent the contact of ketchup with the metallic portion to avoid the “black neck” formation. However, nowadays sauce and ketchup is also packed in laminated flexible packaging materials consisted of polyethylene (PE), polyester (PET) and aluminum. These polymers may be co-extruded in different combinations to get the desired functional and mechanical properties. Sauce and ketchup require protection from oxidation and moisture migration/ingress. Moreover, certain squeezable bottles are also used for the packaging of these products. Bottled and packaged products are stored under ambient temperature (30-35^{0}C) under dry places.

22.4.7 Pasteurization

Although, hot filling of the ketchup in bottle is considered safe for consumption and have sufficient shelf-life, but still come manufacturers prefer further thermal treatment. The hot filled bottles are pasteurized in hot water (85-88^{0}C) for 30-35 minutes. Care must be taken to cool the bottle immediately after pasteurization to avoid the degradation of nutrients and over-processing. Shelf-life is also enhanced by using preservatives.

22.5 Defects in Ketchup

The two most common observed defects in ketchup are: serum separation and blackening specially around the neck. The latter defect is referred as “Black neck defect”. The tannins present in spices get extracted into the ketchup and when these phenolic compounds come in contact with iron leached out either from processing vessels or from the closure of ketchup bottles, they form ferrous tannate. This compound undergoes oxidation and form ferric tannate and it is a black coloured compound. To check it one should not use iron or copper utensils and headless clove should be used. The inner lining of bottle cap should be of PVC. Problem of serum separation as already been discussed in Section 2.4.5. Among the microbiological problem mold growth is the most serious one. Microbial growth can be taken care by adding chemical preservatives specially benzoic acid. Benzoic acid is added in the form of its sodium or potassium salt because of almost 54 times higher solubility of salt as compared to benzoic acid. As per FSSAI guidelines the maximum permissible limit of benzoic acid is 750 ppm.

Fig. 22.5 Black neck defect in tomato ketchup

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Lesson 23

NOVEL TOMATO BASED PRODUCTS

23.1 Technology of Tomato-Chili Sauce

Tomato sauce is equally popular like tomato ketchup and there is lot of scope of innovation in formulation and manufacturing process to develop newer variant of it. Several such commercial preparations like Tom-chi (Tomato-Chili Sauce), Tom-Imli (Tomato & Tamarind sauce) etc; are available in Indian market. The purpose of developing such novel products is to utilize tomato, offer new products to consumer and diversify the product profile. Tomato sauce is slightly thinner in consistency than tomato ketchup and may contain certain thickening agents derived from vegetable starch (potato, cassava) or cereal (maize). It also contain higher amount of acetic acid i.e. around 1.60 percent to improve the keeping quality. The amount of sugar is usually higher (15-23 percent) to counteract harsh acidic taste and flavour. The concentration of spices is kept less as compared to ketchup.

The manufacturing technology for the tomato-chili sauce is similar to as discussed for tomato ketchup. The green chili is pureed by hot break method and seed as well as coarse fibrous portions are removed. The pureed chili is added in the formulation and ratio of sugar-acid-pungency is maintained in such a way that resultant product provide the flavour sensation of all the three in balanced way. Similarly, in tomato-imli sauce, the tamarind pulp is added along with tomato pulp and to balance more acidity slightly higher percentage of sugar is added. These novelty products are popular among all age groups and consumed with snacks.

23.2 Dried Tomato Products

Tomatoes are quite perishable in nature and can be processed as dried product for value addition. Tomato slices can be dried by using tray or tunnel drying process or alternatively tomato pulp of juice may be spray dried to yield tomato powder of excellent quality. Drying process increases their availability round the year in convenient form.

23.2.1 Dried tomato slices

Dried tomato slices are versatile ingredient and find its application in various food formulations. Tomatoes of good quality are after through washing are blanched either in plain water or in 2.5% salt solution for 1 min. These blanched tomatoes are dropped in cold water to quickly cool the product. This also helps 1.5 cm thick slices, and excess juice is drained off. Tomato slices are dipped in 2.5% gelatinized starch containing 5% potassium meta-bisulphate for 9 min. They are spread over perforated or aluminum trays. Drying is carried out at 65-70°C in a tray drier till the moisture reached to 4.5%. These slices may be packed in polythene bags or grind as powder (Fig. 23.1).

Tomatoes

↓

Blanching in 2.5% Salt Solution for1 min

↓

Dipping in cold water for quick cooling

↓

Cutting into 1.5 cm thick slices

↓

Draining of free juice

↓

Dipping into 2.5% gelatinized starch containing
5% Potassium metabilsuphite for 2 min

↓

Spreading on trays

↓

Drying in cabinet dryer at
75°C for 4 h and 50°C for 8 h

↓

Grinding

↓

Packing in polyethylene bags

↓

Storage at room temperature

Fig 23.1 Tray Drying Process for Tomato Slices

23.2.2 Tomato powder

Tomato powder preparation is another technique for the preservation of tomato solids during off-season and offer convenience to consumers. The powder may be used in formulation of other processed products like culinary recipes or can be reconstitute in the form of juice or used as starting material for the manufacture of secondary products like sauce, ketchup and chutney. The tomato powder can be manufactured by using tray drying, foam mat drying or spray drying process. The powder obtained by different methods also varies in their properties mainly colour, nutrients and reconstitution.

For the manufacture of tomato powder whole tomatoes are cleaned, washed and surface moisture is allowed to evaporate. The juice is extracted by hot pulping methods and pulp is filtered to obtain pulp free juice which is subjected to vacuum concentration. The concentrated juice is mixed with foaming agent to form foam which is dried by using hot air. The dried powder is cooled, conditioned and ground in the form of powder.

Tomato Juice or Pulp
(Strained)

↓

Vacuum Concentration
(Vacuum pan or multiple effect evaporators)

↓

Tomato Juice Concentrate

↓

Atomization of Feed
(25,000 rpm)

↓

Spray Drying
(Inlet Air Temperature 200^{0}C
Outlet temperature 70^{0}C)

↓

Cooling & Storage

Fig.23.2 Spray drying process for the preparation of tomato powder

The spray drying process for the manufacture of tomato powder is outlined in Fig 23.2. The tomatoes with thick walled, bright red colour, high solids and high pectin content are the best for dehydration. The juice is extracted by hot break method and may also be subjected to enzymatic treatment to improve the recovery of juice, solids and colouring pigments. Seeds and skin pieces are removed prior to particle size reduction. The juice is concentrated in vacuum pan or double effect evaporators to desired total solid level. Maltodextrin (10 DE @ 10%) and SiO_2 (@ 1%) are added in concentrated juice to improve the colour and reconstitutional properties of the powder. The atomization speed of 25,000 rpm and inlet air temperature of 200^{0}C is recommended for obtaining good quality tomato powder.

Colour of tomato powder depends on the lycopene content which is affected by thermal treatment. Therefore, optimization of feed rate, temperature of inlet and outlet air, additives and atomization speed determine the extent of thermal damage and quality of powder. The powder can be packaged in oxygen and moisture impermeable films. Further it can be also packed under vacuum for prolonging the shelf-life.

23.3 Whole Tomatoes in Sauce

This product is a new kind of product. In this product whole tomatoes are preserved in their natural form, which is quite appealing to the consumers. The tomatoes dark red in colour, firm and free from any defect, are selected, washed thoroughly in water. The uniform elliptical shape or round shaped tomato varieties are preferred. These tomatoes are blanched in boiling water for 230-60 seconds and quickly cooled to avoid softening. They may be placed in 5% brine solution or 20% sugar solution or a combination of these two to remove excess moisture for 230 min. Alternatively, they may be surface dried in a stream of hot air (45°C). The dipping solutions may contain calcium salts to improve the firmness of the product. The pH of the covering liquid tomato may be adjusted to below 4.5 by adding citric acid and thermally processed at 80-85°C for 20-30 min., cooled quickly. The glass jar should be air tight.

23.4 Whey-Tomato Soup

Soups are served as appetizers before meals as they stimulate the secretion of gastric enzymes that leads to feeling of hunger. In market a large number of ready-to-make soup mixes are available to suit the palate of consumers. But certain additives in such soups mixes are considered harmful particularly to children. Moreover apparently they do not seem to provide quality nutrients and utilization of whey for soup preparation is attractive possibility.

The process for the manufacture of whey based soup involves blending of vegetables in whey and cooking of corn flour followed by heating (Fig. 23.4). The time-temperature combination of cooking of vegetables, corn flour and seasoning is important for dispersion of vegetables, gelatinization of starch and flavour perception of soup respectively. The developed product could be stored for a week under refrigeration and UHT treatment can be adopted to improve the shelf-stability. The soups can be packaged in retort pouches as well and processed in boiling water bath (85-90^{0}C) for at least 30 min.

Cheese whey is preferred for the manufacture of vegetable soups than paneer whey, the latter being acidic. Whey based soups have been reported to be more viscous as compared to water based most probably due to gelation of whey proteins on heating. Whey based soups require less amount of salt, thickener and fat.

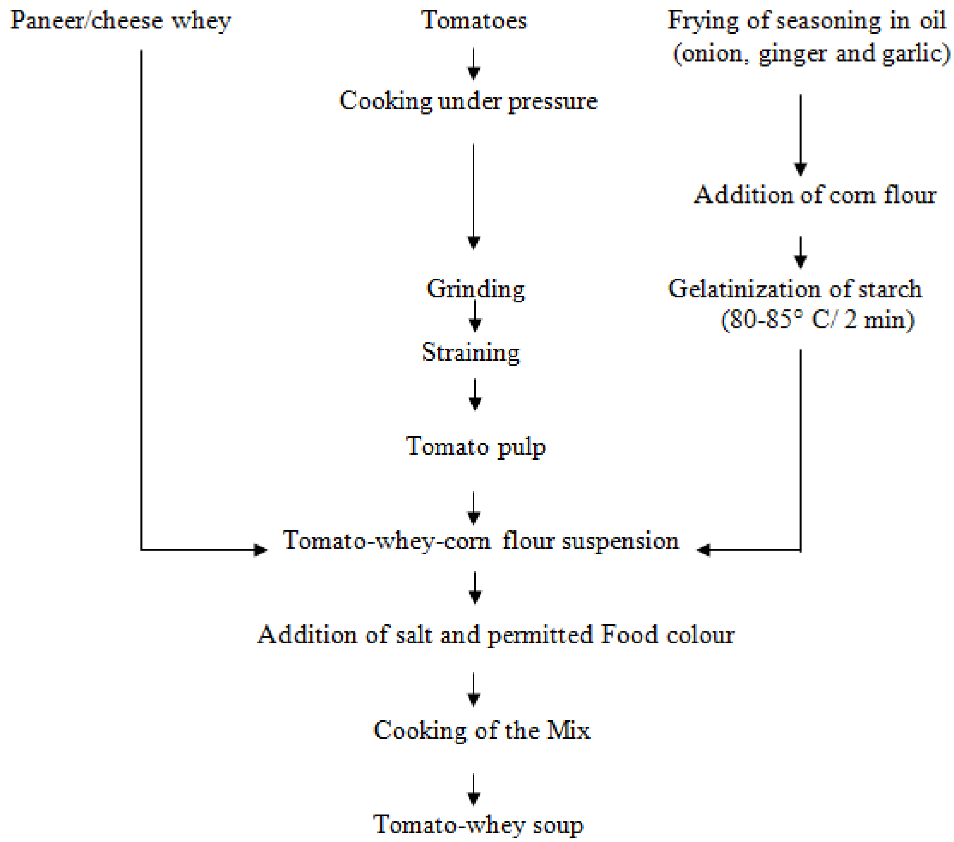

Fig. 23.4 Manufacturing Process for Whey-Tomato Soup

Lesson 24

SCOPE AND CLASSIFICATION OF BEVERAGES

24.1 Definition of Beverage

Beverages are an integral part of human diet, starting from new born. The cycle starts with the infant formulas-highly complex drink, rich in many key nutrients. As human age and their nutritional requirements change, product designer keeps pace by developing new and innovative beverages to meet these needs.

Beverages can be defined as **"any fluid which is consumed by drinking"**. It consists of diverse group of food products, usually liquids that include the most essential drink "water" to wide range of commercially available fluids like fruit beverage, synthetic drinks, alcoholic beverage, milk, dairy beverages, tea, coffee, chocolate drinks etc. Despite differences in their properties one common feature that exists in all beverages is their ability to act as thirst quencher. In simple words beverages can be defined as "liquid which is essentially designed or developed for human consumption". The beverages are rarely consumed for its food value but it is vital for life. Although their prime role is to fulfill the human need but these are part of our culture.

However there are important pre-requisite for beverages:-

- All are made from food ingredients
- All are subject to pure food law
- Consumed in enormous quantities – sometimes safer than potable supply

24.2 Health Importance of Beverages

Beverages are essential for growth, development as well for carrying out various physiological processes that are critical for living a healthy life.

- In adult individuals 70 percent of body weight, 73 percent of lean muscle, 25 percent of adipose tissues, 22 percent of bone and 80 percent of blood consists of water. Consumption of beverages help in maintaining the water content in body and prevent dehydration
- The water assists in digestion, assimilation and excretion of foods. It also helps in removing the toxic substances produced in body as a result of metabolisms such as urea, uric acid, ammonia etc. through kidney.
- Water in beverages help in regulating the temperature of body through the process of sweating.
- Beverages specially the fruit and vegetable based ones are source of micronutrients (vitamins and minerals) and anti-oxidants (carotenoids, flavonoids).
- Certain beverages like tea and coffee contain alkaloids which stimulate the central nervous system.
- Consumption of alcoholic beverages specially wine is recommended for its heart healthy image due to the presence of flavonoids.

- Fermented dairy beverages are consumed because of the beneficial microflora present in them which assist in restoration and improvement of gastro-intestinal health.

24.3 Classification of Beverages

Beverages may be classified on various ways. The classification criteria may depends on various factors as mentioned below:

- Natural and Synthetic (Ingredients used in manufacture)
- Carbonated and Non-carbonated (Degree of mechanical carbonation)
- Alcoholic and Non-alcoholic (presence or absence of alcohol)
- Hot and Cold (Temperature of serving)
- Stimulating and Non-stimulating (Based on physiological effect)

24.3.1 Natural and synthetic beverages

The natural beverages are prepared from the naturally derived ingredients including fruit juices or milk or malt, sugar, acid, flavouring and colouring materials. The examples of this group are fruit based beverages, malt beverages and dairy beverages.

Synthetic beverages are analogue of natural beverages and may contain ingredients which are prepared synthetically like flavouring and colouring materials. These are primarily developed to offer pleasure to consumers at affordable cost. The major group of synthetic beverages is soft drinks which contain flavoured sugar syrup as base material that may or may not be carbonated. The high potency sweetener based beverages also belong to the category of synthetic beverages as they contain artificial sweeteners mainly to reduce the calorific value.

24.3.2 Carbonated and non-carbonated beverages

Carbonated beverages are the one where carbon dioxide is dissolved in syrup or water. The presence of carbon dioxide creates bubbles upon release of pressure and fizzing in the beverage. The carbonated beverages are commonly referred as “Soft Drink”. Cola or lemonade beverages are typical examples of carbonated beverages. The process of fermentation also produces carbon dioxide in certain beverages like beer. Carbonation is done for various reasons. Consumers find the fizzy sensation pleasant, and like the slightly different taste that dissolved carbonic acid provides. Soda water is another popular type of carbonated beverage which may also be flavoured.

Majority of fruit and dairy based beverages falls into the category of non-carbonated beverages. The category also includes hot beverages and alcoholic beverages that do not contain carbon dioxide.

24.3.3 Alcoholic and non-alcoholic beverages

Alcoholic beverages contain ethyl alcohol which can be consumed for its intoxicating and mind-altering effects. Alcoholic beverages are produced by the process of natural or controlled fermentation. On the basis of raw material used and process technology used in their manufacture alcoholic beverages may be classified into three major groups:

a) Beer

It is the world's third most consumed beverage. Beer is prepared by fermenting the "wort" (soluble liquid of barley malt digest) with appropriate yeast to attain an alcohol level in the range of 4-8 percent. Apart from alcohol, beer is also characterized by the "effervescence" i.e. foam which is produced by carbon dioxide and bitterness. The bitterness and aroma in beer is contributed by the hops (*Humulus lupulus*) solids as α-iso-acids and other polyphenols. There are many variants of beer but two are more popular. These are called as "Lager" beer which is fermented by bottom yeast i.e. *Saccharomyces pastorianus* at lower temperature (7-12 ^{O}C) for longer period, while the "Ale" is manufactured by using top fermenting yeast i.e. *Saccharomyces cerevisiae* at relatively higher temperature (18-25^{0}C) (Fig. 24.1).

b) Wine

Wines are made from variety of fruits. Such as grapes, peach, plum or apricots. However, the most commonly used one is grapes, both green as well as red grapes. The grapes are macerated to release juice which is fermented naturally by wide range of yeasts including *Saccharomyces spp., Pichia spp., Stellata spp.* and certain lactic acid bacteria. The duration of fermentation is also longer as compared to beer and mostly fermented wine is aged (months to year) to develop desirable sensory characteristics (Figure 24.1). There are two major type of wines i.e. white wine (made from green grapes) and red wine (from red or blue grapes). The red wine contain anthocyanin (as colouring pigment) and subjected to secondary fermentation termed as **"Malolactic fermentation"** to mellow the flavour of wine. The alcohol content in wine ranges from 9-16% (v/v). Sparkling wines are characterized by "effervescence" produced by carbon dioxide and clarity, example: Champagne.

c) Spirit

Spirit is a class of alcoholic beverages which are unsweetened and produced by distillation of fermented base. The fermented base may be molasses (by-product of sugar industry), fruit juices, cereal extract or sometime a combination of many fermentable substrates. Spirits are characterized by relatively higher alcohol content which may be as high as 20 percent. The process of distillation increases the concentration of alcohol but reduced the level of congeners. Some of the alcoholic beverages belonging to the category of spirit are listed in Table 24.1.

Table 24.1 Alcoholic beverages belonging to the category of spirit

Alcoholic Beverage	Base Material	Alcohol Content (by volume)	Remark
Brandy	Fruit Juices mainly grapes	35-60%	Normally consumed after-dinner, preferred for medicinal purpose. Aged in oak barrels
Rum	Molasses or sugarcane juice	40-55%	Dark Coloured and quite popular in Caribbean nations. Aged for not less than three years
Gin	Wheat & rye may contain herbs	37.5-50	Flavoured and not aged. Mostly consumed with citrus juices
Whisky	Cereal (Barley, Rye,	40-55%	Most famous one is "Scotch Whisky"

	corn malt)		
Vodka	Malted cereals, potatoes etc.	38-40%	Popular in Russian federation countries, two variants white and flavoured Vodka
Cider	Apple juice and other temperate fruits	2-7%	Characterized by acidic-alcoholic taste

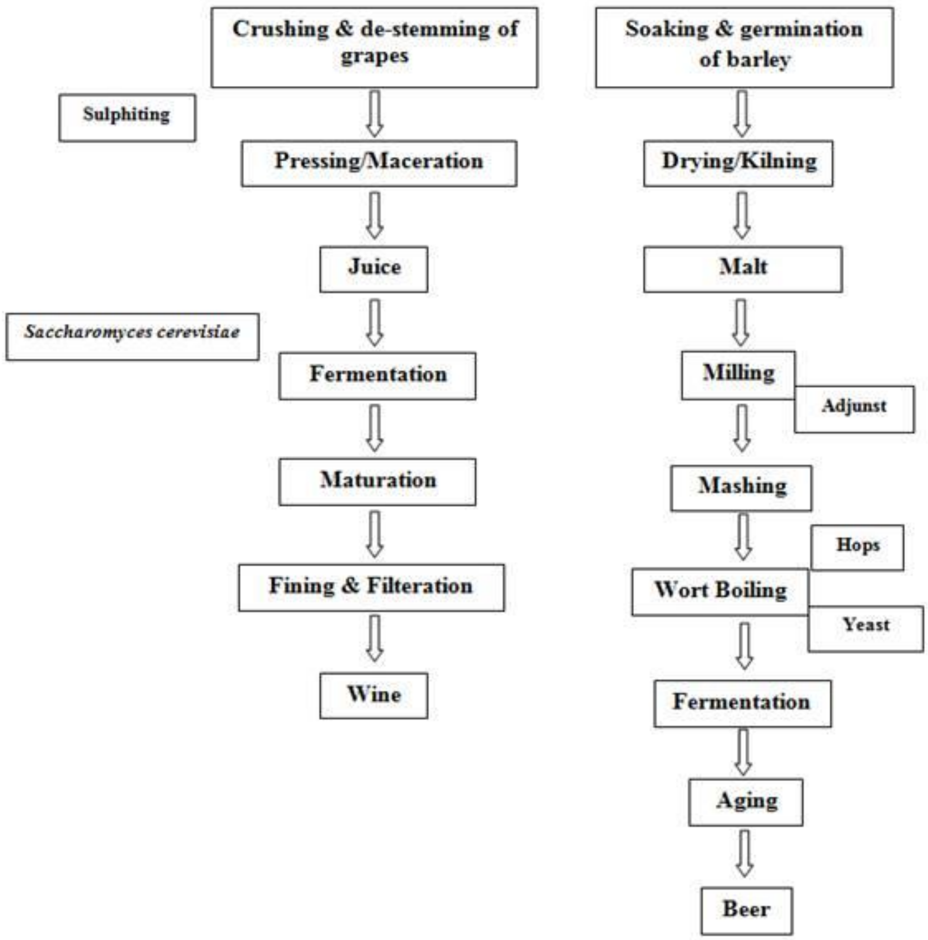

Fig. 24.1 Manufacture technology for beer and wine

24.3.4 Hot and cold beverages

Another criterion for classifying beverages is the temperature of serving. Certain beverages are consumed only hot i.e. temperature above 65-70^{0}C which are termed as “Hot beverage” while those served at chilled temperature are called as “cold beverages”. The examples of hot beverages are tea, coffee, chocolate and milk. However, iced tea and cold coffee are served chilled. Most of the fruit beverages, dairy drinks, alcoholic drinks and soft drinks are example of cold drinks. Term “cold drink” is synonymous to “carbonated drinks” as well.

24.3.5 Stimulating and non-stimulating beverages

Consumption of some beverage stimulates the body systems mainly to nervous system and circulatory system. It is mainly due to the presence of certain chemical compounds like caffeine in coffee and tea, many phenolic compounds in herbal drinks and ethyl alcohol in alcoholic beverages. The chemical constituents present in these beverages influence the physiological processes as follows:-

- Increase in basic metabolic rate (BMR)
- Increase in blood circulation and heart beat
- Stimulation of central nervous system (CNS) and release of neuro transmitter
- Diuretic (increase in frequency of urination)
- Enhancement in secretion of gastric juice

24.3.6 Other beverages

There are many other categories of beverages and it includes nomenclature like herbal drinks, mood drinks, energy drinks and sports drinks.

Energy drinks are those beverages which boost energy and mainly contain sugar and caffeine. In recent past there has been rapid growth in the demand of energy drinks. These drinks may also contain variety of stimulants and vitamins.

Herbal drinks are prepared by using the infusion of herbs in water. A wide variety of herbs may be used in preparation of such drinks. Many herbs like aloe vera, ginseng, *shatavari, Arjuna,* lemongrass, thyme etc. may be used for as base material for herbal drinks.

Sports beverages are also called as "electrolyte drinks" are basically designed to replenish the loss of fluid & electrolytes and provide quick energy during the exercise and sports activity. The monosaccharides such as dextrose, glucose syrup are added so that they can be transported easily into the muscle cells and produce energy apart from sucrose and maltodextrin. The carbohydrate content of sports beverage varied in the range of 4-8 percent. Electrolytes are many essential minerals such as chloride, calcium, phosphate, magnesium, sodium, and potassium. Electrolytes control osmosis of water between body compartments and help maintain the acid-base balance required for normal cellular activities.

There are three types of sports drinks all of which contain various levels of fluid, electrolytes, and carbohydrate.

- Isotonic drinks have fluid, electrolytes and 6-8% carbohydrate. Isotonic drinks quickly replace fluids lost by sweating and supply a boost of carbohydrate. This kind of drink is the choice for most athletes especially middle and long distance running or team sports.
- Hypotonic drinks have fluids, electrolytes and a low level of carbohydrates. Hypotonic drinks quickly replace flids lost by sweating. This kind of drink is suitable for athletes who need fluid without the boost of carbohydrates such as gymnasts.
- Hypertonic drinks have high levels of carbohydrates. Hypertonic drinks can be used to supplement daily carbohydrate intake normally after exercise to top up muscle glycogen stores. In long distance events high levels of energy are required and hypertonic drinks can be taken during exercise to meet the energy requirements. If used during exercise, hypertonic drinks need to be used in conjunction with isotonic drinks to replace fluids.

24.4 Present Status of National and Global Beverage Market

In India, traditional cuisine includes drinks, which were primarily developed to provide aesthetic appeal, but they also contained certain components having nutritional and therapeutic values as well. However, with course of time these traditional health drinks diminished. According to an estimate Indian consumers drink 120 billion litre of marketed beverages out of which only 4 percent is ready-to-drink packaged once. The carbonated soft drink industry in India consists of more than 100 plants spread throughout the country. The current value of Indian beverage industry is around 1,049 million US$. In fact the soft drinks form the third-largest packaged food sector after packaged tea and packaged biscuits. However, the penetration of soft drinks in Indian market is still low. For a long period the Indian beverage industry was dominated by aerated synthetic drinks. However, the situation has changed dramatically, the aerated soft drinks, which had registered a whopping 20% growth during late 90's, could manage its present share in market against possible slide. In contrary to this last few years have witnessed a significant development in fruit based beverages newly introduced fruit beverages fall into the category of functional foods or nutraceuticals. Energy drinks, isotonic (sport) beverages herbal and green teas, fortified waters, caffeinated drinks, recreational soft drinks are some of the functional beverages which have gained popularity in recent years. The market size for the bottled water in India had an estimated value of US$ 570 million in 2008. With annual growth rate of 14.5 percent, the market of bottled water is expected to increase rapidly in coming years.

Fruit juice market is growing at the rate of 15 percent annually and expected to reach 796 million liters by 2013 from the current volume of 624 million liters. The market of packaged fruit juice is in the range of Rs. 500-600 crores, which is quite smaller as compared to fruit drink market which is around Rs. 1300 crore. The major sale of these beverages occurs in summer months which are quite extended in India. The sale volume of beer is highest among alcoholic beverages followed by spirits. Drinking milk products constitute the largest segments among the dairy products and are growing at the annual rate of 6.8 percent. Future of Indian beverage market is quite promising and sectors that may attract processors and consumers alike include the functional dairy drinks, fruit beverages and wine. Advancement in processing and packaging technology in the form of UHT/Aseptic processes and tetrapak packaging offers newer opportunity to deliver nutritious beverages in log-life version.

Lesson 25

ADDITIVES FOR FRUIT BASED BEVERAGES

25.1 Definition and Function of Food Additives

A food additive is a substance which is added to food and is involved in its production, processing, packing and/or storage without being a major ingredient. The food additives are functional chemicals that are used at very low level (from ppm level to few percentages) and their usage is regulated by the laws. The major function which is performed by the food additives are as follows:

25.1.1 Improve nutritive value of food

Additives such as vitamins, minerals, amino acids derivatives are utilized to increase the nutritive value of food. Certain additives like soluble dietary fibers, low calorie sweeteners, bioactive components are newer entrants in the list of nutritive food additives.

25.1.2 Enhancement of sensory quality of food

Colors, odour, taste and consistency or texture are important for the acceptability of any food product as they are perceived by senses. These sensory attributes are affected by the level of ingredients and processing methodology adopted. Storage temperature and packaging atmosphere also determine the quality of processed foods. Any adverse effect can be corrected or readjusted by additives such as colourings, aroma compounds or flavour enhancers. Development of 'off-flavour' for instance that derived from fat or oil oxidation can be prevented by using antioxidants. Likewise viscosity and suspension stability of beverages could be improved or maintained by careful addition of hydrocolloids.

25.1.3 Prolongation of shelf life of food

The extension of shelf life involves protection against microbial spoilage, for example by using additives that inhibit the growth of microbes, and use of active agents which suppress and retard undesired chemical and physical changes in foods, is the another objective of food processing.

25.1.4 Processing aids

Certain additives are added to facilitate various processing operations during beverage manufacture. These include enzymes, emulsifiers, stabilizer and anti-caking agents. Enzymes are invariably used for the extraction as well as clarification of fruit juices. Emulsifiers are required for the formation of stable flavour emulsion mainly in lemonades.

These additives are diverse in nature and derived from wide range of sources, which are listed below (Table 25.1).

Table 25.1 Nature and sources of food additives

S. No.	Nature	Sources
1.	Inorganic Chemicals	Salt, Sulphites, phosphates etc.
2.	Synthetic Chemicals	Dye, Silicones, Vitamin A, Benzoates etc.
3.	Extraction Products	Gums, Essential oils, tocopherols etc.
4.	Fermentation Products	Enzymes, Acid and Yeast etc.

25.2 Beverage Additives

There is great diversity in beverages and accordingly a wide range of ingredients are required in their formulations. There are certain additives like sugar or sweeteners (except in low calorie beverages) which are added in higher amounts whereas additives like preservatives are added in minute quantity. Hence according to the amount the additives may be grouped as Major and Minor additives.

25.2.1 Major additives

Apart from fruit juice, sugar and acid constitutes the major percentage of the beverage formulation, hence these two belongs to the category of major beverage additives:

25.2.1.1 Sugar

Sugars are added primarily as flavouring additive to impart the sweetness in the beverages. Conventionally sugar performs number of basic functions in beverages.

- They improve the palatability of certain bland and insipid tasting fruits & vegetables
- They provide bulk and body to beverages thus enhance mouthfeel
- They modify the freezing point and control viscosity
- They also act as mild preservative, modify the osmotic pressure and check spoilage

Sweeteners may be classified in a variety of ways: nutritive or nonnutritive, natural or synthetic, regular or low-calorie/dietetic.

1. **Natural or Synthetic Sweeteners**

   The sweeteners derived from the food sources are termed as natural. Example: Crystal sugar obtained from cane sugar or beet root, glucose syrups manufactures from maize starch, honey etc. The sweeteners which are manufactured by chemical synthetic processes are termed as synthetic sweeteners. Example includes high intensity sweeteners like saccharin, aspartame, acesulfame-K etc.

2. **Nutritive or Non-Nutritive Sweeteners**

   Certain sweeteners are metabolized in body and generate energy, hence are termed as nutritive and caloric sweeteners. Nutritive sweeteners also cause dental carries. Sweeteners that are metabolized but do not contribute towards the energy significantly are called as non-nutritive or non-caloric sweeteners. Traditional sweeteners fall into the category of nutritive whereas synthetic ones belong to non-nutritive sweeteners.

3. **Regular or High-intensity Sweeteners**

The classification of sugars on the basis of quantity required to give equivalence sweetness give rise to two categories i.e. regular or high-intensity. High-intensity sweeteners required much less amount for yielding the similar sweetness intensity. All low calorie sweeteners are considered as high-intensity sweeteners. The relative sweetness of various sugars is listed below (Table 25.2).

Table 25.2 Relative sweetness of various sweeteners

Sweeteners	Sweetness Relative to sucrose
Sugar (Sucrose)	1
High-fructose corn syrup	1-1.5
Fructose	1.2-1.7
Invert sugar	1.3
Glucose	0.75
Sorbitol	0.5-0.7
Mannitol	0.7
Xylose	0.4
Maltose	0.32
Galactose	0.32
Raffinose	0.23
Lactose	0.16
Saccharin	300
Cyclamate	30
Aspartame	200
Acesulfame K	200

25.2.1.1.1 Various classes of sugars

a) Sucrose

Manufactured from cane sugar or beetroot and may be added either in dry form or as syrup (65-70% strength) in beverage manufacture. Sucrose is available in various particle size and colour grades which depend on the degree of refining. In beverage manufacture normally the cane sugar obtained by carbon-refining process is preferred as it does not cause blackening of content. In cola type or malt beverages brown sugar may also be used.

b) Glucose Syrup

On industrial scale corn starch is hydrolyzed by using acid or enzymes to produce corn syrup and these syrups are available in different Dextrose Equivalent (DE) values. The term DE value refers to the percentage of dextrose in the mixture of carbohydrate produced on hydrolysis. DE value also indicates the sweetness and viscosity of the syrup. High DE value reflects more sweetness and less viscous syrup.

Typically glucose syrups having DE value 42-65 are used in beverage manufacture. Glucose syrups are used in energy drink, where a carbohydrate that yields quick energy is desired. The advantage of using glucose syrups is higher level of solids as compared to sucrose syrup. However, higher viscosity of glucose syrup at low temperature (below 30^{0}C) create problem in mechanical operations.

c) High Fructose Corn Syrup

High fructose corn syrup (HFCS) is manufactured by first hydrolyzing the corn starch to dextrose then enzymatically converting dextrose into fructose. HFCS contain around 42% fructose plus 51% dextrose and have sweetness equal to sucrose. HFCS is mainly used in USA and to a lesser extent in Europe. These syrups are also liable for browning.

d) Invert Sugar Syrup

Invert sugar syrup is produced by acid or enzymic hydrolysis of the sucrose into its constituents sugars i.e. glucose and fructose. Invert sugar usually contains a mixture of sucrose, dextrose and fructose. The major benefits of using invert sugar are an increase in osmo-molality and decreased tendency of crystallization. The application of invert sugar is also restricted to cola type of beverages where brown colour is desired.

e) Saccharin

Saccharin has been used as a food additive since the early 1900s and is the most widely used non-nutritive sweetener worldwide. Saccharin occurs as white, crystals or a white crystalline powder, is odorless, or has a faint aromatic odor. It is slightly soluble in water, sparingly soluble in alcohol and soluble at 0.05% in a fixed oil. It is about 300 times as sweet as sucrose. In its bulk form, saccharin and its salts have been shown to be stable for several years. In aqueous solutions, saccharin demonstrates high stability over a wide pH range. It is commercially available in three forms: acid saccharin, sodium saccharin, and calcium saccharin. Sodium saccharin is the most commonly used form because of its high solubility and stability. Due to its bitter aftertaste and health implications, saccharin has limited potential. It had been linked with occurrence of bladder cancer in rodents, however later investigations in higher animals did not confirm the relation between bladder cancer and saccharin consumption.

f) Acesulfame K

Acesulfame K has a rapidly perceptible sweet taste 200 times as potent as sucrose. Acesulfame potassium occurs as a colorless to white-colored, odorless crystalline powder with an intensely sweet taste. It dissolves readily in water, even at room temperature, and is very stable, with virtually no change in concentration observed in the pH range common for foods and beverages after several months. It is being used in dry beverage bases. Beverages containing acesulfame K can be pasteurized under normal pasteurization conditions without loss of sweetness. It blends well with other sweeteners and is especially synergistic with aspartame and sodium cyclamate. It is non-caloric and has a taste closer to sucrose when combined with other non-caloric sweeteners. It is not considered to be carcinogenic and mutagenic. The adequate daily intake (ADI) of acesulfame-k is 15 mg/kg body weight/day of an adult.

g) Aspartame

Aspartame was approved in 1981 for use in dry beverages mixes and later on 1983, in liquid soft drinks in USA. However, in India application of these artificial sweeteners was permitted in certain food stuffs including beverages. Aspartame occurs as off-white, almost odorless crystalline powder with an intensely sweet taste. The approximate sweetening power is 200 times that of sucrose. It is slightly soluble in water and sparingly soluble in alcohol. The ADI of aspartame is 50 mg/kg body weight/day. The use of aspartame has been of some concern due to the formation of the potentially toxic metabolites, methanol, aspartic acid and phenylalanine. Despite it, aspartame is the most successful high intensity sweetener currently used. Its role as a food ingredient that enhances fruit flavours makes it suitable for soft drinks and yoghurt. Two major disadvantages of aspartame are its instability in acidic conditions and its loss of sweetness during prolonged heating.

h) Cyclamates

Cyclamates were discovered in the mid-1950s. It is 30 times sweeter than sucrose and has been particularly useful in fruit products. In 1969, it was banned because of some carcinogenic effect by FDA.

i) Sucralose

Sucralose occurs as anhydrous, white, crystalline, orthorhombic needle-like crystals with an intensely sweet taste. It is a chlorinated sucrose derivative that is 500 to 600 times sweeter than sucrose. It has no calories and is exceptionally stable. The ADI is 5 mg/kg body weight/day. Sucralose is not metabolized in the body and does not break down as it passes rapidly through the body. The sweetest of the currently approved sweeteners, it has a clean, quickly perceptible sweet taste. Still the safety of sucralose is not fully conclusive.

Besides these there are other low calorie and high-intensity sweeteners which need permission from regulatory authorities. These include alitame, neotame, stevia,nehesperidin dihydrochalcone and glycyrrhizin.

j) Sugar substitutes

Sugar substitutes are those compounds that are used like sugars for sweetening, but are metabolized without influencing of insulin and producing much calorie.Polyols (sugar alcohols or polyalcohol) are chemically reduced carbohydrates. These compounds are important sugar substitutes because polyols are absorbed more slowly from digestive tract than is sucrose. Sorbitol, Mannitol, Xylitol etc are being used in food application.

25.2.1.1.2 Acidulants

Acidulant are acids that either occur naturally in fruits and vegetables or are used as additives in beverage formulation. Mainly, citric acid, adipic acid, fumaric acid, tartaric acid, phosphoric acid, lactic acid malic acid and acetic acid are used to play different roles in different beverages. Acidulants functions includes

- Provide sourness to product
- Enhance palatability by balancing the sugar to acid ratio
- Enhance flavours
- Act as thirst quenching by increasing flow of saliva
- Act as buffer to control acidity level

- Act as a mild preservative by regulating pH

a) Citric acid

Citric acid is the most versatile and widely used food acidulant. It is useful characteristics include excellent solubility, extremely low toxicity, chelating ability and pleasantly sour taste. FDA classifies citric acid and its sodium and potassium salts as GRAS food additives when used in accordance with the good manufacturing practices. Citric acid is produced commercially by mold fermentation of sugar solutions (most commonly, dextrose and beet molasses) using strains of *Aspergillus niger*. Beverages are the major food use for citric acid, accounting for an estimated 65% of citric acid's total food acidulant consumption. Citric acid and its sodium salt are used extensively in carbonated beverages as a buffer to regulate tartness if the acid level is high. It is also used as flavor enhancers and preservative.

b) Malic acid

Malic acid is prepared by hydrolyzing maleic anhydride to malic acid and, at elevated temperature and pressures, forming an equilibrium mixture of malic acid,fumaric acid, and malic acid. Malic acid is used in a variety of products, but mostly in fruit-flavoured sodas such as those with apple and berry flavor. Malic acid is preferred acidulant in low-calorie drinks, and in cider and apple drinks, it enhances flavor and stabilizes the color of carbonated and noncarbonated fruitflavoured drinks and cream sodas. In sugar-free drinks, malic acid masks the off-taste produced by sugar substitutes.

c) Tartaric acid

Tartaric acid has a strong, tart taste and augments natural and synthetic fruit flavours, especially grape and cranberry. It is utilized in fruit juices and drinks. High prices and limited availability inhibit tartaric acid from widespread use as a food acidulant.

d) Phosphoric acid

Phosphoric acid and its salts account for 25% of all the acids used in the food industries. Phosphoric acid has a characteristic flavor and tartness and is used almost entirely in cola flavored carbonated beverages. A small quantity is also used in some root beer brands. It is least costly of all the food-grade acidulant; it is also the strongest, giving the lowest attainable pH.

e) Fumaric acid

Fumaric acid is principally used in fruit juices and gelatin desserts and wines. Fumaric acid competes with other acidulants such as citric acid, tartaric acid, and malic acid. Although it is less costly than some alternatives, its relatively strong acid taste and low solubility make it less appropriate for certain food uses. Its limited solubility coupled with an extremely low rate of moisture absorption makes fumaric acid a valuable ingredient for extending the shelf life of powdered dry mixes.

There are certain other acidulants like ascorbic acid, adipic acid, acetic and lactic acid that may also be used in beverage formulation mostly in combination with major acids. Ascorbic acid also acts as antioxidant.

25.2.2 Flavourings

Flavors are concentrated preparations used to impart a specific aroma to food or beverages. Flavors may be added to food products for the following reasons:

- To create a totally new taste
- To enhance, extend, round out or increase the potency of flavours already present

- To supplement other more expensive flavors or replace unavailable flavors
- To mask less desirable flavors- to cover harsh or undesirable tastes naturally present in some food
- Stimulation of flavour perception of expensive flavours

Flavouring is most critical operation in food processing as acceptability of any products largely governed by the flavour perception by consumers. Various food processing operations often lead to loss of flavouring chemical either due to volatilization or because of conversion of flavouring compounds into off-flavouringcompounds. However, flavour of beverage must be identical to the fruit which is used as base material. Fruit aroma consists of few hundreds to thousand compounds for example orange flavour contain more than 200 compounds ranging from simple phenolic to complex terpenoids, esters etc. Therefore, mimicking of fruit flavour in beverages is quite complex task and requires great expertise. Various compounds used for flavouring purpose may be categorized into three groups.

25.2.2.1 Natural flavours

Natural flavours include extracts from natural sources in the form of essential oils, oleoresins, essence or extractive, distillate or any product formed during normal processing such as roasting, heating etc. Example of natural flavour is extracts of vanilla roots, roasted coffee beans, herbs etc. Practically natural flavours are essential oils, oleoresins, and true fruit extracts. A special type of natural flavour is fruit flavour concentrate. Fruit flavour concentrate is prepared by removing the water under vacuum and added back aroma back into the concentrate. The most common fruit flavour concentrate include apple, berry, grape and citrus fruits.

25.2.2.2 Nature identical flavours

These can be defined as flavouring substances that are synthesized or isolated by chemical processes. These compounds are chemically and oragnoleptically identical to the naturally occurring substance. They do not contain any artificial substances. Example of nature identical flavouring include ethyl vanillin for vanilla, benzaldehydefor bitter almond, isoamyl acetate for banana, limonene for orange, methyl anthranilate for grape etc.

25.2.2.3 Synthetic flavours

Term synthetic flavour is used for those substances which are not identified in naturally occurring products intended for human consumption. They are produced by fractional distillation process and additionally chemical modification of naturally sourced chemicals, coal tar or crude oil. Although, they are chemically different from natural compounds but identical in flavour perception. These are essence and produced by various processes or by mixing various compound specified in the aroma of any fruit. Example: esters give the characteristics fruity aroma and γ-undecalactone is included in peach flavour formulation.

25.2.3 Colourings

Colours are used in processed foods to improve the appearance and thus also influence the perception of texture and taste. The colours are permitted additives in beverage to provide different shades and improve the aesthetic quality of beverages. Food colours are added in beverages because of the following reasons:-

- To give attractive appearance to foods that would otherwise look unattractive or unappealing

- For product identification as majority of fruit beverages are characterized by the colour of fruit which is used in its formulation
- To ensure uniformity of the colour due to natural variations in colour intensity because of variation in harvesting period, variety etc.
- Intensification of the colour naturally occurring in fruits & vegetables
- Colours also serve as mean of quality assurance during the production, transportation and storage.

Various compounds which are used for colouring purpose may be divided into three groups; natural colours, nature identical colours and synthetic colours or dyes.

25.2.3.1 Natural colours

These colours are derived from the natural sources and are exempted from the mandatory certifications by the regulatory authorities. These are attractive alternatives to artificial colourings and being of natural origin these are preferred by consumers as well. Some of the natural colourants are listed in Table25.3.

Table 25.3 Natural colourants used in fruit based beverages

Compounds	**Source**	**Colour Impart**
Paprika	*Capsicum anum*	Red colour
Anthocyanin (cyaniding,petunidin, betacyanin)	Beet root, Pomegranate, grape skin	Blue, Purple and pink
Bixin (Annato extract)	*Bixa orellana*	Yellow colour
Cochineal	*Coccus cacti*	Orange to Red
Curcumin	*Curcuma longa*	Orange yellow
Crocin & Crocetin	*Crocus sativus*	Yellowish red
Caramel	Heated sugar solution	Chocolate Brown

However, the poor stability of natural colourant is major obstacle in their wider application in beverage formulation. The extraction of these colouring pigments at cost-effective manner is still a major challenge in usage of natural colours.

25.2.3.2 Nature identical colours

These compounds are similar chemically to naturally occurring compounds but are extracted using solvents. These are relatively more stable than natural counterparts. These include β-carotene, apocarotenal (β-apo-8'-carotenal) which produce yellow to orange hue, canthaxanthin that impart red colour and riboflavin which give greenish yellow to yellow colour. The stability of these colourants is a major problem. Mostly these are available in oil-soluble forms.

25.2.3.3 Synthetic colours

These are certified food colours which may be divided into dyes and lakes. These dyes are water soluble and relatively stable under wide range of pH, processing temperature and storage. Lakes are generally not used in beverage formulations. These dyes are popularly called as coal tar dyes. Azo dyes are brighter in colour and of high tinctorial strength. Initially there were 11 permitted synthetic dyes but now three of them have been omitted due to safety concerns. The permitted dyes are carmosine (Red), Ponceau 4R (Red), Sunset yellow FCF (Red), Tartrazine (Lemon yellow), Brilliant blue FCF (Green blue), Erythrosine (Pink to Blue), Indigo carmine (Deep blue), Fast green FCF (Turquoise). The three dyes which have been removed from the list are Amaranth, Fast Red E and Green S. The dyes have fastness properties with alkali, acid, light and additives. They can withstand processing temperature of up to 110^{o}C. The maximum permissible limit of these dyes is 100 ppm as higher concentration may cause cancer.

25.2.4 Hydrocolloids

These consists a group of substances all of colloidal dimensions, having great affinity for water and hence called as hydrocolloids. These hydrocolloids perform a number of functions in fruit juices and beverages:

- Prevent gravitational suspension or sedimentation of suspended particles in beverage
- Improve the viscosity of juices and beverage
- Act as clouding agent in products like nectar, lemonades, where cloud formation is a desirable attributes
- Act as clarifying agent in certain beverages like guar gum, alginates, gelatin, They cause flocculation of impurities
- Assist in encapsulation of additives in powdered mixes
- Prevent crystallization in high sugar containing beverages

These hydrocolloids may be classified into several categories as mentioned below.

- Source (natural/natural identical/synthetic)
- Chemical nature (polysaccharides/protein)
- Ionization (Ionic/non-ionic/neutral)
- Gelling behaviour (Gelling/thickening/stabilizing)

25.2.4.1 Carboxymethylcellulose (CMC)

It is the primary cellulose ester compound in food and beverages applications. CMC is used at approximately 0.5% to thicken fruit juices and to prevent floating or settling of fruit, as well as impart a clearer, brighter appearance, produce a desirable gel texture, and reduce syneresis.

25.2.4.2 Alginates

It includes various salts of aliginic acid and propylene glycol alginate (PGA). Alginate is extracted from a brown algae *Macrocystis pyrifera*. PGA is used at 0.1-0.2% concentration to suspend pulp in fruit drinks. The major application of sodium alginate is in dairy beverages.

25.2.4.3 Guar gum

Guar gum is extracted from the pods of leguminous plants. India is the largest producer and exporter of guar gum. It is water soluble and produces very high viscosity even at low concentration. It is available in different particle size and also hydrolyzed for certain specialized applications. It is used as a thickening and viscosity control agent in fruit nectars.

25.2.4.4 Gum arabic

Gum arabic is water-soluble natural gum which is obtained as exudates form the trees of *Acacia senegal*. It is also known as gum acacia. The solutions of gum acacia are of low viscosity. It is mainly used as an emulsifier in beverages for stabilization of fruit flavors especially in citrus beverages. In powdered beverage mixes it is used to encapsulating flavours.

25.2.4.5 Pectin

Pectin is a hydrocolloid obtained commercially from the citrus peel or apple pomace. It consists of α-galacturonic acid molecules which are linked through α-glycosidic linkages and the side chain of pectin molecule is esterified. Pectin is mainly used for gelling purpose but nowadays it is gaining popularity as beverage stabilizers. Major application of pectin (High methoxyl) is in stabilization of acidified dairy drinks. Besides it the major application of pectin is in preparation of gelled products such as jam, jelly and marmalade.

25.2.4.6 Gelatin

Gelatin is obtained from the collagen or connective tissue of meat animals. It is used extensively for clarification or fining of cider, fruit juices, and wine. Amount of gelatin used is in the range of 50-300 g per 1000 liter juice to be treated. As per legal requirements in India, use of gelatin in fruit based products shall be labeled with non-vegetarian symbol on the pack.

25.2.5 Preservatives

A chemical preservative may be defined as any additive substance that tends to prevent or retard deterioration when added to foods. It may prevent or retard changes in odour, flavor, nutritive value, or appearance. They inhibit the contamination of foods by microorganisms such as yeasts, bacteria, molds or fungi. The principal mechanisms are reduced water availability and increased acidity. Only sorbates, benzoates, propionates and sulfites are used broadly in fruit processing. The principal mechanisms are reduced water availability, change in redox-potential and increased acidity. Many of these preservatives target microbial membranes and affect the permeability of it, thus the viability of microbe. Preservatives may be classified as Class I & Class II preservatives. Class I preservative includes additives from natural sources which also exhibit preservative effects in foods. Example of Class I preservatives are salt, sugar, vinegar, spices, honey, edible oils etc. Class II preservatives are chemically derived compounds. Only sorbates, benzoates, propionates and sulfites are used broadly in fruit processing. I n case of Class I preservatives level of addition is regulated by Good Manufacturing Practices (GMP), while in Class II preservatives it is fixed by regulatory agencies on the basis of safety and toxicity evaluation.

25.2.5.1 Benzoic acid

Benzoic acid and sodium benzoate is permitted to the maximum level of 0.1%. Benzoic acid and its sodium salt are most suitable for preserving foods and beverages that naturally are in a pH range 2.5 – 4.0. The narrow pH of its activity limits wider application of this preservative in foods. Benzoic acid and sodium benzoate are used to preserve carbonated @ 0.03-0.05% and non-carbonated beverages @ 0.1%, fruit pulps and juices, jams and jellies, salad dressings, sauces and ketchups. Sodium benzoate is more effective against yeasts and bacteria than molds. The antimicrobial activity varies with foods, its pH and water activity and with types and species of microorganisms. Pathogenic bacteria may be inhibited by concentrations of 0.01-0.02% undissociated benzoic acid. As an antimicrobial agent, benzoate acts synergistically with sodium chloride, sucrose, heat, carbon dioxide, and sulphur dioxide.

25.2.5.2 Sorbic acid

Sorbic acid is widely used food preservatives in the world. Sorbates exhibit inhibitory activity against a wide spectrum of yeasts, molds and bacteria including most food borne pathogens. They can be used to suppress yeasts during lactic fermentation. The inhibitory activity of sorbates is attributed to the undissociated acid molecule and hence is pH dependent. The upper limit for its activity is at about pH 6.5 in most applications, and the activity increases with decreasing pH. Potassiumsorbate is used where high solubility is desired. Sorbates are frequently used in dried fruits, fruit salads, carbonated and noncarbonated beverages. Usage rates ofsorbates in fruits are low, being 0.025-0.075% in fruit drinks and 0.1% in beverage syrups.

25.2.5.3 Salts of sulphite, bisulphite and metabisulphite

Salts of sulphite, bisulphite and metabisulphite is decomposed by weak acids such as citric, tartaric, malic and carbolic acids to form potassium salt and sulphur dioxide, which is liberated from potassium sulphurous acid with water, when added to the fruit juice or squash. Free sulphurous acid is more effective (120 times) than combined sulphurous acid. The undissociated sulphurous acid molecule prevents the multiplication of yeasts, while the sulphurous acid ion inhibits the growth of bacteria. Glucose, aldehydes, ketones, pectin and breakdown products of pectin, etc., which are found in fruit juices, combines with sulphur dioxide reducing the effectiveness of sulphur dioxide. Being more effective against molds than yeasts, sulphur dioxide has found wide use in the fermentation industries. It cannot be used in the case of some of the naturally coloured juices like *phalsa, jamun,* pomegranate, strawberry pulp, etc. on account of its bleaching action on anthocyanin. It cannot also be used in products, which are to be packed in tin container, because it not only acts on tin container causing pinholes, but also forms hydrogen sulphide, which has an unpleasant smell and also forms a black compound with the iron on the base plate of the tin container.

25.2.6 Nutritive additives

25.2.6.1 Vitamins

Beverages are enriched with vitamins to adjust for processing losses or to increase the nutritive value. Such enrichment is essential for fruit juices canned vegetables, and other beverages. Vitamin C (ascorbic acid) is the most commercially important vitamin used as a food additive in terms of volume. The most important applications for vitamin C include fruit juices, fruit flavoured drinks, juice-added sodas, and dry cocktail or beverages powder mixes. As an antioxidant, this vitamin is frequently added to fruit juice to preserve and protect against color change of fruit ingredients.

25.2.6.2 Minerals

Beverages are usually an abundant source of minerals as they contain fruits, but due to dilution the relative intake of minerals is quite less. Normally the electrolytes i.e. sodium, potassium and chlorides are added in energy drinks and other soft drinks. Nowadays, beverages are also considered an important vehicle for mineral fortification. The minerals normally used for fortification are calcium, iron, zinc and magnesium.

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Lesson 26

CARBONATED BEVERAGES

26.1 Introduction

Carbonated beverages in the form on naturally occurring carbonated mineral water have been known to exist since long. Presence of carbon dioxide in aerated water and carbonated drinks enhance both palatability as well as appearance of these products. The origin of carbonated water is traced back to the work of Joseph Priestly who produced first man-made carbonated water in 1767. Carbonated drinks are invariably consumed without dilution and include crushes, lemonades, cola drinks and mixed drinks. Carbonated beverages are quite popular across the globe with an impressive dominance in world beverage market.

26.2 Ingredients Used in Preparation of Carbonated Beverage

26.2.1 Water

It is the main ingredient of carbonated beverage that comprises more than 90% of the total volume. The water which is used in preparation of carbonated beverages must of very high potable standards. Therefore, water pre-treatment is necessary to ensure the high standards of finished beverage such as removal of microscopic and colloidal particles by coagulation, filtration, softening and pH adjustment in the areas where water is of poor quality. Disinfection and chlorination remains the preferred method for the destruction of microorganisms. High level of nitrates in the water could be considered as possible risk for infants. It may also cause corrosion of tin plate and perforations of lacquer lining of cans. De-aeration of water is also required to facilitate subsequent carbonation and filling operations to minimize foaming problems.

Water used in carbonated beverage must possess following properties:

- Low alkalinity–to check neutralization of acids otherwise it would affect flavours and may decrease preservation effect of acids.
- Low iron and manganese – to prevent reaction with flavouring and coloring compounds
- No residual chlorine- as it affects flavour adversely and cause oxidation
- Very low turbidity and colour – to impart attractive appearance to the drink.
- Organic matters and inorganic solids must be very low – as it provides nuclei for CO_2 – resulting in beverage boiling and gushing at the time of filling or opening of bottles.

Water used in carbonated beverage manufacture must meet the following standards.

Particulars	Maximum Permissible Limit
Alkalinity	50 ppm
Total solids	50 ppm
Iron	0.1 ppm
Manganese	0.1 ppm
Turbidity	5 ppm
Colour	Colourless
Residual chlorine	None
Odour	Odourless
Taste	Tasteless
Organic Matter	No objectionable content

*The water used for carbonated beverage production is often subjected to treatment to remove various impurities and make it suitable for production of soft drinks. The water treatment includes filtration, water softening, coagulation, chlorination, membrane filtration and ozonization. However, the sequence of pre-treatments depends on the quality of RAW water.

26.2.2 Sweetener

Sweetener serves three basic functions in carbonated beverages; impart sweetness, provide body and calorie. Sweetener used primarily in carbonated beverages is crystal sugar which must be of very high purity. It is used in the form of sugar syrup and final concentration of sugar varies between 8 to 14 percent in finished beverage. However, other sweeteners like glucose syrups, invert syrup, High fructose corn syrup (HFCS) etc. may also be used. Low calorie carbonated drinks invariably contain high intensity sweeteners or artificial sweeteners such as saccharin, aspartame, acesulfame-k and/or sucralose.

26.2.3 Carbon dioxide

Carbonated beverages contain carbon dioxide which "sparkle" the beverage and impart "fizziness". CO_2 gas is inert, non-toxic, almost tasteless, easy to produce and impregnate in the liquid as compared to other gases. It is also available at relatively lower cost in liquefied form. It is soluble in liquids where its solubility increases when the temperature of liquid is decreased and it can exist as gas, liquid or solid. CO_2 produces carbonic acid when dissolved in water which in combination with other ingredients produces acidic and characteristic biting taste of carbonated water and beverages.

CO_2 may be obtained from carbonates, limestone, burning of organic compounds and industrial fermentation processes. CO_2 obtained by any process is purified to ensure that it is free from impurities and fit for human consumption. Purification of CO_2 is done by scrubbing with water to remove sulphurous compounds and passing through activated charcoal or carbon tower to remove odorous compounds. Many beverage manufacturers produce their own CO_2 on site by using packaged system.

26.2.4 Acids

Application of acids enhances the flavour and it also contributes towards the preservation of the beverage. Wide varieties of acids are available for carbonated beverage manufacture, but citric, malic; fumaric, tartaric and phosphoric acid are most commonly used. Phosphoric acid is mainly used in cola type of beverages.

26.2.5 Flavouring and colouring ingredients

The flavouring component of the sugar syrup has the major influence on the flavour of the final product, used at very minor amounts i.e. 0.01 to 0.02 %. The nature of flavouring usually is determined by the type of the product. Fruit flavours are most commonly used, except in colas, which are flavoured by extract of cola root together with about 10% caffeine and a mixture of essences. Fruit flavour may be added in the form of juice, as comminuted (in the case of citrus fruit) or as an essence. Juice is normally used as a concentrate, citrus fruits; especially oranges are most widely applied. Citrus juice is debittered to avoid flavour defects. Essences may be prepared from artificial or natural sources. Artificial flavouring is not preferred because of doubtful safety. Natural citrus essences are composed largely of essential oils from the peel of the fruit. Hydrocarbons mostly limonene, constitute more than 90% of the oil, but contribute little or nothing, to flavour, acting primarily as a carrier.

Important colouring agents for carbonated beverages synthetic colours particularly certified coal tar colours. Caramel obtained from heated or burnt sugar is non – synthetic colour and are widely used in cola beverages. Permitted food dyes are generally preferred over natural fruit colours because of their greater colouring power and stability. Even when natural fruit extracts or juices are used their colours are generally supplemental with synthetic colours.

26.2.6 Emulsifiers, stabilizers and clouding agents

Emulsions may be used to impart cloudiness in the form of neutral emulsions and/or as flavouring agent as flavoured emulsions. The oil phase typically consists of a citrus essential oil containing an oil-soluble clouding agent, while the aqueous phase consists of a solution of gum arabic, or a suitable hydrocolloid of similar properties. An oil-in-water (O/W) emulsion is formed using a two stage homogenizer to yield droplets 1-2 µm in diameter for optimal stability and cloudiness. The clouding agent must contribute to opacity without affecting stability by producing creaming, ringing or separation and must also have no effect on colour, taste or odour. Brominated vegetable oil (BVO) was used as clouding agent for many years, however it is now been banned because of potential toxicity. Many alternatives have been attempted including sucrose esters, such as sucrose diacetate hexa-isobutyrate, rosin esters, protein clouds, benzoate esters of glycerol and propylene glycol, waxes and gum exudates. However, none of them have proved satisfactory. A soy protein based clouding agent has been found effective.

Stabilizers are used both to stabilize emulsions and also maintain the fruit components in dispersion. Besides they also improve mouthfeel and viscosity of the beverages. Most commonly used ones include guar gum, gum arabic, pectin, CMC and alginates.

26.2.7 Foaming agents

Presence of foam in headspace is considered desirable in certain carbonated soft drinks, such as ginger beer and colas. The most effective foaming agents are saponins which are extracted either from the bark of Quillaia or Yucca trees. The permitted level is up 200 ppm (in European Union) and 95 ppm in USA.

26.3 Manufacturing Process of Carbonated Beverages

Carbonated beverages are prepared following the steps as outlined in Figure 26.1.

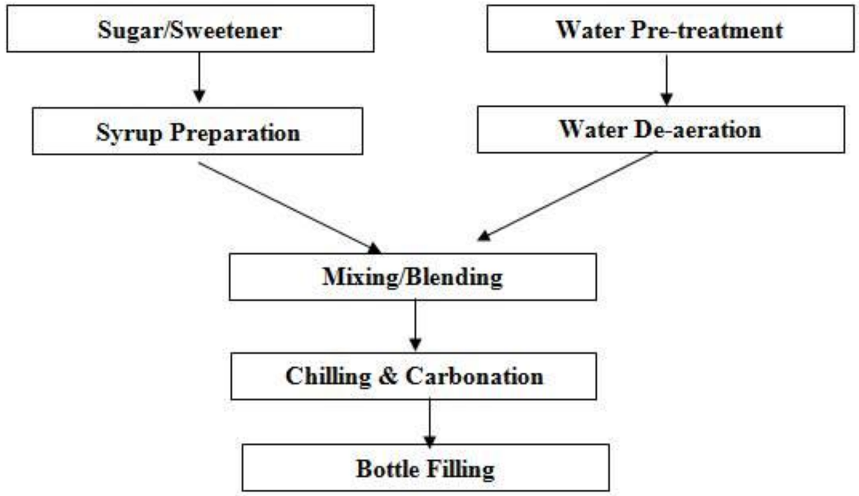

Fig. 26.1 Process flow diagram for the manufacture of carbonated beverages

26.3.1 Syrup preparation

Syrup is usually prepared by mixing 1 part (volume) syrup to 3-6 parts (volume) water in stainless steel tanks fitted with top driven agitators. In sugar based product the syrup typically consists of sugar syrup of 67° Brix strength, citric acid, flavouring, colourings, preservatives and water. Sugar syrup is passed through a plate heat exchanger to decrease the microbial load. Syrup is pre-prepared, tested and diverted to proportioner for mixing with water and carbonation. Flow meters are most frequently used for proportioning. The syrup is dosed through a mass flow meter and the water dosing is done volumetrically by using a magnetic induction flow meter.

26.3.2 Carbonation and filling

Carbonation may be considered as the impregnation of a liquid with CO_2 gas. Earlier some the pre-syruping method was employed in which carbonated water and sugar syrup were metered separately into the bottle or other container. This method has been replaced in modern plants by pre-mix filling in which sugar syrup; water and CO_2 gas are combined in the correct ratio before transfer to the filler. The final beverage thus prepared before filling and regulation of carbonation and of the relative proportions of syrup and the water is of critical importance. The fundamental role of the carbonator is to obtain close contact between CO_2 gas and the liquid being carbonated. Factors determining the degree of carbonation are:

- Operating pressure in the system and temperature of the liquid
- Contact time between the liquid and CO_2
- Area of the interface between the liquid and CO_2
- The affinity of the liquid for CO_2 (affinity decrease as the sugar content increases);
- Presence of other gases.

Presence of air in syrup or water affects the carbonation process. Presence of air in beverage may also lead to mould growth and other oxidative reactions. Generally 1 volume of air exclude 50 volumes of CO_2.

Carbonation may be done in three different ways as follows:

I. Pre-syruping or syruping-filling process or post mix process: Containers are filled with flavoured syrup and now carbonated water is added in it to prepare carbonated drink.
II. Finished Product filling or Pre-mix: Flavoured syrup is added to water in correct proportion and then homogenous mix is carbonated to produce beverage.
III. Carbonation of water is done in the first stage, then flavoured syrup is metered and added into it to prepare carbonated beverage.

Degree of carbonation is judged by the amount of effervescence produced and it is most important characteristic of carbonated beverages. The optimum level of carbonation varies with the type of beverage. Higher level of carbonation in orange type of carbonated beverages and too low in cola or ginger ale is not liked by consumers. The level of carbonation varies between 1 to 4.5 volumes of CO_2 per litre of beverage; 1 volume for fruit based carbonated drinks, 2-3 volumes for colas and around 4.5 volumes for mixer drinks like tonic water, ginger ale. Use of polyethylene terephthalate (PET) bottles also requires slightly higher level of carbonation as some loss of CO_2 is bound to occur during storage. Carbonated soft drinks are filled into either bottles or cans. Thick-walled, reusable, glass bottles were used for many years, but are being replaced by thin-walled, non-reusable glass and increasingly, PET bottles.

26.4 Carbonated Water

The consumption of carbonated water has increased rapidly. As per FSSAI definitions carbonated water conforming to the standards prescribed for packaged drinking water under Food Safety and Standard act, 2006 impregnated with carbon dioxide under pressure and may contain any of the listed additives singly or in combination. Permitted additives include sweeteners (sugar, liquid glucose, dextrose monohydrate, invert sugar, fructose, Honey) fruits & vegetables extractive, permitted flavouring, colouring matter, preservatives, emulsifying and stabilizing agents, acidulants (citric acid, fumaric acid and sorbitol, tartaric acid, phosphoric acid, lactic acid, ascorbic acid, malic acid), edible gums, salts of sodium, calcium and magnesium, vitamins, caffeine not exceeding 145 ppm, ester gum not exceeding 100 ppm and quinine salts not exceeding 100 ppm. It may contain Sodium saccharin not exceeding 100 ppm or Acesulfame-k 300 ppm or Aspartame not exceeding 700 ppm or sucralose not exceeding 300 ppm.

26.5 Mineral Water

As per FSSAI guidelines mineral water means all kinds o mineral water or natural mineral water by whatever name it is called or sold. All mineral waters shall conform to the following standards, namely:-

S. No.	Characteristics	Requirements
1	Colour, Hazen unit/True	Not more than 2
2	Odour	Agreeable
3	Taste	Agreeable
4	Turbidity (Turbidity unit, NTU)	Not more than 2 nephelometric
5	Total Dissolved Solids (TDS)	150-170 mg/Litre
6	pH	6.5-8.5

Besides these levels of mineral salts, heavy metals, toxic elements, environmental contaminants and microbial counts have also been specified.

26.6 Packaged Drinking Water (other than mineral water)

It can be defined as water derived from the surface water or underground water or sea water which is subjected to herein-under specified treatments, namely decantation, filtration, combination of filtration, aerations, filtration with membrane filter depth filter, cartridge filter, activated carbon filtration, de-mineralization, re-mineralization, reverse osmosis and packed after disinfecting the water to a level that shall not lead any harmful contamination in the drinking water by means of chemical agents or physical methods to reduce the number of micro-organisms to level beyond scientifically accepted level for foods safety or its susceptibility. The standards, packaging and labelling requirements have also been specified under FSSAI rules.

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Lesson 27

FRUIT BEVERAGES AND DRINKS

27.1 Introduction

Fruit beverages and drinks are one of the popular categories of beverages that are consumed across the globe. The fruit beverages and drinks are easily digestible, highly refreshing, thirst quenching, appetizing and nutritionally far superior to most of the synthetic and aerated drinks. In recent past the consumption of fruit based beverages and drinks has increased at a fast rate. Fruit juices or pulp used for the preparation of these products are subjected to minimal processing operations like filteration, clarification and pasteurization. The fruit juice or pulp, are mixed with ingredients like sugar, acid, stabilizers, micronutrients and preservative to develop beverages and drinks. There are various categories of fruit juice or pulp based beverages and drinks which are listed below.

Natural fruit juices, sweetened juices, ready-to-serve beverages, nectar, cordial, squash, crush, syrup, fruit juice concentrate and fruit juice powder belong to the category of non-alcoholic and non-carbonated beverages. The principle groups of fruit beverages are as follows:

- Ready-to-Serve (RTS) pre-packaged Beverages
- Fruit juice and Nectars
- Dilutable beverages

27.2 Ready-to-Serve (RTS) Beverages

The ready-to-serve beverages as per FSSAI specifications should contain at least 10 percent fruit content and not less than 10 percent TSS besides 0.3% acid maximum as citric acid. The levels of permitted preservatives include 70 ppm (maximum) for sulphur dioxide and 120 ppm (maximum) for benzoic acid. The total plate count and yeast and mold counts should not exceed, to 50.0 cfu/ml and 2.0 cfu/ml, respectively. The Coliform counts should be nil in 100 ml beverage samples.

Since these beverages are consumed as such without dilution, hence are termed as “Ready-to-serve” beverage. The majority of packaged fruit beverages belong to this category. Wide range of fruits including mango, citrus fruits, berries, litchi, guava, pineapple, grapes etc. are preferred for RTS beverages. Required amount of sugar, acid, stabilizer, colouring and flavouring ingredients are added in juice or pulp along with water and the mixture is blending properly, filtered if desired. The RTS mix is pasteurized (80-90^{0}C) in bottle (20-30 min), continuous juice pasteurizer (few seconds to one minute) and cooled immediately. Nowadays, UHT processing of RTS beverages is quite popular because of longer shelf-life and less loss of nutrients during processing.

The amount of fruit juice or pulp may vary according to fruit and cost effectiveness. The presence of oxygen in headspace often leads to oxidation resulting in off-flavour and loss of nutritive value, hence anti-oxidants such as ascorbic acid is often added in RTS beverages. Besides it, colour and flavour ingredients which are stable to heat and oxygen are preferred.

27.2.1 Natural fruit juice

Natural fruit juices also falls in the category of RTS beverage. It may be defined as pure juice which is extracted from ripe and mature fruits and contain 100 percent fruit content. The juice is extracted by various methods and contains mainly sugars, acids, vitamins, minerals and other minor components. These are preserved by thermal processing and freezing. The commonly available fruit juices are apple, pineapple, citrus, grapes, pomegranate and mango.

The sweetened juices are beverages which possess at least 85 percent juice and 10 percent TSS. The sugar and acids are added to increase the TSS content and also to balance the acid-to-sugar ratio. A wide variety of fruit juices are used for the purpose. Sometime two or more juices are mixed to develop a palatable and refreshing drink with better flavour and balanced nutrition. Such beverages are also called as “fruit punch”. In certain fruits the blending or mixing of juices is done to balance the acidity and minimize the flavor changes. Use of fruit juice concentrate with suitable dilution with water is mostly used on commercial scale to produce uniform quality product.

Example:

- Very sweet (grape) and very bitter (grapefruit)
- Highly acidic (lime, lemon, sour cherry) with bland tasting fruits (pear, apple)
- Highly flavoured (guava, banana) with bland & insipid tasting fruits (pear, loquat)

The freshly squeezed juices have very short shelf-life; hence they have to be stored at 0-5^{0}C to check spoilage. Some of them may have low pH (below 4.5) hence they require thermal processing in the range of 85-95^{0}C for a minimal period to ensure commercial sterility. The minimum TSS and acidity for various natural fruit juices has been specified by FSSAI.

27.3 Nectar

Nectar is prepared from the tropical fruits pulp such as mango, litchi, guava, papaya, citrus fruits and pineapple by adding sugar, acid and other ingredients. As per FSSAI specifications nectar should contain TSS not less than 15^o Brix and not less than 20 per cent fruit content, except for pineapple and citrus fruits where fruit content should not be less than 40 percent. Fruit pulp or puree or juice or concentrate may be used as starting material. The acidity of the nectar should not be more than 3.5 per cent as anhydrous citric acid. The maximum permissible limit of preservative in nectar is sorbic acid at 50 ppm. The sorbic acid is added as sodium or potassium salt of sorbic acid. Nectar is also not diluted before consumption. Nectar is also characterized by cloudy appearance and thick mouthfeel. The cloudiness in nectar and other beverages is because of the presence of polysaccharides such as pectin, cellulose, hemicellulose and starch. The loss of cloudiness specially in citrus juices is due to the activity of pectin methyl esterase (PME), which cause de-esterification of pectin molecule resulting in settling down of pectin and loss of cloudiness. Therefore, citrus juices or comminutes must be thermally treated to inactive the PME. Sometime hydrocolloids are added to stabilize the cloudiness. Preservation of nectar is achieved in similar way as mentioned for RTS beverages.

The limited shelf-life of nectar (few days at refrigeration temperature) could be overcome by following any of the desired processing operation.

27.3.1 Flash pasteurization

The nectar may be pasteurized in plate type pasteurizer which is provided with heat recovery and cooling unit. Temperature in the range of 85-95^{0}C for 15 to 60 seconds is used for most of the products; however it again depends on type of the juice and initial microbial load. The products where both enzyme and microbial inactivation is desired slightly higher temperature i.e. 90-95^{0}C for not more than 15 seconds is used. Tubular pasteurizer is preferred for slightly viscous nectars. For aseptic packaging operations, pasteurizer is integrated with aseptic packaging unit either directly or via an aseptic buffer tank.

27.3.2 In-pack pasteurization

In-pack pasteurization is most preferred methods on small scale units. The juice is filled in packs, mainly bottles and immersed in heated water tanks which are held at 80-90^{0}C. The pasteurization conditions are 80-85^{0}C for up to 20 minutes to ensure safety of the product. The treated bottles are air-dried and then labeled. Care must be taken to ensure that pack is sealed properly and product is processed at intended temperature.

27.3.3 Hot fill operation

Hot filling offer a simpler mean of ensuring microbial integrity of the nectars. The bulk product is heated to a pre-determined temperature then filled hot (70-85^{0}C) in packs and sealed immediately. In case of glass bottle they should be pre-heated to minimize thermal shock. The packs are inverted for proper mixing of the nectar and held at desired temperature for required time. Finally they are cooled in hydro-cooler to 25^{0}C, surface is air-dried and labeled.

27.4 Dilutable Beverages

Dilutable beverages are the one which are consumed after mixing with suitable diluents like water, alcoholic drinks or milk. The process for making such beverages is quite similar to the syrup manufacture meant for carbonated beverages. These products offer a number of advantages including the ability to use different syrup to water ratio, reduction in bulk, utilization of surplus and bland tasting fruits and offer novel innovations in formulations. The various ingredients and their role in manufacturing of dilutable beverages are listed in Table-27.1. The process diagram for the manufacture of dilutable beverages is outlined in Figure 27.1.

Table 27.1 Ingredients used in dilutable beverages

S. No.	Ingredient	Remark
1	Fruit Components	Added in the form of fruit juice or pulp or comminute (whole fruit preparation), required amount should be more than 25%. For uniformity concentrated fruit juice or pulp or comminute of standard degree brix is used. Source of fruit sugar, acid, pectin, colouring pigments, flavouring compounds and micronutrients.
2	Syrup	Carbohydrate syrup is added in various forms like sucrose, invert syrup, glucose syrup or modified syrup. Provide body, impart sweetness; assist in development of flavour, mild preservative effect. Always added after filtration and sterization.

3	**Acid**	Citric acid is most preferred acidulant, other that may be used are malic, lactic and tartaric. Balance acid to sugar ratio, anti-microbial. Impart flavour as well.
4	**Preservatives**	Mainly added to prevent growth of fungi, yeast, lactic acid bacteria. Permitted are sulphur dioxide, benzoic acid and sorbic acid.
5	**Flavourings**	Mostly natural or natural identical flavourings are used. Must improve the flavour of beverages without affecting other properties.
6	**Colourings**	A permitted food colour that may enhance the aesthetic appeal of the beverage is used. It may include natural, natural identical or synthetic dyes. Maximum permissible limit is 100 ppm for coal tar dyes.
7	**Other Additives**	It may include stabilizers to keep the fruit solids in suspension and improve mouthfeel of the beverage. Acidity regulators, emulsifiers, anti-oxidants and clouding agents are also used to enhance the acceptability of these beverages.

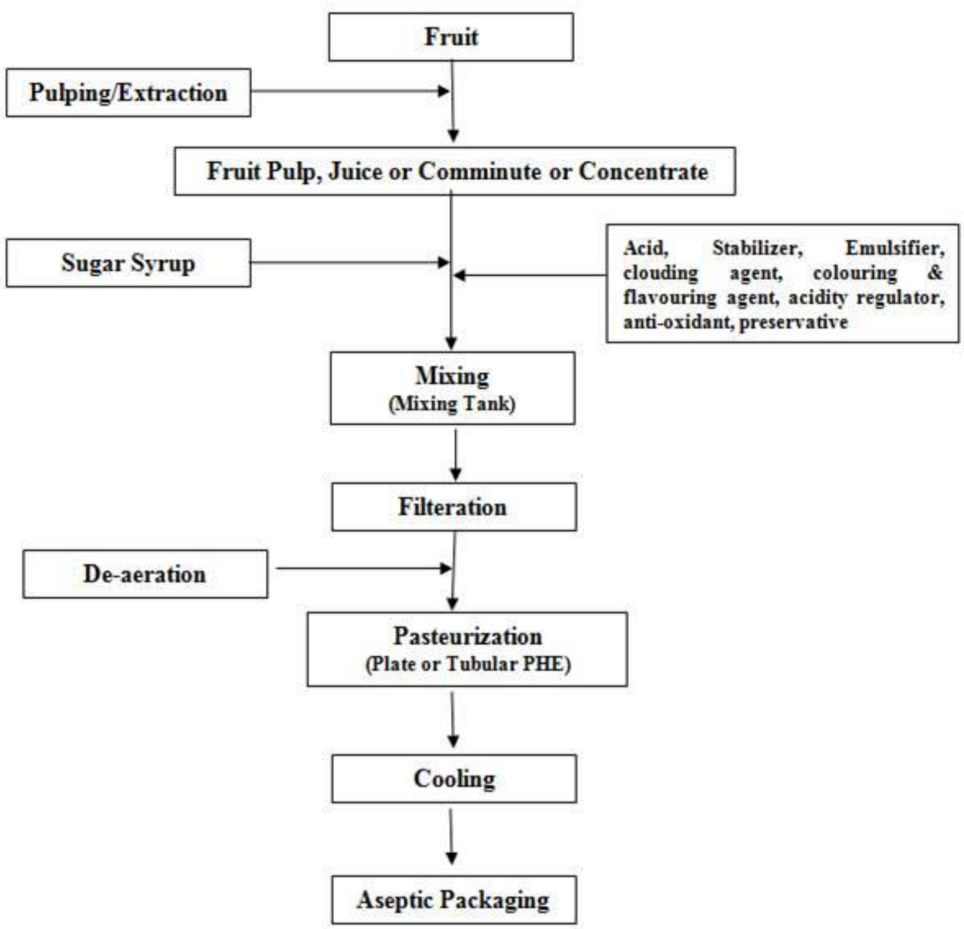

Fig.27.1 Process flow diagram for the manufacture of dilutable beverages

Two major products fall into the category of Dilutable beverages are discussed hereunder.

27.4.1 Cordial

Fruit juice cordial is a sparkling clear sweetened fruit beverage from which all the pulp and other suspended materials have been completely eliminated. Cordial is prepared by mixing clarified fruit juice, with sugar syrup, acid and other ingredients. As per FSSAI specification, cordial should contain not less than 25 percent fruit content and the TSS content should not be less than 30° Brix .The acidity of the cordial should not be more than 3.5 per cent as anhydrous citric acid. The maximum permissible limit of preservative in cordial is 350 ppm of sulphur dioxide or 600 ppm of benzoic acid. The citrus juices such as lime and lemon are preferred for making cordial. The cordial are generally consumed by mixing with alcoholic beverages like gin.

The fruit juices are either stored for longer period to remove suspended solids and pectinous materials or it may be treated with commercial enzyme preparations like pectinase to hydrolyze pectin. The clarified juice is used for cordial preparation.

27.4.2 Squashes and crushes

Squash is the product, which is prepared by mixing of calculated quantity of fruit juice or pulp, with sugar, acid and other ingredients. As per FSSAI specifications, squash should contain not less than 25 per cent fruit content in finished product and the total soluble solids content should not be less than 40° Brix. The acidity of the squash should not be more than 3.5 per cent as anhydrous citric acid. Mango, orange, lemon, pineapples, grape and litchi are used for making squash commercially. Squash can also be prepared from lemon, bael, guava, pear, apricot, muskmelon, papaya, passion fruit, peach, plum, mulberry, raspberry, strawberry, grapefruit, etc. The maximum permissible limit of preservative in squash is 350 ppm of sulphur dioxide or 600 ppm of benzoic acid. Potassium metabisulphite is not added in dark coloured fruits as it may bleach the anthocyanin pigments. In such beverages sodium benzoate is used.

Commercially available squash contain 40 to 50 percent sugar and around 1.0 percent acid. They are diluted in the ratio of 1:4 before consumption. There is another category of dilutable beverage called crush. As per FSSAI guidelines, crush must contain not less than 25 percent fruit content and 55 percent TSS. Mostly, the comminutes of citrus fruits and pineapple are used for crush manufacture.

Syrup is a type of fruit beverage that contains at least 25 percent fruit juice or pulp and not less than 65 percent TSS. It also contains 1.25-1.5 percent acid and diluted before consumption. The syrups from rose petals, almond, mint, khus, sandal and kewra are quite popular.

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Module 8. Tea

Lesson 28

TEA-INTRODUCTION AND CLASSIFICATION

28.1 Introduction

Tea is one of the most popular beverages in the world. It also provides valuable source of income to many tea producer countries. It is a capital earning industry. To promote its development, the Govt. of India has set up Tea Board under the Ministry of Commerce. Tea Taster's academy has recently come up in Coonoor in theNilgiris.

Tea is a perennial plant having a lifespan extending 100 years.

The popularity of tea is due to:

- Its sensory properties
- Relatively low retail price
- Apparent health benefits

28.2 History

The history of tea production in India spans more than 160 years. In 1838, the first consignment of tea from Assam was shipped to England.

The word *'Chai'* is derived from a Cantonese word *'Chah'*. Plantations in Darjeeling, Tarai and Dooars regions of northern Bengal and Nilgiris and other regions of South India.

28.3 Origin and Distribution

Centre of origin – Southeast China

Later it spread to Southern portion of China, parts of India, Myanmar, Thailand, Laos and Vietnam

Early part of 19th Century – An unsuccessful attempt was made to establish Chinese tea in India. Only when the native 'wild' tea plants found in Assam were used, the tea production in India became successful.

Tea industries in India are there in Assam, West Bengal, Kerala, Karnataka, Tamilnadu and to some extent in Tripura and Himachal Pradesh.

28.4 FSSAI Definition of Tea

Tea means tea other than Kangra tea obtained by acceptable processes, exclusively from the leaves, buds and tender stems of plant of the *Camellia sinensis* (L) O.Kuntze. It may be in the form of black or oolong tea. The product shall have characteristic flavour free from any off odour, taint and mustiness. It shall be free from living insects, moulds, dead insects, insect fragments and rodent contamination. The product shall be free from extraneous matter, added colouring matter and harmful substances.

Tea may contain 'natural flavours' and 'natural flavouring substances' which are flavour preparations and single substance respectively, acceptable for human consumption, obtained exclusively by physical processes from materials of plant origin either in their natural state or after processing for human consumption in packaged tea only. Tea containing added flavour shall bear proper label declaration. Tea used in the manufacture of flavoured tea shall conform to the standards of tea. The flavoured tea manufacturers shall register themselves with the Tea Board before marketing flavoured tea. The product shall conform to the following requirements expressed on basis of material oven-dried at 103±2^{o}C. The specifications for tea are furnished in Table 28.1.

Table 28.1 Specific requirements of Tea by FSSAI

Parameters	Requirements
Total ash (w/w)	Min. 4.0% and Max. 8.0%
Water soluble ash	Min. 45% of total ash
Alkalinity of water soluble ash expressed as KOH (w/w)	Min. 1.0% and Max. 3.0%
Acid insoluble ash (w/w)	Max. 1.0%
Water extract (w/w)	Min. 32.0%
Crude fibre (w/w)	Max. 16.5%

28.4.1 Kangra tea

It is derived exclusively from leaves, buds and stems of plants of the *Camellia sinensis* grown in Kangra and Mandi valleys of Himachal Pradesh.

Tea for domestic market may contain added vanillin flavour up to a maximum extent of 0.5% by weight and other flavours as depicted in Table 28.2.

Table 28.2 Permitted flavors for inclusion in tea by FSSAI

Flavours	Per cent by weight (Max.)
Cardamom	2.8
Ginger	1.0
Bergamot	2.0
Lemon	1.6
Cinnamon	2.0
Mixture of above flavours	The level of each individual flavour shall not exceed the quantity specified above

28.4.2 Green tea

It means the product derived solely and exclusively, and produced by acceptable processes, notably enzyme inactivation, rolling or comminution and drying, from the leaves, buds and tender stems of varieties of the species *Camellia sinensis* (L) O. Kuntze, known to be suitable for making tea for consumption as a beverage. The product shall have characteristic flavour free from any off odour, and rodent contamination visible to the naked eye. The product shall be free from extraneous matter, added colouring matter and harmful substances. The other specifications for such tea are same as for Tea, except for total catechins which should be min. 9.0 and max. 19.0% w/w.

28.5 Health Benefits of Tea

Black tea leaf contains significant amounts of vitamin E & K. Vitamin C is present in green tea, but only traces are found in black tea. The phenolic constituents (referred to as vitamin P) strengthen the walls of capillary blood vessels. Tea also contains vitamin A (carotenoids) and vitamin B. It is too low in Fe, Cu and Fluoride.

5 cups of tea supplies 25% and 10% of the daily requirements of minerals like Mn and Zn respectively.

Catechins (viz., epigallocatechin gallate) have antimicrobial and anticancer properties. The black tea polyphenols absorb metals from the diet i.e. lead from contaminated water. Moderate amount of caffeine present in a cup of tea is mildly stimulating whilst provoking minimal irritability.

Decaffeinated teas have already appeared in the market.

28.6 Adulteration

Common adulterant is ‘spent’ or ‘used’ tea plus some colouring substances unfit for human consumption.

28.7 Health hazards

Caffeine is toxic to cardiovascular and nervous systems, when consumed excessively. Tea contains tannin which interferes with Fe absorption. Thus, it is prudent to avoid tea either before or after meals.

28.8 Caffeine in tea

It is an important pharmacological agent.

Mild stimulating action – central nervous system is almost indiscriminately stimulated from the top downwards; helps enhancing work efficiency by overcoming fatigue.

Caffeine often prescribed for migraine headache. It induces secretion of catecholamines in mammalian tissue.

Increases the level of serum lipids, but this effect is almost nullified by antilipidemic activity of high levels of polyphenols in tea. It is effective as a respiratory stimulant; produces peripheral vasodilation and increased circulation in kidneys and brain; increases the number of active glomeruli in the kidney and has a diuretic action.

Caffeine causes secretion of both acid and pepsin in the stomach and can aggravate peptic ulcer.

28.9 Classification of Teas

Tea plant *Camellia sinensis* (L) O. Kuntze is the only important economic species of the family Theaceae.

The two botanical varieties are recognized

28.9.1 China Tea (*Camellia sinensis* var. sinensis)

It is a variety found in more temperatate producing regions such as China, Japan, USSR< Turkey, Iran and Northern, higher altitude growing areas of India. It produces delicately flavoured tea.

28.9.2 Assam Tea (*Camellia sinensis* var. *assamica*)

It can survive only at high altitudes near the Equator. It is less resistant to cold than China type and much higher yielding plant, but produces less delicately flavouredbeverage.

28.9.3 Hybrids

Hybrid between China and Assam types e.g. Darjeeling tea.
The desired aroma is produced during cool, clear, dry windy weather with day and night temperatures of 20^{o}C and 6-10^{o}C respectively.

It is referred to in relation to place where it is grown

India – Assam Tea, Darjeeling Tea, Nilgiris Tea
Sri lanka – Orange pekoe Tea
China – Lapsang Tea, Sonchong Tea, Earl grey Tea.

28.10 Types of Processed Tea

28.10.1 Fermented or black tea

They contribute a major proportion of tea consumed in Western hemisphere. They are produced by full fermentation and roughly classified as ‘Plain’ or ‘Flavoury’.

28.10.2 Plain black tea

The taste characteristics are associated with the phenolic substances produced during fermentation e.g. Assam tea.

28.10.3 Flavoury black tea

They are sold on the basis of their aroma characteristics e.g. Darjeeling tea.

28.10.4 Green tea

There is no fermentation; the leaf remains green. When infused, the liquors are greenish, pale primrose or lemon-yellow in colour with no trace of red or brown. They are produced and consumed mainly in China and Japan. Green tea constitutes ~ 20% of total production.

28.10.5 Partially fermented tea

These are partially oxidized so that their appearance is somewhat intermediate between that of green and black tea. They are manufactured primarily in China e.g. Oolong, Pouchong teas.
Oolong or Ponchong or Red Tea forms only 2% of total tea production.

28.10.6 Flavoured tea

Teas are sometimes scented with various plant essential oils such as lemon, bergamot, rose and fragrant olive which impart sweet floral attributes to enhance the natural flavour of tea.
Other teas are blended with flower petals, spices or dried leaf such as Rosemary, Peppermint, Camomile and Chrysanthemum.

28.10.7 Brick tea

These are tea (black or green) which are compressed in the form of bricks or cakes. Portions of bricks are broken off for use and are sometimes cooked with butter or other fats.

28.10.8 Instant tea

It is the water soluble extract of tea leaf, usually marketed as a powder, flake or granule, either pure or as a part of flavoured mixes.

Most Instant tea is made from black tea, but some is made from green tea. Iced lemon teas are popular example in USA.

28.10.9 Products promoted on health grounds

'Decaffeinated tea' is promoted on health grounds. Tea is decaffeinated with methylene chloride or other chlorinated solvents and supercritical CO_2.

Flavours

The flavours used include chocolate, jasmine, mandarin orange peel, Bergamot and other sweet herbs. In India, cardamom, ginger, lemon, bergamot and mint are popular flavoured teas.

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Lesson 29

TEA LEAF PROCESSING

29.1 Introduction

The production of orthodox and CTC tea accounts for 52.0 and 48.0% of black tea production respectively. India is the largest producer of Black tea while China is the largest producer of Green tea in the world.

Most of the teas we buy are blends, mixed from different pure teas so as to ensure same flavour from year to year.

Leaf is more popular in northern India and Dust in Southern parts. Central India – equal consumption of both dust and leaf varieties.

29.2 Chemistry of Tea Leaves

The fresh tea leaf is characterized by large quantities of methylxanthines and polyphenols. The composition of unprocessed tea leaf and young shoot of Assam tea is presented in Table 29.1 and Table 29.2 respectively.

Table 29.1 Composition of unprocessed tea leaf

Constituents	Percentage
Protein	20
Carbohydrates	30
Lipids	2
Polyphenols	33
Caffeine	5
Vitamins and minerals	7

Table 29.2 Chemical composition of young shoot of Assam tea

Components	Dry weight (%)
A. Soluble in water	
Phenolics	30
Flavanols*	18-32
Flavonol glycosides	3-4
Proanthocyanidins	2-3
Phenolic acids	
- Caffeine	3-4
Amino acids	
- Theanine	2
- Others	2
Carbohydrates	4

Organic acids	0.5
B. Partially soluble in water	
Starch	2-5
Other polysaccharides	12
Protein	15
Ash	5
C. Insoluble in water	
Cellulose	7
Lignin	6
Lipids	3
Pigments	0.5
Volatiles	0.01-0.02

* Flavanols comprise of Epigallocatechin gallate: 9-13%, Catechin: 1-2%

29.2.1 Methylxanthines

Caffeine – a purine alkaloid. Its content in fresh leaf is about 3-4% (dry weight basis) which cannot be significantly reduced by conventional tea processing. High caffeine levels leads to good ‘cream’ formation in the liquor. Caffeine reacts with theaflavins and imparts ‘briskness’ to tea infusion.

29.3 Enzyme action

Polyphenol oxidase enzyme in tea leaf plays a key role in fermentation. Other enzymes include peroxidase, amylase, □-glucosidase, peptidase, chlorophyllase, phosphatase and leucine transaminase.

$$\text{Gallocatechin} \xrightarrow[\text{Enzymatic oxidation}]{\text{Catechins \& Polyphenol oxidase}} \text{Theaflavins and Thearubigins}$$

Theaflavins and Thearubigins are the two groups of polyphenolic compounds unique to black tea. Theaflavins account for 0.3-1.8% of dry weight of black tea. They are bright red pigments which gives the liquor the highly sought-after characteristics (i.e. ‘brightness’ and ‘briskness’ (keen/sharp flavour)). Thearubigins comprise between 9-19% of the dry weight of black tea. They are phenolic brown pigments with acidic properties. Aroma forms during fermentation.

29.3.1 Polyphenols and Polyphenol oxidase activity

29.3.1.1 Green tea

The most important biochemical changes to occur during steaming or roasting are inactivation of the enzyme polyphenol oxidase so that the catechins remainunoxidized, preserving the green colour of the leaf.

29.3.1.2 Black tea

Fermentation is the most important stage in ‘black tea’ manufacture, which results in the formation of taste and aroma products, responsible for character of black tea. Fermentation is a misnomer, since microorganisms are not involved.

29.4 Tea Leaf Processing

The processing of tea leaves starts just after harvesting. The sequence of steps is as detailed below:

29.4.1 Harvesting/Plucking

This involves manual or mechanical removal of terminal young tender portions of peripheral shoots. The standard method is to pluck 'two leaves and a bud'.

The quality of final product deteriorates with an increase in mature leaf content.

Hand plucking is preferred. The mechanical harvesting involves use of modified hedge trimmers and motorized machine pluckers.

29.5 Black Tea Processing

29.5.1 Withering

The change which occurs in green leaf from the time it is detached from the plant to the time of maceration or rolling is collectively referred to as 'Withering'.

Air temperature, atmospheric vapour pressure, air velocity and air direction affects the rate and degree of physical wither.

Green leaves are spread over mesh in specially made wooden troughs with a bed thickness of 20 – 45 cm. A cross flow of heated air (temperature raised by 3-5^{o}C by an electric fan) or ambient air during favourable atmospheric condition is maintained during entire stage (16-19 hours). This process reduces the moisture content from 80% to 50-60%.

It is a physical process wherein (a) moisture loss leads to changes in cell membrane permeability; the stomata on the lower surface of the leaf begin to shut gradually, (b) it preconditions the leaf for 'maceration' or 'rolling'.

29.5.1.1 Two-stage withering

The leaf is stored in a holding tank with minimal moisture loss for about 6 h to achieve chemical wither. The leaf is then spread on withering troughs or a moving beltwitherer and moisture is rapidly reduced by use of warm air.

Other methods include Drum withering, Tunnel withering, etc.

29.5.2 Maceration / Rolling

29.5.2.1 Orthodox method

The physically withered leaf is subjected to rolling. The leaf gets damaged, become twisted and the semi-permeable membrane of leaf gets distorted allowing the cell juices to be expelled to cover the leaf surface. This allows the juice to mix with cellular enzyme in presence of oxygen and the chemical reactions necessary for fermentation commences.

29.5.3.1 Cruch, Tea and Curl (CTC) method

The withered leaves are passed through CTC machine, causing severe rupturing of leaf cells. Machine consists of two steel engraved rollers rotating at different speeds in opposite direction (70 and 700 rpm). The leaves are allowed to consecutively pass through 2-3 such machines to achieve rupturing of cells and desired size.

The CTC machine has 3 sets of rollers: (a) first cut (coarse), (b) second cut (fine) and (c) third cut (super fine), after which the leaves are completely rolled. The capacity of CTC machine ranges from 750 to 1000 kg/h.

Other maceration methods include Legg-cut, Rotorvane, Triturator. A modern factory uses Rotorvane plus three CTC machines in series.

29.5.3.1.1 Advantage of CTC over Orthodox process

- Leaf distortion is much greater
- Fermentation is faster
- Liquoring properties are improved
- CTC and Lawrie Tea Processor (LTP – a modern CTC machine) teas have higher levels of theaflavins and thearubigins and therefore have more colour and are brighter and brisker than orthodox teas.

29.5.3 Fermentation

The liquor characteristics of black tea can be determined by control of temperature and time of fermentation (chemical transformation). The rolled leaf mass is placed on floor in thin layers at room temperature and with increased humidity (90-95% RH) using humidifiers. Fermentation is continued till the colour of leaf mass turns golden brown (1-2 hours).

Batch method uses troughs or trolleys, while *Continuous method* uses perforated moving belt fermentation machines through which air is passed.

The fermentors are connected to air supply by a duct, which can be humidified, if necessary, to reduce the temperature of fermenting tea (dhool).

The enzymatic oxidation, originally termed as 'fermentation' since it affects liquor quality and cuppage of tea. Such operation influences the colour, brightness and briskness of liquor. It also imparted mellowness to brew. After fermentation, the colour of leaf mass changes from green to bright coppery red. Generally, the lower the fermentation temperature, the better is the black tea.

29.5.4 Firing/Drying

Once optimum fermentation is achieved, it is necessary to destroy enzymes. The 'dhool' is fed to the driers by conveyors at a temperature of 90-120^{o}C for 12-15 minutes. This process reduces the moisture content of fermented tea from ~ 60% to < 4%. It terminates fermentation by inactivating the enzymes. It makes the product fit for sorting and packaging.

In driers the inlet and outlet temperature may range from 82-98°C and 45-55°C respectively. Fluidized bed driers are being used recently. In this the blown hot air moves the dhool by process of fluidization. The disadvantage of firing is loss of considerable amount of volatile aroma compounds.

29.5.5 Grading and Sorting

Tea after firing is a mixture of particles of different sizes, ranging from 'dust' to 'leaf' of about 5 cm long and 1.3 cm wide. They are sorted into uniform grades acceptable to the buyers. The grading and sorting of tea is carried out using mechanically oscillatory sieves fitted with meshes of many different sizes. Winnowing in some form or other is routinely employed and according to the size and density of the particles, separates 'fannings' and 'dust', carrying away the fibrous residues which is of no commercial value as a grade.

29.5.6 Packaging and Storage

For bulk transport, Tea chests are used to contain 60 kg tea. Chest is made up of plywood, lined inside with Aluminium foil. Other packaging material includesmultiwalled paper sacks – 2 plies of Kraft paper with an additional layer of Aluminium foil on the inside.

29.6 Green Tea Processing

It is manufactured from fresh leaf which has not been fermented. It depends on arresting the enzyme activity in green leaf. The different methods of green tea production are depicted in Fig. 29.1 and 29.2.

29.6.1 Chinese process of Green Tea manufacture

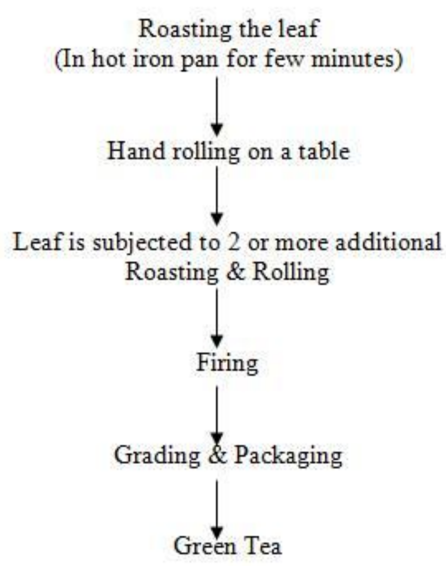

Fig. 29.1 Green tea processing by Chinese process

29.6.2 Japanese process of Green tea manufacture

Leaf steamed in revolving cylinder with an agitator
(15-20 min)
↓
Cooled by a Fan or by Air
on a Belt conveyor
↓
Primary Heating and Rolling
↓
Further Heating & Rolling
↓
Pass through secondary Rollers
↓
Drying
(3-4% moisture)
↓
Grading &Packaging
↓
Green Tea

Fig. 29.2 Green tea processing by Japanese process

29.7 Processing for Partially Fermented Tea

The typical processing method adopted for preparing partially fermented tea is shown in Figure 29.3.

Fresh leaf
↓
Withered at room temperature for ~ 16 h
OR
At 40°C for 2 h, then 4 h at room temperature
↓
During last 4 h, leaf rolled by hand for 30 min, every hour
↓
Roasting/Parching/Pan frying
(160°C/20 min)
↓
Tea rolled further
↓
Firing
↓
Grading & Packaging
↓
Oolong Tea

Figure 29.3Tea processing for partially fermented tea.

Varieties of Tea based on processing

Country	Type of teas
India	Both orthodox and CTC
China	Green tea and orthodox tea for export
Sri Lanka	Mostly orthodox variety
African countries	Only CTC teas

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Lesson 30

SPECIALTY TEA PRODUCTS

30.1 Introduction

Value addition to tea has been a reality and since people are fond of stimulating beverages, there has been introduction of an array of specialty tea products. Some of the examples of such specialty tea products are discussed herein.

30.2 Flavoured Tea

Teas are sometimes scented with various plant essential oils such as lemon, bergamot, rose and fragrant olive which impart sweet floral attributes to enhance the natural flavour of tea.

Other teas are blended with flower petals, spices or dried leaf such as Rosemary, Peppermint, Camomile and Chrysanthemum.

30.2.1 Flavours

The flavours that have been used include chocolate, jasmine, mandarin orange peel, Bergamot and other sweet herbs. In India, cardamom, ginger, lemon, bergamot and mint are popular flavoured teas.

30.3 Brick Tea

These are tea (black or green) which are compressed in the form of bricks or cakes. Portions of bricks are broken off for use and are sometimes cooked with butter or other fats.

30.4 Herbal Tea

This type of tea can be made using dried rosemary herb. Prepare dark out of optimum level of concentration of Rosemary herb. Blend black tea and rosemary; combination of other herbs like basil, mint, lemongrass, thyme, chamomile with rosemary.

30.5 Tea Bag

The first tea bags were hand-sewn silk bags and tea bag patents dated as early as 1903. First appearing commercially around 1904, tea bags were successfully marketed by the tea and coffee shop merchant Thomas Sullivan from New York, who shipped his tea bags around the world. Modern tea bags are usually made of paper fibre. The heat-sealed paper fiber tea bag was invented by William Hermanson, one of the founders of Technical Papers Corporation of Boston. The rectangular tea bag was invented in 1944. Prior to this tea bags resembled small sacks.

The tea bag is referred to as 'Cinderella' of tea industry – now dressed in paper instead of silken gown.

A tea bag is a small, porous sealed bag containing tea leaves and used for brewing tea. Tea bags are commonly made of paper, silk or plastic. The bag contains the tea leaves while the tea is brewed, making it easier to dispose of the leaves, and performs the same function as a tea infuser. Some tea bags have an attached piece of string with a paper label at the top that assists in removing the bag while also identifying the variety of tea.

A broad variety of teas, including herbal teas, are available in tea bags. Typically, tea bags use fannings, the left-overs after larger leaf pieces are gathered for sale as loose tea, but some companies such as Honest Tea sells teabags containing whole-leaf tea.

30.6 Products Promoted on Health Grounds

30.6.1 Decaffeinated tea

This type of tea is promoted on health grounds. Chloroform or methylene chloride is an effective solvent for isolating caffeine from tea leaf. However, it is not widely accepted by consumers because of its toxicity. Decaffeination using supercritical carbon dioxide is effective and leaves no solvent residues, but it needs expensive equipment. Sawdust lingo-cellulose columns can be used to separate caffeine from tea extracts, but they are difficult to use for decaffeination of tea leaf.

30.6.1.1 Hot water treatment – an alternate safe method

When fresh tea leaf was decaffeinated with a ratio of tea leaf to water of 1:20 (w/v) at 100^{o}C for 3 min, caffeine concentration was decreased from 23.7 to 4.0 mg/g, while total tea catechins decreased from 134.5 to 127.6 mg/g; 83% of caffeine was removed and 95% of total catechins was retained in the decaffeinated leaf. Hence, hot water treatment can be considered to be a safe and inexpensive method for decaffeinating green tea. However, a large percentage of tea catechins were lost if rolled leaf and dry tea were decaffeinated by such treatment and so this process is not suitable for processing black tea.

30.7 Aseptic Packaging Tea Concentrates

These are produced from top quality tea leaf (*Camellia sinensis*) through hot water extraction and Reverse Osmosis (RO) concentration at low temperature. It is then subjected to Ultra High Temperature (UHT) treatment and aseptically packaged. The products include Green tea, Jasmine tea, Oolong tea and Black tea.

The liquid concentrates look crystal clear and retain the flavor characteristics of tea leaf and are ideally suitable for making iced tea mixes and Ready-to-Drink (RTD) tea beverage.

30.8 Instant Tea

It is the water soluble extract of tea leaf, usually marketed as a powder, flake or granule, either pure or as a part of flavoured mixes.

Most Instant tea is made from black tea, but some is made from green tea. These are produced especially in USA and UK. Iced lemon teas are popular example in USA.

Instant tea is presently manufactured by spray/freeze drying of the concentrated brew of processed tea leaves/dust. A new technique has been developed for the production of instant/soluble tea powder from the expressed juice of green leaves. After plucking, the leaves are crushed and juice pressed out. The juice is then subjected to fermentation under specified conditions. The fermented juice is steamed, centrifuged and freeze-dried to get instant tea powder. At the same time, the pressed leaf residue is subjected to fermentation and drying for preparation of tea granules. The instant tea produced is of good liquoring characteristics. The theaflavin to thearubigin ratio was 10.71 for instant tea and 12.12 for tea granules. The caffeine content was 40.4 mg and 96 mg per cup for instant tea and tea granules respectively. There is considerable savings in the economy as the juice and residue are converted into value-added products using this method.

30.8.1 Manufacturing process for instant tea

The processing in tea processing plant includes extraction, separation of waste, evaporation and spray drying. The plant size varies from 5 kg/h to 1000 kg/h of instant tea.

The processing steps are as outlined below:

- Instant tea is manufactured from black tea by extracting the brew from processed leaves, tea wastes or undried fermented leaves.
- The extract is concentrated under low pressure, and dried to a powder by any of the processes including freezing, drying, spray-drying and vacuum-drying.
- Low temperature is used to minimize the loss of flavor and aroma.

The flow chart for production of Instant tea is furnished in Fig. 30.1.

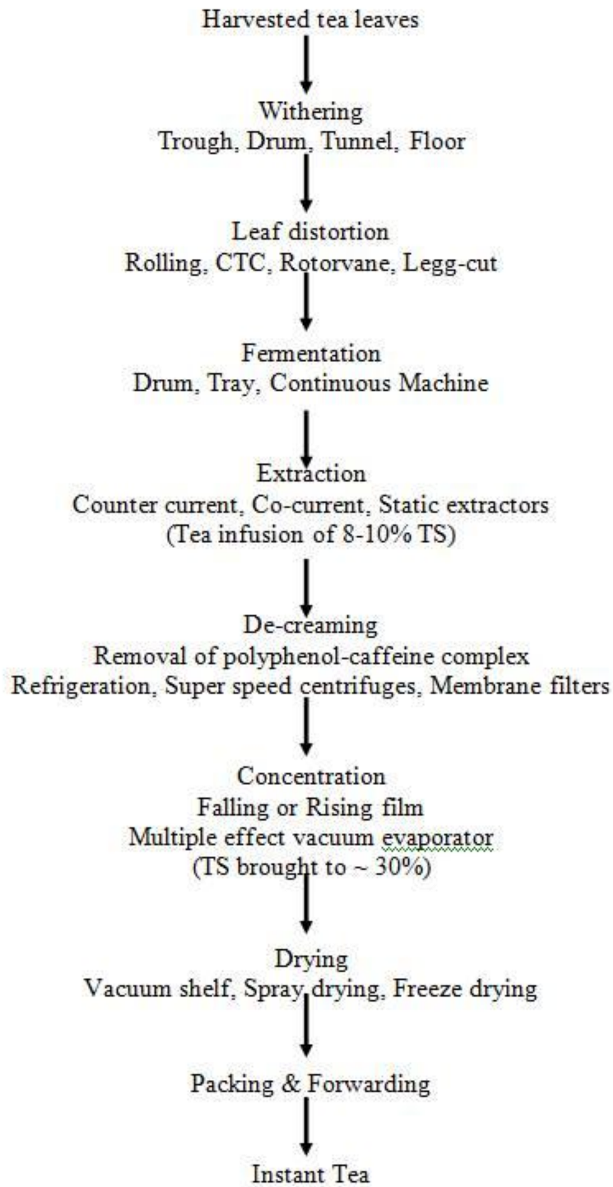

Fig. 30.1 Process flow-chart for production of Instant Tea

30.9 Recent advances in tea industry

In recent past, products like value added tea, Ready-to-drink or Instant type or complete tea powder. A leading tea manufacturer developed ‘Chicory tea’ comprising of 70% tea, 20% chicory and 10% tapioca. In USA, the non-conventional tea products include instant tea, flavoured tea, decaffeinated tea, tea beverage (RTS), carbonated tea, liquid tea concentrates, tea mixes. Vacuum packed teas can retain freshness better.

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Module 9. Coffee

Lesson 31

COFFEE - TYPES AND CHARACTERISTICS

31.1 Introduction

Coffee was allegedly born before 1,000 A.D. when legend has it that a shepherd named Kaldi, in Caffa, Ethiopia noticed that his sheep became hyperactive after grazing on some red berries. Coffee was first introduced in Turkey during the Ottoman Empire around A.D. 1453 and coffee shops opened to the public. Coffee came to India via Mysore in Karnataka, brought secretly by a Sufi Saint from Meccan named Baba Budan.

Coffee is pleasure. Its taste, flavour, aroma and refreshing effect makes it unique.

Green coffee – A green coffee bean is a commercial term which designates the dried seed of the coffee plant. It has about 10.0% moisture. Coffee plant or tree belongs to Coffea genus.

31.2 Classification of Green Coffee Beans

Two species are commercially important for green coffee:
Coffea canephora (also referred to as *C. robusta*)
Coffea arabica L.
Arabica accounts for 75% of global coffee production.
Arabica coffee bush bears about 5 kg fruit per year which corresponds to 300-400g of Instant coffee. Robusta bushes yield slightly higher.

31.3 Comparison of *C. robusta* with *C. arabica*

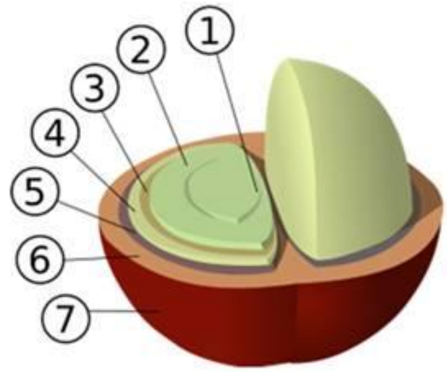
- Flavour quality (roasted and brewed) is generally considered to be inferior for *C. robusta.*
- Less expensive per unit weight of green coffee.
- Characteristics found favourable in manufacture of some instant coffees.
- Often features in Espresso coffee.
- Consumed as regular brewed coffee.

Arabica has more aroma. Robusta contains more caffeine and is consequently slightly bitter.

Indian coffee is the most extraordinary of beverages, offering intriguing subtlety and stimulating intensity. India is the only country that grows all of its coffee under shade. Typically mild and not too acidic, these coffees possess an exotic full-bodied taste and a fine aroma.

India's coffee growing regions have diverse climatic conditions, which are well suited for cultivation of different varieties of coffee. Some regions with high elevations are ideally suited for growing Arabicas of mild quality, while those with warm humid conditions are best suited for Robusta's.

31.4 Structure of coffee bean



1. center cut
2. bean (endosperm)
3. silver skin (testa, epidermis)
4. parchment (hull, endocarp)
5. pectin layer
6. pulp (mesocarp)
7. outer skin (pericarp, exocarp)

When the fruit is ripe, it is almost always handpicked, using either ‘selective picking’, where only the ripe fruit is removed or ‘strip-picking’, where all of the fruit is removed from a branch all at once. Because a tree can have both ripe and unripe berries at the same time, one area of crop has to be picked several times, making harvesting the most labor intensive process of coffee bean production.

There are two methods of processing the coffee berries. The first method is ‘wet processing’, which is usually carried out in Central America and areas of Africa. The flesh of the berries is separated from the seeds and then the beans are fermented – soaked in water for about 2 days. This dissolves any pulp or sticky residue that may still be attached to the beans. The beans are then washed and dried in the sun, or, in the case of commercial manufacturers, in drying machines.

The ‘dry processing’ method is cheaper and simpler, used for lower quality beans in Brazil and much of Africa. Twigs and other foreign objects are separated from the berries and the fruit is then spread out in the sun on cement or brick for 2–3 weeks, turned regularly for even drying. The dried pulp is removed from the beans afterward.

After processing has taken place, the husks are removed and the beans are roasted, which gives them their varying brown color, and they can then be sorted for bagging.

31.5 Organic Coffee

Organic coffee are those produced by such management practices which help to conserve or enhance soil structure, resilience and fertility by applying cultivation practices that use only non-synthetic nutrients and plant protection methods. Further, there has to be credible certification by an accredited certification agency.

Organic coffee is being produced by about 40 countries in the world with major production share coming from Peru, Ethiopia and Mexico. Organic coffee is chiefly consumed in the Europe, US and Japan. Organic coffee products are now marketed in the form of regular, decaffeinated, flavoured and instant coffee as well as in other foods like ice creams, yoghurt, sodas, candies and chocolate covered beans, etc.

31.6 Green Bean Processing

Green bean itself has no comestible value for humans and must be roasted before use as a flavourful and stimulant aqueous beverage.

Green coffee beans are dried, cleaned and packed usually in 60 kg bags and stored before they are roasted.

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Lesson 32

COFFEE PROCESSING

32.1 Introduction

The previous lesson dealt with origin and classification of coffee. In this lesson the processing of coffee bean will be discussed. The green bean has no comestible value for humans and must be roasted before use for developing the desired colour and flavor, enjoyed as a stimulant beverage.

32.2 Green Bean Processing

32.2.1 Roasting process

It is a time-temperature dependent process, whereby chemical changes are induced by pyrolysis within the coffee beans, together with marked physical changes in their internal structure. The required change takes place with a bean temperature from 190^{o}C upwards; bean temperature up to 240^{o}C may be reached in less than 12 minutes.

Batch operated horizontal rotating drum roaster with either solid or perforated walls, in which hot air from a furnace/burner passes through the tumbling green coffee beans. Green coffee beans under movement are subjected to heat by conduction from hot metal surfaces, or convection from hot air, or more generally a mixture of both methods of heat transfer, together with contribution by radiation.

A typically sized roaster holds 240 kg of green coffee, with an outturn (charging to discharging) of 15 min. The furnace or burner will be either oil or gas fired.

Other roasters include:

Vertical static drum with blades

Vertical rotating bowl

Fluidized bed

Pressure roasting

The latest roasters have shorter roast times i.e. of the order of 3-5 min. Fast-roasted coffee is advantageous because of lower bulk density and 'high yield' on brewing.

The degree of roast may vary from 'Very light to very dark'.

Consumer preference is usually 'medium roast'.

32.2.1.1 Physico-Chemical Changes in Coffee

32.2.1.1.1 Chemical changes

The chemical changes include Maillard type reactions and caramelization of sucrose. The composition of roasted coffee is furnished in Table 32.1.

Volatile complex comprising of furan derivatives, pyrazines,
pyridines, benzenoid aromatics, aliphatics, alicyclics and various sulphur compounds. These are important for the flavour/aroma in medium-roast Arabica coffee.

Some compounds are generated by straight pyrolysis of single compounds e.g. chlorogenic acids in generating phenols; there is overall 40% residual content for a medium roast. The change in chlorogenic acid content is used as analytical measure of **'degree of roast'**.

Similarly, coffee oil leads to formation of small amounts of aldehydes and hyrdrocarbons. The coffee oil is practically unaffected, as is the caffeine content.

Newly formed residuum of ~ 25% by weight of roasted coffee is melanoidins/humic acids. The loss of mass is 2-3% on dry basis for **'Light roast'**, whereas it is up to 12% on dry basis for **'Very dark roast'**. The beans lose 15-20% of their weight, but increases up to 25% in size.

32.2.1.1.2 Physical changes

The physical changes that occur include:

Change in colour.

Formation of cavities/cracking of surface.

Void volume is 47% of **'medium roast bean'** vs. 0% in green bean.

32.2.2 Cooling

In batch operation, the roasted beans have to be quickly discharged at the end of required roasting period into a cooling car, or vessel, allowing upward passage of cold air.

In addition, water may be sprayed from within the rotating drum, just before the end of the roast – so called **'Water quenching'**.

32.2.2.1 Advantages of water quenching

- Assists in necessary cooling.
- Adds a small percentage of water by weight to roasted beans, thereby assists uniformity of particle size in subsequent grinding.

Table 32.1. Composition of Roasted Coffee

Component	Typical average content for (%)	
	Arabica	Robusta
Alkaloids (caffeine)	1.3	2.4
Trigonelline (including roasted byproducts)	1.0	0.7
Proteinaceous		
‘Protein’	7.5	7.5
Free amino acids	0	0
Lipids (Coffee oil with unsaponifiable)	17.0	11.0
Sugars:		
Sucrose	0	0
Reducing sugars	0.3	0.3
Polysaccharides (unchanged from green)	33.0	37.0
Lignin	3.0	3.0
Pectins	2.0	2.0
Acids		
Residual chlorogenic	2.5	3.8
Quinic	0.8	1.0
Aliphatic	1.6	1.6
Minerals (oxide ash)	4.5	4.7
Caramelized/condensation products (Melanoidins, etc.)	25.5	25.5
Total	100.0	100.0

32.2.3 Grinding

Multistage twin horizontal rollers up to 4 stages may be used to ensure more uniform particle size distribution.

1st and 2nd stages – Essentially performs cracking or crushing the beans into smaller units.

3rd and 4th stages – Leads to progressively finer grinding.

The grind size required is related to subsequent method of brewing to be adopted and whether for home use or subsequent large scale extraction i.e. coarse, medium, fine, very fine. The ground size of roasted and ground coffee beans for different applications is presented in Table 32.2.

Table 32.2. Grind size of roasted and ground coffee beans

Grind size	Actual size (µm)
Fine grind	430 (Europe), 800 (USA)
Coarse grind*	850 (Europe), 1130 (USA)

* for household percolators

The number of different screen sizes numbered by aperture size within the range of 1400 µm to 250 µm. Newer method performs sizing by laser beams.

32.2.4 Packaging

Roasted and ground (R & G) coffee releases substantial quantities of entrapped CO_2 gas which develops high internal pressure, leading to bursting of package.

The usual packaging material is laminates.

32.2.4.1 Packaging under vacuum

It allows a low percentage of oxygen content in headspace to be established within the package and accommodate release of CO_2. Alternatively CO_2 scavenger may be used.

32.2.4.2 Degas over a sufficient time period

The R & G coffee is allowed in bulk to degas over a sufficient time period to a low level, followed by gas purging whilst individual packages are being filled.

Gas purging is used to ensure that the residual oxygen in headspace is below 1.0%.

In Europe, use of plastic packages to which a non-return valve is securely attached allows release of excess CO_2, when internal pressure exceeds a certain predetermined level.

32.3 A Glance at the Processing Steps

32.3.1 Green bean treatment

Cleaning

Blending

Storage

32.3.2 Roasting

32.3.2.1 Roast bean treatment

Storage

Grinding

Conditioning

32.3.2.2 Extraction

Fast instant coffee extractors (FIC)

Conventional batch percolators

Continuous counter current extractors (CONTEX)

- *FIC extraction unit*

It reduces extraction time by 50% compared to batch percolators. Water is directed through the ground coffee in two stages. The process results in two completely separated extract fractions viz., aroma and hydrolysis. After extraction, the extract is filtered and centrifuged.

32.3.2.3 Extraction treatment

Aroma recovery

Clarification

- *Clarification*

It is a system consisting of filters and centrifuges to separate insoluble parts from the extract to achieve international standards.

32.3.2.4 Concentration

Falling film and plate evaporators

Freeze concentration

Membrane filtration systems

- *Concentration*: It serves to increase the solids content in extract prior to freeze or spray drying.

a) **Thermal concentration –** Multistage non-recirculating evaporators operating under vacuum in a plug flow mode.

b) **Membrane filtration –** The aroma fraction of the extract can be pre-concentrated using 'reverse osmosis' in a membrane filtration system.

c) **Freeze concentration –** By cooling the extract to subzero temperatures, excess water is removed as ice crystals.

Freeze and thermal concentration, membrane filtration, Falling film and plate evaporators are used for the purpose of concentration.

32.3.2.5 Drying

Nozzle Tower spray dryer

Fluidized bed spray dryer

Continuous freeze dryers (CONRAD)

Batch freeze dryers (RAY)

32.3.2.6 Agglomeration

Rewet agglomerators (RWA)

32.3.2.7 Packing

32.4 Domestic and Catering Methods of Brewing

Brewing is extraction of soluble substances contributing to the basic taste plus of volatile substances for overall flavour. Roast coffee must be ground before brewing.

The two main mechanical principles are:

32.4.1 Steeping/Slurrying of R & G coffee with water, with or without agitation, followed by sedimentation or filtration or both.

32.4.2 Percolation in fixed beds of R & G coffee held in an open or closed container. Water may be passed through either in a single pass under gravity or under pressure (including steam, as in Espresso making), or in a multipass.

32.5 Extraction

Extraction of coffee solids can be carried out by

Fast instant coffee extraction.

Conventional batch percolators.

Continuous countercurrent extractors.

32.6 Factors in Brewing

Coffee-to-water weight ratio

The appliance used for brewing.

The temperature employed.

Of the components of roasted coffee, only some will be extracted completely with variable amounts of the others to reach ~ 28% w/w total maximum and 21% optimum under household brewing conditions, by hot or boiling water – so called 'yield'.

Mechanical operation involved is a means of separating the undesired so-called 'Spent coffee grounds' from the required brew formed by sufficient contact with water. The brew should contain as little of spent ground particles as possible and must be presented hot (i.e. 50-55^{o}C).

32.7 Flavour Quality of Coffee Brew

The factors determining flavour quality of brew include:

The choice of blend used.

The degree of roast.

Brewing conditions.

Choice of grind.

32.8 Filter coffee

South Indian Coffee, also known as Filter Coffee is a sweet milky coffee made from dark roasted coffee beans (70-80%) and chicory (20-30%), especially popular in the southern states of Tamil Nadu and Karnataka. The most commonly used coffee beans are Arabica and Robusta.

Outside India, a coffee drink prepared using a filter may be known as Filter Coffee or as Drip Coffee as the water passes through the grounds solely by gravity and not under pressure or in longer-term contact.

Fig. 32.1 South Indian metal based coffee filter

32.9 Aromatization of Coffee

It is a term applied to a process, whereby essentially the headspace coffee aroma volatiles are made available by plating coffee aroma oil, prepared by expression methods from roast coffee, or other sources onto the soluble coffee, usually at the packing stage. This is a treatment imparted to improve the flavour and aroma. The powder lacks full flavour and aroma of freshly brewed coffee. The flavour and aroma constituents are trapped and recovered during roasting, grinding and extraction and from oils pressed from coffee bean. The cold CO_2 does not damage the flavour and aroma compounds in coffee oil and it is easily separated from extracted oil for recompression and reuse.

After CO_2 removal of the oil, the 'Roasted and Ground coffee' is still highly suitable for extraction of water soluble solids in the regular extraction battery operation.

32.9.1 Aroma recovery

The extract fractions are stripped of their volatiles in an aroma recovery unit. After being stripped from the concentrate in a flash evaporator, the aroma is recovered in a 2-stage condenser system.

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Lesson 33

INSTANT COFFEE

33.1 Introduction to Instant Coffee

Instant coffee, also called **soluble coffee** and **coffee powder**, is a beverage derived from brewed coffee beans. It is the dried soluble portion of roasted coffee, which can be presented to the consumer in either powder or granule form for immediate make-up in hot water. Instant coffee is commercially prepared by either freeze-drying or spray drying, after which it can be rehydrated.

Instant coffee was invented in 1901 by Satori Kato, a Japanese scientist working in Chicago.

Historically, most instant or soluble coffees first contained added carbohydrates (~ 50% w/w) such as corn syrup solids, as simple aqueous extract of roasted coffee, extracted under atmospheric conditions (100^{o}C). However, it could not be spray dried to a satisfactorily free-flowing low-hygroscopic powder.

In 1950, Instant coffee of 100% pure coffee solids became commercially available. In 1965, Instant coffee in soluble form, somewhat darker in colour and improved retention of aromatics became available.

The manufacture of instant coffee is accompanied by some slight hydrolysis of the polysaccharides in the roasted coffee (by further aqueous extraction at temperatures up to 175^{o}C and addition to the simple extract before drying), which is reflected in the slightly increased reducing sugar content (i.e. arabinose, mannose and galactose) and probably assists solubilization of these polysaccharides, not otherwise easily possible at 100^{o}C. This provides a powder of satisfactory physical properties.

Advantages of instant coffee include speed of preparation (instant coffee dissolves instantly in hot water), lower shipping weight and volume than beans or ground coffee (to prepare the same amount of beverage), and long shelf life.

About 20% of all processed coffee beans are used for making Instant coffee. The capacity of the plant available is up to 500 kg of Instant coffee per hour.

33.2 Classification of Instant Coffee Powder

33.2.1 Non-agglomerated instant coffee powder

This type of powder consists of individual spherical bead-like particles giving the powder its free-flowability and good solubility in hot water. It is most economically produced in spray dryers with tower drying chambers. Powder bulk density is adjusted through inert gas injection into the concentrated coffee extract prior to high pressure atomization.

33.2.2 Agglomerated instant coffee powder

This type of powder consists of either medium-sized or large agglomerates with a minimum of fines, giving the powder superior free-flowability and solubility in hot and cold water. Medium sized agglomerates are most economically produced in spray bed dryers incorporating fluid bed agglomeration within the drying chamber. Large agglomerates are produced in a powder agglomerator where spray dried instant coffee is rewetted and dried, under strictly controlled conditions.

33.2.3 Granulated instant coffee powder

This type of powder consists of large granules, free from fine particles that gives the powder excellent free-flowability and solubility in hot water. It is most economically produced in freeze dryers, where the low temperature drying environment maximizes aroma retention. The size of the granules is determined by the degree of size reduction and size classification applied to the frozen extract.

33.3 Production Method for Instant Coffee

As with regular coffee, the green coffee bean itself is first roasted to bring out flavour and aroma. Rotating cylinders containing the green beans and hot combustion gases are used in most roasting plants. When the bean temperature reaches 165°C the roasting begins, accompanied by a popping sound. These batch cylinders take about 8–15 min to complete roasting with about 25-75% efficiency. Coffee roasting using a fluidized bed only takes from 30 sec to 4 min, and it operates at lower temperatures which allow greater retention of the coffee bean aroma and flavor. The yield of soluble solids from roasted coffee is presented in Table 33.1.

Table 33.1 Yield (on dry basis) of soluble solids from roasted coffee

Conditions	**Yield (on dry basis)**
Brewed coffee	21.0% w/w
Exhaustive extraction at 100°C	Up to 32.0% w/w
Instant coffee	40.0-55.0% w/w

The beans are then ground finely. Grinding reduces the beans to 0.5–1.1mm (0.020–0.043 in) pieces in order to allow the coffee to be put in solution with water for the drying stage. Sets of scored rollers designed to crush the beans.

Once roasted and ground, the coffee is dissolved in water, referred to as ‘extraction’. Water is added in 5-10 percolation columns at temperatures of 155-180°C; this concentrates the coffee solution to about 15-30% coffee by mass. This may be further concentrated before the drying process begins by either vacuum evaporation or freeze concentration.

Although freeze drying is expensive, it generally results in a higher-quality product.

33.3.1 Manufacturing process for instant coffee

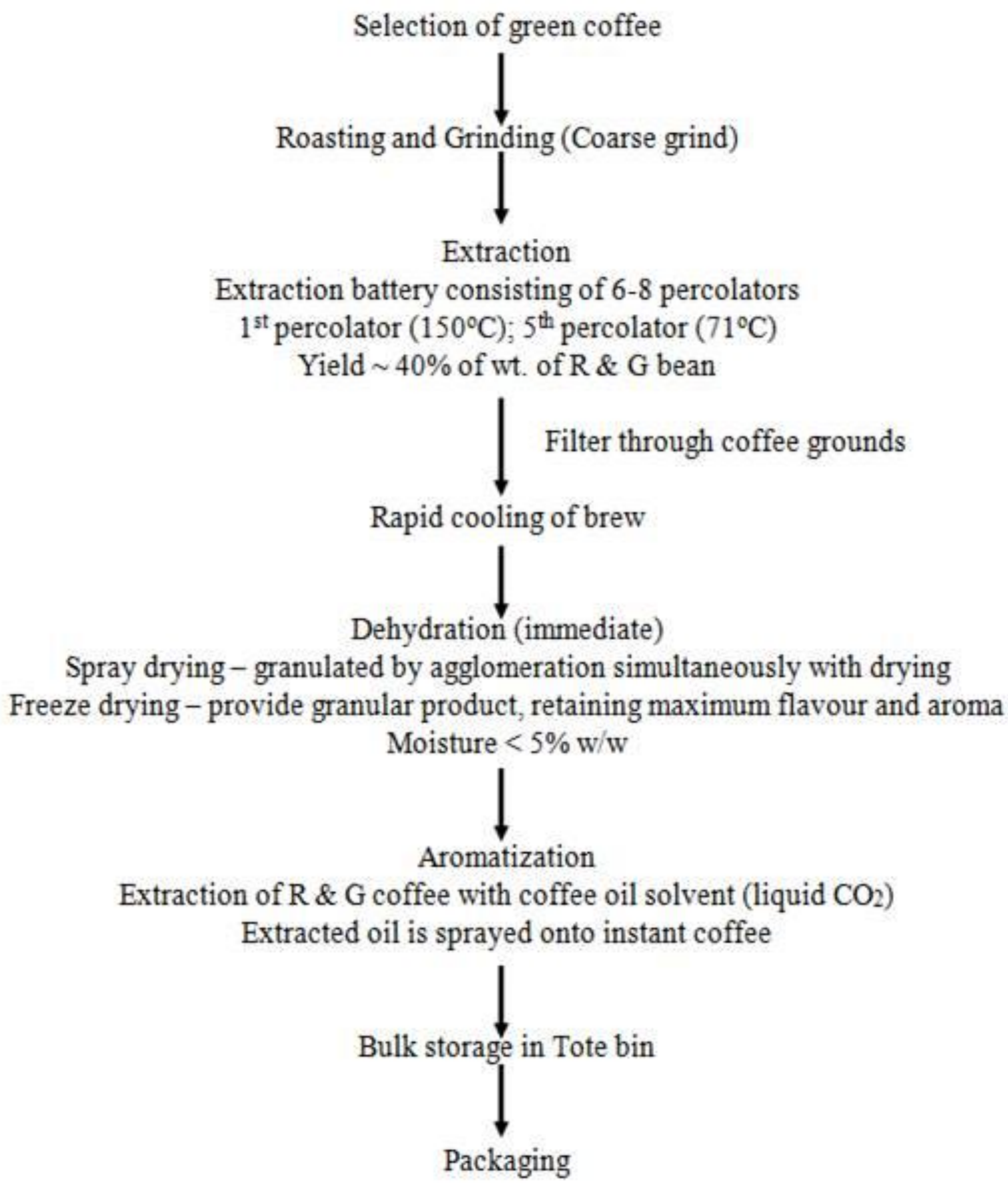

Fig. 33.1 Flow chart for preparation of Aromatized coffee

33.4 Drying Techniques

33.4.1 Spray drying

Spray drying is the most economic method to obtain soluble coffee which is free-flowing and agglomerated/granulated powders. The dried powder has about 3.0% moisture.

Spray drying features the spraying (atomization) of concentrated extract into hot drying air. The spray droplets dry to form a non-agglomerated, free-flowing powder consisting of large individual spherical bead-shaped particles. An agglomerated powder with low fines content can be produced by combining spray drying with powder fluidization in an integrated fluid bed built into the spray drying cone base. Powders consisting of very large agglomerates are produced in a separate agglomeration process, in which spray dried powder is rewetted by steam, agglomerated, and dried using fluidization and cascading powder principles.

Spray drying produces spherical particles about 300 µm (0.012 in) size with a density of 0.22 g/cm³. To achieve this, nozzle atomization is used. High speed rotating wheels operating at speeds of about 20,000 rpm may be used. The use of spray wheels requires that the drying towers have a wide radius to avoid the atomized droplets collecting onto the drying chamber walls. The drying is completed in 5–30 sec. (dependent on factors such as heat, size of particle, and diameter of chamber). The inlet and outlet air temperature are typically 270^{o}C and 110^{o}C respectively. The moisture content of the feed and powder is 75-85% and 3-3.5% respectively.

Spray drying is preferred to freeze drying in some cases because of its economy, short drying time, usefulness when dealing with heat-sensitive product, and the fine, rounded particles it produces.

One drawback with spray drying is that the particles it produces are too fine to be used effectively by the consumer; they must first be either steam-fused in towers similar to spray dryers or by belt agglomeration to produce particles of suitable size.

33.4.1.1 Nozzle tower spray dryer

It gives a free-flow powder with average particle size of 100-250 µm; however the residence time in dryer is longer.

33.4.1.2 Fluidized spray dryer

It gives a free flow agglomerated/granulated coffee. The powder has average particle size of 100-300 µm. Lower drying temperatures are employed with improved aroma in powder.

33.4.1.3 Filtermat spray dryer

This employs even lower temperature and longer drying times. It yields coarse, agglomerated/granulated, free-flowing and dustless powder with particle size of 250-1000 µm and with increased aroma retention.

Nozzle tower, Fluidized spray dryer, Filtermat spray dryer, Freeze dryers may be utilized for drying purpose.

Certain important criterion that needs to be controlled in drying technology includes:

- Colour (brightness) of the final soluble coffee powder
- Particle size distribution and powder structure / morphology
- Bulk density
- Residual moisture content
- Aroma retention
- Flowability
- Solubility

- Mechanical stability

The latest technology in vogue in spray dryers are the air disperser and drying chamber designs that enable production of powder having the desired particle morphology and taste through enhanced retention of desirable aromatic volatiles.

The Spray dryer coupled with extract concentrate gas injection and dosing unit installed on the high pressure side of the spray dryer feed line represents the latest design concept in the important area of powder bulk density control and coffee powder brightness.

33.4.2 Agglomerated Powder

Powder is processed in Rewet Agglomerator to obtain dustless powder and customized granules. The average particle size obtained is > 1000 µ.

33.5 Freeze Drying

Freeze drying gives a premium product. It preserves all the desirable aspects of the concentrated coffee extract. Actual freezing can take place on a continuous Air blast belt freezer or for smaller capacities on Rota drum freezer. Granulation of frozen coffee slabs is done to get the right granule size and size distribution.

Quality parameters include colour, density and solubility.

Freeze drying includes pre-freezing, foaming and freezing of the concentrated extract followed by granulation - sieving of the frozen granules, which are dried in trays (batch processing) or on a moving conveyer belt (continuous processing).

On freezing, the water in the concentrated extract forms ice crystals, which sublime under

the influence of vacuum and applied heat to leave a dry granular product. Sublimation is the direct phase transition from solid state (ice) to gas phase (vapour). The conveyer belt permits much shorter drying times, promoting improved aroma retention as the coffee granules are exposed only for a relatively short time, to the vacuum conditions inside the freeze drying sublimation chamber.

Module 10. Pickles and sauerkrauts

Lesson 34

PICKLES: PRINCIPLES AND CLASSIFICATION

34.1 Introduction

Pickling is one of the oldest and most successful methods of food preservation known to humans. It is difficult to suggest a date for production of the first pickled foods, but it is known that both vinegar and spices were being used during biblical times. Pickles of various kinds are known throughout India and many parts of the world. They are good appetizers and add to the palatability of a meal. Fermentation of plant and animal foods was known to the early Egyptians, and fish were preserved by brining in prehistoric times. By the third century BC, Chinese labourers were recorded to be consuming acid-fermented vegetables while working on the Great Wall. The Koreans created *kimchi* from acid-fermented Chinese cabbage, radish, and other ingredients centuries ago. Corn, cassava and sorghum were fermented and became staples of the African diet. In the west, acid fermentation of cabbage and cucumbers produced sauerkraut and pickles, which are still popular today. Early explorers carried kegs of sauerkraut and pickles that prevented scurvy on their voyages. Pickles from India or *achaar* are unique because these are mixed with spices that only India produces. Some common Indian spices include cumin, mustard seeds, fenugreek, turmeric, coriander, etc. Some of the typical Indian pickles made from mango (*aam ka achaar*), lime (*nimbu ka achaar*), turnip, cabbage, cauliflower, etc. have become popular in several countries.

34.2 Principle of Pickling

There are mainly two methods of preserving fruits and vegetables namely (i) by killing all the microorganisms responsible for spoilage, by heat or other means and then checking the entry of fresh microorganisms into the preserved product, and (ii) by making the conditions most unfavourable for the growth and multiplication of microorganisms. The first method is generally employed in the preservation of fruits and vegetables for making fruit juices, fruit powders, etc. and the second method in the preparation of pickles. The process of preservation of food in common salt or vinegar is called as pickling. Spices and edible oils also may be added to the product. Salt, vinegar, lactic acid and oil are the important ingredients used in pickle production. These substances when used in sufficient quantities, act as preservatives either singly or in combination. The preservative action of these substances are given below:

34.2.1 Salt

Vegetables do not ferment when they are covered with strong brine or packed with a fairly large quantity of salt. Spoilage is prevented by adding sufficient common salt, bringing its final concentration in the material from 15 to 20 percent. At this high salt concentration, mould and even lactic acid-forming bacteria do not grow. This method of preservation is only applicable to vegetables which contain very little sugar because sufficient lactic acid cannot be formed by fermentation to act as preservative.

34.2.2 Vinegar

In vinegar pickles, vinegar acts as a preservative. In order to ensure satisfactory results, the final concentration of acid as acetic acid, in the finished product should not be less than 2 percent. To avoid dilution of the vinegar by the water liberated from the tissues, the vegetables are generally placed in strong vinegar of about 10 percent acidity for several days before final packing. This treatment also helps to expel the gases present in the intercellular spaces of the vegetable tissue.

34.2.3 Lactic acid

Bacteria prefer for their growth media with little or no acid. The lactic acid bacteria, however, can grow in acid media and can also produce acid through their action on the substrate. They can grow in the presence of 8 – 10 percent salt. The growth of undesirable organisms is inhibited by adding salt while allowing the lactic fermentation to proceed. In fermented pickles, microorganisms ferment sugars to lactic acid. When vegetables are placed in brine, the soluble material present in them diffuses into the salt water owing to osmosis and the liquid penetrates into the tissues. The soluble material, besides containing mineral matter, contains fermentable sugars. These sugars serve as food for lactic acid bacteria, which convert them into lactic and other volatile acids.

34.2.4 Oil

In oil-based pickles, fruits or vegetables are completely immersed in the edible oil. It acts as a barrier for air and creates an anaerobic condition which is utilized by the native bacteria for the production of lactic acid. Oil prevents growth of spoilage yeasts and moulds. Generally mustard oil is used.

34.3 Classification of Pickles

Depending on the method of preparation, pickles can be classified into three types such as pickles in vinegar, pickles in citrus juice or brine and pickles in oil. Fruit pickles are generally preserved in sweetened and spiced vinegar, while vegetable pickles are preserved in salt.

34.3.1 Pickles in vinegar

These are most important pickles in the world.

34.3.2 Pickles in citrus juice or brine

Steeping of the vegetable in a salt solution of pre-determined concentration for a certain length of time is called brining. Vegetables which do not contain sufficient water are better fermented by covering them with a weak brine solution. Alternately, dry salt is also used for vegetables which contain sufficient water content. It involves packing vegetables with a small quantity of dry salt (about 2-3 kg for every 100 kg) without adding water. Salt extracts the water from the vegetables owing to osmosis and forms the brine. The sugars present in the vegetables are extracted into the water and are fermented by the lactic-acid forming bacteria which are naturally present in great numbers on the surface of the fresh material. After certain time, enough lactic acid is formed to kill the bacteria and prevent any further change in the material, provided certain precautions are taken to prevent the growth of moulds. The lactic acid permeates to the fermented vegetables and gives characteristic flavour. It is the same acid which is present in sour milk and it is digested and utilized by the body as a source of energy. *Leuconostoc mesenteroides*was identified as one of the most important microorganisms for initiation of vegetable fermentation.

34.3.3 Pickles in oil

These are pickles containing some edible oil and are highly popular in India. Usually oil pickles are highly spiced. Cauliflower, lime, mango, turnip pickles, etc are prepared in this manner. The method of preparation of some of the oil pickles vary in different parts of the country. In north India, rapeseed or mustard oil is commonly used, but in south, gingelly (sesame) or groundnut oil is preferred. For example, the method of preparation of mango pickle is different in different parts of the country. However, "*Avakai*" pickle in Andhra Pradesh is well-known mango pickle in oil.

34.4 Desired Quality of Ingredients Used in Pickling

Raw materials used in pickling should possess certain definite characteristics for achieving a wholesome pickle. The desired qualities of ingredients used in pickling are given as follows:

34.4.1 Salt

In general, pure common salt is generally preferred for pickling. It should not contain more than 1.0% percent of impurities, should not contain chemicals liketricalcium phosphate or magnesium phosphate which are generally added to salt as anticaking agents. Salt should be free from lime (calcium oxide), as it reduces the acidity of the vinegar in which brine vegetables are pickled and also causes lime deposits of the bottom of the container. Salt should be free from iron, which in contact with the tannin of the fruit, vegetable and spice produces blackening of the pickle. It should not contain magnesium salts which impart a bitter taste to the pickle.

34.4.2 Vinegar

Vinegar of good quality should contain at least 4 percent acetic acid. Usually malt or cider vinegar is used. Vinegars of low acid content or imitation or synthetic vinegars are not suitable for pickling. Vinegar should not come in contact with iron as it leads to blackening of the pickle.

34.4.3 Oil

Good quality oil free from rancidity or oxidation is preferred.

34.4.4 Sugar

Sugar used in the preparation of sweet pickles should be of high quality.

34.4.5 Spices

Spices are added practically to all pickles, the quantity added depending upon the kind of fruit or vegetable taken and the kind of flavour desired. The spices generally used are bay leaves, cardamom, chillies, cinnamon, clove, coriander, ginger, mustard, black pepper, cumin, turmeric, garlic, mint, fennel, etc. These should be of good quality and should be stored in tin cans in a cool and dry place.

34.4.6 Water

Only potable water should be used for the preparation of brine. Hard water contains salts of calcium, sodium, magnesium, etc. which interfere with the normal salt-curing of the vegetable. If hard water is to be used, a small quantity of vinegar should be added to brine to neutralize its alkalinity. Iron should not be present in the water in any appreciable quantity as it causes the blackening of the pickle.

34.7 Legal Definition and Specifications

In India, the Food Safety and Standards (FSS) Rules (2006) defines pickles as “preparation made from fruits and vegetables or other edible plant material including mushrooms free from insect damaged or fungal infection, singly or in combination preserved in salt, acid, sugar or any combination of the three. The pickle may contain onion, garlic, ginger, sugar, jaggery, edible vegetable oil, green or red chillies, spices, spice extracts/oil, lime juice, vinegar/acetic acid, citric acid, dry fruits and nuts. It shall be free from copper, mineral acid, alum, synthetic colours and shall show no sign of fermentation”. Pickles may be of following combinations confirming to the requirements as given below:

34.7.1 Pickles in citrus juice or brine

a) Drained weight: Not less than 60 percent
b) Sodium Chloride content
when packed in brine: Not less than 12 percent
c) Acidity as Citric acid when
packed in Citrus Juice: Not less than 1.2 percent

34.7.2 Pickles in oil

a) Drained weight: Not less than 60 percent
b) Fruit and vegetable pieces shall practically remain submerged in oil

34.7.3 Pickles in vinegar

a) Drained weight: Not less than 60 percent
b) Acidity of vinegar
as acetic acid: Not less than 2.0 percent

Lesson 35

TECHNOLOGY OF SELECTED PICKLES-I

35.1 Introduction to Fermented Pickles

As one of the oldest forms of food preservation, fermentation has played a key role in enabling people to survive periods of food shortage. Fermented foods originated several thousand years ago, in different parts of the world, when microorganisms were introduced incidentally into local foods. Fermented foods are foods that have been subjected to the action of microorganisms or enzymes, in order to bring about desirable changes such as improved flavour, etc. Once harvested, fruits and vegetables are perishable due to the activity of bacteria, fungi, moulds, yeasts and enzymes. When acting on organic matter, these microorganisms and enzymes split their constituents, and turn them into simple compounds. Destroying these agents or controlling their activity help to keep fruits and vegetables in good condition. Creation of unfavourable conditions, such as humidity and temperature, extends the duration of storage for a certain period of time without changes in the nutritional value. In vegetable processing, salting and fermentation are related to each other. The fermentation of vegetables is a complex network of interactive microbiological, biochemical, enzymatic and physico-chemical reactions. Lactic acid fermentation is a valuable tool for the production of a wide range of vegetable products. A large number of vegetables are preserved by lactic acid fermentation around the world. Typically, these fermentations do not involve the use of starter cultures and rely on the natural flora. Food Industry also adapted the same technique. However, in recent years, artificial inoculation with selected strains and anaerobic conditions has been used in order to gain uniformity of the sensory quality of fermented vegetables and to reduce the duration of the process. Although there are an unspecified number of fermented vegetables available in the market, only fermented cabbage (sauerkraut), cucumber pickle and olive pickles are of real economic importance.

35.2 Sauerkraut

Sauerkraut is one of the most consumed fermented vegetables in central and southern Europe and in the United States. Sauerkraut is the product resulting from the natural lactic acid fermentation of shredded fresh cabbage to which salt is added at a concentration of 2.25–2.5%. A number of microorganisms play a key role in the transformation of fresh shredded cabbage into the fermented product called sauerkraut. Under proper conditions, the fermentation of shredded cabbage is a spontaneous process in which bacteria converts sugars present in cabbage into acids, alcohol and carbonic anhydride. Simultaneously, cabbage proteins undergo biochemical changes. The major end products of this fermentation are lactic acid, and to a lesser amount, other acids. Lactic acid bacteria are the most important organisms responsible for cabbage fermentation. The characteristic organoleptic and nutritional properties of sauerkraut are: low calorific value, high fiber content, absence of lipids and high level of essential micronutrients.

The main steps in the manufacture of sauerkraut are given in Fig.35.1. After removal of the outer leaves, green leaves and the core, the cabbage is washed and sliced into shreds as fine as 2.5 cm of thickness. This mass is placed in a fermenter in 2 kg layers alternating with salt layers, the first and last layers being salt. The salt is added at the rate of 2.5% of the weight of the cabbage to enhance the release of tissue fluids during fermentation. In order to create anaerobic conditions the layers are pressed mechanically, to remove the cabbage juice which contains fermentable sugars and other nutrients required for microbial activity. Anaerobic conditions promote the growth of lactic acid bacteria. This process takes about 31 days during which the average temperature is 14°C. The progress of fermentation is monitored every 2-4 days, by measuring the ascorbic acid and sugar content of the solid part, and the pH and acidity of the fermentation brine.

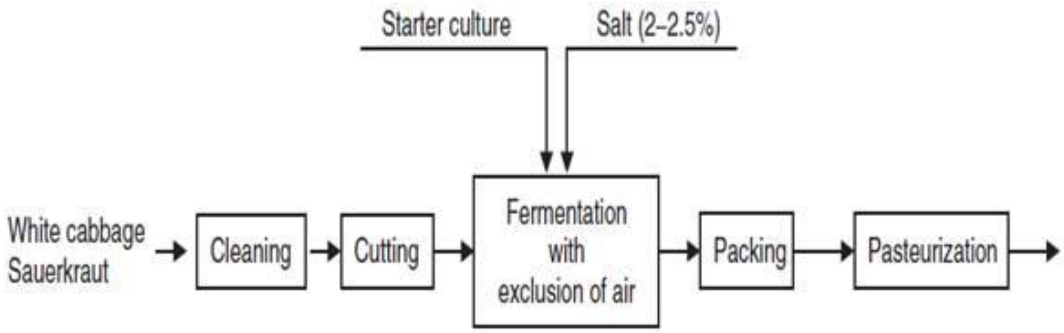

Fig.35.1 General Flow Chart for the Production of Sauerkraut

Anaerobic conditions should be maintained to prevent growth of microorganisms that might spoil the sauerkraut. It has been found that different species of LAB sequentially involve in sauerkraut production. It is now well established that *Leuconostoc mesenteroides* grows first producing lactic acid, acetic acid and CO_2. The pH of the product is lowered quickly, thus limiting the activity of undesirable microorganisms and enzymes that might soften the cabbage shreds. The carbon dioxide flushes out residual oxygen making the fermentation anaerobic which stimulates the growth of many lactic acid bacteria. Then *Lactobacillus brevis* grows continuing the acid production. Finally *Lactobacillus plantarum* grows which produces more acid and lowering the pH to below 4.0, allowing the cabbage to be preserved for long periods under anaerobic conditions. The end products formed contain significant amounts of lactic acid and a small amount of acetic acid and propionic acid, and a mixture of gases, CO_2 being the most important. Minor end products such as diacetyl and acetaldehyde are also found. The major amount of the volatiles in sauerkraut is accounted for by acetal, isoamyl alcohol, n-hexanol, ethyl lactate, cis-hex-3-ene-1-ol, and allyl isothiocyanate.

35.3 Pickled Cucumber

Pickled gherkins are very popular and are mostly consumed without any other vegetables. The fermentation of cucumbers varies according to the salt concentration used, and two quite different products can be produced, namely high-salt stock (8–10% increasing to 15%) and low-salt dill pickles (3–5% salt containing dill and spices). Usually, the salt solution is poured onto the cucumbers in tanks and then fermentation is allowed to proceed, if necessary, glucose is added to stimulate activity. Fermentation takes place at 18–20°C and yields lactic acid, CO_2, some volatile acids, ethanol and small amounts of various aroma substances.

Cucumbers for pickling must be harvested while still immature. They should not be crushed or bruised and should have a stalk of 1-2 cm. There should not be more than 6-8 hr between harvesting and brining to avoid spoilage. To obtain a uniform product, crushed, unsound, decomposed, defective and too mature cucumbers should be removed from the lot. Sorting is followed by size grading. A wooden, clay or glass tank is filled with 10-15% salt brine to cover the bottom to a depth of 15 cm. Then, previously washed cucumbers are put into the container and filled with brine to cover the cucumbers completely. Cucumbers are submerged into the brine with a white, perforated wooden cover. Cucumbers consist of about 90% of water which causes the salt concentration of the brine to be lowered during fermentation. Brine should be kept at 40° salinometer to prevent the activity of putrefying bacteria. However, the salt concentration should not be higher as this would cause inhibition of the activity of LAB. After 5-6 weeks, the brine is increased to 60° salinometer by adding salt. During fermentation, cucumbers change colour from bright green to olive green by action of acids on chlorophyll. The flesh of the pickles turns into an attractive translucent white when the curing process finishes by expulsion of air from the tissue. Initiating cultures are composed of a normal mixed flora of the gherkins. Fermentation is initiated by the following LAB, cited in order of importance: *Leuconostoc mesenteroides, Enterococcus faecalis, Pediococcus cerevisiae, Lactobacillus brevis* and *Lactobacillus plantarum*. Of these,*Pediococcus* and *Lactobacillus plantarum* are important, whereas *Lactobacillus brevis* is undesirable because of its ability to produce gas. *Lactobacillus plantarum* is the essential or indispensible species.

The two main defects of cucumber pickles are swelling or bloating and softening. Swelling, a serious problem in cucumber fermentation, generally increases with larger cucumbers, high fermentation temperatures, and/or an increase in the level of CO_2 in the brine. Bloaters are those pickles that float on the brine and are hollow or have large air spaces in the interior. This condition is caused by gas-forming microorganisms, i.e. gaseous fermentation. *Enterobacter* spp., lactobacilli, and Pediococci have been implicated as causes of bloaters. Pickled cucumbers are often softened due to endogenous or microbial pectolytic enzymes. Softening is caused by microorganisms growing inside or on the cucumbers. Pectolytic organisms causing pickle softening belong to the genera *Bacillus*, *Fusarium*, *Pencillium*,*Phoma*, *Cladosporium*, *Alternaria*, *Mucor*, *Aspergillus* and others.

35.4 Olive Pickle

Olives *(Olea europaea)* are produced in great amounts in the Mediterranean area, California, South America and Australia among others. This fruit is processed for oil production (about 85%) and for table use (about 15%). Green olives are brined and fermented in a manner similar to cucumbers. Spanish, Greek and Sicilian are the most important types of fermented olives. Before brining, green olives are treated with a 1.25 to 2 % lye solution, depending on the type of olives usually at 21 to 25°C for 4 to 7 h. This treatment is necessary to remove some of the oleuropein, a bitter principle in the olives. After treatment, the lye is removed by soaking and washing the olives in fresh water. Excessive washing may induce a loss of some nutrients and a low acidity development due to a high loss of carbohydrates. To overcome these problems inoculation with *Lactobacillus plantarum* may be necessary to neutralize any residual lye. Adding sugar to the brined olives for acid production has also been suggested. Washed olives are then placed in a brine solution, the concentration of which varies from 5 to 15 % salt, depending upon the variety and size of olives. Additional salt is added during fermentation of olives in order to maintain a constant salt concentration, usually at 28° to 30° Salinometer level. Sugars, vitamins and amino acids pass, by osmosis, from the olives into the brine solution, gradually converting it into a suitable medium for the growth of microorganisms which produce lactic fermentation. The fermentation takes as long as 6 to 18 months, and the acidity of the final product varies from 0.18 to 1.27 % LA. A level of at least 0.6 to 0.7 % acid is needed for proper preservation and flavour of the product.

The lactic acid fermentation involves a number of microbial strains. The normal olive fermentation is divided into three stages. The initial stage is the most important from the standpoint of potential spoilage if the brines are not acidified. If the fermentation develops normally, potential spoilage bacteria are rapidly eliminated principally due to developing LAB which belong to the genera *Streptococcus*, *Pediococcus* and *Leuconostoc* and to a minor extent *Lactobacillus*. Acidification eliminates Gram-negative and Gram-positive spoilage bacteria and at the same time provides an optimum pH for activity of the LAB. If fermentation follows a different pattern, spoilage microorganisms become predominant. Generally, these are Gram-negative bacteria, which, if not controlled, produce gas and are very proteolytic. During the second or intermediate stage of normal fermentation LAB become predominant. Among these there are less acid-tolerant species belonging to the genus *Leuconostoc* and high acid tolerant *Lactobacillus* species. Initially, *Leuconostoc* species are predominant, declining rapidly in number by the end, when they are replaced by more acid-tolerant *Lactobacillus* species.If the fermentation is normal, Gram-negative bacteria disappears completely after 12-15 days. This stage takes 2-3 months. During the final stage, which lasts about ≤ 25 olive fermentation is dominated by highly acid tolerant *Lactobacillus* species.

For the fermentation of black lactic-fermented olives, the ripe, violet to black fruit is washed and directly allowed to undergo spontaneous lactic fermentation in 8–10 % salt solution. A alkali treatment is not performed on black olives. Lactobacilli and yeasts are involved, but the yeasts normally dominate. The final product has a pH value of 4.5–4.8 and contains 0.1–0.6% lactic acid. Olives may undergo spoilage owing to the growth of undesirable microorganisms. Zapateria spoilage is characterized by a malodorous fermentation, due apparently to the production of propionic acid by *Propionibacterium*. Sloughing spoilage is a defect that includes severe softening, skin rupture and flesh sloughing. It is caused by Gram negative pectinolytic bacteria, especially *Cellulomonas flavigena*. Softening of olives is caused by the pink yeasts, *Rhodotorula*, and fermenting pectinolytic yeasts, *Saccharomyces* and *Hansenula*.

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Lesson 36

TECHNOLOGY OF SELECTED PICKLES-II

36.1 Introduction to Oil-Based Pickles

Oil-based pickles containing one or more edible oils are highly popular in India. Mango, lime, cauliflower and turnip pickles are the most important oil pickles. Mango pickle is largely sold pickle in the country followed by cauliflower, onion, turnip and lime pickles. Cauliflower pickle is highly popular in Northern parts of India. For preparing the oil-based pickles, fruits or vegetables should be completely immersed in the edible oil. Oil pickles are generally highly spiced. The technology for the preparation of some of these pickles is given in this lesson.

36.2 Mango Pickle

The method of preparation of oil-based mango pickles varies in different parts of the country. The "*avakai*" pickle of Andhra Pradesh is a well known mango pickle in oil. It is very pungent and hot to taste. In north India, rapeseed /mustard oil is commonly used. But in south India, gingelly or sesame oil or groundnut oil are preferred. Hygienically prepared mango pickle should have a shelf life of about 1 to 2 years at room temperature. India, being the largest producer of mangoes, has great scope for export of mango pickles. Because of regional variations in taste, there are numerous recipe combinations of mango pickle. One of the recipes is given in Table 36.1.

Table 36.1 Recipe for mango pickle

S. No.	Ingredients	Quantity (g)
1	Mango slices	900
2	Common salt, powdered	226
3	Grounded Fenugreek (*methi*)	113
4	Grounded Nigella (*kalaunji*)	28
5	Turmeric powder	28
6	Red chilli powder	28
7	Black pepper	28
8	Fennel or aniseed (*saunf*)	28

In the preparation of mango pickles, cultivar or variety which is rich in fibre is chosen e.g. ***Ramkhela, Sukul, Ashmina***, etc. The flow diagram for the preparation of mango pickle is given in Fig. 36.1. For making mango pickle, fully developed but under-ripe tart varieties of mango are selected. They are washed with water; peeled or unpeeled and sliced longitudinally with a stainless steel knife. The mango kernel stones obtained during slicing are discarded. Sliced raw mangos are mixed with common salt to extract some of the moisture from the slices or immersed in brine solution of 2-3% strength to prevent blackening of the cut surface. To the drained slices, a partially ground mixture of spices including onions and garlic are added. Depending on the choice, availability and regional preferences the spices are selected and may include coriander, fenugreek seeds, nigella, fennel, cumin seeds, powdered turmeric and red chillies. The whole admixture is filled into a clean glass or glazed jars and covered with the chosen edible oil i.e. mustard or gingelly or groundnut oil. Table sugar is sometimes added in small amounts along with spices to produce a good taste blend. Also, if the mango variety is not sour enough, a small amount of acetic acid is sometimes added. Spices, oil and mango slices can be subjected to heating at low temperature for about 10-15 min. without softening the texture of the slices. Such heat treatment reduces the initial bacterial load and would help in attaining a longer storage life of mango pickle. Usually it takes 2-3 weeks for the completion of fermentation by natural microbiota. Pickles usually have a shelf life of about slightly more than 1 year when prepared and packed in hygienic conditions.

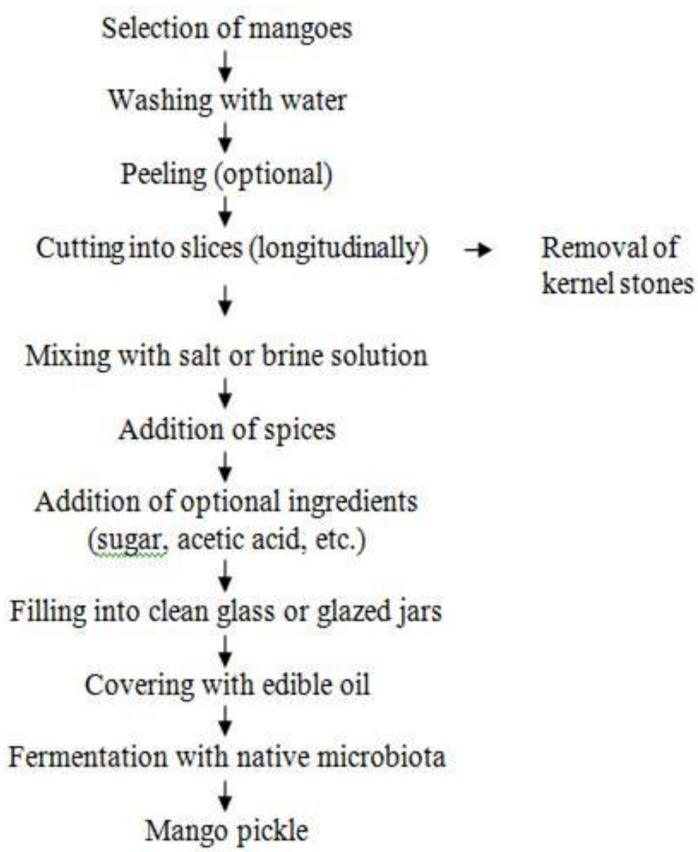

Fig. 36.1 Flow diagram for the preparation of mango pickle

36.3 Lime Pickle

Good quality lime are selected for making lime pickle and washed thoroughly before use. The cleaned lime fruits are sliced and cut into four pieces. About one-fourth of the cut lime fruit pieces are squeezed to extract juice. Later, the remaining lime pieces are mixed with selected spices, salt and extracted lime juice. Spices such as turmeric, red chilli powder, cardamom, cumin, aniseed, black pepper, etc. are used. The mixture is filled into clean glass or glazed jars kept usually in sunlight for about a week. During this period the useful biochemical changes takes places. At the end of one week, selected edible oil which is previously heated and cooled is mixed with the mixture and stored.

36.4 Aonla Pickle

Aonla, also called as amla or Indian Gooseberry, is a minor sub-tropical deciduous tree indigenous to Indian sub-continent. Aonla fruits are round, ribbed and pale green. It is divided into six segments through pale liner grooves. It is quite hard with a thin and translucent skin. The raw fruit, due to its high acidic nature and astringent taste, is unacceptable to consumers. Besides, aonla has been an important ingredient in chavanprash, an ayurvedic health tonic. Aonla fruits are rich in ascorbic acid and tannins. It contains 500-1500 mg of ascorbic acid per 100 g of pulp which is greater than that of guava, citrus and tomato fruits. Aonla has been used for pickle and preserve making since ages in India. ***Chakaiya*** is a popular cultivar or variety of aonla used for pickle preparation. The principle of manufacture of aonla pickle is the same as that of mango pickle. For making pickle, aonla fruits of suitable size are selected and thoroughly washed with water. The fruits are manually pricked and treated with salt and kept aside for few days. Spices such as turmeric, nigella seeds, red chilli powder, fenugreek, headless cloves, etc. and oil as per recipe are mixed to the salt treated aonla fruits and filled in suitable glass jars. The filled jars are kept for about a week in sunshine for the biochemical reactions to take place. Such pickle can be stored at room temperature and relished.

36.5 Spoilage of Pickles

Different kinds of spoilages occur in pickles. Some of them irrespective of the type of the pickle are briefly described as follows:

36.5.1 Shrivelling

Shrivelling occurs when vegetables like cucumber are placed directly in a very strong solution of salt, sugar or vinegar. Use of weak solutions to start with and later gradually increasing their strength avoids such defect.

36.5.2 Bitter taste

Bitter taste in the pickle may result from use of strong vinegar or prolonged cooking of spices or addition of excess amounts of spices.

36.5.3 Blackening

Blackening defect in pickles may result from use of iron knives for cutting the fruits and vegetables and use of iron containers for processing. Further, it may also result from growth of specific molds that cause blackening.

36.5.4 Dull or faded products

Pickles become dull and faded either due to use of inferior raw material or due to insufficient curing.

36.5.5 Softness and slipperiness

This is a most common defect and results due to the action of bacteria. Insufficient covering with brine or use of weak brine or insufficient covering with oil are invariable causes for this defect. By using a brine of proper strength and by keeping the pickle well below the surface of the brine or oil, this kind of spoilage can be eliminated.

36.5.6 Scum formation

When vegetables are placed in the brine for curing, a white scum is invariably formed on the surface due to the growth of wild yeast. This scum retards the formation of lactic acid and helps the growth of putrefactive bacteria that causes the vegetables to become soft and slippery. Hence, it is essential to remove the scum as soon as it is formed. Addition of about 1% acetic acid helps to prevent the growth of wild yeast in the brine, without hindering the formation of lactic acid.

36.5.7 Cloudiness

This defect is usually found in case of onion and some other vegetables and occurs when vinegar become cloudy and turbid, thereby spoiling the appearance of the pack. This could be due to microbial activity or due to the use of inferior quality or possible chemical action between vinegar and impurities such as calcium, magnesium and iron compounds.

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Module 11. Confectionery products

Lesson 37

CONFECTIONARY PRODUCTS: PRINCIPLES AND CLASSIFICATION

37.1 Introduction

Confectionery is an important food item of great popularity among wide range of population. It has been enjoyed as a major food delicacy from ancient times. The term confectionery is ambiguous and describes a spectrum of sweet goods and takes on different meaning depending on the country in which it is used, for example in the United Kingdom the term applies to any sweet product including cakes. In the United States confectionery is candy and includes sugar confectionery and chocolate confectionery. Globally, confectionery foods represent 50% by volume of foods produced and 60% by value. The Indian confectionery market is estimated to be 1,38,000 metric tonnes (in 2005) and is segmented into sugar-boiled confectionery, chocolates, mints and chewing gums. Sugar-boiled confectionery consisting of hard-boiled candy, toffees and other sugar-based candies, is the largest of the segments and it is valued at around Rs. 20,000 million. Some of the largest companies active in the confectionery sector are Cadbury, Nestle and Perfetti. In India, confectionery foods are worth Rs.2,250 Crore with an annual growth rate of 2%.

37.2 Classification of Confectionery

Confectionery can be classified into four major groups. They are as follows:

37.2.1 Sugar confectionery

It includes products using mainly sugar such as boiled sweets,fondants, fudge, jellies, toffees, etc.

37.2.2 Chocolate confectionery

It includes mainly cocoa, chocolate and chocolate products. Sugar confectionery coated with chocolate is also included in it.

37.2.3 Flour confectionery

It includes baked products such as cakes, biscuits, cream rolls, etc. Traditional Indian cereal and legume flour based sweets such as *mysorepak*, *soanpapdi*,*badushah*, *jalebi*, etc. are also included in this category.

37.2.4 Milk-based confectionery

It includes mainly Indian traditional milk-based sweets such as *burfi*, *peda*, *rasogolla* etc.

In sugar confectionery, sugar is the main or principal ingredient while in other confectionery sugar is used as one of the ingredient.

37.3 Sugar Confectionery Groups

Depending on the structural geometry, sugar confectionery is grouped into two major groups: amorphous and crystalline.

37.3.1 Amorphous sugar confectionery

These products are characterized by hard, chewy, homogenous and non-crystalline nature. It includes hard boiled candy, caramels, toffee, taffy, brittles, gums, jellies, etc.

37.3.2 Crystalline sugar confectionery

These are characterized by crystal structure. It includes chocolate, fondant, nougats, fudge, marshmallows, etc.

37.4 Raw Materials and Ingredients Used in Sugar Confectionery

The raw materials and different ingredients used in sugar confectionery are sucrose and its derivatives, glucose syrups, other sugars, other sweeteners, fats, milk products, foaming agents, gelling agents, thickeners and stabilizers, colours, flavours, acids, nuts and some processing aids.

37.4.1 Sucrose

White sugar extracted from sugar cane or sugar beet is very nearly pure sucrose with traces of mineral matter.

37.4.2 Sucrose derivatives

Alternative to sucrose, sometimes liquid sugar with less than 75% solids, brown sugar, icing or milled sugar, golden syrup with about 80-83% soluble solids, invert sugar, refinery syrups which are darker than golden syrups with more flavour, molasses and dark treacle, etc. are used.

37.4.3 Glucose syrups

Glucose syrup is occasionally called as "***confectioners' glucose***". It contain a number of different sugars all built up from dextrose units, with dextrose and maltose predominating. The pH of the glucose syrup ranges between 4.8 and 5.2. The grading of glucose syrup is based on the solids content as indicated by Baume reading and on the reducing sugar content of the solid matter calculated as dextrose (termed as DE value or ***dextrose equivalent*** value). Many grades of glucose syrup are available to the sugar confectioner including 35 DE (low DE), 42 DE (regular DE), 55 DE, 63 DE (high DE) and high maltose glucose syrup. The average TSS content for glucose syrups ranges between 78 and 83%. ***High maltose glucose syrups*** contain maltose as high as 75% with very low dextrose contents. ***High fructose corn syrups*** (HFCS) are produced by isomerization of dextrose to fructose by enzymes. Usually HFCS contain fructose in the range of 42 to 90%. Confections made with HFCS are sweeter than those made with conventional glucose syrups.

37.4.4 Honey

Honey is a clear liquid ranging in colour from pale straw to brown. The water content of most honey ranges between 15-20% depending on the area of origin. It contains about 40% fructose, 34-38% dextrose and 4-5% sucrose. Upon prolonged storage, the dextrose may crystallize out.

37.4.5 Intense sweeteners

Sugar replacers are sometimes used in sugar confectionery for making low-calorie or dietetic confectionery products. The intense sweeteners such as aspartame,acesulfame-K, saccharin, cyclamates, etc. exhibit sweetness many times that of cane sugar. The relative sweetness of aspartame and acesulfame-K is 180 and 200 times, respectively compared to sucrose. Their use is widespread in chewing gums than in other confectionery.

37.4.6 Bulk sweeteners

Bulk sweeteners provide sweetness to a lesser extent compared to equal weight of sucrose and hence provide fewer calories. However, they provide significant bulk to the formulation. They include polyols such as sorbitol, mannitol, isomalt, maltitol, etc. Substances which are non-caloric or low-calorie fillers and provide no sweetness are often used in low-calorie confectionery and are called as bulking agents. These provide functionality similar to sugar e.g. polydextrose.

37.4.7 Fats

Fats for confectionery use must be completely or almost completely melted at about 37°C. If they have higher melting point they give an unpleasant greasy sensation in the mouth. On the other hand, low melting fats lack body and tend to make sweets oily, which can also result in bloom defect on chocolate covered products. Cocoa butter has almost ideal properties for use in confectionery. Lauric fats such as palm kernel and coconut oils, partially hydrogenated oils such as soy, ground nut, rapeseed, etc. are also used. Butter is used mainly for its flavour.

37.4.8 Emulsifiers

The usual emulsifiers used in confectionery are lecithin or glycerol monostearate. Both are used to assist the emulsification of fat into product but while the lecithin is generally used for hard boiled sweets, glycerol monostearate is preferred for toffees and caramels as it provides lubrication for cutting knives during processing.

37.4.9 Milk products

Milk products such as spray dried milk powder, sweetened condensed milk, sweetened condensed skimmed milk, whey powder, sweetened condensed whey, etc. are used for their nutritive value, flavour and sometimes colour generated due to Maillard browning and caramelization.

37.4.10 Gelling agents, thickeners and stabilizers

These substances are mainly used for binding water and gives strength to the confectionery products. Gelatin, starch and modified starches, pectin, gum arabic, guar gum, locust bean gum, xanthan gum, alginates, etc. are commonly used.

37.4.11 Colours

Many foods in the natural state are coloured and in many cases the colour influences the consumer's perception of flavour. Most confectionery products are not naturally coloured so colours are added to assist in flavour perception and to provide a means of differentiation between sweets in an assortment of flavours. Natural colours such as caramel and permitted artificial colours are commonly used in confectionery.

37.4.12 Flavours

Natural flavours, essential oils, and artificial flavours are used in confectionery applications. All flavours are to a greater or lesser extent volatile and in confectionery applications they are often added at high temperatures.

37.5 Confectionery Production Principles

All confectionery products have a number of common requirements. They must have an extended shelf life under ambient storage conditions and although this may be assisted by protective packaging their inherent properties must provide stability against microbial deterioration and stability of shape. In sugar confectionery, shelf life is achieved by reducing water activity through control of the composition and RH during storage. Stability of the shape is aided by the inclusion of ingredients such as gelling agents or fats which create structure and prevent flow during storage.

By formation of a gloss as in hard boiled sweets, toffee and nougat or by allowing crystal growth as in fondant creams. Also, soft or liquid centres may be held firm by being enclosed within a rigid shell.

37.5.1 Key ingredients used in sugar confectionery

The prime ingredients of the sugar confectionery are sugar, glucose syrup or invert sugar and water. The purpose of reducing sugars is to control or prevent crystallization in the product; whether crystallization occurs or not, it is essential to ensure that the level of dissolved solids in the water never falls below 76% in order to prevent microbial deterioration.

37.5.2 Equilibrium relative humidity

In a perfectly dry atmosphere all sweets will lose moisture. As the relative humidity of the atmosphere increases, a point will be reached when the sweet ceases to lose moisture and at higher relative humidities the sweet will absorb moisture from the air. The relative humidity of the atmosphere when a sweet neither gains nor loses the moisture is equilibrium relative humidity (ERH) of the sweet and is a function of its water vapour pressure. This is mainly dependent on the moisture content of the sweet, or of the liquid portion in the case of sweets containing liquid and solid components. It is affected to a lesser degree by the molecular weight of the dissolved sugars. Crystalline solids such as sugar crystals have no effect on the ERH of a syrup in which they are dispersed. Other solids such as cocoa, starch and desiccated coconut absorb moisture and the amount depends on the ERH of the solution in which they are contained. The effect is usually small. In sugar confectionery, any ingredient which reduces ERH is called as a ***humectant***. The commonly used humectants are glycerol, sorbitol, etc. The typical ERH values for confectionery products are given in Table 37.1

Table 37.1 Equilibrium relative humidity (ERH) values of some confectionery products

Type of Confectionery	ERH Value (%)
High boilings	20
Toffees and nougats	45
Fudge	60-65
Jellies	70
Fondants and coconut ice	75-80

37.5.3 Sugar solubility

Sugar dissolves in water to give a saturated solution of 67.1% solids at 20 C. However, up to 74% solids, undisturbed sugar syrup will not crystallize unless seed crystal is present or mechanical or thermal shock is encountered. This metastable state is utilized in the wet crystallization process. The presence of invert sugar or glucose syrup increases solubility of sugar and TSS in solution at saturation. It has been found experimentally that total solids up to 84% can be obtained assuming that glucose or invert solids dissolve in water in the ratio 6.69 to 1 to give an 87% solution and the remaining water dissolves sugar in the ratio of 1 to 2.03 to give a 67.1% solids solution.

37.5.4 Sugar boiling

The quantity of water evaporated when a sugar solution is boiled under constant conditions is related to the boiling temperature. Water boils at 100 C under standard atmospheric conditions. The addition of sucrose, or any other sugar, increases the boiling point in a non-linear manner and is related to the concentration of sugar in solution. The boiling point of some common sugar confectionery products is given in Table-37.2. Problems arise at higher temperatures because heat transfer through fairly viscous syrups is not good. The presence of sugars other than sucrose will affect the boiling point of the solution in different ways. Variations in barometric pressure will affect the boiling the point of a sugar syrup. The variation in the height of the mean sea level for the location of a sugar confectionery factory can give rise to differences in the boiling point of sugar syrup.

Table 37.2 Boiling point ranges of some common sugar confectionery products

Type of confectionery	Temperature range for boiling (C)
Hard-boiled sweets	149-166
Hard toffee	146-154
Fudge	116
Fondant	116-121
Caramels and regular toffee	118-132

37.5.5 Sugar crystallization

The structures of products such as fondat creams, coconut ice and fudge are produced with formulations which contain enough sugar to crystallize on cooling. When a supersaturated solution is seeded with existing crystals, usually by the addition of fondant, crystallization occurs throughout the mass. The crystal size may be controlled by varying the degree of supersaturation, the amount of seed crystal and the temperature. By varying these, textures ranging from firm pastes to hard products (where the crystals have grown into each other and formed a rigid structure) may be achieved.

37.5.6 Aeration

Aeration may be applied for a number of reasons such as increasing volume for a given weight of product and creating opacity, but the main reason is texture modification. It can be achieved by beating where foaming agents and stabilizing agents are necessary, or it may be done by pulling or liberation of gas under vacuum where the setting of the matrix by cooling stabilizes the structure. Egg albumin, whey proteins and enzyme modified soy proteins are commonly employed as aerating agents.

37.6 Confectionery Production Processes

The processes commonly employed for the production of confectionery products are briefly described below:

37.6.1 Cooking

Cooking of sugar is usually carried out in either gas fired cooking pans or in steam-jacketed kettles. Sometimes vacuum is applied for cooking at low temperatures. Cooking is carried out to achieve high temperatures for dissolving sugar. It also frequently involves caramelization of sugars.

37.6.2 Drop rolling

The drop roller was one of the earliest sweet forming machines. It consists of two synchronized brass rolls engraved with matching impressions. The processed confectionery mix in the form of a plastic mass is fed into the rolls and forced into the impressions.

37.6.3 Moulding

Depending on the type, confectionery products are moulded in different ways. Boiled sweets are deposited into teflon-coated aluminium moulds fitted with ejector pins. After cooling, the pins are depressed from the underside of the moulds to eject the solid boilings. Toffees are deposited in silicone rubber moulds. After setting, the mould is deformed by plungers which push the toffee out.

37.6.4 Extrusion

Extruders of various types are used for forming bars and sheets from pastes and plastic confectionery bases. Lozenges are formed by passing the paste through a screw extruder and die to form a sheet which is then reduced in thickness by subsequent sizing rollers. In case of bars, the sheets are slit by rotary knives and sized to desired length.

37.6.5 Plastic forming

The plastic forming operation is widely used in the confectionery industry for converting plastic masses such as boiled sugar or toffee into individual sweets. In this process, the product will be tempered to correct consistency and flavour ingredients incorporated during the kneading process in the case of boiled sugar or on a slab, cooling drum or cooling conveyor in the case of toffees. The mass is then fed into a batch roller for obtaining the product in the form of a rope. The rope is the fed to a presizer followed by sweet former (to give desired shape to final product) and later packaged.

37.6.6 Wet crystallizing

Wet crystallizing is the process of building up a thin coherent coating of sugar crystal on the surface of a sweet. This seals the surface, and when used on products such as fondant creams or marzipan, retards drying out, extending the shelf life from a few days to 6 months or more.

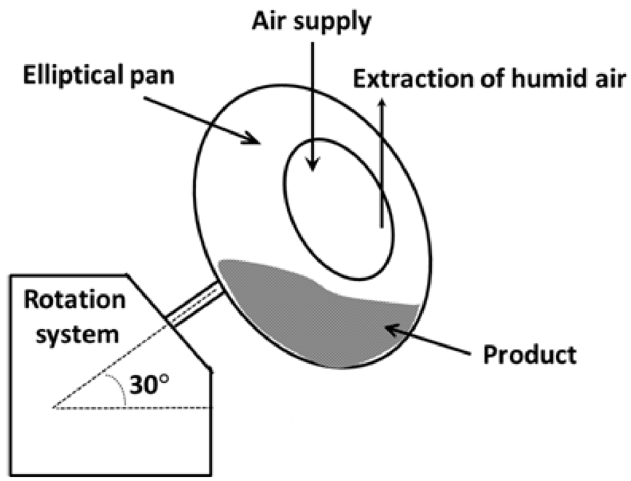

Fig. 37.1 Schematic diagram of a simple dragee pan

37.6.7 Panning

Panning is an operation which has been used by the confectionaries for centuries. In principle it is the application of coating to centres tumbling in a revolving pan mounted at about 30 to the horizontal (Fig 37.1). The operation consists of adding enough coating medium to cover the centres completely with no surplus and drying this off either with hot air (hard panning), extra sugar (soft panning) or cold air (for chocolate). Coatings may be sugar syrup (hard panning), glucose syrup dried off by the application of fine sugar (soft panning) or chocolate, solutions containing food grade colours, edible gums, etc.

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Lesson 38

CANDIES

38.1 Introduction

Candies represent a subgroup of amorphous sugar confectionery which are characterized by hard, chewy, homogenous and non-crystalline nature. These are also called as glass. The glassy state of matter is not a thermodynamic phase but a supercooled liquid and exhibit a sharp transition temperature between glassy and rubber states. Most sugars will form a glass but pure sucrose does not form a glass. Therefore, commercial sugar glasses are always made from sucrose and some other sugars such as invert sugar, glucose syrup, etc. Any additive required to stabilize a sucrose glass is traditionally referred to as a "doctor" by confectioners. Sometimes, acids are added to sucrose for *in situ* generation of invert sugar. In practice, boiled sweets (or high boilings) become unstable by absorbing water. Initially the product becomes sticky, then soft, followed ultimately by crystallization. The rate at which high boilings can absorb water is controlled by diffusion process and the high molecular weight fraction in glucose syrup inhibits the migration of water into the sweet. The important parameter at the formulation stage is the ratio of sugar to glucose syrup. The ratios of sugar to glucose syrup in common types of sugar confectionery is given in Fig. 38.1

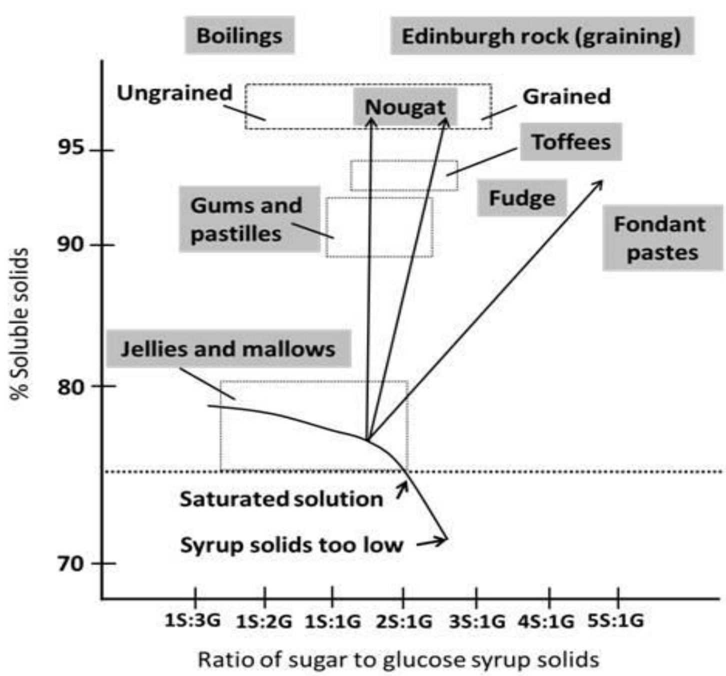

Fig. 38.1 Sugar (S) and glucose (G) composition of different sugar confectionery products

38.2 Hard Boiled Candies

Boiled sweets or high boilings are originally made by boiling a sugar solution with cream of tartar over coke fires to about 150-155□ C. The cream of tartar inverts some of the sugar and the resulting mass, comprising of a mixture of sucrose, dextrose and fructose at about 97% solids. They are usually coloured, flavoured and set to a transparent glassy product. However, the coke fires are now replaced by steam and processing is done in vacuum pans (635-760 mm Hg) for improved heat efficiency. The sugar from high vacuum cookers is a viscous plastic mass. The plastic mass is usually shaped, cooled and wrapped in moisture-proof packs as rapidly as possible, preferably while still hot. The resultant candies have very low residual moisture usually in the range of 1-2%. Candies based on invert sugar are very hygroscopic and readily develops stickiness on exposure to the atmosphere. Hence, glucose syrup is often included in the formulation to avoid stickiness. Sugar/glucose syrup or sugar/glucose syrup/invert sugar combinations are widely used in confectionery. The ratio of sugar to glucose for making hard boiled candies range from 30% sugar and 70% glucose (1S:3G) to 50:50 mixtures (1S:1G) (Fig. 38.1). The process of making boiled candies can be summarized as follows:

a. Dissolving the sugar
b. Boiling the sugar and glucose syrup under vacuum to the final solids concentration
c. Cooling the boiled mass
d. Adding flavour, colour and any acid
e. Shaping the product
f. Wrapping

38.3 Brittle

Brittle is essentially a type of hard candy to which nuts like peanuts are very commonly added. The nuts are added to the hot syrup and the mixture is poured out in a very thin layer and then stretched to make it as thin as possible. Baking soda (sodium bicarbonate) is sometimes added to produce a light texture. The resulting candy is hard and snaps easily, hence the term “brittle”.

38.4 Compressed Tablets

Candies produced by application of high pressure processing are called compressed tablets or pressed candies. It involves use of punches and dies to provide desired shape. For tablet sweets, icing sugar and dextrose are normally used as a base, with gelatin, gum acacia or gum guar as binding materials. Stearic acid and its salts are normally used as lubricants. The amount of binding agent and lubricant used in compounding the formulation influences the physical properties of the tablet. There are two methods of producing compressed tablets: slugging and wet granulation. In ***slugging***, the powder mix is treated with a lubricant before precompression into large granules. The slugging operation of tablet press is shown in Fig.38.2. For ***wet granulation***, sufficient binder solution is added to the dry ingredients to make a malleable paste. The paste is then forced through a wide meshed sieve and dried in an oven at 32-65° C. The dried mixture is treated with a lubricant and flavour and sent for pressing. Pressing is carried out in continuous machines which operate at high speed. The tablets can be formed either in single or multiple die actions in which the lower and upper dies are brought together under pressure.

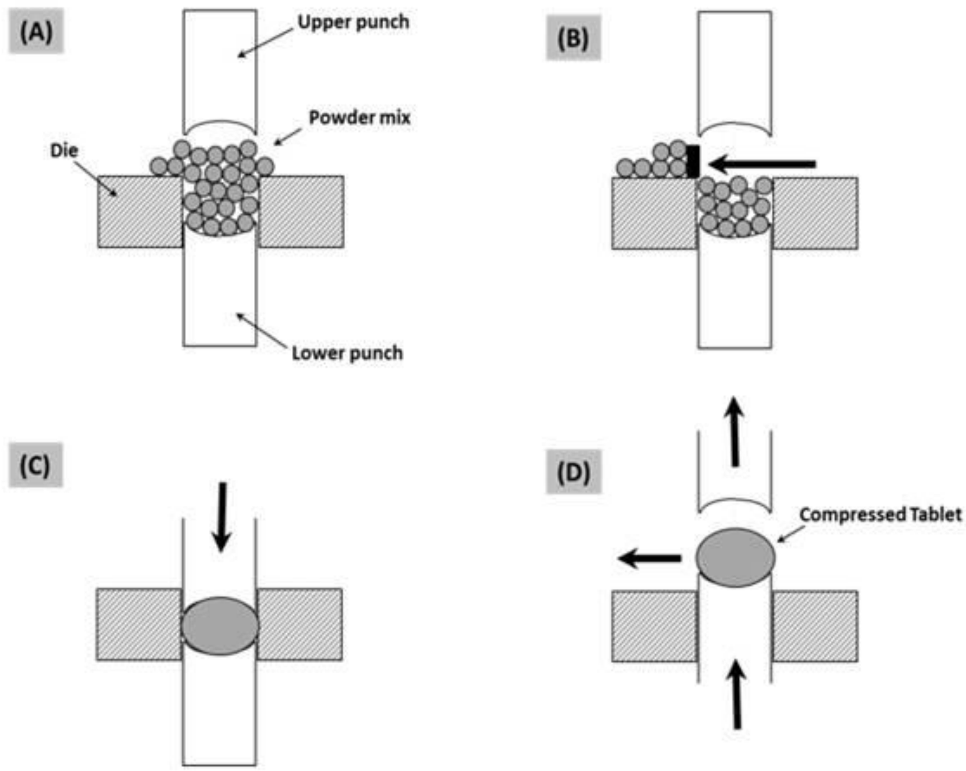

Fig. 38.2 Operation of a slugging tablet press

(A). Die is filled with powder; **(B)**. Excess powder is removed; **(C)**. Powder is compressed between punches; and **(D)**. Upper punch is raised and tablet is ejected by lower punch.

38.5 Crystalline Fondants and Creams

Fondants are more solid and are used in preparing items such as peppermint patties, while creams are softer and used in making chocolate covered products. The main difference is in the degree of hardness and crystal size. All fondants are prepared from a blend of sucrose and other sugars such as invert syrup or corn syrup. Blend is usually heated to a temperature of 115-120° C and cooled to about 37.8° C without agitation. When agitated, it initiates crystallization to produce a product with a crystal size of about 15 μm.

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Lesson 39

CHEWING GUMS AND BUBBLE GUMS

39.1 Introduction

Chewing gum is a type of gum traditionally made of chicle, a natural latex obtained from the sapodilla tree (*Manilkara chicle*) and jelutong-pontianank, latex of jeluotong tree. Either of the latexes was considered as main components for making chewing gum base. However, for economical and quality reasons, modern confectioners use natural or synthetic rubber (polyisoprene) or hydrocolloids instead of chicle. Bubble gums are essentially chewing gums which are less sticky and stretch more easily. Different gum bases are used for chewing gum and bubble gum. Bubble gum base contains either higher levels of polymers or polymers of high molecular weight. Either of these makes the gum base more extensile and hence able to form bubbles. Special non-sticking gum bases have been developed in order to avoid the problem of discarded gum becoming nuisance.

39.2 Role of Ingredients Used in Chewing Gum

39.2.1 Hydrocolloids

Hydrocolloids are the key ingredients for gums manufacture. They are high molecular weight polymers of plant, animal or microbial origin that form viscous solutions or gels on addition of water. They gel and thicken but also stabilize by preventing syneresis, fixing flavours and inhibiting sugar crystallization, give transparency, brilliance, adhesion and ease foaming. Some of the hydrocolloids commonly used in confectionery are described below:

a. **Agar agar**: It is a seaweed and swells in water and exhibits a high gelling power at low (1-2%) concentrations to give a hard-brittle short-breaking bite with good clarity. It is one of the most potential gel-forming agents known. The strength is mainly proportional to the agarose rather than agaropectin content, which forms double helices on gelation. It has a unique property to form gels which only sets at 32-39°C yet does not melt until temperature reaches 85-90°C. This aspect is advantageous in allowing the incorporation of flavours, acids, colours, etc. at cooler temperatures prior to shaping and setting.

b. **Bacterial gums**: Xanthan gum from *Xanthomonas campestris*, gellan gum from the fermentation of *Pseudomonas elodea*, etc. are potential gums which find applications in confectionery. Gellan is functional at very low concentration (about 0.5%) to give hard-brittle short-textured gels. Setting temperature is 40-50°C yet melting temperature is 90-100°C.

c. **Gelatin**: Food grade gelatin is made by aqueous extraction of mammalian collagen by lime or acid treatments of skin, bovine or porcine raw materials. Religious reasons may prevent the use of porcine sources. The thermoreversibility of gelatin gels (at around 40°C) gives its main organoleptic feature of a smooth elastic texture which melts agreeably in the mouth. Commercial gelatin is available in leaf, sheet, granule and powder forms. In India, as per Food Safety and Standards (2011) Rules, food grade gelatin is permitted as an additive.

d. **Gum acacia**: It is a tree exudate, where it forms as 'tears' and also called as gum arabic. Each tree yields between 50 and 100 g of gum per year. It is available in lumps, powdered and as purified, standardized, spray-dried. It is the preferred hydrocolloid for many long-lasting, chewy, gum sweets and is used at levels from 10-60%. Resistance to melt away, shape stability, good clarity, bland taste and odour with minimal sweetness and pliable texture with low adhesion during consumption are the key factors of this gum. Its viscosity reduces greatly with increased temperature, making it suitable for fluid-deposited goods.

e. **Pectin**: It is a polymer of galacturonic acid obtained mainly from apple or citrus fruits. Pectins are characterized by their degree of esterification or methoxylation and gel strength. It forms gels at 0.5-4.0% concentration and have a delicate fruit-like short texture and mouth feel with very good flavour release. Low-methoxy pectin does not require acid and a good gel can be obtained by diffusing calcium ions into the system.

f. **Modified starches**: They are the starches modified by chemical reaction or physical means in order to adapt it for a specific application or improve its stability. Chemical modifications include cross linking, acetylation, phosphorylation, oxidation, etc. Physical modifications involve pre-gelatinization of starch by drying or heating. Corn or maize starch is the most commonly used starch although tapioca (sago), rice, wheat and potato starches can be employed to modify textures.

39.2.2 Sugars

In the chewing gum manufacture, sugar used shall be of very fine particle size (less than 20 microns) to avoid gritty feel in the mouth. Chewing gum, therefore, has to be made from milled sugar similar to icing sugar. Milled sugar is difficult to handle and if exposed to high humidity they agglomerate. Therefore, the confectioners procure crystalline sugar and mill it on-site and feed the milled sugar directly into the manufacturing process. Sugar is usually added at a rate of about 25% of the gum base. Dextrose monohydrate is sometimes used as an alternative to sucrose in chewing gum. The endothermic heat of solution of dextrose gives a cooling sensation in the mouth, a property that goes well with mint flavours but not with others. To achieve a final TSS content of at least 75%, glucose syrup or doctors are incorporated.

39.2.3 Texturizers

Texturizers are substances that are added to the gum base to modify the mouth feel and facilitate processing. Common texturizers are food grade calcium carbonate or talc. Both of these are less expensive than the other ingredients in gum base. Low cost chewing gum bases contain about 45-55% texturizers whereas high quality chewing gum base contains 18-20%. Bubble gum bases have a texturizer level varying between 30 and 60%. Calcium carbonate is not an acceptable texturizer in products where there is an acid component to the flavour as it reacts with the acid to produce carbon dioxide. Typically acids are only used in fruit-flavoured products, and here, talc must be used as a texturizer.

39.2.4 Humectants

Chewing gum can be spoiled by either loss or gain of moisture. If the gum picks up too much moisture it will become too soft and could darken; if the gum dries out it becomes too hard. Either of these problems can be prevented by wrapping the product in a moisture-proof barrier. However, it is common to add humectants to chewing gum in order to lower the water activity and hence reduce drying out. Common humectants used are sorbitol and glycerol. While sorbitol is a purely vegetable product, glycerol can be produced by the hydrolysis of fat including animal fats, which can cause problems with some religious and ethnic groups. Glycerol can also be produced from petrochemical origin. Excess use of humectants can make the products soft and sticky.

39.2.5 Antioxidants

Gum bases are prone to oxidation and antioxidants help in preventing it. Typically, they contain permitted antioxidants such as butylated hydroxytoulene (BHT), butylated hydroxyanisole (BHA) or tocopherols. However, in India, only BHA maximum up to 250 ppm is permitted in chewing gums as per Food Safety and Standards Rules (2011).

39.2.6 Colours

Permitted colours are invariably added as solutions at the end of the mixing operation in the process. Colours must be acid-fast, resistant to reducing sugars, stable to operating temperatures and should not separate into basic colours during the gel-setting operation.

39.2.7 Flavours

Addition of flavours enhances the acceptability of chewing gums. Adding flavours to warm liquors under atmospheric conditions can lead to loss of volatiles, and hence, in-line mixing is preferable. ‘Medicated’ flavours such as menthol and ‘alcohols’ such as gin are especially susceptible. Small quantities of salt can sometimes be used to enhance the perception of non-fruit flavours. However, the choice of flavouring agent must take into account the stability in the chosen hydrocolloid system.

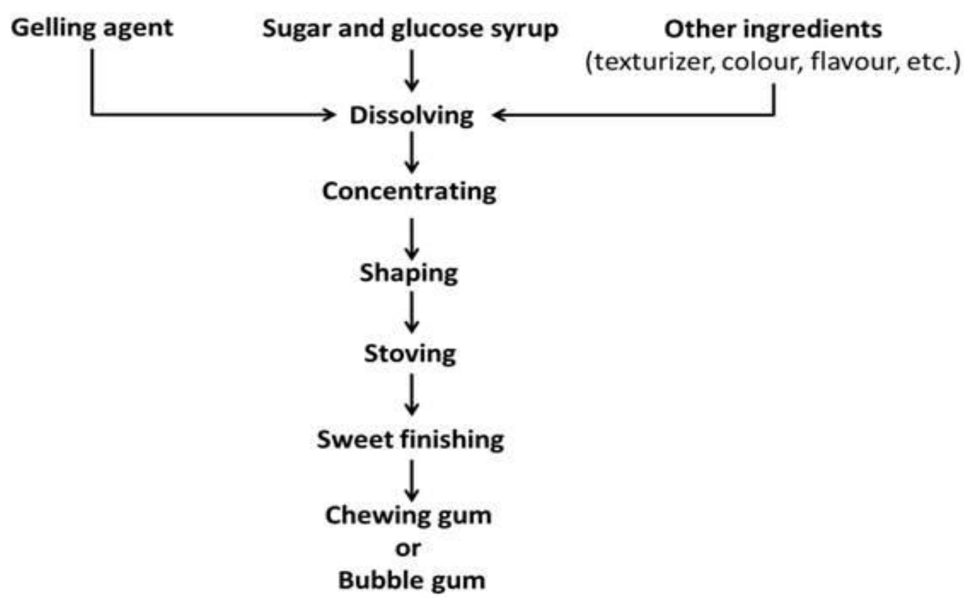

Fig. 39.1 Generalized flow diagram for the manufacture of chewing gum or bubble gum

39.3 Manufacturing of Chewing or Bubble Gum

Gums are prepared by mixing sugar syrup, high dextrose equivalent (DE) glucose syrup, gelling agent or hydrocolloid and other minor but important ingredients such as texturizer, flavours, colours, etc. The generalized manufacturing process for making chewing gum or bubble gum is given in Fig. 39.1. The gelling agent used in the process is cleaned, ground, purified, soaked, made soluble or dissolved or in some way standardized before incorporated in the sugar liquors. In case of bubble gum manufacture, as mentioned earlier, gum base should contain either higher levels of polymers or polymers of high molecular weight that yield a more extensible product able to form bubbles. Whenever hydrocolloids are used in combination, they have to be prepared separately and blended later to avoid coacervation (process of holding organic molecules together by hydrophobic forces from a surrounding liquid). The liquor is prepared from processed sugar syrups. It is necessary to achieve a final liquor of at least 75% TSS to prevent mould growth. As sucrose is saturated at 67% at ambient temperature, glucose syrup, invert sugar or other doctors are used to inhibit crystallization. The main objective in preparing liquor is to produce a high-solids fluid mass that can be shaped. The dissolved ingredients in the syrup are concentrated using plate or film evaporators. The concentrated mass is shaped either by depositing, slabbing or extrusion methods. In depositing method, the product is deposited in starch or starchless moulds of a variety of shapes. Slabbing is an ideal way of producing multi-layered products because each layer can set before the addition of the next. Shaping at the cooled extrusion die has the advantage that all the unit operations are done on the one piece of equipment. Shapes such as laces, round or star strings, sheets, round or star tubes, corrugated ribbons, co-extruded centre-filled strings, etc. can be formed after shaping, the product is dried to a final moisture content, the process which is called as “stoving”. As per FSSR (2011), chewing gum and bubble gum shall not have less than 12.5 and 14.0 percent (by weight) moisture. It is a simple process in which the trays are placed in a heated chamber and hot air is blown over the sheets. The rate at which a given product can be stoved is determined by the size of the sweet, the viscosity of the sweet and the maximum temperature that can be used without damaging the product. Finishing treatments such as oiling and polishing are followed after stoving. Oiling and polishing not only serve to provide extra glossy appearances but also prevent chewing gums from sticking together.

39.4 Common Defects In Chewing Gums

39.4.1 Cloudiness

This is caused by low-grade or undissolved hydrocolloid, coacervation, salting out, calcium precipitation or air entrapment. Use of more water, a longer time or higher temperature for dissolving colloid prevents this defect. Increasing liquor standing time or vacuum deaeration removes entrapped air.

39.4.2 Crystallization

It is normally caused by sucrose crystallization and hence reducing sucrose content or increasing doctoring by adding reducing sugars helps in reducing crystallization.

39.4.3 Mis-shapes

Sweets overbunched while still soft or insufficiently hardened before finishing processes is usually responsible for this defect.

39.4.4 Stickiness

This can be caused by the ERH being too low, excess reducing sugar, variable acidity, incorrect total solids, under cooking or over cooking, insufficient gelatinzation, etc.

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Lesson 40

TOFFEES AND CARAMELS

40.1 Definition of Caramel and Toffee

Caramel and toffee are one of the most basic and yet versatile candy products and constitutes a large part of the confectionery industry. Both are versatile and widely used confectionery products after chocolate. They produce images of delicious, chewy taste in the minds of consumers.

Word "Toffee" was used to denote those products that do not contain milk solids and prepared by using brown sugar, glucose syrup and fat mainly butter fat. They appear in many aspects quite similar to butterscotch but differ in the intensity of heating. Unlike butterscotch they contain slightly higher moisture content. Processing of milk led to the inclusion of milk solids in toffee formulation and resultant product contains slightly higher moisture in the range of 8-9 percent. The demarcation line between caramel and toffee is very thin. Differentiation between the two can be done on the basis of moisture content which is slightly higher in caramel as compared to toffee. Term "Caramel" is also used to describe products made by the breakdown of carbohydrate by heat or heat and alkali treatment. These are mainly used ascolouring matter.

Caramel may be found in a range of textures, colors, flavors and products. This common confection may be consumed alone as or in combination with chocolate, nougat, marshmallows, nuts and other inclusions. Some applications include caramels wrapped for consumption, for depositing into chocolate shells, as ice cream toppings and ingredient in other confections or desserts. Likewise "Toffee" is also available in various textures ranging from soft to hard brittle, which is mainly governed by the composition and final cooking temperature.

Fudge is another type of confectionary product which resemble to caramel or toffee but differs in the processing as in it sugar crystals are developed during the cooking. Normally it contains more sugar and milk as compared to toffee or caramel. The mixture of sugar, milk and butter or vegetable fat is heated to soft-ball stage (116^0C) and then beating the mixture when it cools so that it can acquire a soft, creamy consistency. The characteristics of fudge are more dependent on processing conditions rather than formulation. The three important criteria for good quality fudge are:

- Must be microbiologically safe
- Must be firm
- Should have uniform texture

40.2 Properties of Caramel and Toffee

They may be described as **'soft glasses'** that are viscous in nature and contain a dispersion of milk protein and an emulsion of fat in highly concentrated sugar solution. Caramel is manufactured by heating mixture of sugar, corn syrup, fat and milk solids (protein) at 110-130^{o}C, followed by cooling and moulding of cooked mass. Soft caramel which is used as a layer in confectionery bars is prepared by heating to the lower temperature range and has a moisture content of about 10%. The resulting product is a viscoelastic liquid consisting of fat droplets in a matrix of sugars and protein. Toffee or caramels can be deliberately made to crystallize or grain and are then called as grained caramels or soft toffees. These products are quite similar to fudge but are made by adopting altogether different process.

The texture of caramel must be controlled in order to achieve the desired flow patterns and machinability in the production lines, to maintain product specifications and to ensure a long shelf life.

40.3 Technology for the Manufacture of Caramel and Toffee

40.3.1 Equipment for toffee and caramel manufacture

Traditionally toffees were made on fuel or gas fired pans or steam-boiling pans. These pans were fitted with a bow-shaped stirrer and hinged scrappers which are thrown outward by centrifugal forces to remove the cooking toffee from every part of the heating surface. However, a continuous toffee plant consists of following parts.

40.3.1.1 Auto-feeder

It is maintained at 35^0C and receives all the raw material except flavouring and butter and followed by a reservoir to surplus feed before transferring into pre-heater through metering pump.

40.3.1.2 Pre-heater

The feed material is fed into this section which is attached with scrapper to dissolve and mix all the content with heating to a temperature of 95^0C. The cooking is done by steam and by changing the steam pressure, temperature can be controlled. The residence time is regulated by a weir and the section contained a variable-speed rotor assembly. The rotor is designed to give a thorough mixing with a degree of back-mixing.

40.3.1.3 Blender

The heated mix is transferred to a blender which is quite similar to cooker but smaller than it. This unit is for the addition of butter and flavour. This section also has a weir to control the residence time.

40.3.1.4 Cooker

In the cooker, the emulsified mass is cooked thoroughly to desired cooking temperature which is adjusted by steam pressure. The residence time is also controlled by the speed of shaft to remove sufficient moisture and allow caramalization to occur.

40.3.2 Manufacturing process

Caramel is manufactured either following traditional batch process or continuous method. The process can be considered taking place in five basic steps viz. pre-mixing, emulsification, cooking, cooling and forming either through slab formation or depositing. A generalized process flow diagram for the manufacture of toffee and caramel is given in Fig.40.1.

40.3.2.1 Pre-mixing

Pre-mixing of ingredients is done separately for fat phase and aqueous phase. For fat phase preparations butter/milk fat is mixed with melted vegetable fat and emulsifier at desired speed to mix the components. Sugar is dissolved in required quantity of water, mixed with milk solids and melted corn syrup.

40.3.2.2 Emulsification

Both aqueous and fat phases are emulsified by using high speed mixer. Emulsification must be adequate to get the desired texture and other quality attributes in the finished product. Emulsifier and milk protein assists in emulsification.

40.3.2.3 Cooking

Cooking of caramel or toffee at desired temperature is essential to develop proper texture and organoleptic quality specially the flavour and colour. Cooking temperature also affects the final moisture and it influences the texture and chewiness. The end product moisture content in caramel cooking is generally controlled by the final cooking temperature. Caramel or toffee cooked to 125°C-130^{o}C contains around 6-8% moisture. Provided sufficient fat is present, the product so produced will have a pleasant chewing characteristic. Higher cooking temperatures of up to 145^{o}C must be employed with these products meant for hot climate. These are less likely to grain (crystallize) during storage.

40.3.2.4 Cooling and depositing

The cooked mixture is transferred to depositor or forming unit where both cooling as well as shaping takes place. The cooling is essential to prevent over-cooking of the caramel or toffee. There may be three distinct processes for shaping. It includes slab process, the cut and wrap process and depositing process.

40.4 Role of Ingredients in Manufacture of Caramel and Toffee

The ingredient used in caramel formulation can be categorized into two group *viz.* functional ingredient and optional ingredient.

- **Functional ingredients** include sugar, corn syrup, fat and milk solids
- **Optional Ingredient**s include water, salt, flavouring and emulsifiers

The rheological, textural, thermal and structural properties and sensory characteristics of caramel depend on the functionality of four basic ingredients in the formulation viz. carbohydrate, fat, milk solids (milk protein) and water.

40.4.1 Carbohydrate in caramel

Carbohydrate contributes to final stand up texture to caramel. Carbohydrate generally used in caramel formulation is from sugar and corn syrup.

40.4.1.1 Sucrose

The major carbohydrate in caramel formulation is sucrose which provides bulking and sweetness. Sugars in confections can exhibit textural differences due to its amorphous state and/or crystallization (number and the size of crystals). Sugar counteract to corn syrup, as it reduces the stickiness and cold flow caused by higher amount of corn syrup in formulation. Typically, with an increase in sucrose there is a decrease in chewy texture of caramels. If there is a higher proportion of sugar in the formulation, there is an increase in graining potential. Graining occurs when the sugar in a confection crystallizes and causes an appearance that may be desirable or undesirable, depending on final application. Increasing the level of sucrose will increase the toughness of the caramel and the likelihood of graining during storage.

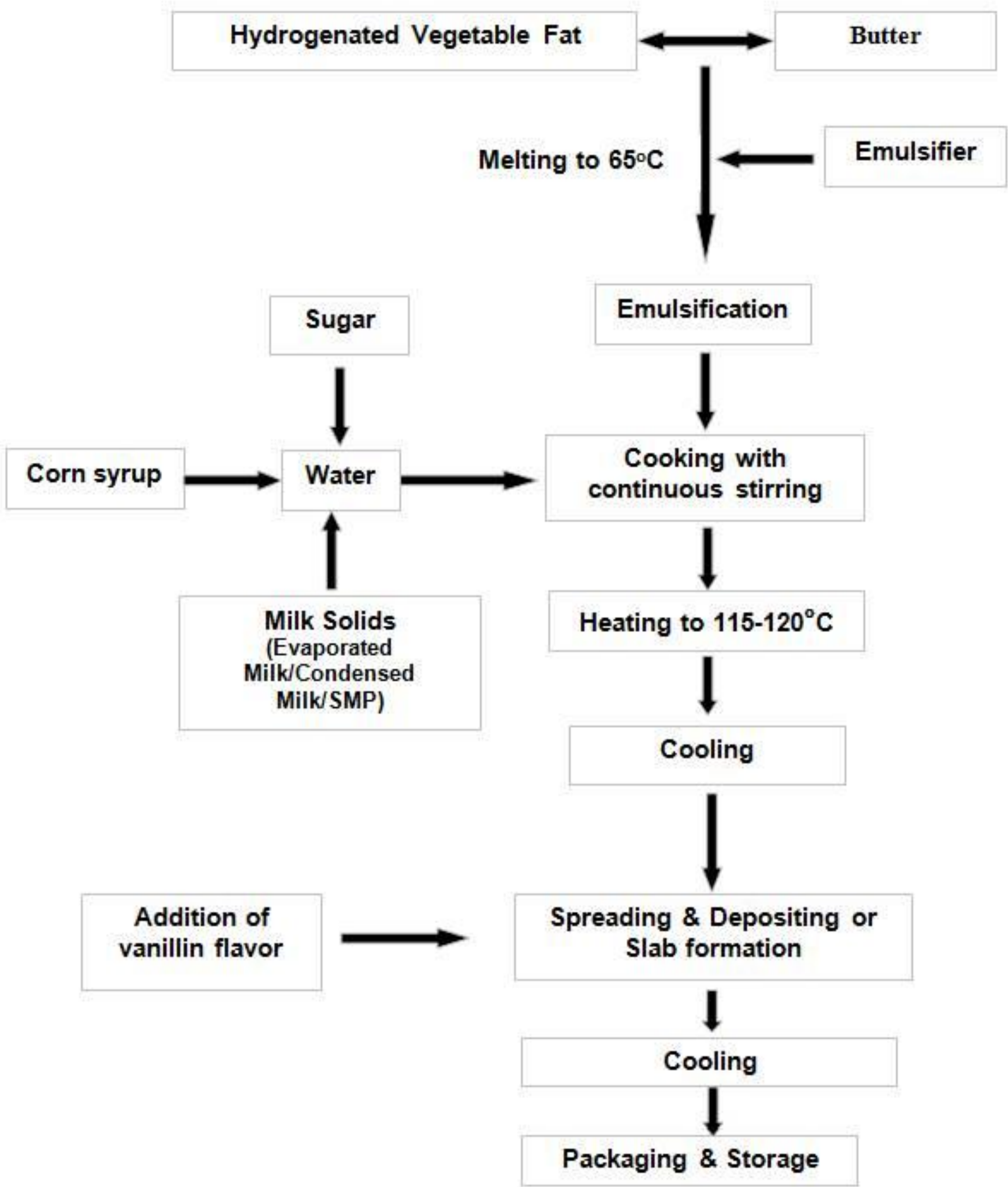

Fig. 40.1 Process flow diagram for the toffee and caramel manufacture

40.4.1.2 Sugar syrup

Glucose syrup/corn syrup and invert sugar syrup (containing an equivalent level of dextrose and levulose) are known traditionally as doctor sugar from their properties of increasing the total sugar concentration. Corn syrup plays a vital role in deciding caramel texture and its sensory appearance particularly colourdevelopment and chewiness of caramel. The dextrose equivalent of corn syrup is governing parameter with 42 DE being widely adopted. Corn syrup with higher DE results in darker colour, whereas low DE corn syrup provides excessive chewiness and stickiness to caramel. Corn syrup prevents sugar crystallization in caramel, thus checks product dryness. The ratio of sugar to corn syrup has a significant effect on the graining potential, and thus the shelf life, of a caramel. The higher proportion of sucrose in the caramel leads to an increased tendency to grain but it bites more cleanly. If the amount of corn syrup in the formulation is higher there is an increase in browning, stickiness and elasticity. A ratio of 40:60 sugars: corn syrup is sufficient to inhibit graining. Caramels are normally produced to a moisture content of between 6 to 7%. At this water level solution of sucrose, glucose syrup and invert sugar are supersaturated. Crystallization is inhibited by the highly viscous nature of the caramel boil. This is due to presence of low water content, from the presence of higher saccharides in glucose syrup and the chemical reaction which takes place between the milk protein and the reducing sugar that are present.

40.4.2 Fat

Fat in caramel aids richness to flavour and improves textural properties. The presence of fat makes significant contribution to the texture, chewing characteristics, color and flavor of caramel. The fat should have a balance between butter to contribute flavour and texture and hardened plant oil (hydrogenated fat) for stability. Fat, generally, used in caramel is from dairy source and vegetable fats such as coconut oil, hydrogenated vegetable oils, and partially hydrogenated palm oil (HPO) or palm kernel oil (HPKO). The fat also acts as lubricants, and phospholipids present in milk fat act as emulsifiers. The level of fat in caramel ranges from 5 to 20%, typically at 10 to 12%. Low fat levels tend to produce caramels that are sticky and difficult to chew while a high fat product without the addition of an emulsifier will lead to 'oiling out' on the surface of the confection. The melting point of fat source used is very important in terms of functionality in product. The melting point of fat should range between 29.4 and 46.1^{o}C when vegetable fat is used for good standup quality and mouth-feel. A melting point higher than the recommended range could lead to a waxy mouth-feel upon consumption. Fat provides shortening effect to caramel and reduces the stickiness in product. Fat also affects the adhesion properties of caramel. Lipid may also affect the shelf life stability of a caramel with the potential for rancidity or fat expression. Fat expression is a defect that occurs when there is poor emulsification and results in a greasy caramel surface.

40.4.3 Milk solids

Milk solids impart three important characteristics to caramels, (a) they produce the background milk flavor, (b) the protein and fat aid in producing the texture and chew and (c) the proteins and lactose interact during heating to produce the characteristic caramel flavour. The most common form of milk solids used for high quality caramel is cream, evaporated milk, and sweetened condensed milk. Whey powders and sweetened whey have gained popularity as economical substitute for nonfat milk solids. But due to higher amount of lactose they can substitute only up to 50% of the nonfat milk solids can be replaced by whey. The resulting caramel is slightly softer. Milk fat imparts a richness to flavour. It also serve as a lubricant, which in turn facilitate its machinability, affects candy texture, controls sugar crystallization and adds flavor.

Milk proteins can have pronounced effects on the texture and rheological properties of a food system, by forming complexes among themselves and with the other constituents in the system. The functional properties of milk proteins result from their interactions at three levels: 1) protein-water interactions; 2) protein-protein interactions; 3) protein surface interactions. Caramel is an example of a complex food product in which milk proteins are expected to play a major role in controlling the textural properties. The functional properties of milk proteins in food systems can be categorized into solubility, viscosity, water binding, gelation, cohesion/adhesion, elasticity, emulsification, foaming, fat and flavour binding (Except for foaming, all of the above functionalities are exhibited in caramel.

Caseins and whey proteins, two major classes of proteins in milk, aid in efficient mixing of ingredients by promoting emulsification and improving emulsion stability. Caseins have the ability to bind more than twice their weight of water, thus producing a drying effect. Water absorption capability of whey proteins can be increased by heat denaturing. The foaming properties of whey protein exceed those of caseins. Caseins can produce a firm chewy body, neither sticky nor tough, while whey proteins form a soft coagulum with less resilience. The final colour and flavour of confection also reflect contribution from milk proteins. Caseinates, largely responsible for milk's white colour, contributes to whitening effect. Caramel is a multi-component system, in which interactions between casein and whey proteins and the interactions of these proteins with the other ingredients are inevitable. The firmness of caramel was significantly affected by both whey and casein proteins. The increased firmness is not only attributed to higher amount of protein but this is due to physical and/or chemical interaction between these two proteins. Furthermore, there appeared to be a synergistic effect between whey and casein proteins on the caramel firmness. Maximum firmness occurred when the two proteins i.e. casein and whey protein, were adjusted to 1:1 ratio.

Lactose can have an important effect on the flavour, colour, and texture of confection. Flavours depend on cooking temperature and time, acidity of mixture, and presence of free amino group. Lactose, the least sweet of the principal sugars used in confections, can be added to establish flavour balance.

40.4.4 Emulsifier

The naturally present lecithin in milk is helpful in exerting emulsifying properties in the caramel but the level is present is insufficient to emulsify the mix effectively. It is necessary to boost the emulsifier content by adding glycerol monostearate (GMS) or oleate or oilseed lecithin, butylated glyceryl monostearete, sucrose esters or acetylated monoglyceride. Lecithin and GMS are the emulsifiers typically used in caramels at 0.2 to 0.3% of the lipid content. The emulsifiers are believed to increase the average size of the fat droplet at the caramel surface.

It is essential that the fat dispersed in the syrup phase should be in a small globule size if a greasy taste is to be avoided.

40.4.5 Salt

Salt is added to caramel to enhance the flavour. It also acts as humectant and is necessary to prevent the product from being too bland. An optimum mixture of carbohydrates, protein and fats in caramel product largely dictates the rheological, thermal and structural properties, and, therefore, affects the operation and functional properties. Interaction of three basic ingredients namely carbohydrates, proteins and fats along with water and other minor additives during shearing, mixing and heating make an interesting combination in product formulation.

40.5 Packaging and Storage of confectionary

Confectionary products are rich in sugar and hence they are hygroscopic in nature. Moreover, some of them contain appreciable amount of fat and milk solids which make them susceptible to hydrolysis and oxidation. Hence, they require protection against the ingress of moisture, oxidation and exposure to high temperature. Some of the products are also prone to graining and stickiness and their equilibrium relative humidity (ERH) value is below 30 percent. Selection of packaging materials for these confectionary products required complete knowledge of water vapour transmission rate (WVTR), oxygen transmission rate (OTR), permeability to volatiles and flavours, grease resistance, tensile strength and elongation, tear strength and heat & seal strength. A wide variety of packaging materials, besides cellulosic and aluminum foil are used for confectionary items. The choice of packaging material depends on required shelf-life, performance of wrapping machine, and the cost. The most common choice is plastic and their laminate based flexible packaging materials have replaced the paper and aluminum based packaging materials owing to their better properties and lower cost. Low density polyethylene (LDPE), is an economical packaging material with a very low WVTR, but permeable to volatiles/flavoursand have poor grease resistance. High-density polyethylene (HDPE), is stiffer, more translucent, has better barrier properties but needs high sealing temperature. Polypropylene (PP), are better suited for confectionary packaging because of better barrier properties, clarity than polyethylenes and superior machineability but lack good sealability. This problem could be overcome by applying PVDC and vinyl coating. Apart from this poly vinyl chloride (PVC), polyesters (PET) and polyamide (PA) and metalized films are also being used in certain confectionary products. For long term storage toffee and caramel are kept at room temperature (25-30^{0}C) at low relative humidity.

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Module 12. Cocoa and chocolate products

Lesson 41

COCOA BEAN PROCESSING

41.1 Introduction

The Swedish botanist Linnaeus named cocoa bean *Theobroma cacao*, meaning ‘food of the Gods’ to reflect its spiritual and social importance to the Mayans and Aztecs.

41.2 Varieties of Cocoa

There are three types of cocoa:

41.2.1 Criollo

It has white cotyledons. The chocolate made out of it is of light brown colour quite like milk chocolate. It has pleasant flavour, nutty type with only a mild typical chocolate flavour. Criollo is rare in production. Criollo (regarded as flavour cocoa) is mostly grown in Central and South America.

41.2.2 Forastero

Most of the world’s cocoa is derived from Forastero trees (i.e. 95% of world cocoa crop). It is made up of small, flattish and purple beans.

41.2.3 Trinitario

It is a hybrid between Forastero and Criollo trees. It is a disease resistant hybrid, regarded as a flavour bean. It has a strong chocolate flavour; in addition ancillary flavours such as fruity, raisin, caramel, molasses and spicy notes. It is the most fully-flavoured cocoas. It is ~ 3% of world production.

The Trinitario and Criollo varieties produce mainly the ‘fine’ and ‘flavour’ cocoas.

Cocoa tree was exclusive to the Americas around the Valleys of Amazon and Orinoco rivers. West Africa produces over 70% of world cocoa. Now, cocoa trees are cultivated in more than 40 countries around the world.

Certain cocoa trees become productive in 3-4 years, while in past 6-7 years was common. The pod contains some 40 seeds or beans. After fermentation and drying, one pod produces some 40 g of beans, 1 bean typically weighing around 1 g.

41.3 History of Cocoa beans

On his fourth voyage to America, Columbus reportedly discovered a canoe off the Yucatan Peninsula laden with fruit and cocoa beans. Years later (i.e. beginning of 16th Century), Cortez confirmed the remarkable value assigned to the cocoa beans.

Cocoa processing developed during the 18^{th} Century in the Netherlands. In 1828, to reduce the fattiness of chocolate drink, Coenraad Johannes Van Houten developed a mechanical pressing process to fractionate the cocoa liquor into cocoa butter and cocoa cake. In 1947 discovery was made by John Fry in England that by adding cocoa butter to mixture of liquor and sugar, chocolate was created.

41.4 Cocoa Bean Processing

41.4.1 Fermentation of beans

Chocolate obtained from slaty, unfermented beans tastes extremely unpleasant, being very bitter and astringent without any apparent chocolate flavour.

Cocoa beans are subjected to microbial fermentation for 7-12 days in large bin; the colour, flavour and texture of bean are modified. Fermentation begins with yeasts converting the sugars in the pulp to ethanol. This produces the initial aerobic conditions, and then bacteria start to oxidize the ethanol to acetic acid and further to CO_2 and water; producing heat, raising the temperature during the first 24 h to 40^oC in a good active fermentation.

On the second day, the pulp starts to break down and drain away. Bacteria further increases, lactic acid is produced and an acetic acid bacterium, under slight more aerobic conditions, actively oxidizes alcohol to acetic acid; temperature reaches to ~ 45^oC.

Total 5-6 days fermentation is necessary; bacterial activity continues under increasingly good aeration; high temperature is maintained by bacterial activity. Turning helps in securing an even degree of fermentation.

41.4.1.1 Chemical changes

The proteins and polyphenols are essential for development of chocolate flavour.

Anthocyanins and other polyphenolic compounds in the pigment cells can diffuse out into the adjacent main storage cells. The enzymes breakdown the coloured anthocyanins resulting in some bleaching of cotyledons. As more air reaches, oxidative or browning reactions start to predominate and the tissue darkens.

41.4.2 Cleaning

The adhering pulp and mucous is removed.

41.2.3 Drying

41.2.3.1 Sun-drying

It takes about a week of sunny weather to dry down to 7.0% moisture, needed to prevent mould growth during storage.

41.2.3.2 Forced-air driers

Artificial drying poses two problems

(a) Beans are dried too quickly resulting in beans becoming very acidic.

(b) Smoke may find its way onto the beans, producing unpleasant acrid, smoky or tarry taste.

41.2.4 Cleaning and grading

From the silo storage/burlap bags, cocoa beans pass through cleaning machines: screens, magnets and controlled air streams. The extraneous material removed includes sticks, stones, string and metal objects.

41.2.5 Blending

Substantial variation in flavour exists among cocoa beans, produced in different countries; difference is due to fermentation. Blending provides opportunity to obtain a certain flavour and cope up with inconsistency of cocoa beans in flavor and other quality aspects. This contributes to uniformity.

41.2.6 Thermal pre-treatment

Loosening of cocoa shells by means of a thermal shock; achieved with hot air, saturated steam or infra-red radiation.

41.2.7 Breaking and Fanning (winnowing)

The cocoa shell is polluted with sand, high bacterial count and pesticide residues.

To remove shell, the beans are first broken between adjustable toothed rollers. The broken pieces are subsequently separated in fractions by sieving. Each fraction is treated with a stream of air which carries away the light shell pieces.

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Lesson 42

CHOCOLATE LIQUOR, COCOA BUTTER AND COCOA BUTTER REPLACERS/EXTENDERS

42.1 Introduction

In the previous lesson we learnt about the cocoa bean varieties and some preliminary cocoa bean processing methods. Herein processing of cocoa beans into several products like chocolate liquor, cocoa powder, cocoa butter, etc. will be dealt.

42.2 Processing of Cocoa Bean

42.2.1 Roasting

42.2.1.1 Objectives of Roasting

- Reduction of moisture
- Release of the beans from the shell
- Develop chocolate flavour
- Changes the colour of the beans (nibs) affecting the appearance of the finished chocolate.

42.2.1.2 Batch or Continuous roasters may be used:

- Hot air treatment
- Saturated steam treatment
- Infra-red treatment

Depending on the bean type, the beans are heated to 110-220^{o}C. Temperatures from 70-200^{o}C are reported depending on machine, and also on the use that will be made of the beans.

Certain type of milk chocolate requires beans with a very mild roasting. When pressing process is involved, a high roast is used to: (i) obtain sufficient reduction in bacteria count, and (ii) good reduction in thermo-resistant spores.

Prior to roasting, beans may taste astringent, bitter, acid, musty, unclean, nutty or even chocolate-like. Roasting reduces the acidity; significantly decreases the concentration of volatile acids (especially acetic acid) reducing the acidic taste. Roasted beans possess typical intense aroma of cocoa.

a) Flavour generation

Maillard browning forms glucosylamines or fructosylamines Other compounds formed include pyrazines, pyrroles, pyridines, imidazoles, thiazoles andoxazoles. The pyrazine content of certain cocoa bean types is mentioned in Table 42.1.

Table 42.1. Concentration of pyrazines depending on the cocoa bean utilized

Cocoa bean type	Concentration of pyrazines
Ghanaian roasted beans	698 mg/100g beans
Tobasco beans (Mexico)	142 mg/100g beans

Production of aldehydes from amino acids plays an important role in flavour balance of final chocolate; generation of carbonyls also takes place.

42.2.1.3 Roasting methods

Some of the methods used for roasting of cocoa beans are detailed hereunder.

i) Bean roasting

This involves roasting of whole cocoa beans.

a) Advantage

Loosens the shell making it easier to remove.

b) Disadvantages

i. Shells from raw cocoa beans contain in dry state about 2% fat vs. 5-6% in roasted beans.

ii. Combustion gases produced foreign materials on shell which is detrimental to flavour of cocoa mass.

iii. Energy is lost when the shell is removed.

ii) Nib roasting

a) Advantage

i. Particles roasted are of more uniform size.

ii. Poorer cocoas can be upgraded by use of reducing sugar solutions or other treatments during roasting.

b) **Disadvantage**

It is necessary to remove the shell from unroasted beans.

iii) Mass roasting

It is done continuously in thin-layer columns; need to have particles of a uniform size to obtain uniform heating. Heating can be done in scraped surface heat exchanger.

a) Advantages

i. Uniformity of heat treatment is ensured.

ii. Bacteria on shell gets inactivated; lower initial bacterial count; better microbiological status.

The moisture content is critical for the roasting procedure, which must not be started when the beans have < 2.5% moisture, otherwise poor flavour develops.

42.3 Grinding

The cocoa nib consists of 55% cocoa butter and 45% solid material coming from plant cells; the latter is ground finely. When eating chocolate or drinking chocolate milk, no grittiness should be felt in the mouth.

In cocoa powder/chocolate, we desire a narrow particle size distribution. Grinding confers the following advantages:

- Ø Facilitates pressing operation.
- Ø Improves the rheological properties of chocolate.

Several grinding steps are followed; desired fineness is 15-70 um.

Pre-grinding is carried out with Disc mills, hammer mill, pin mill.

Ultimate fineness is achieved with Triple stone mill, Vertical ball mills (attrittors).

In chocolate industry, roller mills with five rolls are most commonly used for refining the mass; used to grind chocolate mass, after adding preground sugar and milk powder.

42.4 Types of cocoa mass

Cocoa mass may be used for the production of:

(a) Chocolate or

(b) For pressing i.e. production of cocoa butter and cocoa powder.

The mass for processing is already alkalized.

Cocoa powder is either alkalized or non-alkalized. Alkalized cocoa powder contains potassium carbonate, sodium carbonate, sodium hydroxide or magnesium, all of which neutralizes the naturally occurring acids and make the powder easier to dissolve in liquids. Cocoa powder may also contain added starch (i.e. corn starch) to keep it free from caking during storage. Unsweetened cocoa powder is used primarily in baking. Sweetened cocoa powder is often mixed with hot milk or water to product 'hot chocolate' or 'hot cocoa'.

42.5 Quality criteria for cocoa mass

The quality parameters for cocoa mass is presented in Table 42.2.

Table 42.2 Quality criteria for cocoa mass

Parameters	Value
Fat	50-58
Moisture	Max. 2.50
pH	5.2-6.0
Shell content, % Max.	1.75
Total bacteria	Max. 10,000/g
Moulds	Max. 50/g
Yeasts	Max. 50/g
Enterobacteria/g	Negative
E. coli/g	Negative
Salmonella/25 g	Negative

42.6 Cocoa Powder

After roasting and winnowing (removing the outer shell from the cocoa beans) they are ground making cocoa liquor. The heat which is generated melts the cocoa fat thus generating a liquor, and sometimes additional heating is employed. The liquor hardens to unsweetened chocolate when it cools below 35^{o}C.

Pressure is employed to the cocoa liquid (while slightly heated) to remove some of the fat which is referred to as cocoa butter. The remaining cocoa solids contain 10-25% cocoa butter. The solids are then ground to cocoa powder.

Sometimes the cocoa is made alkaline by treatment with potassium carbonate; this is called 'Dutched cocoa'. This gives a darker color and a stronger flavor.

42.6.1 Production of Cocoa powder

The press cakes are ground to powder, which is packed after complete cooling. The alkalizing process can be used to create many types of cocoa powder with differing colours.

42.6.1.1 Alkalizing: It was developed in the 19th century in Holland and hence often referred to as 'Dutching' process. Cocoa nib (less frequently cocoa mass, cake or powder) is treated with an alkaline solution. The process is executed by adding a solution of an alkali (mostly potassium carbonate/potash) to the cocoa; legal maximum being 3% potash calculated on nib.

The process improves the quality of cocoa powder in two ways:

- It results in a milder taste – mainly the result of the neutralization of the light acidity of fermented cocoa beans.
- It makes the colour darker. Careful control of reactions can lead to different shades of colour – Orange, red, brown and even black.

The specific colour is reached by choice of reaction conditions such as temperature, time, amount and concentration of the alkaline solution.

A light alkalization might improve the flavour, if highly acidic cocoa beans are used. The pH of cocoa powder will not be very much above 8.0, even after using the maximum quantity of potash.

42.6.1.2 Pressing

The cocoa mass is pumped to horizontal hydraulic presses, with pots lined up face to face, each equipped with very fine mesh filter screens. When all the pots are filled with mass at a temperature of 90^{o}C, the hydraulic ram is set in motion and the cocoa butter begins to flow through the screens on both sides of pot (each). The pressure is then increased to 400 bars. The hard cocoa cakes remaining are then discharged from the press. Cocoa butter collected also has small amount of tiny nonfat particles and so filtered through filter paper.

42.6.1.3 Blending of cocoa cake, grinding and cooling

Blending of pieces of broken cake before grinding allows standardization of colour, or preparation of blends with intermediate colours.

The press cakes are broken and then ground to powder in pin or other mills. The cocoa powder leaves the mill hot. Hence, it should be completely cooled before packing otherwise the setting fat will turn it into hard lumps inside the package.

42.6.2 Types of cocoa powder

Pressing can be performed to a fat content in the cake of 20% (giving cocoa powder) or to 10% (giving low-fat cocoa powder), while alkalizing process creates many different colours. Cocoa powder with 20% fat is the common household type. The food industry uses mostly low-fat cocoa powder (10%) in many differentcolours.

42.6.3 Packaging, transport and shelf life

Paper or tin is used for retail packaging; for bulk 25 kg multiple paper bags are used. When packed in air and moisture-proof containers, the flavour remains good even after 10 years. Only some fading of colour may be noticed, comparable with fat bloom on chocolate. This disappears when the cocoa is used in milk.

42.7 Cocoa Butter

Pure press butter needs no cleaning at all (besides filtration), but is frequently deodourized for use in milk chocolate in order to obtain the desired milk flavour.

42.7.1 Deodourization and blending

Crude cocoa butter has a strong flavour. This is desirable in dark chocolate.

In milk chocolate much more cocoa butter is used and cocoa flavour would become too strong, suppressing the milk flavour. To get cocoa butter with a weakflavour, or no flavour at all we can resort to steam deodorization of cocoa butter and blending crude and deodourized butter to desired flavour.

42.7.2 Composition of cocoa butter

Palmitic, Stearic and oleic acid generally account for ~95% of the fatty acids in cocoa butter. Of the remaining acids, linoleic acid is present at the highest level. Cocoa butter comprises of 52-57% of the cotyledon dry weight. The triglycerides consist of 37% oleic, 32% Stearic, 27% palmitic and 2.5% linoleic acids (as % of total fatty acids). POS, SOS and POP by far are the predominant triglycerides.

42.7.3 Properties of cocoa butter

Cocoa butter is one of the most expensive natural fats, due to its unique melting behaviour. Some important properties of cocoa butter is provided in Table 42.3.

The quality of cocoa butter is based on:

- Hardness of fat at room temperature, and
- Melting and solidification behaviour.

Table 42.3 Properties of Cocoa butter

Parameters	Pure pressed cocoa butter	Expeller/Refined cocoa butter
FFA, % Max.	1.75	1.75
Unsaponifiable, % Max.	0.53	0.50
Moisture and volatiles, % Max.	0.20	0.20
Iodine value	33-42	33-42

Cocoa butter has a much narrower melting range than any other fat. Cocoa butter starts melting at 31.7^{o}C and is completely fluid at 33.3^{o}C. This quality is fundamental to chocolate. Chocolate should be hard, even in hot weather and it should not stick to the fingers. On eating, the cocoa butter in the chocolate should melt completely in the mouth or else get waxy sensation in the mouth.

At room temperature, a substantial part of the triglycerides in cocoa butter are solid (~60%), whereas all become liquid in the mouth. The melting takes up a considerable amount of heat, causing a cooling in the mouth which greatly contributes to the pleasant taste sensation, when eating chocolate.

When chocolate is cooled and the fat solidifies, a considerable decrease in volume takes place. This contraction makes it easy to release chocolate articles from their moulds.

42.7.4 FSSAI requirement for Cocoa Butter

Cocoa butter means the fat obtained by expression from the nibs of the beans of *Theobroma cocoa L*. It shall be free from other oils and fats, mineral oil and addedcolours. It shall conform to the following standards (Table 42.4):

Table 42.4 FSSAI requirements for Cocoa butter.

Free fatty acids (calculated as % oleic acid)	Not more than 1.5
Iodine value	32 to 42
Melting point	29 to 34^{o}C
Butyro refractometer reading at 40^{o}C OR Refractive Index at 40^{o}C	40.9 to 48.0 1.4530-1.4580
Saponification value	188 to 200

42.7.5 Packaging, transport and shelf-life of cocoa butter

Cocoa butter is packed in 30 kg slabs or transported and stored in a liquid form. The shelf life of cocoa butter is good, due to its high degree of saturation and the shelf life of solid cocoa butter is several months to a year, if properly packed and stored.

42.8 Cocoa Butter Extenders/Replacers

Since Cocoa butter is highly expensive, the food industry tries to utilize some cocoa butter alternatives that may reduce the cost of the resultant product, at the same time have properties similar to the one provided by cocoa butter.

42.8.1 Cocoa butter equivalents (CBE)

They have characteristics and properties similar to those of cocoa butter and can be mixed with cocoa butter in any proportion.

42.8.2 Cocoa butter extenders (CBX)

They do not necessarily have the physic-chemical characteristics similar to those of cocoa butter and they are used as extenders, where partial replacement of cocoa butter is to be used.

42.8.3 Cocoa butter substitute (CBS) fats

They have their own physic-chemical properties which may not be similar to those of cocoa butter. CBS serve as the cheaper source of fats which perform as cocoa butter and which can be processed like cocoa butter. These fats include Sal, Mowrah, Kokum, Mango, etc.

Cocoa butter replacer fats, which replace cocoa butter partially or fully in different chocolate or chocolate products, can be classified into three groups:

(1) Laurics (hydrogenated palm kernel oil or hydrogenated coconut oil)

(2) Hydrogenated fat fractions

(3) Fats with symmetrical disaturated, monounsaturated glycerides, so called cocoa butter equivalents (CBEs).

The first two types are not compatible with cocoa butter and are used in cheaper products. The use of these fats produces blooming and softening of the product. Blooming results from incomplete fat crystallization. The examples of some cocoa butter alternatives are furnished in Table 42.4.

Table 42.5 Cocoa butter alternatives – typical examples, properties and composition

Alternatives	Plant fat types	Functions	Main Triglycerides
Cocoa Butter Equivalents	Palm oil, Illipe butter, Shea butter, Kokum butter, Sal fat	Non-lauric frat, Does not alter the properties of cocoa butter in mixture	POP, POS, SOS
Cocoa butter Replacers	Soya oil, Rape seed oil, Cotton	Partially compatible with different trigylcerides	PEE, SEE
Cocoa Butter Substitutes	Coconut oil, Palm kernel oil, MCT	Lauric fat, suitable for 100% substitution only	LLL, LLM, LMM

P – Palmitic, S – Stearic, O – Oleic, E – Elaidic, L – Lauric, M – Myristic, MCT – Medium chain triglycerides

The fats called CBEs are totally compatible with cocoa butter and can be mixed with it in any proportion without affecting the physical characteristics of cocoa butter. Palm oil contains high amount of POP glyceride; some natural butter such as Shea contain SOS in large quantities and Illipe is rich in both SOS and POS. Thus, a judicious mixture of solvent fractioned palm oil, solvent fractionated shea and illipe make a blend with matches with cocoa butter. Sal or Sal fractions are the main CBE of Indian origin.

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Lesson 43

CHOCOLATE PRODUCTS-I

43.1 Introduction

Although the first chocolate processing plant appeared in 1580, it wasn't until 1847 that the first chocolate bar was manufactured in England and introduced to the popular market.

Chocolate was prepared by roasting the cocoa beans in earthenware pots, before grinding them between stones. The mixture was added to cold water, often with other ingredients such as spices or honey, and whipped to a frothy consistency.

The solid form of milk chocolate is normally attributed to Daniel Peters of Vevey, Geneva in 1876. Over the years, many different flavours of both milk and plain (dark) chocolate have been developed. A sweet centre such as a fondant may be best complemented by a relatively bitter chocolate and vice versa.

43.2 Types of Chocolate

Plain chocolate: It is a homogeneous product obtained by an adequate process of manufacture from one or more of cocoa nibs, cocoa mass, cocoa press cake, cocoa powder including low-fat cocoa powder with sugar and cocoa butter.

43.2.1 Plain covering chocolate

As for plain chocolate, but suitable for covering purpose.

43.2.2 Milk chocolate

It is the homogeneous product obtained by an adequate process of manufacture from one or more of cocoa nib, cocoa mass, cocoa press cake, cocoa powder including low-fat cocoa powder with sugar and milk solids including milk fat and cocoa butter.

43.2.3 Milk covering chocolate

As for Milk chocolate, but suitable for covering purposes.

43.2.4 White chocolate

It is the homogeneous product made from cocoa butter, milk solids including milk fat and sugar.

43.2.5 Filled chocolate

It is the product having an external coating of chocolate with a centre clearly distinct through its composition from the external coating. Filled chocolate does not include flour confectionery, pastry and biscuit products.

The amount of chocolate component of the coating shall not be less than 25% of the total mass of the finished product.

43.2.6 Composite chocolate

It is a blend of milk and plain chocolates in varying proportions.

The formulations for some variants of chocolate are provided in Table 43.2.

43.3 FSSAI Requirements for Chocolate

Chocolate means a homogeneous product obtained by an adequate process of manufacture from a mixture of one or more of the ingredients, namely, cocoa beans, cocoa nib, cocoa mass, cocoa press cake and cocoa dust (cocoa fines/powder), including fat reduced cocoa powder with or without addition of sugars, cocoa butter, milk solids including milk fat. The chocolates shall not contain any vegetable fat other than cocoa butter. The specific requirements for various types of chocolates as specified by FSSAI is shown in Table 43.1.

The material shall be free from rancidity or off odour, insect and fungus infestation, filth, adulterants and any harmful or injurious matter.

The chocolates shall be of the following types:

Milk chocolates is obtained from one or more of cocoa nib, cocoa mass, cocoa press cake, cocoa powder including low-fat cocoa powder, with sugar and milk solids, including milk fat and cocoa butter.

Milk Covering Chocolate is as defined above, but suitable for covering purposes.

Plain Chocolate is obtained from one or more of cocoa nib, cocoa mass, cocoa press cake, cocoa powder including low fat cocoa powder, with sugar and cocoa butter.

Plain Covering Chocolate is same as that of plain chocolate but suitable for covering purposes.

Blended Chocolate means the blend of milk and plain chocolates in varying proportions.

White chocolate is obtained from cocoa butter, milk solids, including milk fat and sugar.

Filled Chocolates means a product having an external coating of chocolate with a centre clearly distinct through its composition from the external coating, but does not include flour confectionery pastry and biscuit products. The coating shall be of chocolate that meets the requirements of one or more of the chocolate types mentioned above. The amount of chocolate component of the coating shall not be less than 25.0 % of the total mass of the finished product.

Composite Chocolate means a product containing at least 60.0 % of chocolate by weight and edible wholesome substances such as fruits, nuts. It shall contain one or more edible wholesome substances which shall not be less than 10.0 % of the total mass of finished product.

Table 43.1 FSSAI requirements for various types of Chocolates

Parameters	Milk chocolate	Milk covering	Plain chocolate	Plain covering	White chocolate	Blended chocolate
Total fat (DB) % Min.	25	25	25	25	25	25
Milk fat (DB) % Min.	2	2	-	-	2	-
Cocoa solids (moisture-free, fat-free) % Min.	2.5	2.5	12.0	12.0	-	3.0
Milk solids (moisture-free, fat-free) % Min. % Max.	10.5 -	10.5 -	- -	- -	10.5 -	1.0 9.0
Sugar (sucrose), DB, % Max.	55.0	55.0	60.0	60.0	55.0	60.0
Acid insoluble ash (Moisture, fat & sugar-free) %, Max.	0.2	0.2	0.2	0.2	0.2	0.2
Microbiological requirements						
E. coli	Absent in 10 g					
Staph. aureus	Absent in 10 g					
Salmonella	Absent in 25 g					
Yeast and Mold	Max. 100 /g					

43.3.1 Packing

Bulk chocolates shall be packed in clean, sound and odour-free containers made of tin-plate, plastic, grease-proof paper, aluminium foil, cellulose film or other suitable flexible packaging materials.

In case of moulded chocolate bars, each unit of chocolate shall be wrapped in aluminium foil, printed or otherwise, and may be lined with glassine or grease-proof paper. Such units may be overwrapped. These units, in turn, shall be collectively packed in clean and odour-free cartons.

43.5 Other Versions of Chocolate Products

43.5.1 Unsweetened chocolate

It contains up to 75.0 % cocoa solids and no added sugar or milk products. It is primarily used for baking, because although it has chocolate flavour, it is too bitter to eat on its own.

43.5.2 Dark chocolate

It is also known as ‘bitter sweet’ or ‘semis weet’ chocolate. It contains a high percentage (up to 75.0%) of cocoa solids, and little (or no) added sugar. Semisweet chocolate has a rich, intense flavour and is found in candies and the chocolate morsels (chips) are used in baking.

43.5.3 Milk chocolate

It contains powdered or condensed milk. It is a sweet, mild-flavoured type of chocolate. It contains approximately 20.0 % cocoa solids. Many candy bars are made with milk chocolate.

43.5.4 Baking chocolate

Both semisweet and unsweetened baking chocolates are available. Baking chocolate is sold in one ounce (28 g) squares, which are convenient for use in recipes.

43.5.5 Couverture

It is a high-quality chocolate used in making speciality candies and truffles. It contains a high percentage of cocoa solids, which gives it a high gloss.

43.6 Legislation of Cocoa Products

Most EEC and USA, the name ‘chocolate’ may only be used if no other fat is present but cocoa butter. Cocoa butter equivalent fats, up to 5.0% of the total chocolate content may be used in UK, Ireland, Denmark and Sweden.

Table 43.2 Formulation for Some Types of Chocolate

Types of chocolate	Cocoa mass,%	Cocoa butter,%	Milk powder,%	Sugar, %
Dark chocolate	40	10	-	50
Milk chocolate	10	20	15	55
Enrobing chocolate	40	15	-	45
White chocolate	-	25	25	50

43.7 Ingredients in Chocolate

43.7.1 Milk solids

Roller dried WMP is preferred over spray dried ones. Roller dried powders tend to have somewhat spicy and salty taste, whereas spray dried ones have a distinct milky flavour. The high content of free suface fat (~ 95% vs. 10% in spray-dried powder) results in favourable rheological properties during the manufacturing steps of mixing and conching. Energy consumption is reduced considerably and the amount of cocoa butter can be reduced (2-3% of cocoa butter) under constant rheological conditions.

Na-caseinate can be used to replace dried milk. Incorporation of buttermilk powder can exert some emulsifier action. Whey products would be advantageous with respect to:

Reducing the sugar content and chocolate liquor.
Enhance flavour.
Give resistance to ‘fat bloom’.

43.7.2 Milk crumb

For milk chocolate, one of the biggest flavour differences between the chocolate made from milk powder (Continental Europe) and the 'Milk crumb' (UK and parts of America). Milk crumb is obtained by dehydrating milk, sugar and cocoa mass. This was developed where milk production was very seasonal. As cocoa is a natural antioxidant, it was possible to improve the keeping properties of the dehydrate form of milk over extended periods without refrigeration. The drying process also produced a distinct cooked flavour, not normally present when the milk is dried separately. Addition of cocoa mass acts a a natural antioxidant and stabilizes the product against rancidity. The essential part is Maillard reaction. The organoleptically active compounds generated add a typical flavour (caramel flavour) to the end product. Such effect and the removal of undesirable flavour elements during the evaporation and drying stages in crumb manufacture reduces conching time considerably.

43.7.3 Crumb recipe

The recipe for 'Crumb' used in chocolate manufacture is as given below:

Moisture 1.0%, Sucrose 53.0%, Milk solids 32.0%, Cocoa liquor 14.0%

43.7.4 Process of making milk crumb

Milk, with or without standardization of fat, is concentrated in a multiple effect evaporator to 30-40% TS. A sucrose solution of ~60% dry matter is added and mixture further concentrated to 88-92% TS under vacuum. When producing 'chocolate crumb', cocoa mass or cocoa powder is added at this stage. A further vacuum drying step follows to obtain a moisture content of < 1.5%.

Atmospheric pressure process: Sweetened condensed milk or reconstituted milk, sugar and water are thoroughly mixed and heated to 74^{o}C and cocoa mass is added and mixed until completely blended with other ingredients. Some water is added to enhance solubility of sugar and to obtain a mixture containing about 70% TS. The premix is concentrated to 94% TS at 125^{o}C in a scraped surface evaporator. Maillard reaction takes place during 2-4 minutes that the paste is in the evaporator. Crystallization of sugar occurs in a specially designed crystallizer. Moisture of the crumb is about 3.5-4.5% at 55^{o}C, when it leaves the crystallizer. In the final stage, the crumb is dried to a moisture content of 1.5-3.0% on an open conveyor.

Where chocolate crumb is used, this dehydrated mixture of condensed milk and cocoa mass is normally preground to a maximum size of 2 mm (0.1 inch). This is then crushed and mixed with cocoa butter in order to provide a suitable paste for processing in a refiner. To make chocolate, only cocoa butter has to be added.

43.7.5 Advantages of using crumb

Darker in colour and higher flavour intensity
Smoother texture and better mouthfeel.

43.8 Butter Oil

It is cheaper than cocoa butter. It can be used to replace 1-5% of total fat (up to 30% replacement attempted). Excess replacement softens the chocolate and has adverse effect on gloss, demoulding and hardening.

43.8 Cocoa butter

It provides flavour, gloss, desired viscosity, keeping quality, nutrition and smooth texture.

43.10 Sugar

Sugar is pre-crushed to powdered or icing sugar before mixing with other ingredients. Impact stressing is the most effective method. For organoleptic reasons, the maximum particle size is 30 mm in chocolate. Minimum size should be 6 mm, if optimum rheological properties are to be achieved in chocolate masse.

43.10.1 Purpose of using sugar

(a) Stabilization of product
(b) Reduced bacterial growth and possibility of lipolytic rancidity
(c) Uniform flavour to product
(d) Balances some of the bitter taste of cocoa

43.11 Emulsifiers

43.11.1 Lecithin

Addition of 0.1-0.3% soya lecithin has the same viscosity reducing effect as over 10 times this amount of cocoa butter. If the level exceeds 0.3-0.5%, thickening of chocolate occurs.

43.11.1.1 Advantages

(a) Prevents fat bloom.
(b) Lowers viscosity of chocolate mass by reducing its surface tension.
(c) Fixes the flavour and essential oils into product.
(d) Exerts an antioxidant effect.

43.11.2 Sorbitan mono-stearate

As it has low solubility (i.e. 0.03%) in cocoa butter at 35oC, polyoxyethylene sorbitan mono stearate acts as a carrier.

43.11.2.1 Advantages

(a) Prevents fat bloom.
(b) Forms a layer on starch, sugar and fibre.

Other surface-active agents are Sucrose esters, Ca-stearoyl lactoyl lactate and Polyglyceryl polyricinoleate better known as ‘Admul-WOL’.

43.12 Flavourings

Vanillin, Coumarin, Essential oils of natural fruits or synthetic; dried fruit and nuts such as figs, raisins, dates, walnuts, almonds, hazelnuts, cashews, etc may be used for flavouring.

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Lesson 44

CHOCOLATE PRODUCTS - II

44.1 Production of Chocolate

The major ingredient of chocolate is cocoa mass, which is mixed with sugar, and in case of ‘milk chocolate’, also with milk powder. The conching process then follows, which is important for the development of full chocolate flavour. Melted cocoa butter is added, the chocolate mass becomes liquid and is cooled, tempered and poured into moulds to form chocolate products. The flow chart for production of Chocolate is given in Figure 44.1.

44.2 Mixing of ingredients

Sugar, cocoa mass and milk powder are intensively mixed forming a dry powder. This powder is pre-ground in various types of mills and then finely ground in a 5-roll refiner. The size of particles in chocolate is between 15-70 mm (average 25 mm). Small operators use vertical ball mills.

Optimum flow properties are required for further processing. The yield value required differs according to the potential use (e.g. hollow moulding or enrobing). The particle size affects both the yield value and the plastic viscosity.

In order to reduce recipe costs, the most expensive major constituent (i.e. fat) should be used in the smallest possible proportion which will give correct flow characteristics.

44.3 Refining

Refining is essentially a grinding process during which the broken cocoa bean cotyledons (i.e. nibs) are further reduced in particle size. The process is high temperature (250^{o}C) for a short time because of the high pressure rollers used. The refining of sugar, cocoa butter and nibs promotes the formation of amorphous sugar which absorbs aromatic components and in turn masks burnt flavours from the sugar due to the high heat of refining.

The roasting process reactions may continue during refining, but it does not affect the flavour to the same degree as roasting. Steel roll refiners are used for precision grinding. An internal water circulation system ensures that the heat generated by the grinding action of the rolls is dissipated evenly and a constant temperature is maintained throughout the length of the roll.

An average palate cannot detect differences in fineness < 35 mm. The finer the chocolate, the better the gloss – as a smoother surface gives greater reflection of light. Finer particles provide greater adhesion and retention of fat, when chocolates are exposed to higher temperatures.

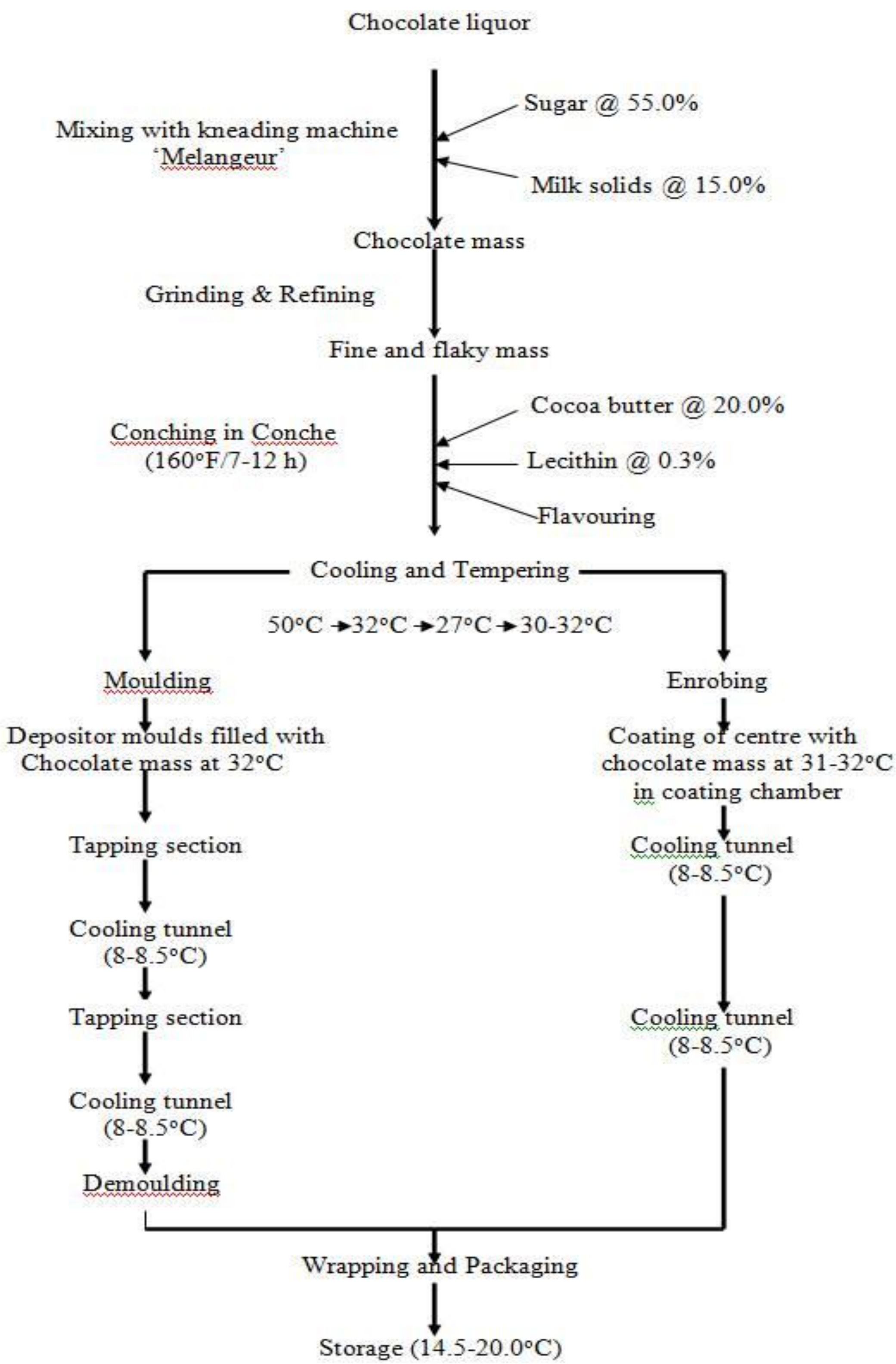

Fig. 44.1 Production of 'Milk chocolate' from cocoa mass

44.4 Conching

It is the working of chocolate flake and crumb into a fluid paste. It produces the finest eating chocolate. It uses a machine 'conche', so named because of its resemblance to the conche shell.

44.4.1 Objectives

The objective of conching are as follows:

(a) Conversion of powdery, crumbly refined product into a flowable suspension of sugar, cocoa and milk powder particles in a liquid phase of cocoa butter.

(b) Allows the chocolate mass to be further mixed.

(c) Removes the undesirable flavour while developing the pleasant ones; bitterness is reduced, perhaps allowing other flavour notes to be more pronounced.

(d) Develops a mellow chocolate with a smooth mouthfeel.

(e) Develops the flow properties as well as flavour by coating the new surface with fat.

It is a mechanical treatment of chocolate mass in large containers fitted with rollers, paddles or a variety of other devices. The refined chocolate mass is placed in longitudinal/circular conche with other ingredients (i.e. cocoa butter, lecithin and flavouring). The outer casting containing granite beds and rollers are designed to hold single or twin pots. The pots are steam-jacketed and the temperature of the mass is thermo statistically controlled. Chemical and physical changes take place under the influence of air, which is brought into the mass, at a temperature of about 60^oC and of rubbing and shearing process. The time taken for 'circular Conche' is about 7-9 hours.

Some manufacturers prefer to limit the conching time by restricting the conching process to primarily one of liquefying the chocolate. This is made possible by treating the cocoa mass at an earlier stage in order to remove some of the less desirable volatile chemicals.

44.5 Type of Conches

Batch Conches – (i) Longitudinal conches, (ii) Rotary (round) conches.

Continuous Conches.

44.5.1 Phases in conching process

44.5.1.1 Dry phase

Shearing, moisture evaporation, removal of other volatiles.

44.5.1.2 Pasty phase

Flavour development by means of shearing and heating, moisture removal, homogenizing.

44.5.1.3 Liquid phase

Homogenizing by means of intense stirring, shearing.

Cocoa butter is added during this phase of conching; chocolate mass becomes liquid.

A 0.15% reduction of moisture content obtained by intense dry conching is equivalent to a 1.5% saving of fat. The final reduction of viscosity is usually made at or near the end of conching by the addition of emulsifying agent lecithin @ 0.3%. One part of commercial lecithin can substitute for 9-10 parts of cocoa butter.Conching is carried out at 82^{o}C for 0 to 24 h or even 44 h.

44.5.2 Effect of conching

In the Conche, the water content of chocolate masse is lowered from ~ 1.6% to 0.6-0.8%. As the moisture is removed, it takes with it many unwanted flavourcomponents. In this way approximately 30% of short chain volatile fatty acids (viz., acetic acid) and up to 50% of low-boiling aldehydes are volatilized. Such removal of volatilized acid component is necessary to give the finished chocolate a full 'rounded' flavour.

The Strecker degradation, which starts during roasting is continued during conching leading to significant formation of free amino acids, contributing to flavourdevelopment.

There is rapid loss of phenols. There is loss of polyphenols through oxidation and enzymatic mechanisms (in tanning process) forming complexes with amino acids, peptides and proteins. The decrease in phenols during conching may be due to irreversible protein-phenol interactions. This reduces the astringency character of phenols, providing a more mellow chocolate after conching. The bitterness of cocoa mass is muted by the coating of the particles with cocoa butter. The same happens with sugar particles also. Clean sweetness of sugar is not as obvious in conched chocolate.

The head space volatiles decreased by almost 80% during the first hours of conching before leveling off. Conching continues the process of changing the Phlobataninscontained in the raw beans into brown or red, insoluble amorphous Phlobaphenes (this determines the colour of chocolate), which has already been partially accomplished by the roasting process (i.e. colour is enriched).

The previous grinding process will have created many surfaces, particularly of sugar, which are not coated with fat. These prevent the chocolate flowing properly when the fat is in liquid state. Conching process coats these new surfaces with fat and develops the flow properties as well as the flavour. The solid particles on being coated with a film of fat give rise to increased palate solubility. There is wearing off of the jagged edges of sugar granules giving chocolate a smooth feeling in the mouth.

44.5.3 Variables affecting conching

44.5.3.1 Temperature

Plain chocolate is conched at 71.1-76.7^{o}C for about 10 h. Milk chocolate is conched at very much lower temperature. It should be sufficient to eliminate the fatty aroma of the milk, but not destroy the characteristic flavour of milk chocolate.

44.5.3.2 Time of conching

Since the temperature of chocolate masse determines the degree of liquidity of the cocoa butter and thus the length of time needed to conche, there exists a relation between time and temperature.

44.5.3.3 Size of particles

Controlling the particle size might allow for maximum conching. Larger particles require less cocoa butter per unit volume of coverage; it is easier to conche. More liquid the cocoa butter, the faster the conching and coating can proceed. The final degree of viscosity is very important; the melted chocolate must be sufficiently thin to fill all the cavities of the moulds.

44.6 Cooling and Tempering

It is critical to the appearance, gloss, shelf life and mouthfeel of chocolate i.e. the way it is cooled before solidifying in moulds.

44.6.1 Objectives of cooling and tempering

To develop a sufficient number of seed crystals to encourage the total fat phase to crystallize in a more stable polymorphic form. This in turn, will produce a better overall contraction and a more stable product.Temper is the induced partial pre-crystallizaiton of cocoa butter. Tempering, in general, involves reducing the temperature of the chocolate to induce crystallization of both stable and unstable polymorphs. The temperature is subsequently raised to a point where the unstable polymorphs melt, leaving only polymorphically stable crystals which can then ‘seed’ the crystallization of the bulk chocolate in a stable polymorphic form.

It is the technique of controlled crystallization, which is necessary to induce the most stable solid form of cocoa butter in the finished product.

44.6.2 Polymorphism of cocoa fat

It is the ability of a molecule to crystallize in a number of different crystal packing configurations.

Six forms: Form I to Form VI

Three forms: a (Alpha), b (Beta prime) and b (Beta)

Form V is the state which is produced in a well-tempered chocolate. On lengthy storage, this can very slowly transform into form VI, a change which would occur after some hours or days. This results in a loss of gloss and the formation of white fat crystals (> 5 μm) on the surface of chocolate, the so-called 'fat-bloom'.

If tempering is omitted, it results in:

(a) Fat bloom and (b) Softening of product.

44.6.3 Tempering process

The tempering steps include the following:

1. Complete melting
2. Cooling to the point of crystallization
3. Crystallization
4. Melting out of unstable crystals.

Tempering for 'Dark chocolate' would be 2-3^{o}C higher than those indicated.

The liquid chocolate at a temperature of 45-50^{o}C is cooled to 32^{o}C, then to 27-27.5^{o}C; stable and unstable crystals are formed during this cooling. The temperature is now raised to 30-32^{o}C, causing the crystals of unstable forms to melt.

The actual temperatures for tempering chocolate vary depending on:

(a) the equipment used

(b) the fat composition of chocolate i.e. type of chocolate.

For instance, 'Milk chocolate' needs lower tempering temperatures than 'Dark' ones.

During tempering, the amount of solid particles is slightly increased and so too is viscosity.

After the tempering, the chocolate is still liquid, ready to be poured into the moulds i.e. pumped into enrobers or into the depositor of the moulding machine.

44.7 Moulding and Enrobing

Chocolate articles are made in two distinct ways (a) Moulding and (b) Enrobing.

44.7.1 Moulding

The chocolate is poured into the mould at 32^{o}C; the filled moulds pass over a tapping section to remove the air bubbles. The moulds then moves on a belt through a cooling tunnel (7.7-8.3^{o}C). After setting, the mould is turned upside down and as a result of volume contraction of cocoa butter, the article will easily fall out of the mould. Solid bars are then ready for packaging.

To make 'Easter eggs' and other 'hollow products', a small quantity of chocolate is poured into a split mould. The mould is then closed and put in a shaking machine to cool. The chocolate sets against the inner wall.

44.7.2 Enrobing

In enrobing, the liquid chocolate is poured over a solid centre. Many different products are made in this manner such as candy bars, biscuits, cakes and ice cream. In the well of the enrobing machine, the chocolate is again agitated gently and maintained at a temperature of 31-32^{o}C. All the centers to be coated should themselves be a 26.1^{o}C, as they enter the coating chamber of the machine.

This prevents undue expansion taking place in the cold centre, which otherwise causes:

(a) burst coatings, or

(b) retard cooling.

The viscosity of the chocolate determines the thickness of the layer. This can be controlled with the fat content of the chocolate, which is usually a bit higher than that of moulding chocolate.

44.8 Cooling

The coated centres pass from the enrober to a cooling tunnel, controlled at a temperature of 7.7-8.3^{o}C. The room should be air-conditioned. The room temperature should not exceed 22.2^{o}C.

To cool and solidify chocolate properly, it must first be allowed to cool gently, in either radiant or gently moving air conditions. If the chocolate leaving the enrober is subjected to fierce cooling, it has effect of drawing the cocoa butter up to the surface of the product, quickly resulting in 'fat bloom'.

The second stage of cooling may be by forced cooling at mild temperature (13^{o}C) or by convection/radiation.

44.9 Packaging

The Packing room conditions should favourably be at 16^{o}C, 55% RH.

The packaging materials should be able to protect product against moisture and against odours, which can easily be picked up by the chocolate fat. The outside of packaging must radiate the delicacy and luxury, which is the image of chocolate.

The packaging materials include decorative foils and papers. Polyethylene films of at least 100 m are used to provide protection against attack by insects. 'Saran' based on polyvinylidene is a vermin resistant package. Multi layered package can include Aluminium foil – Paper or heat-sealed foil – Cardboard box. Amongst the three layers, the centre one is impregnate with insecticide.

44.10 Storage and shelf life

Chocolate with its very low moisture content (< 1.0%) and natural antioxidants has a very good shelf life. The desired storage temperature is between 14.5 to 20^{o}C. However, for 'Dark covered chocolates' and 'Chocolates containing milk fat' storage temperatures of 26.7-29.4^{o}C and 22.8 -25.0^{o}C is recommended respectively.

Irregular storage temperature may cause formation of 'fat bloom'.

Other defects can be:

(i) Sugar bloom

(ii) Production of off flavour upon prolonged storage due to production of delta-lactones (3,5-octadiene-2-one) from lipids.

44.11 Sugar and Fat Bloom in chocolates

Chocolate bloom is a moldy-looking white coating that can appear on the surface of chocolate. There are two types of bloom: Fat bloom, arising from changes in the fat in the chocolate; and Sugar bloom, formed by the action of moisture on the sugar ingredients. The unsightly crystals of fat and sugar bloom limit the shelf life of many chocolates. Chocolate that has 'bloomed' is still safe to eat, but may have an unappetizing appearance and surface texture.

44.11.1 Sugar bloom

While the most common is fat bloom, sugar bloom also occurs and is not necessarily distinguishable from the fat bloom by appearance. In freshly sugar bloomed samples, sugar bloom feels dry and does not melt to the touch, while fat bloom feels slick and melts. With fat bloom, the droplet simply beads up. With sugar bloom, the droplet quickly flattens and spreads, as the water dissolves the microscopic sugar particles on the surface. Alternatively, gentle warming of the surface will cause the crystals of fat bloom to melt, removing the appearance of bloom, while leaving sugar bloom unchanged.

Sugar bloom is caused by moisture. Condensation on to the surface of the chocolate or moisture in the chocolate coating causes the sugar to absorb the moisture and dissolve. When the moisture evaporates, the sugar forms larger crystals, leaving a dusty layer. It is caused by:

- Storage of chocolates in damp conditions
- Deposit of 'dew' during manufacture from damp cooler air or allowing chocolates to enter a packing room at a temperature below the dew point of that room
- Use of hygroscopic ingredients (low grade or brown sugars)
- High-temperature storage conditions of chocolate-covered confectionary, where the centers have a high relative humidity and the water vapor given off is trapped in the wrappings

44.11.1.1 Method to minimize sugar bloom

- Maintain an appropriate storage temperature (< 20^{o}C) for chocolate products. A psychrometric chart is a valuable tool in determining the temperature above which food must be maintained in order to avoid condensation.

44.11.2 Fat bloom

It is generally accepted that visual fat bloom in chocolate is the cocoa butter that has separated toward the surface. It is caused by:

Poor (incorrect/incomplete) tempering of the chocolate

Incorrect cooling methods, including covering cold centers

The presence of soft fats in the centers of chocolate-covered units

Warm storage conditions

The addition to chocolate of fats incompatible with cocoa butter

44.11.2.1 Methods to minimize fat bloom

Maintain an appropriate storage temperature (< 20^{o}C) for chocolate products

Use an appropriate recipe for the fat (use compatible fat extenders)

Add a bloom inhibitor such as surfactants like lecithin

Add seeding crystals

44.12 Uses of Chocolate

Chocolate can be consumed as such.

Much used as an ingredient on or in other foodstuffs e.g. enrobing of biscuits. Chocolate drops go into biscuits. Chocolate used in between wafers.

Chocolate is a popular flavour for desserts, ice cram, cakes, etc.

In UK, milk chocolate with typical crumb caramel note is predominant.

Cocoa flavour combines very well with many others; the popular combinations are Vanilla, peppermint, coffee and orange. Fruit flavours include nuts, cardamom, etc.

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Module 13. Functional foods

Lesson 45

PRESENT AND FUTURE SCOPE OF FUNCTIONAL FOODS

45.1 Introduction

At the time of independence the major emphasis was to increase the food production to feed the people, however after achieving the self-sufficiency the focus shifted towards the quality of food. Food composition specially the protein quality was the major concern in 1960's followed by attention of calorie in diet in 1970's. Wide-spread malnutrition has attracted the attention of food producers, processors and policy makers for inclusion of micronutrient fortification as mandatory in certain staples in 1980's. In the beginning of 21st century people started viewing food from altogether different perspectives. Some cases of cancers, coronary heart diseases (CHD), osteoporosis and many other chronic diseases, have been attributed to our diet. The missing linkage between food consumption and occurrence of increasing awareness among consumers to know which specific molecules present in their food possess disease preventive or curative properties has led to the concept of "Functional Foods". Now the attention of scientific investigations has moved towards exploring the role of biologically active components on human health. Basic temptation in human being towards nature and the products that are natural, for every little disturbances related to health resulted in flourishing of market with products containing various therapeutic ingredients.

Functional foods, pharma foods, designer foods and nutraceuticals are synonymous for foods that can prevent and treat diseases. Epidemiological studies and randomized clinical trials carried out in different parts of the world have been demonstrated or at least suggested numerous health effects related to functional food consumption, such as reduction of cancer risk, improvement of heart health, enhancement of immune functions, lowering of menopause symptoms, improvement of gastrointestinal health, anti-inflammatory effects, reduction of blood pressure, antibacterial & antiviral activities, reduction of osteoporosis. But beyond these known nutrients i.e. vitamins, proteins, milk and milk constituents have clearly more to offer and scientists are scurrying to discover exactly which milk components might fend off specific diseases. But their exact metabolic role and how these can be utilized in designer food need to be elucidated

All over world there has been growing demand for functional foods. Currently Japan leads the world in the production and consumption of functional foods, with more than 100 products on shelf.

45.2 Defining Functional Foods

The term **"functional food"** was first used in Japan, in the 1980s, for food products fortified with special constituents that possess advantageous physiological effects. Functional foods may improve the general conditions of the body or decreases the risk of some diseases and could even be used for curing some illnesses.

Although the term "functional food" has already been defined by many scientific and regulatory bodies, so far there is no universally accepted definition for this group of food. In most countries there is no legislative definition of the term and drawing a borderline between conventional and functional foods is challenging even for nutrition and food experts. To date, a number of national authorities, academic bodies and the industry have proposed definitions for functional foods. The definitions as given by some scientific and regulatory bodies globally are given in Table 45.1. In general, functional foods have been defined as **"foods that, by virtue of the presence of physiologically active components, provide a health benefit beyond basic nutrition"**. The general classes of functional foods are given in Table 45.2.

Table 45.1 Definition of functional foods as given by various scientific and regulatory bodies

Institute of Food Technologists **(IFT), USA**	Foods and food components that provide a health benefit beyond basic nutrition (for intended population) including conventional foods, fortified, enriched or enriched foods and dietary supplements. They provide essential nutrients often beyond quantities necessary for normal maintenance, growth and development and/or other biologically active components that impart health benefits or desirable physiological effects.
International Food Information Council**(IFIC)**	Any food or food component that may provide a health benefit, beyond basic nutrition.
Food and Nutrition Board of the National Academy of Science**(USA)**	Potentially healthful products that may include any modified food or food ingredient that may provide a health benefits beyond the traditional nutrients it contains.

However, under Indian food laws functional foods have not yet been defined. Food Safety Standard Authority of India (FSSAII) have initiated for defining functional foods and formulating regulations related to their development, labeling and marketing.

The concept of Functional food is not new in India and it is more closely associated with Indian System of Medicine (ISM) popularly referred as '*Ayurveda*" in which many plant and milk based products are used for curing the various diseases since ages. For a lay man functional foods are normal foods that provide essential nutrients and also contain certain compounds which are helpful in preventing certain diseases.

To qualify as functional food, the food should meet following conditions:

- Food (not capsule, tablet or powder) derived from naturally occurring ingredients.
- It can and should be consumed as part of daily diet.
- When ingested it has capacity to regulate or influence certain physiological processes, such as

1. Improvement of biological defense mechanisms i.e. immune enhancer
2. Prevention and recovery of specific disease i.e. repair of tissue injury
3. Control of mental and physical conditions i.e. regulating the nervous system
4. Retard the ageing process i.e. check degenerative processes

Many food items which we consume since centuries possess certain health promoting components for example whole grains like wheat, rice, barley, millets etc. provide dietary fibers that assist in regulating the bowel movements, prevent constipation and also prevent the absorption of cholesterol from Gastro-Intestinal (GI) tract. Similarly fermented foods possess nutrients in pre-digested form, improve the bioavailability of micronutrients and assist in excretion of toxic compounds formed during the normal metabolism from the body.

Table 45.2 Some examples of functional food

Classes of Functional Foods	**Definition**	**Example**
Fortified product	A food Fortified with additional nutrients	Vanaspati (vegetable ghee) fortified with Vitamin A
Enriched products	A food with added new nutrients or components not normally found in a particular food	Margarine with plant sterol ester, Inulin (soluble fiber) containing yoghurt
Altered products	A food from which a deleterious component has been removed, reduced or replaced with another substance with beneficial effects	Lactose hydrolyzed milk, Low calorie sweets based on artificial sweeteners
Enhanced commodities	A food in which one of the components has been naturally enhanced through special growing condition, new feed composition, genetic manipulation.	Conjugated Linoleic Acid (CLA) enhancement in milk through feeding of green fodders, Golden rice

There are many other terms which are used for denoting to similar kind of food products available in market. These products are explained hereunder.

45.3 Nutraceuticals

Term “Nutraceutical” consists of two words “Nutrition” and “Pharmaceuticals”. It was coined by Stephen DeFelice, Chairman, Foundation for Innovation in Medicine (FIM). He defined “a food or part of food that provides health benefits including the intervention and treatment of a disease”. It means nutraceuticals are either food or dietary constituent that positively improve the health status of individuals by modulating the body functions. Nutraceuticals could be considered as broad group under which functional foods, functional beverages and dietary supplements are included. Nutraceuticals are those available in the form of powder, pills and capsules.

Examples of Nutraceuticals include β-glucan in oat and barley that assist in preventing the cholesterol absorption and improve cholesterol status in cardiac patients. Supplementation of diet with micronutrients like iron and calcium assist in recovering from anaemic and osteoporotic conditions.

Nutraceuticals are considered to fall in between the continuum of diet and medicines. Certain classes of Nutraceuticals which have been identified are listed here under.

45.3.1 Dietary supplements

These are known as nutritional supplement or food supplement. These are preparations which are developed to complement the diet and provide nutrients, such as vitamins, minerals, fiber, amino-acids, fatty acids, etc. which may either absent or available in low amounts in food that one consume. In some countries Dietary supplements are included in the category of foods whereas in other nations it has been classified as drugs. The recent list also includes botanicals, herbs, and enzymes in the list of dietary supplements.

45.3.2 Functional foods

Functional foods are those foods that provide additional health benefits besides delivering nutrients when consumed. They possess certain health promoting components that might have disease preventing or disease alleviating role.

45.3.3 Functional beverages and drinks

These are those beverages or dink that exhibit health promoting attributes by being rich in certain health promoting components. These may be helpful in improving the health or in sustaining the normal healthy life. Traditional functional beverages include sports or high energy drinks that meet the requirement of quick energy and electrolytes for athletes. Newer type of products consists of fortified fruit juice, probiotic dairy beverages, high calcium beverage and malted milk beverage.

45.4 Medical Foods

Medical food are foods that are specially designed to meet the nutritional requirement of critically ill persons or for those persons who are having diverse kind of nutritional needs which cannot be provided by simple diet. These products can be differentiated from the broader category of foods meant for special dietary use like geriatric and any other category of functional foods. In order to be called as medical food it must meet following requirements:

- Be a food for oral ingestion or tube feeding
- Be labeled for the dietary management of a specific medical disorder, disease or condition for which there is distinct nutritional needs
- Be intended to be used under medical supervision.

Medical foods could be classified into following groups:

I. Nutritionally complete formulas
II. Nutritionally incomplete formulas
III. Formulas for metabolic disorders
IV. Oral rehydration products

The food developed for allergic persons such as lactose intolerant or gluten intolerant persons belongs to the Medical foods. Likewise persons suffering with renal disorders or those required to undergo some major surgery needs specialized foods.

45.5 Significance of Functional Foods

In recent years, there has been a vast and rapidly growing body of scientific data showing that diet plays an important part in diseases. Diet is thought to contribute to 6 of the 10 leading causes of death. Widespread malnutrition or under nutrition in our country is mainly due to the absence of certain key macro as well as micronutrients in foods the people consume. Inadequate nutrition contributes to more than 40% mortality and 30% of overall disease burden in the developing countries.

In India, around 380 million people are under nourished and needs all basic & essential nutrition for normal growth and adequate life-span. On the other hand, 570 million people consume a diet normally adequate in calorie but lack micronutrients or they may have condition specific dietary requirements. This segment also consists of diabetic and CHD persons. According to survey conducted in 2011 the population of diabetic person to 50.8 million which is highest among the world. It is expected that 60% of the heart patients will be in India by 2016. Almost 2 million people have lost their life in last year only because of the cardiac ailments. Surprisingly half of the heart patients are below the age of 40 years. 36 million Indians are suffering with osteoporosis, a bone degenerative disease affecting the strength of bone and occur due to calcium deficiency. Anaemia is a major killer in our country and it is estimated that every second women is anemic. The situation is even more alarming among children as more than 50% children below the age of five are suffering with moderate to severe anaemia. The mortality and disease burden is costing about 1 percent of our National GDP.

Nutrients and nonnutritive food components have been associated with the prevention and/or treatment of chronic diseases such as cancer, CHD, diabetes, hypertension, and osteoporosis. According to an estimate about 70% of certain cancers are directly related to the type of food we eat. As the data supporting the role of diet in health promotion and disease prevention continue to mount, it is likely that the quantity of enhanced foods will expand substantially. There is an increasing demand by consumers for quality of life, which is fueling the nutraceutical revolution. Functional foods are viewed as one option available for seeking cost-effective health care and improved health status. Moreover, the large segment of the population is ageing and considerable health care budget in most country is focused on treatment rather than prevention. Thus, the use of nutraceuticals in daily diets can be seen as means to reduce escalating health care costs that will contribute not only to a longer lifespan, but also more importantly, to a longer health span.

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Lesson 46

PHYTOCHEMICALS IN RELATION TO HUMAN HEALTH

46.1 Introduction

Increasing awareness among consumers to know which specific molecules present in their food possess disease preventive or curative properties has led to the concept of "Functional Foods". In human being there is always temptation to move towards nature and the products that are natural, for every little disturbance related to health. In our country "Ayurveda" system of medicine exists since centuries. It is mainly based on the preparation or extracts from natural plant products.

Nutritional significance of plant molecules is well documented and increasing cases of cancers, cardio vascular diseases (CVD), diabetes and many other chronicdiseases, have been attributed to under consumption of fruits and vegetables in our diet. But beyond these known nutrients (vitamins, fibers) plants have clearly more to offer and scientists are studying to discover exactly which plant components might fend off specific diseases. The bioactive molecules are commonly termed as plant chemical or phytochemicals.

46.2 Defining Phytochemical

Consumption of fruits and vegetables has since long been associated with lesser incidences of certain diseases like cataract, scurvy, cancer and CVD in populations consuming them. The disease prevention ability of fruits and vegetables is mainly attributed to the phytochemicals present in minor quantities.

"Phytochemicals"- consisted of two words "Phyto" and "Chemicals"."Phyto" from Greek word for plants, denoting their plant origins and it refers to the chemicals which are present in plant. These phytochemicals are secreted or developed as a part of the plants own defense mechanism against environmental insult and fortunately beneficial to human beings. These phytochemicals are very effective anti-oxidants thus checks free radical mediated degenerative diseases like cancer, CHD etc.

The number of identified physiologically active phytochemical has increased dramatically in the last decades and overwhelming evidence from epidemiological, in vivo, in vitro and clinical trial indicate that plant rich diet can reduce the risk of certain chronic diseases. Health professionals are gradually recognizing the role of phytochemicals in health improvement.

46.3 Prospective Phytochemicals

Some phytochemicals with proven health benefits can be grouped under following categories.

46.3.1 Phytoestrogens

Phytoestrogens are a broad group of plant-derived compounds that structurally mimics endogenous 17 beta-estradiol. Two major phytoestrogens, which are of great importance from nutritional and health perspectives, include lignans (Flaxseed) and isoflavones (soy bean).

Isoflavones are flavonoids compounds and major flavonoids that have been identified in soybeans are genistein, daidzein and glycitein. These compounds exist naturally in soy bean in several glycoside forms, but it is the aglycone form that is biologically active.

These compounds either compete with/antagonize estradiol action. Dietary soy products showed antitumor activity, by directly affecting the tumor cell proliferation and reduction in tumor angiogenesis (microvessle density). Research has shown that diets rich in soya help to reduce blood levels of Low Density Lipoprotein (LDL also called as bad) cholesterol by an estimate of 12-15%. The isoflavones in soy foods are converted in the gut to phytoestrogens that may reduce LDL blood cholesterol.

46.3.2 Organosulphur compounds

These compounds are also called as “Promise of Garlic”. Garlic and other alliums are popular recipe seasoning, but these also have long been promoted as a medicinal agent. Garlic and other alliums – onions, chives, leeks and scallions contain allylic sulphides.

Garlic has acquired a reputation as a formidable prophylactic and therapeutic medical agents. Plant extracts containing organosulfur compounds have been shown to exhibit antimicrobial, hypolipidemic, hypoglycemic, antithrombotic, antioxidant and anticarcinogenic. The anti-hypertensive properties of garlic are believed to be the major preventive factor. Animal studies indicate that garlic supplementation in diet depressed the hepatic activities of lipogenic and cholesterogenic enzymes such as malic enzyme, fatty acid synthase, glucose-6-phosphate dehydrogenase and 3-hydroxy-3-methyl-glutaryl CoA (HMG-CoA) reductase.

Active components identified is a family of thioallyll compounds and the intact garlic bulb contain an odorless amino acid called alliin, which is converted enzymaticallyby allinase into allicin, when the garlic cloves are crushed. Formation of allicin is responsible for characteristic garlic flavour. Allicin then immediately decomposes to form numerous sulphur-containing compounds.

Epidemiologic studies have established an inverse relationship between garlic consumption and the incidence of certain types of cancer including gastrointestinal, laryngeal, breast and colon cancer. The proposed mechanisms includes, inhibition of N-Nitroso compounds formation, suppression of metabolic activation of carcinogen, enhanced DNA repair, reduced cell proliferations and /or induction of apoptosis. It is believed that many of these events occur simultaneously at cellular level and are responsible for chemoprotection role of garlic compounds.

46.3.3 Glucosinolate

About 100 glucosinolate have been identified in more than 450 plant species including 16 higher plant families, marine sponges and red algae. Cruciferous vegetables comprising of cauliflower, broccoli, radish, horseradish, cabbage, Brussels sprout contain relatively high content of glucosinolate, a potent anti-carcinogen.Glucosinolate (GS) are a group of glycosides stored within cell vacuoles of all cruciferous vegetables. The function of glucosinolate in plants is not very clear but their potent odour and taste suggests a role in herbivore feeding and microbial defense. Glucosinolate consist of a β-D-thioglucose group; a sulfonated oxime group and a side chain derived from methionine, phenylalanine, and tryptophan or a branched chain amino acid. The sulfate group of a GS molecule is strongly acidic and plants accumulate GS by sequestering them as potassium salts in plant vacuoles. GS is not bioactive in animals until they have been enzymatically hydrolyzed to an associated isothiocynates.

Myrosinase, an enzyme found in plant cell, catalyze these GS to a variety of hydrolytic products, including isothiocynates indoles. Di-indolylmethane (DIM), indole-3-carbinol (I3C), phenethly isothiocynate (PEITC) and sulphoraphane seems to be promising chemo preventive molecules, in Brassica plants. These cause induction of phase I and II xenobiotic metabolizing enzymes that results in the inhibition of the oxidative activation of carcinogens. Phase I enzymes are mainly related with detoxification mechanisms and composed of Cytochrome P_{450} family of enzymes. These act as first line of defense against foreign compounds. The oxidation product of Phase I enzyme reactions are further transformed into water soluble compounds by the activity of Phase II enzymes, which are ultimately removed from the body via urine or bile. These reactions are conjugation ones. Hence, toxic compounds are removed from the body without affecting the cells, DNA, RNA or proteins. I3C may reduce cancer risk by modulating estrogen metabolism. The C-16 and C-2 hydroxylation of estrogens involve competing cytochrome P-450-dependent pathways, each sharing a common estrogen substrate pool. Another isothiocynate isolated from broccoli, “sulforphane” has been shown to be the principal inducer of a particular type of phase-II enzyme, quinone reductase.

46.3.4 Carotenoids and flavonoids

Carotenoids are major pigments in majority of fruits and vegetables, algae, certain fungi and bacteria. They are responsible for characteristic deep red, yellow or orange colour of foods including tomato, carrots, citrus fruits, egg yolk, cow milk, liver, lobster and salmon. Many green colour plants also contain carotenoids which are masked by the chlorophyll specially in green leafy vegetables like spinach, cabbage, lettuce and mustard leaves. Structurally carotenoids consist of C-40 poly-isoprenoid with an extensive conjugated double bond system. Of the 600 or so carotenoids that have been identified, about 50 serve as precursors for vitamin A. Out of which 50-60 percent are typically present in diet and around 18 have been identified in human plasma. These carotenoids are grouped into two major classes namely carotenes (hydrocarbon carotenoids) and xanthophyll (oxygenated carotenoids). The various dietary carotenoids are listed in Table 46.1.

Table 46.1 List of various dietary carotenoids and their sources

S. No.	Carotenoids	Source	Remarks
1	α-Carotene	Carrot, Lemon, Water melon, Papaya, Banana, Pumpkins. Squash	Precursor of Vitamin A
2	β-Carotene	Apricot, Oranges, Mango, Papaya, Pumpkin, Carrot, Spinach, Red pepper, Crude Palm oil	Pro-vitamin A activity, Anti-oxidant prevent cancer and check conversion of LDL cholesterol into its atherogenic form
3	Lycopene	Tomato, Water melon, Pink Guava. Red Grapefruit, Pink Papaya	Higher amount in deep red coloured tomatoes, lack Vitamin A activity but higher singlet oxygen scavenging activity, prevent cancer
4	Lutein	Spinach, Egg yolk, Broccoli, green bell pepper	Required for protection of macula in retina, play role in age related macular degeneration (AMD)
5	Cryptoxanthin	Mango, Tangerine, Orange, Papaya, Apricot,	Possess pro-vitamin A activity and free radical scavenging activity
6	Zeaxanthin	Kale, Collard, Turnip green, Spinach, Brussels Sprout	Similar function as Lutein also assist in prevention of cataract
7	Capsanthin	Paprika, Red Chili	Exhibit anti-oxidant activity and act as Vitamin A precursor

Among the carotenoids as mentioned above β-carotene & lycopene, have been thoroughly investigated for their disease preventing ability. Carotenes are tissue specific in their biological activity. b- Carotene, a–carotene and e-carotene have vitamin A activity. Vitamin A regulates the action of certain genes associated with cellular functions.

46.3.4.1 Lycopene and cancer prevention

Tomatoes with their distinctive nutritional attributes may play an important role in reducing the risk of cardiovascular and associated disease through their bioactivity in modulating disease process pathway.

Cis–isomers of lycopene are more readily absorbed through the intestinal wall into the plasma because of the greater solubility in micelles, preferential incorporation into chylomicrons, lower tendency to aggregate and crystallize more efficient volatilization in lipophilic solutions, and easier transport within cells, across plasma membrane and tissue matrix. The greatest increase in cis-isomer formation occurs when tomato products are heated at very high temperatures. Likewise, lycopene bioavailability increases in the presence of oil.

Lycopene's ability to act as an anti-oxidant and scavenger of free radicals that are often associated with carcinogenesis is potentially a key for mechanism for its beneficial effects on human health. Lycopene may prevent carcinogenesis and athrogenesis by interfering passively with oxidative damage to DNA & lipoproteins. Lycopene is the most effective quencher of singlet oxygen in biological system.

46.3.4.2 Flavanoids

Flavonoids are polyphenolic compounds and were originally regarded as nutritionally inert, are implicated in anticarcinogenic properties. A great deal of attention has been directed to the polyphenolic constituents of tea, particularly green tea. Catechins are the predominant and most significant of all tea polyphenols. The four major green tea catechins are epigallocatechin-3-gallate, epigallocatechin, epicatechin-3-gallate and epicatechin.

However, epidemiological studies are inconclusive; on the other side research findings in laboratory animals clearly support a cancer chemopreventive effect of tea components. Other flavonoids, with promising health stimulating effects include quercetin, kaempferol, myricetin, apigenin and luteolin. Source of these compounds are chocolate, cocoa, fruit juices, nuts, red wine, raspberry, blackberry and citrus fruits.

46.3.5 Phytosterols

Phytosterols are another important terpenes subclass. Two sterol molecules that are synthesized by plants are b-sitosterol and its glycoside. In animals, these two molecules exhibit anti-inflammatory, anti-neoplastic, anti-pyretic and immune-modulating activities. A proprietary mixture of b-sitosterol and its glycoside were tested*in vitro*, in animals and in human clinical trials. Phytosterols were reported to block inflammatory enzymes, for example by modifying the prostaglandin pathways in a way that protected platelets. In the body, phytosterols can compete with cholesterol in the intestine for uptake, and aid in the elimination of cholesterol from the body. Saturated phytosterol appears to be more effective than unsaturated ones in decreasing cholesterol concentration in the body. These actions reduce serum or plasma total cholesterol and LDL cholesterol. In mammals, concentrations of plasma phytosterol are low because of their poor absorption from the intestine and their faster excretion from liver, and metabolism to bile acids, compared to cholesterol.

46.4 Other Phytochemicals

There are certain other compounds present in plant foods, with significant health promoting effect include plant fatty acids, tocotrienols, phenolic derivatives and dietary fibers etc. Docosahexaenoic acid (DHA), which is one of the most important structural component of brain and retina, and de-novo synthesis of DHA, is very rare. The decline in DHA intake could have serious implications for public health, since low plasma, DHA concentrations have been correlated with increased incidence of a number of chronic diseases such as depression, attention deficit disorders and Alzheimer’s dementia. *Crypthecodinium cohmii* a marine algae is used for the commercial production of DHA rich oil. Spirulina, termed as wonder alga is one of rich source of ω-3-fatty acids, quality protein and many other therapeutic molecules.

Plant polyphenols are secondary metabolites widely distributed in higher plants. These are water soluble and varying molecular weight. Polyphenols historically have been considered as anti-nutrients, because some of them such as tannins may affect the activities of digestive enzymes and adversely affect the digestibility of starch, protein and amino acid. Many polyphenol inhibit mineral uptake and have toxic effects. Recognition of the antioxidant activities of many polyphenols has created interests among the researchers for evaluating their prospective health benefits.

46.5 Promising Functional Foods Based on Phytochemicals

Nutrients dense foods that provide benefits beyond basic nutrition have been already developed and commercially available. Such foods can be defined as **"An accepted and tolerable food that has natural, naturally concentrated phytochemical derived from fruits and vegetables or related food ingredients thatare:**

- indicated to be epidemiologically important in disease prevention,
- have shown to be useful in preventing cancer or other chronic diseases in animal bioassays,
- are unique in structure, class, pattern and metabolism.

The concept of fortification is not new and some new formulations based on phytochemicals are discussed here:

46.5.1 Functional drinks & beverage

The beverage market is on the cutting edge in functional food development. Energy drinks, isotonic (spare) beverages, herbal and green teas, fortified waters, smart drugs, caffeinated drinks and fringe. Beverages are relatively cheap to blend, fortify, bottle and distribute. Tea and coffee, constituents can be incorporated into new formulations with other phytochemical to develop herbal drinks. Recently the anti-oxidants or free radial scavenging ability of ascorbic acid, β-carotene, lycopene andtocopherols has been exploited in development of fortified drinks. Free radicals are formed by auto-oxidation, photosensitization, enzymatic reactions and due to pollutants. Some of the fruits and vegetables more important ones from beverage formulation standpoint include licorice, ginger, tea, citrus, carrots, tomatoes berries, mint and other herbs and spices.

46.5.2 Functional dairy products

In recent years, yogurts with oligosaccharides have been developed. These cultured dairy products may also incorporate isoflavones from soy protein, β-glucan of oat, carotenoids and flavonoids of certain fruits in their formulation. Blackberry and raspberry as fruits or their extracts added in ice creams, dairy drinks, frozen desserts, not only as flavouring component, but also as source of anthocyanin and other phenolic derivatives. Similarly imitation dairy products may also include ω-3-fatty acids from flaxseed oil and DHA from algae. Some infant formula have already available in market containing DHA. Dairy analogue, primarily based on soymilk, may be modified to increase the level of phytoestrogens, particularly isoflavones

46.5.3 Confectionery products

Bars either based on fruits or on cereals may serve as vehicle of phytonutrients. Commercially a wide variety of nutritional bars has been developed for specific purpose. These bars can be enriched with fibers, anti-oxidants, phenolic substances and glucosinolate. Oat bar, based on soluble oat fibers, also contain ω-3-fatty acids to further strengthen its heart health image. Fruit preserves, fruit spreads, have been developed, using traditional herbs and products were further enriched by adding other phytonutrients.

Chocolate considered as a culprit for CHD, obesity and dental problems, also moves into healthy arena. The chocolate has neutral effect on cholesterol levels and posses lower levels of caffeine, as compared to beverages. The anti-oxidant activity of polyphenols and potential benefit of procyanidins and epi-catechins on CHD could be an added advantage in consuming chocolate products.

46.5.4 Breakfast cereals

Raspberries and blackberries, reservoirs of phytonutrients are considered as good option available for cereal product formulations. Initial studies conducted with DHA in bread are encouraging. Likewise, breads with garlic compounds and isothiocynates from cruciferous vegetables are prospective options. Soy flour is already an important ingredient in bread, not only because of its nutritional significance, but excellent functional properties it imparts.

However, the incorporation of these phytochemicals in processed food product is a challenging task. Various issues associated with utilization of phytochemicals in development of novel food formulations are as follows:-

- Isolation and efficacy of active components
- Stability in new product system (oraganoleptic acceptability, interaction with food constituents and possible implications)
- Safety and bioavailability
- Minimum dose required; no information is available regarding the minimum amount which must be consumed to get the desired health benefit
- Economics; definitely novel foods with phytochemicals will be costly if compared with their counterparts.

Therefore future research should be targeted to address above-mentioned issues. It would be possible by identifying the optimal marker (i.e. bioactive component) that can be quantifying easily in processed foods at different stage of production, processing, storage and marketing. A detailed investigation related to mechanism of action is also desirable that could provide information pertaining to their absorption, metabolism, interaction with other dietary components and excretion.

46.6 Safety Issues

The optimal levels of the majority of the biologically active components currently under investigation have yet to be determined. In addition, a number of animal studies show that some of the same phytochemicals (e.g.allyl isothiocynate) highlighted in this lesson for their cancer-preventing properties have been shown to be carcinogenic at high concentrations.

The benefits and risks to individuals and populations as a whole must be weighed carefully when considering the widespread use of physiologically-active functional foods. For example, what are the risks of recommending an increased intake of compounds (e.g. isoflavones) that may modulate estrogen metabolism?

Soyphytoestrogens may represent a “double-edged sword” because of reports that Genstein may actually promote certain types of tumors in animals. Knowledge of toxicity of functional food components is crucial to decrease the risk: benefit ratio.

Lesson 47

MILK INGREDIENTS AS NUTRACEUTICALS

47.1 Introduction

Milk is considered as nature's perfect food, that besides meeting the nutritional requirements for the people of all ages also possess wide array of bioactive components. In recent years nutraceuticals and bioactive molecules present in milk have attracted a lot of attention from researchers, nutritionist, medical practitioners, and consumers alike. Since time immemorial, dairy products have been an integral part of human diet. Milk is the only food, which has got the power to sustain life in all the stages of development, and is considered an important part of a balanced diet. It is known to possess 500 different compounds, most of them having certain unique nutritional and disease preventing ability. Besides being a source of quality proteins and energy–rich fat, it contains important micronutrients like calcium, potassium, sodium, magnesium and vitamins, which are vital for overall development of the human body. Also, several health attributes are associated with milk or its constituents.

- Role of calcium in controlling hypertension and colon cancer
- Protective role of carotenenoids and conjugated Linoleic acid (CLA) against cancers
- Butyric acid, the short chain fatty acid has been shown to regulate cell growth and enhance the anti-tumor activities

Certain minor milk components either naturally occurring or formed during processing have also been endowed with many unique health benefits. Examples include lactoferrin, lactulose, galacto-oligosaccharides (GOS), conjugated linoleic acid (CLA), β-lactoglobulin, and bioactive peptides. Some of the important classes of functional dairy foods and nutraceuticals are listed below:

Table 47.1 Examples of functional components in milk and milk products

Class/Components	Source	Potential Benefit
Probiotics		
Lactobacilli, Bifidobacteria	Fermented dairy products like *dahi*, yoghurt, *lassi*, cheese	Improve gastrointestinal health and systemic immunity
Fatty Acids		
Conjugated Linoleic Acid (CLA)	Fat rich dairy products, fermented milk products	Anti-cancer, Anti-atherosclerosis and anti-diabetics

Whey Proteins		
β-Lactoglobulin	Milk, Whey	Enhanced synthesis of glutathione, a natural antioxidant
Lactoferrin	Whey, Colostrums	Anti-bacterial, increase bioavailability of iron
Prebiotics		
Lactulose	Heated milks, Synthesized from lactose	Bifidogenic factor, improve GIT conditions in infants, laxative, prevent allergy
Galacto-oligosaccharides (GOS)	Fermented foods, Galactosyltransferase activity of microbes	Promote growth of probiotic bacteria, anticancer, increase mineral bioavailability
Bioactive Peptides from Milk Proteins		
Caseino-phosphopeptides (CPP)	Fermented milks, Proteolysis of casein in GI tract	Mineral binding specially calcium
Casomorphins	Proteolysis of α & β- casein	Increased intestinal water & electrolyte absorption, increased GI transit times

47.2 Milk Proteins and Derivatives as Therapeutic Components

Proteins are the building blocks of the growing tissues and inadequate quantity may impair the physical and mental development of the individuals. The nutritional quality of dietary protein is essentially related to its amino acid composition as well as to the availability of these amino acids. In this respect milk proteins have a high content of essential amino acids. The body requirement of proteins varies with age and milk proteins have long been considered as food protein for young ones. Apart from being a rich source of essential amino acids, milk proteins contribute to the sensory attributes and consistency of meat, dairy and bakery products. Furthermore many milk proteins possess specific biological properties which make them potential ingredients of health promoting foods.

The milk protein consists of numerous specific proteins that is primarily composed of casein. Casein constitutes about 80% of total milk proteins, remaining 20% are whey proteins. The major whey proteins in milk are β-Lactoglobulin (β-Lg), α-Lactalbumin (α-La), bovine serum albumin (BSA), immunoglobulin (Ig) and proteose peptones (PP).

Table 47.2 Comparative presentation of various milk protein fractions is

Protein fractions	Concentration in milk	
	Buffalo	Cow
α-s1 Casein (g/100 ml)	1.44 - 1.8	1.0
α-s2 Casein (g/100 ml)	0.22 – 0.28	0.26
β-Casein (g/100 ml)	1.26 - 1.58	0.93
κ-Casein (g/100 ml)	0.43 - 0.54	0.33
β-Lactoglobulin (mg/100 ml)	0.39	0.32
α-Lactalbumin (mg/100 ml)	0.14	0.12
Lactoferrin (mg /L)	5 – 32	5 – 28
Bovine Serum Albumin (mg/100 ml)	29	40
Immunoglobulins (mg/100 ml)	9.8	38
Proteose-peptone (µg/100 ml)	172	220

47.2.1 Milk casein

Casein is composed of several almost similar kind proteins which form a multi-molecular granular structure called casein micelles. They contain casein molecules, water; salt specially calcium and phosphorus and certain enzymes. Casein micelles contain 4 types of casein molecules namely $\alpha_{s\text{-}1}$, $\alpha_{s\text{-}2}$, β and ǩ-casein which are bound together by amorphous calcium phosphate. Milk casein exhibits excellent digestibility and unique amino acid composition. Nutritionally casein is known to improve the bioavailability of certain vital minerals including calcium, phosphorus, iron and zinc. However casein on hydrolysis yields various physiologically active peptide. These bioactive peptides are most sought milk derived nutraceuticals nowadays.

47.2.2 Whey proteins as prospective nutraceuticals

Proteins can be separated from whey using ultrafiltration with or without diafiltration technologies. During this process low molecular weight compounds (lactose, non-protein nitrogen, vitamins and minerals) are removed from whey to permeate. The remaining proteins are, in turn, concentrated in the retentate. In general, whey proteins are globular, smaller in size, and heat denaturable. Whey proteins have high nutritional and functional properties and are capable of fulfilling the diverse attributes to satisfy different forms of utilization.

Whey proteins are rich source of all essential amino acids. The Biological Value of 104 and Protein Digested Corrected Amino Acid Score (PDCAAS) of 1.0 for whey protein are quite high. The proportion of sulphur containing amino acids i.e. cysteine and methionine is reported to be higher than that of meat, soy and casein. Whey proteins provide more than 100% of the requirement for sulphur amino acids for growing human being, whereas plant protein is limiting in these amino acids. Tryptophan, which acts as building block for niacin, is present in higher amount in whey proteins. Therefore, whey protein based functional foods can be developed for different groups.

47.2.2.1 β-Lactoglobulin (β- Lg)

It is major whey proteins present in the milk bovine but absent in human milk. In bovine milk it comprises of 10% of the total milk protein or about 50% of whey protein. β-Lg has a free sulfhydryl group which is responsible for its interaction with κ and $\alpha_{s\text{-}2}$ casein through the formation of disulfide bridges on heating. β-Lg is very resistant to proteolytic enzymes of stomach and due to this unique property, β-Lg act as a resistant carrier of retinol (provitamin A) across the gastro-intestinal mucosa. β-Lg is rich source of essential amino acid cysteine, and it stimulates the synthesis of glutathione in the liver. Interaction of β-Lg with Κ-casein is of great significance as these interactions are relevant to allergenicity problems in certain individuals.

β-Lg possess numerous sites for binding of minerals, fat soluble vitamins and lipids and can be utilized for incorporation of antioxidant vitamins into low fat products.

47.2.2.2 α-Lactalbumin (α-La)

It is second most prevalent protein in the whey and represents to about 3% of the total milk protein or about 13% of total whey protein. This is the most heat resistant and the smallest protein having a molecular weight of 14,146. Its molecule has 4 disulfide linkages. α-La is a metallo-protein as it is strongly associated with calcium ion. Biologically α-La is required for the synthesis of lactose which is the principal source of energy for newborns. The a-La contains 2-3 times more tryptophan than an average protein. In body, tryptophan is converted into 5-hydroxytryptophan and then to 3-hydroxytryptamine (serotonin). Inadequate 1evel of serotonin in the brain has been linked to depression, obesity, insomnia and chronic headache.

47.2.2.3 Immunoglobulin (Ig)

These are minor blood proteins that are passed on to mammary gland and secreted into milk. The level of Ig is highest in colostrum but continuously decreases during advancing lactation period. Various immunoglobulins include IgG, IgA and IgM that impart passive immunity to new born.

47.2.2.4 Lactoperoxidase (LP)

Lactoperoxidase (LP) is considered as naturally occurring antimicrobial enzyme present in milk. Enzyme is known to catalyze the peroxidation of thiocyanate (SCN^-) resulting in generation of intermediates products that interact with membrane bound protein and alters its permeability. The concentration of LP is more in buffalo milk than in cow milk, however to induce antimicrobial effect exogenous addition of 12 ppm thiocyanate and 10 ppm of H_2O_2 in raw milk is required.

47.2.2.5 Lysozyme

Lysozyme is an antimicrobial enzyme found in milk. The concentration of lysozyme in colostrum and normal milk is about 0.14-0.7 and 0.07-0.6 mg/l, respectively. Milk lysozyme is active against a number of Gram-positive and some Gram-negative bacteria. There seems to be a synergistic action of lysozyme and lactoferrin against many bacteria.

47.2.2.6 Lactoferrin

Lactoferrin is a dominant whey protein in milk and plays an important role in iron uptake in the intestine. The concentration of lactoferrin in bovine colostrums and milk is about 1.5-5 mg/ml and 32-50 mg/l, respectively. Lactoferrin are single chain polypeptides of about 80,000 Dalton containing 1-4 glycans, depending on the species. Lactoferrin exhibits both bacteriostatics and bactericidal activity against a range of microorganisms. Lactoferrin also causes the release of lipopolysaccharides molecules from outer membrane of the Gram-negative bacteria and acts as an antibiotic. The occurrence of lactoferrin in biological fluids like milk, tear, saliva and seminal fluids suggested that it could have a role in the non-specific defense against invading pathogens.

47.2.3 Antioxidative potential of whey proteins

Dietary whey proteins have a number of putative, biological effects when ingested. The ability of whey proteins to increase the level of natural anti-oxidants within the body and possibly in stabilizing DNA during cell division is emerging as a premier contribution to population health. Possible modes of action maybe biochemical, including levels of sulphur containing peptide, glutathione and the influence of protein on fat metabolites generated in gut, or immunological or a combination of both. The anticarcinogenic properties of whey proteins are related to compounds rich in sulphur containing amino acids, methionine and cysteine. They contain γ-glutamyl-cysteine residue, which makes cysteine readily available for synthesis of glutathione, a strong xenobiotic deactivating and anti-neoplastic agent. Methionine is utilized for glutathione synthesis in times of cysteine deficiency and it also acts as methyl donor. Hypomethylation of DNA is an important risk factor for cancer at number of sites. Glutathione is, believed to act as an antioxidant, anticarcinogenic and in stabilization and repair of DNA.

Experimental animals fed with four different proteins namely whey, soybean, casein and red meat, as sources of protein, were administered with injection of the carcinogen, dimethylhydrazine. Whey protein-fed animals showed the lowest incidence of colon cancer. Experiments in rodents indicate that the antitumor activity of the dairy products lies with protein fraction and more specifically in the whey protein component of milk.

The anticarcinogenic activity of whey proteins can be attributed to their ability to induce bio-synthesis of folic acid, vitamin $B_{12,}$ riboflavin, retinol and vitamin D. Binding of iron by lactoferrin makes this potential pro-carcinogenic unavailable for intestinal damage. Binding of vitamin B to proteins makes them more bio-available and protects them for being utilized by intestinal microorganisms.

Whey protein isolates (WPI) has been used to treat HIV patients because immunoglobulin and BSA present in it, may stave off this disease.

47.2.4 Bioactive peptides as therapeutic components

Dietary proteins or their precursors may occur naturally in raw food materials, exerting their physiological action directly or upon enzymatic hydrolysis *in vitro* or *in vivo*. Several dietary proteins, can act as a source of biologically active peptides. These peptides remain inactive within the parent protein, and are released during gastrointestinal digestion or food processing. Once liberated, the bioactive peptides may provide different functions *in vitro* or *in vivo*. Such peptides can be released during hydrolysis by digestive or microbial enzymes. Microbial enzymes from LAB have demonstrated to be able to liberate theses peptides from milk proteins, in various fermented milk products. Upon oral administration, bioactive peptides may affect the major body systems- namely the cardiovascular, digestive, immune and nervous systems. For this reason, the potential of certain peptides sequences to reduce the risk of chronic diseases or to boost natural immune protection has aroused a lot of scientific interest over the past few years. These beneficial health effects may be attributed to known peptide sequences exhibiting, e.g., antimicrobial, antioxidative, antithrombotic, antihypertensive and immunomodulatory activities. The activity of peptides is based on their inherent amino acid and composition and sequence. The size of active sequences may vary from 2-20 amino acid residues, and many peptides are known to possess multi- functional properties. Milk proteins are considered the most important source of bioactive peptides and an increasing number of bioactive peptides have been identified in milk protein hydrolysates and fermented dairy products. The release of various bioactive peptides from milk proteins through microbial proteolysis has been reported

47.2.4.1 Peptides with opoid activity

Opiates are drugs containing opium, with basic substance morphine in it. They have been used since ancient times in medicine to relieve pain and induce sleep. Opoid peptides, are defined as peptides having both an affinity for an opiate receptor and opiate like effects inhibited by naloxone. The major exogenous opioid peptides,b-casomorphins, are fragments of the b-casein sequence 60 – 70. Whey proteins contain opioid – like sequences, obtained from whey namely a-La and b-Lg, in their primary structure. These peptides have been termed a and b-lactorphins. Proteolysis of a-lactalbumin with pepsin produces a-Lactorphin, and while digestion of b-Lactoglobulin with pepsin and then with trypsin, or with trypsin and chymotrypsin, yields b-lactorphin.

47.2.4.2 Peptides with Angiotensin – I-converting enzyme inhibition activity

Angiotensin, a blood polypeptide exists in two forms, the physiologically inactive angiotensin – I and the active angiotensin – II. The inactive form is converted into active by angiotensin – I converting enzyme (ACE), which is a key enzyme in the regulation of peripheral blood pressure. ACE plays a major physiological role in the regulation of local levels of several endogenous bioactive peptides. Casokinin sequences have been found in all casein fractions, but a_{s1} – and b - caseins, in particular, are rich in ACE inhibitory sequences.

47.2.4.3 Anti-thrombotic peptides

Thrombosis is defined as the formation or presence of a blood clot within a blood vessel. Plasma protein called as fibrinogen is produced in the liver and is converted into fibrin, necessary for platelet aggregation. Milk peptides are known to inhibit this platelet fixation. Hydrolysis of bovine k-casein by chymosin constitutes the first stage of milk clotting. In this reaction, one bond (Phe_{105} – Met_{106}) of k-casein is rapidly hydrolyzed, leading to the release of an insoluble N–terminal fragment (para - k - casein; residues 1 - 105) and a soluble C–terminal fragment (caseinomacropeptide; residues 106 - 169) from which a series of tryptic peptides active in platelet function has been characterized. These peptides are called as Casoplatelins.

47.2.4.4 Antimicrobial peptid

Hydrolysis of lactoferrin by pepsin produces hydrolysates with greater antimicrobial potency. The generated peptide is known as lactoferricin. The iron binding capacity of the hydrolysates is lost, but the antimicrobial activity is not affected by the addition of iron. These results indicate that the antibacterial activity of these lactoferrin hydrolysates is not dependent on iron.

47.2.4.5 Mineral binding peptides

It is well known that casein – derived phosphorylated proteins enhance vitamin D – independent bone calcification in rachitic infants. The extent of phosphorylation is dependent on the casein type. These confer to the proteins the ability to chelae calcium, which is related to their level of phosphorylation; thus αs2> αs1> β> κ. These phosphorylated fragments are believed to play a crucial role in protecting the milk gland against calcification by controlling the calcium phosphate precipitation. Enzymatic hydrolysis of casein using enzymes results in formation of several Caseinophosphopeptides (CPPs). The calcium chelating activity of CPP – fragments *in vitro* has been attributed to the role of phosphoserine residue in stabilizing the colloidal calcium phosphate of casein micelles.

47.3 Probiotic Dairy Foods

Human gastrointestinal tract (GIT) harbours more than 100 trillion microorganisms belonging to 400 different bacterial species. The number of microbial cells present in GI tract is almost 10 times than the rest of the body cells. A delicate balance exists between beneficial and harmful bacteria present in GIT and any disturbance may lead to abnormalities. About 70% of the body’s immune system is localized in GIT. Incorporation of beneficial bacteria into foods to counteract harmful organisms in the GIT has been the most visible component of this new area. Such microorganisms are termed as “Probiotics”. There is a growing scientific evidence to support the concept that beneficial gut microflora may provide protection against gastrointestinal disorders including gastrointestinal infections, inflammatory bowel diseases, and even cancer.

Probiotics are defined **as “living micro-organisms, which upon ingestion in certain numbers exert health benefits beyond inherent basic nutrition”.** But interest in this area was initiated by Metchnikoff more than 100 years ago. The concept of probiotic can be traced to the end of the 19th century when Döderlein, for the first time attributed the inhibition of growth of pathogens to lactic acid production by bacteria. As per FAO/WHO definition: "probiotics are live microorganisms which when administered in adequate amounts confer a health benefit on the host".

The term ''probiotic'' includes a large range of microorganisms, mainly bacteria but also yeasts. Because these bacteria can stay alive until the intestine and provide beneficial effects on the host health, LAB, non-LAB and yeasts can be considered as probiotics. Some examples of probiotics microorganisms are as follows:

Table 47.2: Probiotic Microorganisms

Lactobacillus Spp.	**Bifidobacterium spp.**	**Other Lactic Acid Bacteria**	**Other Species**
L. acidophilus	*B. adolescentis*	*Enterococcus faecium*	*Saccharomyces boulradii*
L. casei	*B. animalis*	*E. faecalis*	*Bacillus cereus*
L. cellobiosus	*B. longum*	*Streptococcus thermophilus*	
L. fermentum	*B. brevi*		
L. lactis	*B. bifidum*		
L. helveticus	*B. infantis*		
L. reuteri	*B. lactis*		
L. brevis *L. plantarum*			
L. curvatus			

47.3.1 Mode of action of probiotics

Although the mechanisms of action of probiotics are largely unknown at the molecular level, a probiotic can act in a number of ways, including the following:

1. By direct interaction within the gut lumen with the complex ecosystem of the gut microbiota, they may produce substances like acids, CO_2, H_2O_2 and bacteriocins that inhibit the growth of harmful microbes,
2. By interaction with the gut mucus and the epithelium, inducing barrier effects, assist digestive processes, enhance mucosal immune and enteric nervous system;
3. Through signaling to the host beyond the gut to the liver, systemic immune system, and other potential organs such as the brain.

The basis for selection of probiotic micro-organisms include safety, functional aspects (survival, adherence, colonization, antimicrobial production, immune stimulation, antigenotoxic activity and prevention of pathogens) and technological details such as growth in milk and other food base, sensory properties, stability, phage resistance and viability. Fermented milk products being a 'live' food, is potentially an excellent vehicle for these beneficial microbial cultures. Several attempts have been made to manufacture probiotic milk products like probiotic dahi, probiotic cheese, probiotic yoghurt and yoghurt drinks. Probiotic dahi developed at NDRI containing *Lactobacillus acidophilus* and *Lactobacillus casei* was found to delay the onset of glucose intolerance, hyperglycemia, dyslipidemia, and oxidative stress in high fructose induced diabetic rats.

47.4 Fortified Milk Products

Milk in its natural form is almost unique as a balanced source of man's dietary need. The various steps in processing and storage have a measurable impact on some specific nutrients. Milk also provides a convenient and useful vehicle for addition of certain nutrients to our diet and has following benefits:

- Easier quality control measure implementation
- Wider consumption by all age groups
- Cost is affordable by target population.
- Higher stability and bioavailability of the added micronutrients
- Addition of fortificants usually caused minimum change in colour, taste and appearance.

Liquid milk fortification with vitamins A and or D is mandatory in several countries. β-carotene is added as a colour-enhancing agent to some milk products such as butter. Dried milk is often fortified with vitamins A and D, calcium, and iron. Milk based infant formula and weaning foods are fortified with a range of vitamins, minerals, and other nutrients such as polyunsaturated fatty acids. Powdered milk used for complementary feeding in Chile is fortified with vitamin C, iron, copper and zinc. However, the milk fortification usually impaired its sensory and processing quality characteristics.

47.4.1 Fortification of milk & milk products with vitamins

Under ambient conditions the water soluble vitamin C and vitamins of the B-complex group such as thiamin, riboflavin, vitamin B_6, niacin, pantothenic acid, folic acid, biotin and vitamin B_{12} are powdered and thus relatively easy to add in milk and other dairy products. The fat soluble vitamins which include vitamin A, D, E and K, exist either as an oil emulsion or as crystals, which may cause processing difficulties during the manufacture of certain fortified dairy products.

One of the problem encountered with the vitamins, is their limited stability in presence of heat, humidity and oxygen. Among the water soluble vitamins, vitamin C, folic acid, vitamin B_6 and vitamin B_{12} are the less stable. In case of fat soluble vitamins vitamin A, D and E are least stable. In order to improve the stability of these vitamins, a number of different coating technologies have been developed such as microencapsulation.

When two or more vitamins are added to a food product at the same manufacturing stage, this is commonly done in the form of premix or as blend. Premix is a homogenous mixture of desired vitamins in a dry powder from, whereas a blend is the same for the fat soluble vitamins, but in an oily form.

47.4.2 Fortification of milk and milk products with minerals

Selection of an appropriate mineral fortificant is based on its organoleptic considerations, bioavailability, cost and safety. The colour of iron compounds is often a critical factor when fortifying milk and milk products. The use of highly soluble iron compounds like ferrous sulfate often leads to the development of off-colours and off-flavours due to reactions with other components of the food material. Infant cereals have been found to turn grey or green on addition of ferrous sulfate. Off-flavours can be the result of lipid oxidation catalyzed by iron. The iron compounds themselves may contribute to a metallic flavour. Some of these undesirable interactions with the food matrix can be avoided by coating the fortificant with hydrogenated oils or ethyl cellulose.

Bioavailability of iron compounds is normally stated relative to a ferrous sulfate standard. The highly water-soluble iron compounds have superior bioavailability. Bioavailability of the insoluble or very poorly soluble iron compounds can be improved by reducing particle size. Unfortunately this is accompanied by increased reactivity in deteriorative processes. The problem of low bioavailability of some of the less reactive forms of iron is often circumvented by the use of absorption enhancers like, ascorbic acid, sodium acid sulfate and orthophosphoric acid, added along with the fortificant.

The other important mineral for the fortification of milk and milk products is calcium. Several commercial calcium salts are available for calcium fortification, which include carbonate, phosphate, citrate, lactate and gluconate. In general, organic salts of calcium are more bioavailable than inorganic salts. The pH adjustment of the milk should be taken care of during Ca fortification. To overcome problems of flavour, texture and colour deterioration due to addition of minerals, some companies have engineered new fortificant preparations, which generally involve the use of stabilizers and emulsifiers to maintain the mineral in solution. 47.5 Commercially Available Milk Based Functional Dairy Products in Indian Market Realizing the potential of functional foods in Indian context, Indian dairy industry has also introduced certain functional and dietetic dairy products. However, the major share of these products belongs to the probtioic segment. Probiotic *dahi* has been launched by Mother Dairy, Nestle (NesVita) and Amul. Besides it low fat*dahi*, ice cream and sweets by incorporating sugar and fat replacer have also been introduced by organized dairies. Yakult Danone’s probiotic drink has already captured a major share in Indian beverage market. Besides these, Nestle and Amul has launched their calcium enriched dairy products in the form of beverage and dahi, respectively. Many more products including milk, fermented dairy products, ice cream/frozen desserts and butter with added long chain poly unsaturated fatty acids (PUFA), Phytosterols, vitamin A & D will soon be available in Indian market.

Fig 47.1 Probiotic dairy products available in Indian market

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Lesson 48

FUTURE OF FUNCTIONAL INGREDIENTS

48.1 Current Trend of Nutraceutical Market

Global nutraceutical market is estimated to be US $ 117 billion (` 5148 billion). India has only 1 percent share which amounts to ` 44 billion, however the growth rate of Indian nutraceutical market is quite impressive i.e. 18 percent. The functional foods consisting of food, beverages and supplements is estimated to reach 176.7 billion US $ by 2013 with compound annual growth rate (CAGR) of 7.4 percent. Functional beverage market is the fastest growing segment with CAGR of around 10 percent. Globally USA, Japan and European Union (EU) are the major market of nutraceuticals with an estimated share of 36, 22 and 21 percent respectively. In Japan, majority of nutraceutical products are classified as FOSHU (Food for Specific Health Applications) and more than 100 products are listed under the category. In India functional foods constitute 54 percent of nutraceutical market (1.0 billion US$) followed by 32 percent for dietary supplements and 14 percent for functional beverages. Functional foods in Indian market mainly consist of fortified foods and probiotics. Functional beverage category largely includes the fortified juices, energy drinks and glucose powder. Dietary supplements are composed of vitamin and mineral supplements, antioxidants, botanical extracts and certain macronutrients like fatty acids and amino-acids. Companies involved in manufacture and marketing of nutraceutical products mainly belong to the food (55%) and pharmaceutical (35%) industries. Strategic alliances are already in place among pharmaceutical and food companies. In India, nutraceuticals are marketed as Indian System of Medicine (ISM) drugs under the over-the-counter (OTC) category. No clinical validation of their safety or efficacy is required if therapeutically usefulness is mentioned in the literature. Currently, Indian functional foods market is estimated at $70 billion or 4% of processed food market and is growing at the rate of three times of processed foods. In developed markets, higher consumer awareness on health and wellness is being addressed through product innovations and marketing prowess of large players. While the ageing population needs more engineered foods, the younger population is demanding more fortified foods to get extra energy. Health-related issues -obesity and CHD -are forcing food processors to launch campaigns to promote low fat and carbohydrate diets or other such foods.

Probiotic dairy foods constitute the largest segment of dairy based functional foods. The global probiotic market is expected to record a CAGR of 12.6 percent and reach 32.6 billion US$ by 2014. Europe forms the largest market for probiotics with estimated value of 13.5 billion US$. Asia is second largest segments with an estimated market of 9.0 billion US$ and CAGR of 11.2 percent. Probiotic yoghurt, other probiotic dairy foods and probiotic supplements form the probiotic segment. Indian probiotic market is valued at US$ 2 million in 2010 and expected to grow four times by 2015. India accounts for less than 1.0 percent of global probiotic market.

At global level, Japan is the single largest market with per capita consumption worth $140 followed by the US and Europe with an estimated figure of $95 and $60 respectively.

There are a lot of products sold in the name of nutraceuticals in the Indian market. Close to around 100 products are even listed on the Internet along with the global companies and around 20 Indian companies have a record of producing nutraceuticals and marketing them globally. India is relatively a new market for such products. All major pharma players are in the process of entering this market. The level of exports from India is still small, estimated to be perhaps less than ` 750 crore, if one excludes Psyllium. The major markets for India are the US, Europe and Japan. India can become leader in this field as we hold key expertises as well as we are rich with the biodiversity.

48.2 Challenges in Development of Functional Dairy Foods

In India, we have traditional products touted as functional but have little scientific validation. Regulations will thus have to evolve to promote R&D, ensure validation and prevent exploitation of consumers. Companies will also have to be sincere and honest in their claims while marketing and communicating with consumers till appropriate regulations for scientific validation are evolved. Processors will need to provide an optimal merger between taste, convenience and health attributes. Companies will require expert knowledge in flavour masking, fortification know-how and delivery systems.

48.2.1 Technological challenges

Four different technological hurdles have to be overcome before a product containing bioactive substances is ready to consider marketing:

- Isolation of the desired components,
- Pre-establishment of the biological activity,
- Incorporation of the bioactive components into a formulated product,
- Verification of efficacy and safety of final product.

Such a sequence of experimental events is also required for the introduction of new food additives. This applies especially when the bioactive component is a completely new substance and never consumed before in significant amounts. Separation, purification and production at industrial level of such nutraceuticals must be thought in terms of integrated and high added value. Membrane technologies (Micro-filteration, Ultrafilteration and Nanofilteration) provide key opportunities to manufacture milk nutraceuticals in native state. The incorporation of bioactive components into processed foods, its delivery and bioavailability are other important issues that need reprisal.

A close interaction among chemist, nutritionists, medical practitioner, technologists and biochemists is essential to formulate, develop and validate the health claim of various types of functional foods and nutraceuticals.

Regulatory authorities have also given due emphasis for the validation of health claims. Recently government has introduced the guidelines for the evaluation of probiotics for health claims.

48.2.2 Scientific validation of functional foods

The scientific evidence for functional foods and their physiologically active components can be categorized into four distinct areas: (a) clinical trials, (b) animal studies, (c) experimental in vitro laboratory studies, and (d) epidemiologic studies. Much of the current evidence for functional foods lacks well-designed clinical trials; however, the foundational evidence provided through the other types of scientific investigation is substantial for several of the functional foods and their health-promoting components. One must ensure the nature of claim for the ingredients present in the newly developed foods. Claims for many ingredients like extracts, amino-acids, minerals, vitamins and fibers etc, are already well known and only care must be taken to ensure the minimum that is required for imparting the health benefits.

48.2.3 Safety Issues

Although increasing the availability of healthful foods including functional foods in the diet is critical to ensuring a healthier population, safety is a critical issue. The optimal levels of the majority of the biologically active components currently under investigation have yet to be determined. The benefits and risks to individuals and populations as a whole must be weighed carefully when considering the widespread use of physiologically-active functional foods. Knowledge of toxicity of functional food components is crucial to decrease the risk: benefit ratio. The safety issues related to probiotic microorganisms that has to be considered includes:

- intrinsic properties of the probiotic strains
- pharmacokinetics of probiotic strains
- interaction between probiotic strains and the host
- Knowledge of toxicity of functional food components is crucial to decrease the risk: benefit ratio.

48.3 Future Prospects of Nutraceuticals and Functional Foods

Consumer interest in the relationship between diet and health has increased the demand for information on functional foods. Rapid advances in science and technology, increasing healthcare costs, changes in food laws affecting label and product claims, an ageing population, and rising interest in attaining wellness through diet are among the factors fuelling interest in functional foods. Credible scientific research indicates many potential health benefits from milk components. It should be stressed, however, that functional foods are not a magic bullet or universal panacea for poor health habits. Growth of nutraceuticals in Indian market is driven by several factors that includes the following:

48.3.1 Affluence

Increasing population with changing life-style owing to increase in proportion of working populations, more women workforce, sedentary life-style, higher disposal income and changing dietary habits indicate demand for health and functional foods. There is a rapid increase in the population of young people who have altogether different nutritional and food demands. Likewise number of aged persons is also on rise that necessasitate introduction of certain specialized foods for them.

48.3.2 Affordability

More than 50 percent household expenditure is only on food items, hence with additional disposal income due to the increase in per capita income would enable consumers to spend on functional foods. Moreover out of pocket expenditure which constitutes 64 percent of health care expenditure and rapid rise in health care cost also forces consumers to look for health and functional foods.

48.3.3 Awareness

Popularization of novel health foods trough print, electronic and other media sources resulted in creation of awareness among common people regarding the diet related health issues and prospective health components present in them. Physicians have started prescribing such products apart from regular medicines. Moreover, availability of diagnostic facilities at affordable cost enable people to monitor the critical health parameters such as Blood pressure, (BP), lipid profile, fasting glucose etc. to ensure the goodness of health and adopt corrective measure if desired.

48.3.4 Accessibility

More and more functional foods, beverages and dietary supplements are emerging at market place. Looking at the potential every year hundreds or multitudes of health and functional foods are being introduced in Indian market. Growth in retail sector has further fuelled the availability of such products to the consumers. Certain companies like Reliance, Apollo Pharmacy, Med Plus etc. have opened their stores for the marketing of functional foods.

Depending on the need these products may be broadly grouped into three sections.

48.3.4.1 Foundation needs

For maintaining normal growth and wellness, these products promote general well being and healthy life-style. The products include macro & micronutrients fortified raw materials like juices, flours, probiotic foods and herbal products such as chyawanprash. At present the market is ` 33.3 billion which is expected to grow ` 38.0 to 71.4 billion.

48.3.4.2 Condition specific needs

These require nutraceuticals under certain specific conditions mostly when these are deficient. The segment includes, diseased, pregnant, lactating, aged persons, infants, etc. The large population suffering with macro or micronutrient deficiency disorders, obese, suffering with cardiac ailments and osteoporotic, may need special dietary components. The products include supplements, antioxidants and botanicals. The market for such products is expected to grow to ` 50-99.5 billion from the current value of ` 10 billion.

48.3.4.3 Enhancement needs

These food items are designed to meet the enhanced nutritional requirement of specific groups including athletes. The products include high energy powders, protein powders or drinks, electrolytes, amino-acids and other ergogenic aids. The market is in infancy and expected to reach Rs. 1.5 billion.