Food Technology II

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FOOD TECHNOLOGY - II

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Index

Module 1. Cereal grains, legumes and oilseeds

Lesson 1

INTRODUCTION TO CEREAL GRAINS, LEGUMES AND OILSEEDS, STRUCTURE AND COMPOSITION OF CEREAL GRAINS, LEGUMES AND OILSEEDS

1.1 Introduction

India has reached to a level of self-sufficiency in the production of cereals, pulses and oilseeds after the green revolution. Cereals are plants which yield edible grains and includes rice, wheat, corn, barley, and oats. Cereal grains are the fruit of plants belonging to the grass family (*Gramineae*). Cereal grains provide the world with majority of its food calories and about half of its protein. They are also good source of micronutrients such as calcium, iron and vitamins of group B. Cereals are staples and are consumed in large quantities by majority of population in the world either directly or in modified form as major items of diet such as flour, bran and numerous additional ingredients used in the manufacture of other foods. Asia, America, and Europe produce more than 80 percent of the world's cereal grains. Cereals are easy to store because of low moisture content, easy to handle and providing variety to the diet. The principle cereal grains grown in India are wheat, rice, corn, sorghum and barley.

Legumes are next to cereals as an important source of proteins. They are flowering plants having pods which contain bean or peas. There are basically two groups of legumes. First is high-protein high-oil group like soybean, groundnut, lupine, etc. which are mainly used for processing and contains high protein (~ 35%) and oil content (15- 45%). The second group comprises the moderate- protein low-oil types like cowpea, gram, pea, lentil etc. India is one of the largest pulse growing countries in the World. Different pulses grown in India are chickpea (bengal gram/chana), pigeon pea (tur/arhar), green gram (moong), black gram (urad), lentils (masur).

Oilseeds have become an increasingly important agriculture commodity, with a steady increase in annual production worldwide. Oilseeds are seeds which contain high oil content and are widely grown as a source of edible oil. Major oilseeds grown in India are groundnut, cottonseed, mustard, rapeseed, soybean, sunflower and sesame seed. The coconut (copra) is also an important oilseed.

Cereal grains are not only low in protein but also deficient in certain essential amino acids, especially lysine. Legumes as well as many oilseeds are rich in lysine, though relatively poor in methionine. Edible oilseed meals obtained from oilseeds are rich in proteins and have been used to improve the nutritional properties of cereal products such as infant food and food for school going children in most of the countries in world.

1.2 Cereal Grains

1.2.1 Rice

Rice (*Oryza sativa*, Linn.) crop originated in Asia and has been a staple food there since the Ice Age in the North. The geographical site of original rice domestication is yet not sure. But according to a general consensus, domestication occurred at three places – India, Indonesia and China – thereby giving rise to three races of rice – *Indica, Javonica* and *Sinica* (also known as *Japonica*), respectively. Actual rice grains and husk have been excavated in India that were more than 4500 years old and in China more than 5000 years. According to ancient Greek writers, rice penetrated Europe around 3000 B.C., having been brought from India by Alexander the Great.

1.2.2 Wheat

Historic documents confirm that wheat (*Triticum aestivum*, *Triticum durum*) is the earliest field crop used for human food processing. The cultivation of wheat reaches far back into history as it was predominat source of food for Human. The precise origin of the wheat cultivation is unclear, but it is thought that man has been cultivating and processing the wheat for at least 12,000 – 17,000 years.

1.2.3 Corn

Corn or Maize (*Zea mays*, L) is native to the America. Corn originated in Mexico, evolving from the wild grass Teosinte. Archeological evidence suggests that corn was domesticated and grown as early as 5000 B.C. in Mexico. Following Columbus's discovery of America, corn was transplanted to Spain from where it quickly spread across Europe, Africa and Asia.

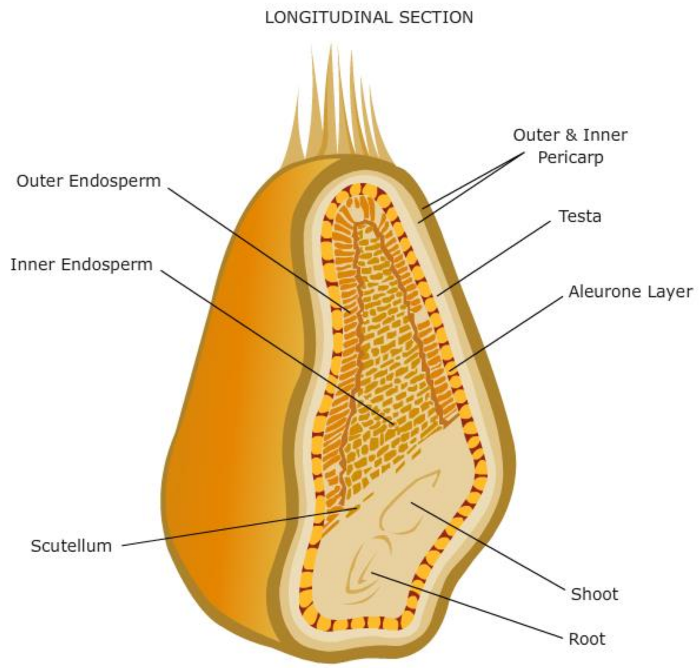
1.2.4 Barley

Barley (*Hardeum vulgare L.*) is among the most ancient of the cereal crops. The original area of cultivation has been reported to be in the Fertile Crescent of the Middle East, in present day Lebanon, Iran, Iraq, and Turkey. There is now considerable evidence that barley was under cultivation in India and China considerably later then in Middle East. Barley played an important role in ancient Greek culture as a staple bread–making grain, as well as an important food for athletes, who attributed much of their strength to their barley–containing training diets. Gladiators were known as *hordearii*, which means "eaters of barley". In almost every culture through the ages, barley foods are described as having almost mystical properties, and barley is often referred to as the "king of grains".

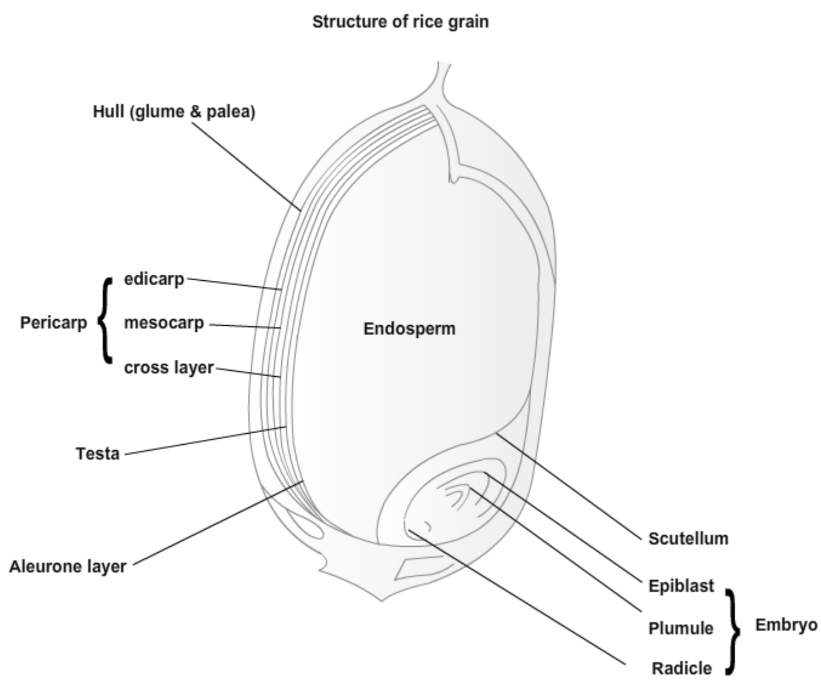
1.3 Structure of Cereal Grains

Cereal grains are the fruit of plants belonging to the grass family (*Gramineae*). Botanically, cereal grains are a 'dry' fruit called a caryopsis (Fig. 1.1). The caryopsis fruit has a thin, dry wall which is fused together with the seed coat. Kernel structure is important with respect to minimizing damage during grain harvest, drying, handling, storage, milling, and germination and in enhancing nutritional value. There are a few important structural features that the cereal grains have in common. All of the cereal grains are plant seeds and contain three distinct anatomical portions – a large centrally located starch endosperm, which also is rich in protein, protective outer layers such as hull and bran, and an embryo or germ.

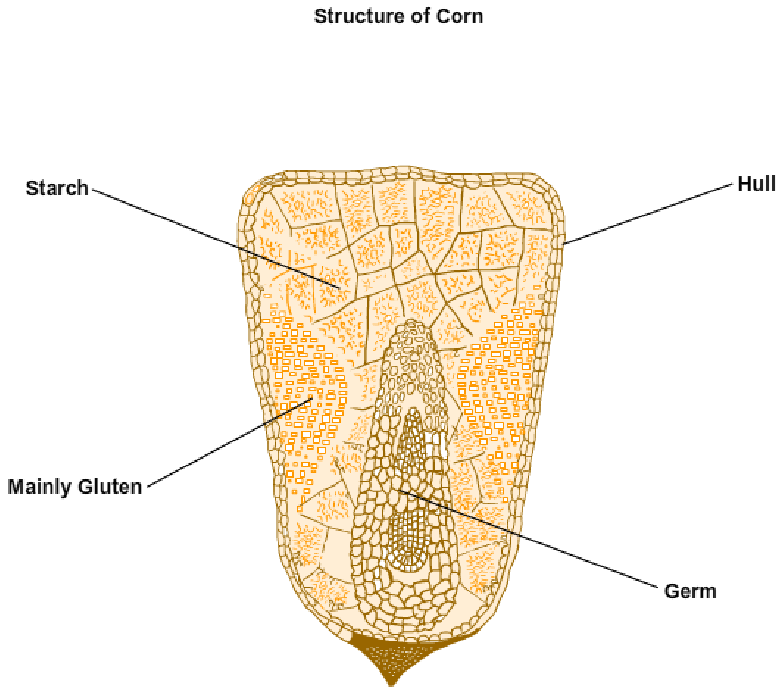
The seed portion of cereals consists of numerous components which basically include three parts: a seed coat or testa (bran), storage organ or nutritive reserve for the seed (endosperm), and a miniature plant or germ. The fruit tissue consists of a layer of epidermis and several thin inner layers a few cells thick. The aleurone layer which is just below the seed coat, is only a few cells thick, but is rich in oil, minerals, protein and vitamins. Starch and protein are located in the endosperm which represents the bulk of the grain and is sometimes the only part of the cereal consumed. Starch is arranged in the form of sub-cellular structures called granules that are embedded in a matrix of protein. The developing endosperm contains protein bodies which become a continuous phase as the grain matures. There is generally a gradient of more protein and less starch per cell from the outer to the inner region of the endosperm. The diameter, shape, size distribution and other characteristics of starch granules vary with different cereals. Starch granules range in size from 3-8 µm in rice; 2-30 µm in corn, and 2-55 µm in wheat. Reserve proteins in the endosperm are in the form of smaller 'protein bodies' that range in size from 2-6 µm that become disordered and adhere to the starch granules in the mature grain of species like wheat.


LONGITUDINAL SECTION
Outer & Inner Pericarp
Outer Endosperm
Testa
Inner Endosperm
Aleurone Layer
Scutellum
Shoot
Root

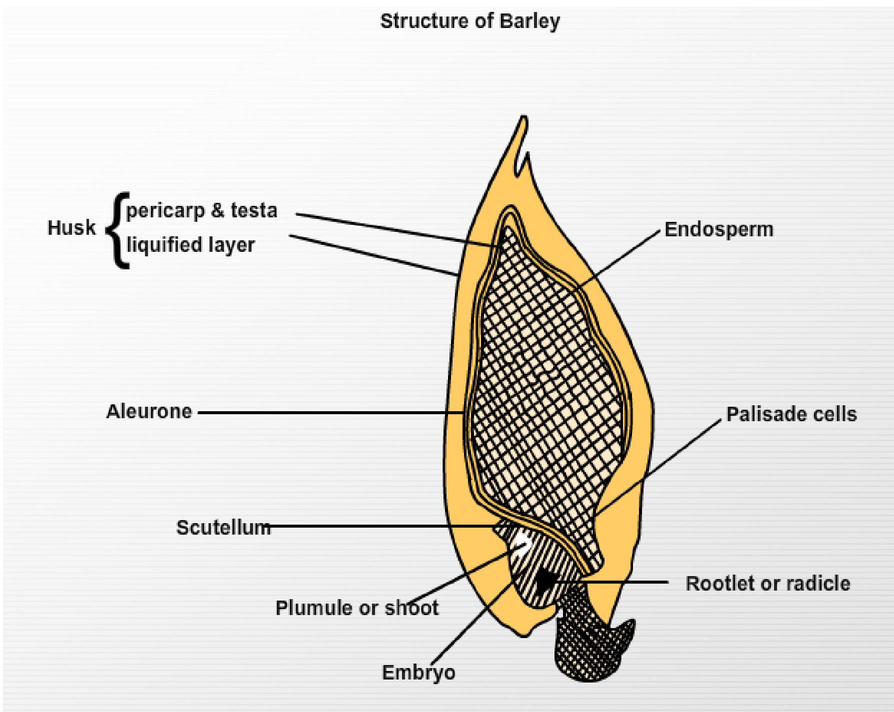
Wheat


Structure of rice grain
Hull (glume & palea)
edicarp
Pericarp
mesocarp
cross layer
Endosperm
Testa
Aleurone layer
Scutellum
Epiblast
Plumule
Radicle
Embryo

Rice



[Corn]



[Barley]

Fig 1.1 Structure of cereal grains

1.4 Chemical Composition of Cereals

Cereals are of plant origin which yield edible grains which are consumed directly or in modified form as major part of diet and also feed to livestock. Rice and wheat are most important cereals forming part of human food. The major constituents of the principal cereals are listed in Table 1.1. Cereal grains consist of about two third carbohydrates, mainly in form of digestible sugars and starches. These grains are also an important source of several other nutrients such as protein, calcium, iron, vitamin B complex and dietary fiber. Cereal grains contain 10-14% moisture, 58-72% carbohydrate, 8-13% protein, 2-5% fat and 2-11% indigestible fiber. They also provide about 300-350 kcal/100 g of grains. Cereals are deficient in vitamins A, D, B_{12} and C.

Table 1.1 Proximate Compositions of Cereal Grains

Cereal	**Mois-ture %**	**Carbo hydrates %**	**Protein %**	**Fat %**	**Fiber %**	**Ash %**	**Calorific value (kcal/100 gm.)**
Wheat (*Triticum aestivum, Triticum durum*)	11	69	13	2	3	2	340
Rice (*Oryza sativa*, L.)	11	65	8	2	9	5	310
Corn (*Zea mays*, L.)	11	72	10	4	2	1	352
Sorghum (*Sorghum bicolor* L.)	11	70	12	4	2	1	348
Barley (*Hardeum vulgare* L.)	14	63	12	2	6	3	320
Oats (*Avena sativa*)	13	58	10	5	10	4	317
Rye (*Secale cereale*)	11	71	12	2	2	2	321

1.5 Structure of Legumes

The term 'pulses' is limited to crops harvested solely for dry grain, thereby excluding crops harvested green for food mainly as vegetables (peas, beans, etc.), crops used mainly for oil extraction (e.g. soybean and groundnut) and leguminous crops for sowing purpose (e.g. seeds of clover and alfalfa). A legume is a plant in the family *Fabaceae* (or *Leguminosae*), or a fruit of these specific plants. A legume fruit is a simple dry fruit that develops from a simple carpel and usually dehisces (opens along a seam) on two sides. A common name for this type of fruit is a pod. Well-known legumes include peas, beans, lentils, black gram, green gram, soy and groundnut.

Pulses all have a similar structure, but differ in color, shape, size, and thickness of the seed coat. Mature seeds have three major components: the seed coat, the cotyledons, and the embryo (Fig. 1.2).

The seed coat or hull accounts for 7–15% of the whole seed mass. Cotyledons are about 85% of the seed mass, and the embryo constitutes the remaining 1–4%. The external structures of the seed are the testa (i.e., seed coat), hilum, micropyle, and raphe. The testa is the outer most part of the seed and covers almost all of the seed surface. The hilum is an oval scar on the seed coat where the seed was attached to the stalk. The micropyle is a small opening in the seed coat next to the hilum. The raphe is a ridge on the side of the hilum opposite the micropyle.

When the seed coat is removed from grain, the remaining part is the embryonic structure. The embryonic structure consists of two cotyledons (or seed leaves) and a short axis above and below them. The two cotyledons are not physically attached to each other except at the axis and a weak protection provided by the seed coat. Thus the seed is unusually vulnerable to breakage.

The outermost layer of the seed coat is the cuticle, and it can be smooth or rough. Both the micropyle and hilum have been related to the permeability of the testa and to water absorption.

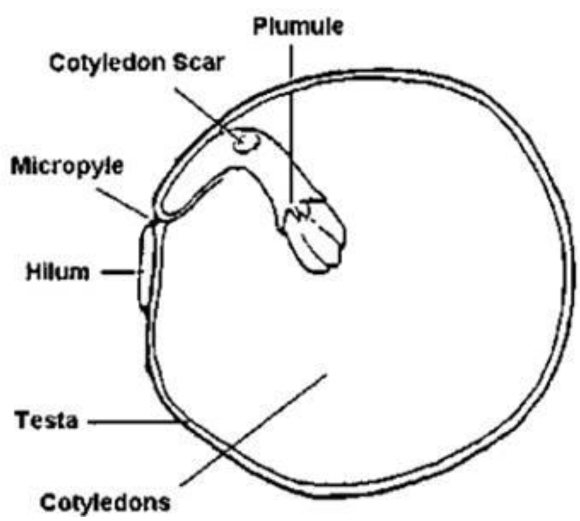


Fig. 1.2 Structure of pulse

1.6 Composition of Pulses

Pulses contain carbohydrates, mainly starches (55-65 percent of the total weight); proteins, including essential amino acids (18-25 percent, and much higher than cereals); and fat (1 - 4 percent). The remainder consists of moisture, fiber, minerals and vitamins. The composition of protein, fat, minerals, fibre, carbohydrates, minerals and vitamins etc of different pulses is given in Table 1.2.

Table 1.2 Proximate composition of pulses (Per 100 g edible portion)

Pulse	Scientific name	Composition /100 g edible portion						
		Mois-ture	Protein	Fat	Carbo hydrates	Minerals	Fiber	Energy (Kcal)
Tuver (Red gram, Pegion pea)	*Cajanus cajan*	13.4	22.3	1.7	57.6	1.7	1.5	335
Bengal gram (Chick pea)	*Cicer arietinum* L.	9.8	17.1	5.3	60.9	3.0	3.9	360
Val papdi (Field bean)	*Dolichos lablab*	9.6	24.9	0.8	60.1	3.2	1.4	347
Moong (Green gram)	*Phaseolus aureus* Roxb	10.4	24.0	1.3	56.7	3.5	4.1	334
Kulad (Horse gram)	*Dolichos biflours*	11.8	22.0	0.5	57.2	3.2	5.3	321
Masoor (Lentils)	*Lens esculenta*	12.4	25.1	0.7	59.0	2.1	0.7	343
Udad (Black gram)	*Phaseolus mungo*	10.9	24.0	1.4	59.6	3.2	0.9	346
Chowli (Cow peas)	*Vigna catjang*	13.4	24.1	1.0	54.5	3.2	3.8	323
Vatana (Peas)	*Pisum sativum*	16.0	19.7	1.1	56.5	2.2	4.5	315

1.7 Structure of Oilseeds

Oil seeds are mainly used for extraction of edible oil. Oilseeds crops grown in India are groundnut, rapseed, mustard, soybean, sunflower, sesame, castor, safflower, niger and linseed. Oilseeds are made up of three basic parts: the seed coat, the embryo, and one or more food storage structures. The seed contains two pieces of cotyledons that function as food reserve structures. The seed coat is marked with a *hilum* or seed scar. The basic function of the coat is to protect the embryo from fungi and bacterial infection.

Unlike seeds of grass family (e.g. wheat, rice, etc.), where oil is concentrated in a germ that lies along the side of the endosperm, the entire hull of oilseeds is the germ. It typically consists of a rootlet (hypocotyl) and two cotyledons leaves (Fig. 1.3) that are pushed above the soil and unfold during the germination. Oil in oilseed is distributed in spheresomes throughout the germ cells. Recovery of oil from oilseeds is facilitated by rupturing the cell walls by heat and pressure during flaking, and by optional extrusion, followed by pressing or solvent extraction. Waxes from the pericarp (hull), which protect the seed against drying are often also solubilized by the sovent or oil.

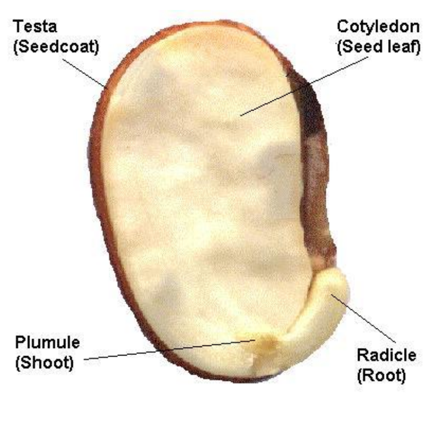


Fig 1.3 Structure of oilseed

1.8 Composition of Oilseeds

Proximate composition of various oilseeds grown in India is given in Table 1.3.

Table 1.3 Proximate composition of whole oilseeds (%)

Oilseed	Scientific name	Moisture	Protein	Fat, EE*	Crude fiber	Ash
Soybean (Whole seed)	*Glycine max*	10.0	36.3	18.9	5.0	4.4
Groundnut (Shelled kernel)	*Archis hypogea*	10.0	26.0	45.0	4.0	2.5
Corn germ (Dry milled)	*Zea mays*, L	10.0	13.0	22.5	4.5	2.5
Sunflower seed, oil-type (Whole seed)	*Helliathus annus*	10.0	21.0	42.0	19.0	4.5
Cotton seed (Cottonseed with linters)	*Gossypium hirsutum* L.	10.0	22.0	19.5	19.0	4.5
Rapeseed/Canola (Whole seed)	*Brassica juncea*	8.0	22.0	41.0	10.0	5.0

EE*- Ether extract

Glossary

- **Monocotyledons**, also known as monocots, are one of two major groups of flowering plants (or angiosperms) that are traditionally recognized, the other being dicotyledons, or dicots. Monocot seedlings typically have one cotyledon (seed-leaf), in contrast to the two cotyledons typical of dicots
- **Poaceae** (also known as the **Gramineae**) is a large and nearly ubiquitous family of monocot flowering plants. Members of this family are commonly called (land) grasses.
- **Caryopsis** is a type of simple dry fruit — one that is monocarpelate (formed from a single carpel) and indehiscent (not opening at maturity) and resembles an achene, except that in a caryopsis the pericarp is fused with the thin seed coat.
- The caryopsis is popularly called a grain and is the fruit typical of the family *Poaceae* (or *Gramineae*), such as wheat, rice, and corn.
- **Husk** (or **hull**) in botany is the outer shell or coating of a seed. It often refers to the leafy outer covering of an ear of maize (corn) as it grows on the plant. Literally, a husk or hull includes the protective outer covering of a seed, fruit or vegetable.
- **Endosperm** is the tissue produced inside the seeds of most flowering plants around the time of fertilization. It surrounds the embryo and provides nutrition in the form of starch,

though it can also contain oils and protein. This makes endosperm an important source of nutrition in human diet. For example, wheat endosperm is ground into flour for bread (the rest of the grain is included as well in whole wheat flour), while barley endosperm is the main source for beer production.

- G**erm** of a cereal is the reproductive part that germinates to grow into a plant; it is the embryo of the seed. Along with bran, germ is often a by-product of the milling that produces refined grain products. Cereal grains and their components, such as wheat germ, rice bran, and maize may be used as a source from which vegetable oil is extracted, or used directly as a food ingredient. The germ is retained as an integral part of whole-grain foods
- **Bran** is the hard outer layer of grain and consists of combined aleurone and pericarp. Along with germ, it is an integral part of whole grains, and is often produced as a by-product of milling in the production of refined grains. When bran is removed from grains, the grains lose a portion of their nutritional value. Bran is present in and may be milled from any cereal grain, including rice, corn (maize), wheat, oats, barley and millet. Bran should not be confused with chaff, which is coarser scaly material surrounding the grain, but not forming part of the grain itself. Bran is particularly rich in dietary fiber and essential fatty acids and contains significant quantities of starch, protein, vitamins and dietary minerals.

Module 2. Cereal processing

Lesson 2

RICE MILLING AND PARBOILING: RICE QUALITY AND GRADING STANDARDS

2.1 Introduction

Rice (*Oryza sativa*, Linn.) is one of the oldest and most important food crops of the world. It is staple food for more than half of the World's population. Rice belongs to the *Gramineae* or grass family and the tribe *Oryzeae*. Rice is a semi-aquatic plant which can thrive under flooded soil condition. Rice plant possesses the roots of a dry land crop, which are able to pass moisture from roots to stem and oxygen from leaf through stem to roots. The total area of rice cultivation varied between 350 – 360 million acres globally during the last few years. About 92% of the World's rice crop is produced in the Asian continent (FAOSTAT).

2.2 Rice Milling

Rice milling is carried out either at small scale or large scale. The objective of the rice milling is to remove the husk and bran with minimum possible breakage of endosperm. Paddy is generally harvested at 18 – 25% moisture and then dried to 12 – 13% moisture either on farm or at the mill before processing.

2.3 Milling Procedure

Combine-harvested rice generally has a moisture content of about 20% (wet basis) and the grain must be dried immediately to about 12% for storage. Rice is consumed mostly in the form of whole kernels, and accordingly the processing of paddy is designed to give a high yield of unbroken kenel.

2.3.1 Small scale milling

In case of small scale milling of rice, paddy is placed in a mortar and pounded with pestles either by hands or with the feet. After some time of pounding, the rice is sifted to separate the husk. The pounding process is repeated several times. Rice obtained by this process is called brown rice/rough rice and contain more amount of vitamins as a proportion of the pericarp, testa and aleurone layers remain on the rice grain.

2.3.2 Large scale milling

Schematic representation of the rice milling process is depicted in Fig. 2.1.

2.3.2.1 Cleaning

Cleaning of paddy comprises removal of sticks, stones, dust and other foreign materials. This is accomplished by use of various separation methods. The paddy is first passed over a screen to remove larger particles, straws and string. After that it is passed through second screen, which is having smaller perforations than first screen, to remove weed seeds and sand. The paddy then flows in the form of a thin layer into a channel where an air current removes dead grains and other lighter impurities. At the last, paddy are passed through magnetic separator to remove metal particles.

2.3.2.2 Hulling/Shelling

Cleaned paddy is then passed through machine (disc huller/sheller) comprising emery/ rubber rolls running in opposite directions; aspirated to remove husk and then sieved to separate from the unhusked and broken rice. The rice with the hull removed is commonly known as "brown rice"/"rough rice".

2.3.2.3 Scouring/Pearling/Whitening

Gradual removal of germ and bran from the rough rice is known as scouring/pearling/whitening process. The hulled rice is passed through a series of "pearling cones". In pearling cones rice passes through the narrow annular space left between an inverted cone coated with abrasive revolving in a conical casing made of steel wire cloth. As it passes down, the bran is pushed through the interstices of the wire cloth. By-product of scouring process is known as "rice-bran" which is used as animal feed. It is also used to extract rice bran oil.

2.3.2.4 Polishing

The rice grain consisting inner layers of bran is passed through polishing machine often referred to as "brush". In this machine last bran fraction is removed. The grain is now called "polished rice".

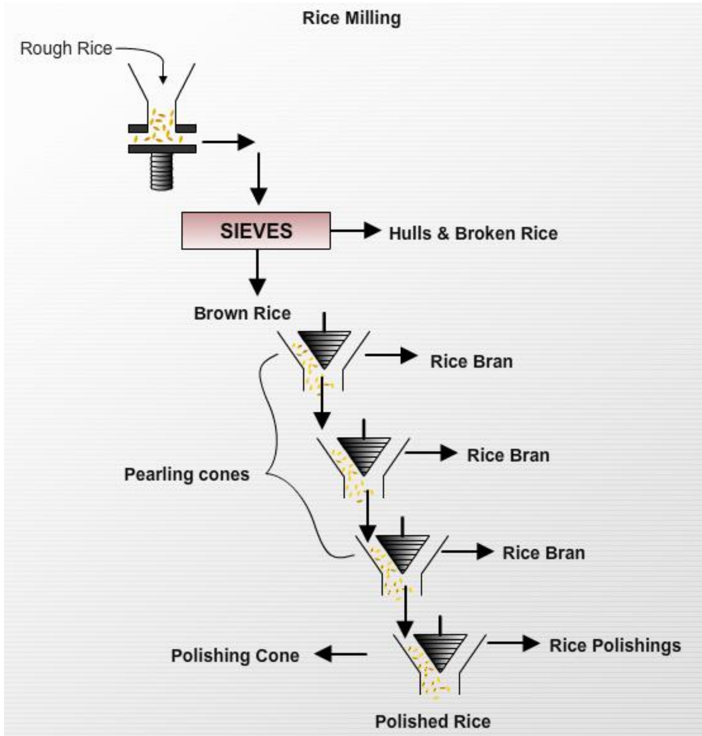


Fig. 2.1 Rice milling processes

2.4 Parboiling of Rice

The technique for parboiling of rice was developed in India to prevent losses occurring due to breakage during hand pounding, especially the long grained varieties. In this technique paddy is soaked in excess water and later on cooked in its husk, the objective being pregelatinizing the starch. Any hairline cracks are sealed due to homogeneous mass of gelatinized starch and thus prevent breakage during milling. The paddy is then drained and dried.

Parboiling can be accomplished in variety of ways. The general scheme is to hydrate (steeping) paddy to 32 – 38% moisture and partially gelatinize the starch by steam heating at 15 lb. pressure for 10 – 20 min. Parboiling causes certain physico-chemical changes such as improved milling yields (66 – 70%), increased resistance to insects and firmer cooked rice texture accompanied by a darker and more yellow endosperm. Parboiling has further advantages like: during soaking and cooking the water soluble vitamins (niacin, riboflavin, and thiamine) which are present in germ and pericarp gets migrated into endosperm and thus improves the nutritional value of parboiled rice. Even proteins present on the grain surface are denatured, become insoluble, and therefore are not removed during washing and cooking.

2.4.1 CFTRI parboiling process (Central Food Technology Research Institute, Mysore)

This was developed to avoid bad smell. The paddy is soaked in hot water (65-70°C). Germ action does not occur in hot water, thus the smell is avoided. Soaking time is reduced to 3-4 hrs.

The CFTRI also developed the pressure parboiling method. Soaking time is only 30-60 minutes and steam is passed through the grain to raise the pressure slowly from an initial 0.28-0.70 kg/cm^2 to 1.41-2.11 kg/cm^2 and this is maintained for 20-30 min. In this method, the processing time is reduced.

2.4.2 PPRC parboiling process (Paddy Processing Research Centre, Thanjavur)

It is also known as chromate soaking process. Chromate at the rate of 50g/100 kg paddy is added to the soaking water which stops germ action and eliminates bad smell.

A high temperature short time process was also developed at the PPRC. Steeped paddy is parboiled and dried concurrently by applying high temperature for a short time. Steeped paddy is fed into sand roaster. The paddy gets completely and uniformly parboiled and its subsequent cooking time is less.

2.4.3 Advantages of parboiling of rice

1. Dehusking of parboiled rice is easy and the grain becomes tougher resulting in reduced losses during milling
2. Higher yield of head rice from milling because kernel is more resistant to breakage.
3. Milled parboiled rice has greater resistance to insects and fungus infection.
4. The nutritive value of rice increases after parboiling because the water dissolves the vitamins and minerals present in the hulls and bran coat and carries them into the endosperm.
5. The water soluble B vitamins, thiamine, riboflavin and niacin are higher in milled parboiled rice than in milled raw rice.
6. Parboiled rice does not turn into a glutinous mass when cooked.

2.4.4 Disadvantages of parboiling of rice

1. It has a bad smell due to prolonged soaking.

2. It has a dark colour due to heat treatment.
3. It requires prolonged cooking time and more fuel.
4. Since the oil content is more, the polisher may got choked.
5. The heat treatment may destroy antioxidants. Hence, rancidity may develop.
6. Due to the high moisture content, mycotoxins may be formed.
7. Drying cost is added to the total processing cost, extra capital investment.

2.5 Rice Quality and Grading Standards

Characteristics of rice known and referred to as grain quality largely determine market price and consumer acceptance. The grain quality has many connotations and is perceived differnently depending upon the end use, field of interest, specialization, ethnic background, etc. quality in rice may be categorized into grain quality indicators and cooking/eating quality indicators.

2.5.1 Grain quality indicators

2.5.1.1 Grain dimension – size and shape

There exist enormous variation in the size and shape of the grins as they are conditioned by large number of genes. Grain dimension is expressed as length, breadth and thickness, whereas shape is expressed as the ratio between the length and breadth. These parameters are the major bases for the characterization of rice varieties. Short grain varieties vary in their length from 3 -6 mm (length-to-breadth ratio, 2.5-3.0) whereas long grain varieties have a length of 6mm and above (length-to-breadth ratio, more than 3.0). There are three major types of rice – long, medium and short grained, whch are classified by the grain shape (length-to-breadth ratio) and tend to have different properties and hence different uses.

2.5.1.2 Grain colour and translucency

White and translucent rice is preferred by people in most parts of the world. The colour of the duhusked, unpolished rice is usually pale white, creamy white, brown or red. On polishing, the kernel becomes white, translucent or opaque according to the nature of the pericarp and endosperm colour of the brown rice.

2.5.2 Cooking/eating quality indicators

Cooking and processing characteristics of the rice are the factors of primary importance in rice eating areas of the world. Milling, cooking and processing qualities are the fundamental components of quality that determine and establish economic value of rice. Upon cooking, long grain rice is dry and fluffy with individual grains, whereas medium and short grain types are moist and chewy with grains that tend to stick or clump together. Major cooking quality parameters are discussed hereunder.

2.5.2.1 Amylose content

Amylose content is considered as the single most important characteristics for predicting rice cooking and processing behavior. In rice it varies roughly from 15-37%. A high amylose content is usually associated with non-sticky cooking characteristics and vice-versa. Glutinous or waxy rice, which has no or very little amylose content, becomes very sticky on cooking.

2.5.2.2 Gelatinization temperature

The gelatinization temperature of starch is the range of temperature within which the starch starts to swell irreversibly in hot water with a simultaneous loss of crystalinity, and usually varies from 56° to 79°C. It is correlated with the extent of disintegration of milled rice in a dilute alkali solution (1.7-2.0% KOH) measured in terms of alkali spread value. Gelatinization temperature is also positively correlated with the cooking time but not with the texture of cooked grains.

2.5.2.3 Gel consistency

The gel consistency test is the index of cooked rice hardness among high amylose rice. Rice is classified on the basis of gel length as soft, medium and hard. Soft to medium gel consistency is preferred to hard gel consistency. Among high amylose rice, intermediate gelatinization temperature and soft gel consistency are preferred by consumers over low gelatinization temperature and hard gel consistency.

2.5.3 Milling quality

Milling quality means the degree to which the endosperm remains intact at the end of milling. Milling quality, indicated by total milling yield or head rice (milled rice kernels that are three quarters or more of the endosperm length) yield, is expressed as a percentage of rough rice. Breakage during milling process is not desirable.

2.5.4 Nutritional quality

Brown rice contains more nutrients (minerals and vitamins) than milled rice. However, status of nutrients is dependent on genetic variability of rice throughout the world.

2.5.5 Specific quality designations regarding cleanliness, soundness and purity

Special grades are provided for the specific qualities or conditions of rice that affect marketability. These special grades:

1 Rough rice: Parboiled rough rice, Smutty rough rice, Weevily rough rice

2 Brown rice: Parboiled brown rice and Smutty brown rice for processing

3 Milled rice: Parboiled milled rice, Undermilled milled rice

In USA rice grade designation follows this order: (1) the letter US (2) no. of grade (3) class (4) applicable special grade (5) milling yield

e.g. U.S. No. 3, long grain rough rice, parboiled, milling yield 50 – 70%.

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Lesson 3

PROCESSED RICE PRODUCTS AND BY-PRODUCTS

3.1 Introduction

There are numerous uses of rice and rice flour for manufactured and for culinary preparations. Food uses of rice can be categorized into four groups: direct food use, brewing, seeds and others. The use of rice for direct food is the highest of the three uses. Milled rice, parboiled rice, brown rice are directly consumed after cooking. Rice and rice products are also used in manufacture of certain processed foods such as breakfast cereals, soup, baby food, packaged mixes, etc. *Idli* and *Dosai* are common foods in South India which is prepared from fermented batter of rice and black gram. Fermented beverage i.e. *Sake* is the traditional Japanese rice wine.

3.2 Modern Convenience Foods from Rice

Pre-cooked rice is used in rice-based convenience foods where non-rice ingredients are separately packaged and mixed only during heating. Such types of convenience foods provide convenience to the consumer as it requires much less time for preparation.

3.2.1 Precooked and Instant Rice (Quick cooking rice)

Because of the demand of the modern consumers, processes have been developed to manufacture quick-cooking rice. Quick cooking rice is precooked and gelatinized to some extent in water, steam or both. The cooked rice is usually dried in such a manner as to retain the rice grains in a porous condition. This pre-packed quick-cooking rice requires just 5 min for preparation compared to 20 – 30 min in case of conventional rice cooking. Process for the quick cooking rice involves soaking of rice in water, cooking to the moisture content of greater than 60%. The cooked rice is then dried to a moisture content of 14%. The finished product should consist of dry, individual kernels, substantially free of lumps or aggregates, and approximately 1.5 to 3 times the bulk volume of the raw rice.

Alternatively, precooked rice is freeze dried. The reconstitution property of freeze dried rice is excellent compared to heat cooked and dried rice.

Retort rice in Japan is made by hermatically sealing cooked non-waxy and waxy rice in laminated plastic or aluminum-laminated plastic pouches and retort processing at 120°C under processing. Steamed waxy rice with red beans accounts for 80% of retort rice in Japan. The aluminum-laminated plastic pouch is warmed directly in hot water for 10 to 15 minutes while plastic pouches may be punctured and heated in microwave oven for 1 to 2 minutes.

Many quick-cooking rice products, varying in texture, bulk volume, appearance, taste, etc., are designed specifically for certain consumer uses depending on the rehydration time and other requirements. Some of the special applications of quick-cooking rice are in dry soup mixes, rice puddings, casseroles, flavor-coated free flowing rice and other dry prepared mixes.

3.2.2 Canned rice products

Rice is used as one of the ingredients in various canned food products such as soups, baby foods, plain and flavoured cooked rice, rice-milk pudding, etc. Long grain varieties with high amylose content are suitable for canned rice products. Parboiled rice are also preferred as they retain integrity throughout the canning process. Lacquered tin cans and retortable flexible pouches are most commonly used packaging material for canned rice products.

In the soups or other canned foods, where the rice must remain in suspension, parboiled rice is cooked enough to prevent settling and then added to the mix. The most successful and well known canned rice product is pudding. If the rice and milk mixture are prepared separately and combined in the can aseptically, the flavour and texture of the product are preserved. Dry products such as fried rice and rice and beans can also be canned.

3.2.3 Puffed rice

Paddy is soaked in water to increase the moisture to about 20%. The moist paddy is puffed by subjecting to sudden heat treatment at 250-270°C for 30-40 seconds. The husk splits and the rice is puffed.

3.2.4 Flaked rice

Flaked rice is made from parboiled rice. Paddy is soaked in water for 2-3 days (or hot water 70-80°C for 20 min.) to soften the kernel, followed by boiling in water for few minutes. After cooking, the water is drained off and the paddy is heated (250-275°C) in a shallow earthen vessel till the husk break open, after which it is pounded by a wooden pestle, heavy iron rollers which flatten the rice kernel and remove the husk. Husk is removed by winnowing.

3.3 Processing of Rice Bran Oil

Rice bran makes up only some 2% of the paddy but it is a valuable source of edible oil and protein-rich animal feed. Rice bran consists of 12 – 15% protein, 15 – 20% lipid, 40 – 50% carbohydrates, 7 – 11% crude fiber and 6 – 9% ash. Heat generated during milling triggers enzymatic activity, resulting in the hydrolysis of lipid, and oxidative changes leading to rancidity. Hence, the bran must be stabilized as quickly as possible after production to prevent the rancidity. Stabilization of rice bran can be achieved by dielectric heating, treatment with hydrochloric acid and treatment with sodium metabisulfite. Recently, extrusion-cooking process has proved very successful and cheaper. Rice bran oil is extracted with light petroleum spirit (n – hexane); the process is thus hazardous.

The flow diagram for extraction of rice bran oil is depicted in Figure 3.1. An asterisk in the Figure indicates that the products are of value e.g. for soap manufacturing, etc.

Fig. 3.1 Flow diagram for rice bran oil extraction

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Lesson 4
MILLING OF WHEAT

4.1 Introduction

Wheat is the one of the important cereal crop of the World, with an estimated annual production of 540 - 580 million metric tonnes. Wheat belongs to the genus *Triticum* of the grass family Gramineae. Common wheat (*Triticum aestivum*) and durum wheat (*Triticum durum*) are the two major wheat groups grown for food use now. Wheat is the most valuable of all food grains and is widely used in all its stages, from whole to finely milled and sifted. In the bakery, wheat flour is the most important ingredient, which provides bulk and structure to most bakery products, including breads, cakes, cookies, and pastries. Wheat is classified into two groups: hard and soft. Hard wheat is higher in protein compared to soft wheat. It yields stronger flour, which forms more elastic dough, and is better for bread making when strong elastic dough is essential for high leavened volume. Soft wheat is lower in protein, which forms weaker dough or batter, and is better for cake making.

4.2 Wheat Processing

4.2.1 Storage

Quality of wheat is to be preserved while moving from field to storage and subsequently to the processing mill. If not properly stored; insects, moisture damage, molds or other conditions may cause losses. Moisture content must be less than 20% before harvesting, and wheat is then carefully dried to moisture below 12.5%, a level which is regarded as safe for storage. The desired moisture content is achieved in kiln or in modern driers taking care of the temperature of grain does not exceed 50°C.

4.2.2 Milling

The objective of wheat milling is to grind cleaned and tempered wheat by separating the outer husk from the internal endosperm. Early processing of wheat was accomplished by means of hand grinding, grinding stones, or a mortar and pestle. Later on wheat was milled between two circular millstones, one fixed and the other mobile and rotating. Recent technology of wheat milling involves metal cylinders or rollers for milling purposes.

4.2.2.1 Cleaning

Wheat received at mill may contain certain impurities entering from field, during storage and transportation, or accidentally. Frequently encountered impurities include: straws, chaff, sticks, weed seeds, other cereal grains, shrunken and broken kernels, infected kernels, mud, dust, stones, metal objects, etc. Wheat cleaning operation makes use of certain characteristics of impurities which are different from those of wheat e.g. size (length and width), shape, terminal velocity in the air currents, specific gravity, magnetic and electrostatic properties, colour, surface roughness, etc.

The grain is initially passed through a series of screens of selected apertures that removes matter either smaller or larger in size than the wheat kernel. Gross foreign material is removed over a set of sieves (rubble separator).

In gravity separator, impurities which are similar to wheat in size but different in specific gravity are separated out. Wheat grains are then moved on tilted screen, through which adjusted air currents are drawn. Heavier materials such as stones are separated and remain closer to screen, while lighter impurities and wheat floats down the screen.

After gravity separation, series of rotating discs separators remove impurities that are similar in diameter but different in shape from the wheat. This rotating discs with indentations pick-up only those wheat kernels that fit into the pockets and allow other grains such as oats, barley to pass through.

Dry scouring of wheat kernel removes any dirt adhering to it. In the scorer wheat kernel is bounced against a wall, which may be of a perforated sheet metal, a steel wire woven screen or any emery surface.

Magnetic separators separate foreign materials such as nails, pieces of metal that could damage equipments or generate spark, which could cause a dust explosion.

In final cleaning operation, wheat is washed by water. Wheat is immersed in water (0.5 – 1.0 lit per kg) and then conveyed by means of a worm to a centrifugal machine called whizzer, where it is vigorously agitated and spun dried. Washing of wheat removes crease dust.

4.2.2.2 Conditioning / Tempering

Conditioning of wheat is carried out primarily to improve the physical state of grain for milling. In conditioning moisture content of wheat kernel is adjusted. This includes heating and cooling of the grain for definite period of time, in order to obtain the desired moisture content and distribution. At this adjusted moisture level of wheat before milling, wheat endosperm becomes mellow and bran becomes tough. Bran that absorbs proper amount of moisture becomes elastic and will not splinter during grinding to contaminate the flour with fine particles, and thus flour becomes whiter in colour. The endosperm becomes mellower and more friable, thereby reducing the amount of power required to grind it.

Several methods are employed to condition the wheat. Heating the wheat, application of warm water, application of live steam, or just intensive mixing of wheat and water are some of the methods used to increase the amount and rate of water penetration into kernel.

Three factors affect the rate and level of water penetration into the kernel: temperature, amount of water (% moisture content) and time. The ideal water and wheat temperature for tempering condition is 25°C. Higher temperature will increase the rate of penetration into the kernel. Temperature above 50°C will change endosperm starch and protein characteristics.

Typical moisture contents of tempered wheat and tempering times are as follow:

Type of wheat	**Optimum moisture content of tempered wheat**	**Tempering time (Hrs)**
Hard spring wheat	16 – 17%	36
Hard red winter wheat	15.5 – 16.5%	24
Soft wheat	14.5 – 15.5%	10
Durum wheat	16 – 17.5%	6

4.2.2.3 Milling / Separation of flour

Objective of wheat milling is to separate the branny cover and germ of the wheat kernel from the endosperm. Wheat flour milling is a process that consists of controlled breaking, reduction and separation.

Wheat flour milling involves three basic processes:

(i) Grinding: Fragmenting the grain or its parts

(ii) Sieving: Classifying mixtures of particles based on its particle size

(iii) Purifying: Separating bran from endosperm particles based on their terminal velocity, by means of air currents.

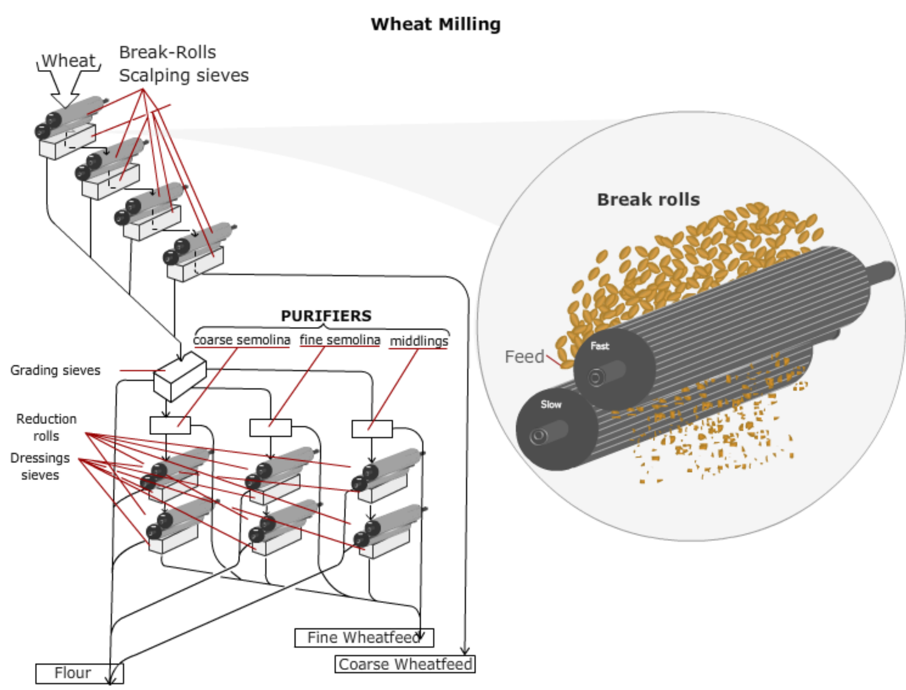

Fig 4.1 Wheat flour milling and Pair of break rolls

Grinding of the wheat occurs between two cast rolls (break rolls) that rotates against each other. These rollers are fluted and they are not in contact with each other. The upper roller rotates two and a half time for each rotation of the lower one. Hence, the grain is engaged between fluted serrations of the rolls and broken or cut by the faster roll as it is held back by the slower roll. This initial stage in milling process is referred as 'breaks'. The breaks are used in the grinding steps to separate the bran, germ and endosperm from each other. The grist coming out from the rolls is sifted through a plansifters. The plansifter is a machine consisting of a vertical nest of horizontal sieves, the whole assembly gyrating in a horizontal plane. A single plansifter consist of four or five different mesh sizes may yield five or six fractions of different particle size.

The series of break rolls and sieves converts the grain into semolina, which is small granule made up of endosperm. The outer husk is collected separately as bran. The semolina is separated into three grades: fine, medium, coarse in an operation called 'gradual reduction system'. Here the rolls are smooth and one rotates only one and a quarter times for each rotation of the other.

These three streams are then put through purifiers. Purifier consists of a long, narrow, sieve set. The sieves become coarser progressively in size of mesh from head to tail. The sieve section is connected to a fan and the air is drawn up through each sieve section to draw off branny particles.

The number of parts of flour by weight produced per 100 parts of wheat milled is known as the flour yield, or percentage extraction rate. The wheat grain contains 82% of white starchy endosperm, but it is never possible to separate it out fully from the bran. Extraction rates of different flours are as follow:

Sr. No.	Flour	Extraction rate (%)
1	Wholemeal flour	95
2	Brownish flour	85
3	Creamy flour	80
4	White flour	70

4.3 Air Classification of Specialty Flour

Air classification of flour is used where there is a demand for extremely precise specification of granulation and protein content of flour. Flour with a narrow range of particle size has the advantage of increasing the tolerance of oven temperature and water absorption during the baking of cakes. Commercial flour particles granulation is between 0-150µm. A flour fraction of 1-17 µm contains a high level of protein. A flour fraction of 17-40 µm will usually be marked as to its higher starch content and lower protein level. It is not practical to separate particles of less than 73 µm with conventional sieves. Accordingly, particles are segregated by air using differences in particle shape, specific gravity and size.

4.4 Milling By-Products

The by-products from wheat milling process are known as 'wheatfeed'. They comprise bran, the coarse residue from break grinds, fine wheat feed, accumulated particles from the purifiers and reduction grinding. Bran and fine wheat feed are used in compound animal feeds.

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Module 2. Cereal processing

Lesson 5

CRITERIA OF WHEAT FLOUR QUALITY, IMPROVERS FOR WHEAT FLOUR, TYPES OF WHEAT FLOUR

5.1 Introduction

Flour produced at every grinding machine is different in terms of proportion of endosperm, germ and bran contained in it. Thus, each ‘machine’ flour is distinct in terms of baking quality, colour, granularity and the ash content. This difference in the composition of flour can lead to non-uniform quality in baked products. Thus to improve the quality of bakery products numerous chemical and biological compounds are added to the wheat flour during processing. They are usually added in very minute quantities to get the desired effects.

These additives must be GRAS (Generally Recognised As Safe) and should be permitted under food laws of the country of use. Wheat flour is major ingredient in manufacture of baked goods. But each type of bakery product requires a specific type of flour or combination of flour with certain improvers to get desired quality of end product. These additives are known as flour improvers, as they improve the technical quality of flour. The examples of flour improver are: bleaching agents, maturing agents, surfactants, enzymes, reducing agents, vitamins and minerals, antimicrobial agents, etc.

5.2 Flour Improvers

5.2.1 Bleaching agents

Flour contains a yellowish pigment, of which about 95% consists of xanthophyll or its esters. Bleaching of the natural pigment occurs very slowly when the flour is stored in bulk. Hence, to accelerate the bleaching process chemical bleaching agents are used. Nitrogen peroxide, chlorine, chlorine dioxide, nitrogen trichloride, benzoyl peroxide and acetone peroxide are the principal agents used for bleaching of wheat flour.

5.2.2 Maturing or improving agents

The bread making quality of wheat flour improves during storage for a period of 1 – 2 months. This change in baking quality is known as maturation or ageing. Chemical improver accelerates the maturing process by modifying the physical properties of gluten during fermentation. The stickiness in dough gets reduced and hence improved handling properties, increased tolerance in the dough to varied conditions of fermentation, and in producing loaves of larger volume and more finely textured crumb.

The action of improvers is believed to be an oxidation of the sulphydral or thiol (– SH) groups present in wheat gluten. Hence, the thiols are not available for participation in exchange reactions with disulphide (– S:S –) bonds. This reaction is considered to release the stress in dough and consequently the dough tightened. Potassium bromated, ascorbic acid, azodicarbonamide, stearoyl lactylates, ammonium/potassium per sulfate, acid calcium phosphate, acid sodium pyrophosphate are widely used maturing agents in wheat flour.

Chlorine, chlorine dioxide and acetone peroxide acts as both bleaching as well as maturing agents.

5.2.3 Biological additives

Enzymes such as amylases, proteases and oxidases are added to improve mixing, fermentation, flavour development, texture and storage properties of the baked products. Amylases break down starch molecules into glucose which is used by yeast to liberate carbon dioxide gas. Glucose oxidase enzyme is used to replace the chemical maturing agents such as potassium bromate which is banned in certain countries. Proteases are usually used in biscuit dough to reduce the mixing time. Lipoxigenase is used in bread dough as bleaching and maturing agent.

5.2.4 Emulsifiers

Emulsifier reduces surface tension and thus facilitates mixing of fat and aqueous phases. Emulsifiers are widely used in biscuit dough, icings, cakes, etc. where it helps in improvement of the texture. Mono/diglycerides, lecithin, polygycerol esters, calcium stearoyl lactylate, polysorbates, sodium stearoyl lactylate are some of the widely used surfactants in manufacture of baked food products. Emulsifiers with low HLB (Hydrophilic Lipophilic Balance) value such as mono/diglyceride, lecithin are suitable for high fat products, while emulsifiers with higher HLB values (sodium stearoyl lactylate) are best suited for low fat high moisture foods.

5.2.5 Antimicrobial agents

Bakery products are susceptible to microbial contamination especially with molds and rope formers owing to its high moisture and nutrient rich composition. Products get contaminated generally during processing steps such as cooling, slicing and wrapping. So wheat flour is usually added with certain mold inhibitors such as calcium/sodium propionate, sorbic acid or its calcium/potassium salts, acetic acid, lactic acid, acid calcium phosphate, sodium diacetate.

5.2.6 Vitamins and minerals

Wheat milling involves removal of bran, germ and aleurone layers. These layers are rich in vitamins and minerals. Hence, to meet the deficit of these nutrients, wheat flour is usually enriched with vitamins and minerals. Even lysine which is an essential amino acid is substantially lost during processes such as milling and baking. So, the flour is enriched with lysine too.

5.3 Types of Wheat Flour

Wheat flour is used in manufacture of numerous baked products. Other than baked products wheat flour is used in making other food products such as meat pie, sausages, chapattis, soups, etc. Biscuit dough should be stiff enough to permit rolling and flattening, while bread dough must be plastic mass that can be moulded and shaped. Wafer batter is a liquid suspension, which is able to flow through a pipe. So for each application flour with specific properties is necessary.

Flour from different stages in the mill are not identical in physical appearance, chemical analysis or baking properties. If all the streams of flour are mixed to one composite, then the resultant flour is known as ‘straight-grade flour’. It is also possible to blend the streams in definite proportions/ratios to produce the flour which is called ‘split milling’ or ‘divide milling’. Flour streams head end middlings, primary sizing and in some cases that of second and third breaks originate from the centre of wheat kernel. The blend of these flour streams is called ‘patent flour’.

In Table 5.1 various types of wheat flour along with their specific characteristics are listed.

5.4 Criteria of Wheat Flour Quality

Flour quality is a subjective concept that relates to the final product usage. For different baked goods wheat flour with specific characteristics is required as discussed earlier in types of wheat flour. Quality parameters such as colour, protein, granulation distribution, gluten quantity and quality, and starch damage play important role in deciding the suitability of flour for the baker.

Table 5.1 Types of wheat flour and their characteristics

Sr. No.	Type of wheat flour	Specific characteristics
1	Bread flour	□ Flour with high level of good quality protein □ Protein content: 10.8 – 11.3% (Mechanical process), 11.8 – 12.3% (Fermentation process)
2	Biscuit flour	□ Milled from weak wheat of low protein content □ Protein content: 8 – 9.5%
3	Household flour	□ Weak wheat of low protein content with admixture of up to 20% of strong wheat
4	Self-raising flour	□ Flour with added raising agents □ Moisture should not exceed 13.5% to avoid premature reaction of aerating chemical
5	Flour for confectionery	*Cakes* □ Undamaged starch granules, free from adhered protein and unattached by amylases □ Protein content: 8.5 – 9.5% □ Particle size: 90 µ *Buns* □ Bread making flour *Pastry* □ Strong baker's flour
6	Flour for soups	□ Steamed flour in which enzymes have been inactivated
7	Flour for sausage rusk	□ Low protein flour milled from weak wheat
8	Batter flour	□ Low protein flour milled from grist comprising 90% weak wheat and 10% strong wheat

5.4.1 Composition of wheat flour

The quality requirements of flour for different products are different. In Table 5.2 proximate composition of flour suited for different products are given.

Table 5.2 Proximate composition of flour suited for different products

Sr. No.	Component (%)	Biscuit	Bread	Cake
1	Protein	9.0	11.5	8.0
2	Fat	1.3	1.4	1.3
3	Fiber	0.15	0.1	0.05
4	Ash	0.6	0.5	0.4
5	Carbohydrate	72.6	70.1	73.5

5.4.2 Physical characteristics of wheat flour

5.4.2.1 Colour

Flour is tested for colour for evaluating either its whiteness, which primarily determines the extent of the oxidation of carotenoid pigments by bleaching agents, or the presence of bran particles indicating milling performance. Hunter device with L*a*b system, ‘Slick’ (Pekar) test, reflectance meter, NIR reflectance meter are some of the analytical techniques used for determination of wheat flour colour.

5.4.2.2 Thousand grain weight

Thousand grain weight or thousand kernel weight is usually expressed as weight of a thousand grains of wheat in grams. It is used to predict how much flour will be extracted from a given weight of wheat.

5.4.2.3 Granularity

Particle size of flour directly affects the amount of water required and rate of hydration for dough. The simple method for estimation of particle size is use of standard sieves with different mesh size.

Other physical characteristics such as test weight, hardness, experimental milling are also performed to evaluate suitability of flour for manufacture of various baked goods.

5.4.3 Alpha-amylase activity and Hagberg Falling Number

Alpha-amylase is an inherent enzyme of the wheat which breaks down the wheat starch into simple sugar during germination. It is used as one of the key indicators of wheat baking quality. The flour having high level of alpha-amylase activity requires less amount of water for mixing, softens the dough, weakens the bread structure and produces a soft, sticky crumb. Alpha-amylase activity is measured using the Hagberg falling number test. A sample of ground wheat is suspended in water using a standard glass tube. The tube is placed in the Falling Number apparatus, where the suspension is heated in water bath at 100°C and stirred for 60 sec. The alpha-amylase breaks down the starch in the suspension, causing a reduction in the viscosity which is measured using the time taken for a plunger to fall through the suspension. The time in seconds is taken as the Hagberg falling number. The greater the number, the higher the viscosity and the lower the alpha-amylase activity. Falling number values of greater than 250 sec are generally acceptable for breadmaking.

5.4.4 Flour quality testing

5.4.4.1 Ash

It is indicator of the amount of mineral matter present in the flour and is commonly considered a quality index for flour. The flour having high bran content will contain more of ash content as bran has a higher mineral content the endosperm. High ash content of flour is not good for baking. The ash content is measured by the combustion of flour at 550°C.

5.4.4.2 Starch damage

Some of the starch granules get damaged during the milling process. Damaged starch absorb more water than undamaged starch and also susceptible to attack by alpha-amylase. Damaged starch can cause problems such as sticky crumb and weak bread structure.

5.4.4.3 Sedimentation value

Sedimentation test is used to assess the gluten quality and bread making potential of the flour by observing the way in which a ground wheat or flour suspension coheres and settles in the presence of sodium dodecyl sulphate. It takes upto 30 minutes for ground wheat and 50 minutes for white flour. Hard wheat flour having high content of glutenin proteins showed high sedimentation value as compared to soft wheat flour.

5.4.5 Rheological characteristics of wheat flour

Dough forming properties or rheological properties of wheat flour dough is important as they determine the suitability of dough for making of various baked food products. Even these properties determine performance of dough during various stages of manufacture. Following are the methodology usually adopted to determine the rheological characteristics of dough:

Dough mixing characteristics can be measured by use of 'farinographs', which give idea about water absorption, mixing time, mixing tolerance, strength of dough against machine abuse. To correct any deficits found, baker can change the wheat mix. Bread flour should have higher water absorption capacity and good mixing characteristics than biscuit dough. Bread flour should have water absorption capacity of 60 – 65%, dough development time of 5 – 7 min and stability of 7 – 9 min. Biscuit flour have 55 – 60% water absorption capacity.

'Extensograph' is used to determine structural transformations of dough during fermentation and maturing in terms of strain/stress relation indicating degree of maturation. This test give idea about ageing of flour, requirement of oxidizers and heat conditioning.

To analyze the gelatinization characteristics of starch in oven, 'amylographs' are used. This test indicates any need of enzymes or diastatic malt.

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Module 2. Cereal processing

Lesson 6

CORN: CLASSIFICATION, DRY MILLING AND WET MILLING

6.1 Introduction

Corn or Maize (*Zea mays*, L) is used for animal feeding, for human consumption and for the manufacture of starch, corn syrup solids, sugar, beer, industrial spirit, etc. The products of milling include maize grits, meal, flour, and protein and corn steep liquor. Corn is consumed as human food in many forms. In its harvested wet form, it is consumed as vegetable. The ready-to-eat breakfast cereal 'corn flakes' is made form maize grits. Popcorn – the first snack food is undoubtedly the oldest snack food. The majority of corn consumed as human food has undergone milling and is consumed as a specific or modified fraction of the original cereal grain. Like other cereal grains, corn is milled to remove hulls and germ.

6.2 Corn Classification

Maize or corn is classified commercially into four main classes as follows:

1. Dent varieties, which, when mature have a pronounced depression or dent at the top of the kernel. These have hard patches of densely packed endosperm cells at the outer edges of their endosperm and soft, opaque cells toward their center. Their shapes vary from long and narrow to wide and shallow.

2. Flint varieties, which have a continuous hard layer surrounding the endosperm. When these kernels dry, they dry evenly and therefore do not form a dent.

3. Flour or soft varieties, which are almost entirely opaque and soft. It is the soft maize varieties that are normally used to make corn flour.

4. Waxy maize varieties that have a waxy appearance especially when broken. The starch consists of very little amylose and is effectively 100% amylopectin (maize starch is normally about 30% amylose and 70% amylopectin).

6.3 Corn Processing

Maize is processed by dry or wet milling. Dry milling may or may not include de-germing as a preliminary step. Non-de-germing dry milling is carried out on a local basis in small grist mills or in modern roller mills using sifters and purifiers. The maize is ground to make coarse wholemeal of 85 – 95% extraction rate. This wholemeal is highly susceptible to the rancidity as the germ is retained which has a high oil content. Wet milling and dry milling involving de-germing are carried out in large commercial mills.

6.3.1 Dry milling

- Two different systems are used for dry milling of corn.
- The non-degerming system grinds corn into mill with hardly any separation of germ. This corn meal has comparatively shorter shelf-life, as the germ is retained, which contains 32 – 35% oil. This oil in presence of oxygen and lipolytic enzymes is prone to oxidative and hydrolytic rancidity.
- Hence, it is necessary to remove the germ from corn to produce corn products with much lower fat content and greater shelf-life.
- Tempering and degerming system remove most of the germ and hull and leave the endosperm as free of oil and fiber as possible to recover maximum yield of endosperm and germ as large clean particles.
- Corn is cleaned to remove dirt, stones, insects, tramp iron, broken kernels and extraneous plant materials.
- The corn is then conditioned by adding water to increase the moisture content to 20%, and the moistened corn is allowed to equilibrate for 1 – 3 hrs. The objective of conditioning is to loosen the germ and toughen the bran and to mellow the endosperm so as to obtain a maximum yield of grits and a minimum yield of flour in the subsequent milling.
- Degerming and dehulling is carried out in one of the three ways:

1. Beall de-germinator (De-germer and corn huller)
2. With roller mills and sifters
3. With impact machines such as entoleters and gravity separators.

- Once the germ and hull are removed, the endosperm is reduced in size to grits with roller mills. A complex array of additional roller mills and particle size separating equipments is used to purify and size endosperm particles. All products must be dried prior to packaging or bulk storage.

6.3.2 Wet milling

- Wet milling of corn is achieved by a combination of chemical and mechanical means. Wet milling begins with steeping of cleaned corn for 30 – 48 hours with water. Sulfur dioxide is added to the water at the rate of 0.1 – 0.2% and the solution is heated to about 50°C. This condition prevents growth of putrefying microorganisms.
- During steeping, the kernel absorb solution and swell, activating enzymes native to the kernel to assist in breaking down the structure; the bisulfite ion reduces disulfide bonds in the protein matrix, increasing protein solubility and diminishing interactions between starch and protein; the lactic acid and/or exogenous enzymes produced by the lactobacilli help soften the endosperm.
- After steeping corn is ready for grinding and fractionating in disc attrition mill. The ground slurry is then pumped to hydroclones (liquid cyclones) to separate lighter-weight germs. The germs are dried and processed for oil and meal. The heavier underflow from the hydroclones is screened, and larger particles are finely reground with an impact mill to free the starch, protein, and fiber from each other.
- Fiber is separated and washed over series of screens.
- The remaining stream of starch and protein is passed through disc nozzle type centrifuges, where heavier starch is separated from the gluten.
- The gluten is dewatered using additional centrifuges and vacuum filters. The remaining starch slurry is washed and passed through hydroclones. Centrifuges and/or vacuum filter dewater the purified starch.

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Module 2. Cereal processing

Lesson 7

BARLEY: CLASSIFICATION, MALTING AND PROCESSING

7.1 Introduction

Barley (*Hordeum vulgare L.*), a major world crop ranks among the top 10 crops and is fourth among the cereals. Barley contributes significantly to the world's food supply as human food, malt products, and livestock feed. However, the barley crop may be considered relatively under–utilized with regard to its potential use as an ingredient in processed human foods. Barley belongs to the genus *Hordeum* and can be considered one of the most ancient crops.

7.2 Barley Classification

Barley is a grass belonging to the family *Poaceae*, the tribe *Triticeae*. The chief taxonomic characteristic of *Hordeum* is its one–flowed spikelet. Three spikelets alternate on opposite sides at each node of the flat rachis of the spike or head. Thus is formed a triplet of spikelets at each node– the central and the two laterals. Each spikelet is subtended by two glumes. When all three spikelets are fertile, the spike is described as six–rowed. When only the central spikelet is fertile, the spike is two–rowed.

Most barleys grown for commerce are husked, that is the palea and lemma of the floret adhere to the outside of the grain. Huskless barley are not suitable for malting, but they are used for human foods as their digestibility is higher than the hulled type.

7.3 Chemical Composition of Barley Grain and Malt

Carbohydrates constitute about 80% by weight of barley grain. Starch is the most abundant single component, accounting for up to 65%, but polysaccharides of cell wall origin are also quantitatively important and may represent more than 10% of grain weight. Barley malt is produced by controlled steeping and germination schedule. The gross chemical changes observed during malting are the net result of degradation of reserve substances. The chemical composition of barley grain and malt is given in Table 7.1.

Table 7.1: The Chemical Composition of Barley and Malt

Component	Proportions (Dry Weight, %)	
	Barley	Malt
Starch	63 – 65	58 – 60
Sucrose	1 – 2	3 – 5
Other sugars	1	2
Water– soluble polysaccharide	1 – 1.5	2 – 4
Alkali– soluble polysaccharide	8 – 10	6 – 8
Cellulose	4 – 5	5
Lipids	2 – 3	2 – 3
Proteins	10 – 12	8 – 11
Albumins and globulins	3.5	2
Hordeins	3 – 4	2
Glutelins	3 – 4	3 – 4
Nucleic acids	0.2 – 0.3	0.2 – 0.3
Minerals	2	2.2
Others	5 – 6	6 – 7

7.4 Processing of Barley

Barley is often milled to obtain blocked barley, pearled barley, barley groats, barley flakes and barley flour for human consumption. The sequence of operations in barley milling may be as follows: preliminary cleaning, conditioning or tempering, bleaching (blue aleurone barley), blocking or shelling, aspiration, size grading by sifting, groat cutting, pearling of blocked barley or large barley groats, grading and sifting and polishing (Fig. 7.1). Some of the commercially available barley products are described below.

i. *Pot and pearled barley* are prepared by gradual removal of hull, bran and germ by abrasive action in a stone mill. Production of pot barley is the first stage of pearling, which may remove 7 – 14% of the weight of the grain. Further abrasion results in the removal of seed coat (testa and pericarp), aleurone, subaleurone layers and the germ leaving behind a central endosperm rich in carbohydrates and proteins.

ii. *Barley flour* is made by roller–milling of pearled or blocked barley.

iii. *Barley flakes* are made by predamping of barley groat, steam cooking of groats or pearled barley, flaking and hot air drying of flakes.

iv. *Barley bran* (excluding the hulls) consists of testa and pericarp, germ, the tricellular aleurone and subaleurone layers. Barley bran is obtained as a by–product during barley milling process.

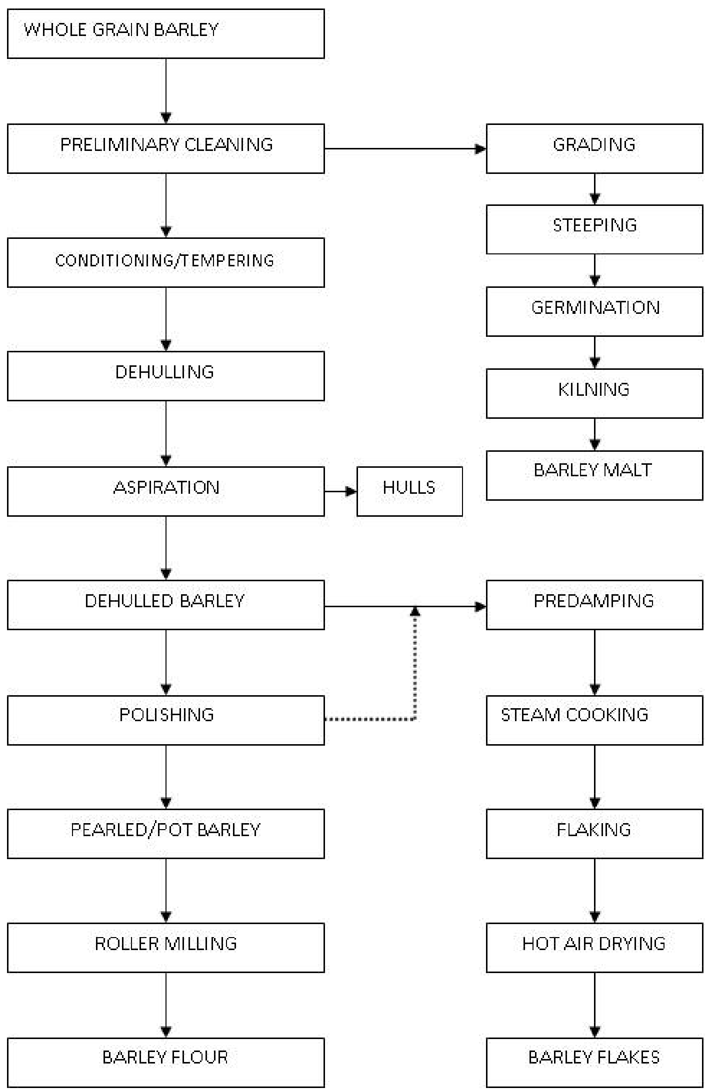

Fig. 7.1 Flow Diagram of barley processing

7.5 Malting of Barley

In the production of malt based beverages and malted milk food, barley grain is first converted into malt. The malting process commence with the steeping of barley in water at a temperature of about 12°C for 36 hours with frequent aeration, to achieve a moisture level sufficient to activate metabolism in the embryonic and aleurone tissues, leading in turn to the development of hydrolytic enzymes. The wet barley is germinated around 14°C for a period of about 144 hours. During germination, enzymes migrate through the starchy endosperm, progressing from the embryo end of the kernel to the distal end. In this mobilization phase, generally referred as “modification”, the cell wall and protein matrix of the starchy endosperm are degraded, exposing the starch granules. After a period of germination, the “green malt” is kilned at a temperature not exceeding 85°C, to arrest germination and stabilize the malt by lowering the moisture levels, typically to less than 5%. In the process, undesirable raw flavours are removed and pleasant “malty” notes are introduced. The kilning process is also responsible for developing the colour of the malt.

7.5.1 Biochemistry and chemistry of malting

Essentially, malting allows the optimal development of hydrolytic enzymes by the aleurone cells of barley and controlled action of these enzymes to eliminate structural impediments to subsequent easy and complete extraction during mashing. Elucidation of the part played by gibberilic acid in stimulating secretion of □–amylase, endopeptidase, endo–□–glucanases and inorganic ions from the aleurone to the central endosperm has encouraged the development of malting modifications.

7.5.2 Steeping

In many respect, the steeping operation is the most critical stage in malting. To produce homogeneous malt, it is necessary to achieve even moisture content across the grain bed. Most barley requires a steeping regime that takes them to 42 – 46% moisture. At the commencement of steeping, the embryo and husk absorb water far more rapidly than does the starchy endosperm. Besides water, barley requires a supply of oxygen to support respiration. Oxygen access is inhibited if the grain is submerged in water for prolonged periods, a phenomenon that dictates use in modern malting regime of steeps interrupted by air rest periods. Additionally the steep water may be aerated or oxygenated. Air rests serve the added role of removing carbon dioxide and ethanol, which are the products of respiratory metabolism and may inhibit germination. A typical steeping regime may involve an initial steep to 32 – 38% moisture, an air rest of 10 – 20 h, followed by a second steep to raise moisture to 40 – 42%. The entire steeping operation in the modern malting plants is likely to cover 48–52 h.

7.5.3 Germination

Germination is generally targeted to generate the maximum available extractable material by promoting endosperm modification through the development, distribution and action of enzymes. Enzyme synthesis occurs during germination in the aleurone and subsequently migrates into the endosperm to effect hydrolysis. During hydrolysis enzyme development follow the sequence: cell wall degrading enzymes, proteases, and then amylases. The process is controlled by maintaining moisture levels within the grain, supplying oxygen, removing carbon dioxide, and eliminating excess heat formed by respiration. Temperature is controlled throughout the germination period, typically in the range of 16 – 20°C. Modification of the barley commences at the proximal end of the grain, adjacent to the scutellum (Fig.7.2). The rate of modification depends on: (1) the rate at which moisture distributes through the starchy endosperm, (2) the rate of synthesis of hydrolytic enzymes, (3) the extent of release of these enzymes into the starchy endosperm, and (4) structural features of the starchy endosperm that determine its resistance to digestion.

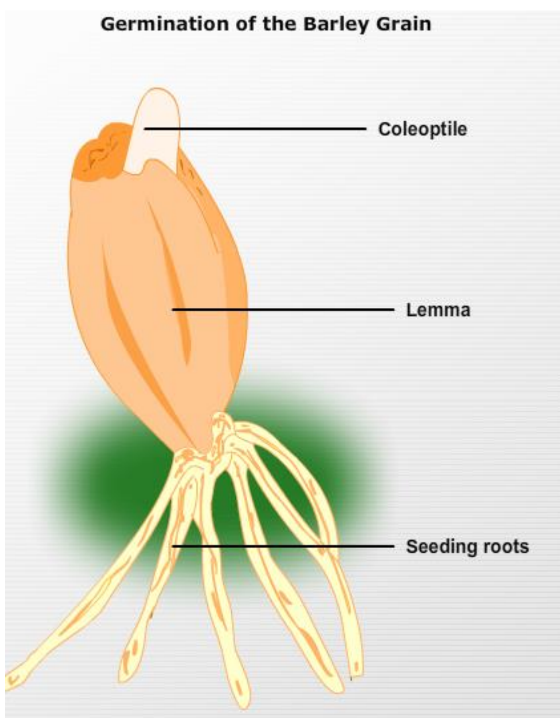

Fig. 7.2 Germination of barley grain

7.5.4 Kilning

Through the controlled drying of green malt, the maltster is able to: (1) arrest modification and render malt stable for storage, (2) ensure survival of enzymes, where appropriate, for subsequent employment in processing, and (3) introduce desire colour and flavour characteristics. Kiln drying is divided into four major phases: (1) free drying down to approximately 23% moisture, (2) an intermediate stage, to 12% moisture, (3) the bound water stage, from 12 to 6% moisture, and (4) curing, in which the moisture is typically taken to 2–3%. Principle changes occurring during kilning is the browning or Maillard reaction. The interaction of reducing sugar and amino acids produces reductones, which in turn can be converted by polymerization to the colourful melanoidins or, by alternative routes, to the heterocyclic pyrazines, thiophenes, pyrrolles, and furans. The oxygen heterocyclics are responsible for toffee or caramel flavours. The pyrazines impart the roasted, coffee like flavours.

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Module 2. Cereal processing

Lesson 8

MILLETS: TYPES AND PROCESSING

8.1 Introduction

The grasses known collectively as millets are a set of highly variable, small seeded plant species indigenous to many areas of the world. Millets are of value especially in semiarid regions because of their short growing season and higher productivity under heat and drought conditions. Pearl millet is the most widely grown millet and is a very important crop in India and parts of Africa. Finger millet is popular in East Africa and India. Foxtail and Proso millets are cultivated primarily in the Near East and China. Proso millet is also widely cultivated in the Russia Federation. Fonio and teff are grown in West Africa and Ethiopia, respectively. Most commonly grown millets with their common name is listed in Table 8.1. The millets originated primarily in East and West Africa, Eurasia, India and China from wild seed stock. Pear millet is one of the earliest domesticated millets; carbonized grains have been found in sub-Saharan and West African sites inhabited 4000-5000 years ago.

8.2 Structural and physical properties

Kernel characteristics of the various millets are extremely diverse. The millets can be divided into two types of seeds: utricles and caryopses. In the utricle, the pericarp surrounds the seed like a sac but is attached to the seed at only one point. Finger millet, proso and foxtail millets are utricles. In these millets, the pericarp usually breaks away from the seed coat or testa, which is well developed, thick and forms a strong barrier over the endosperm. In a caryopsis, the pericarp is completely fused to the seeds. Pearl millet, fonio and teff are caryopses. For pearl millet, the kernels are composed of the pericarp, endosperm and germ, which comprise 8.4, 75.1 and 16.5% of the total kernel weight, respectively.

The endosperm comprises the majority of the kernel weight for all millets. There are four structural parts of the endosperm: the aleurone layer and the peripheral, corneous and floury endosperm areas (Fig. 8.1). All millets have a single layer aleurone that completely encircles the endosperm. The aleurone cells are rectangular with thick cell walls, and they contain protein, oil, minerals and enzymes. The peripheral corneous and floury endosperm areas are beneath the aleurone, in that order.

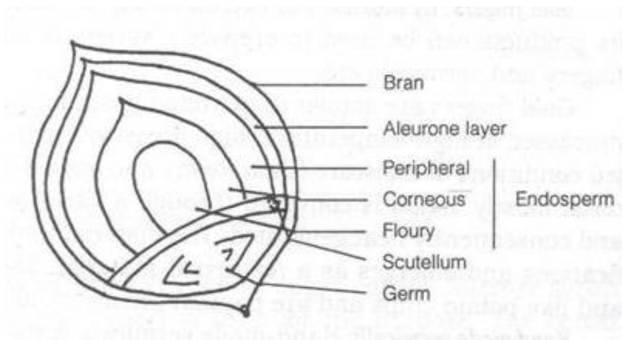

Fig 8.1 Structure of millet

8.3 Composition of millets

The mean values and variations in proximate composition of different types of millets are presented in Table 8.2.

Table 8.1: Common and Scientific Name of Major Types of Millets

Scientific Name	Common Name	Growing Areas
Pennisetum glaucum *P. americanum* *P. typhoiides* *Panicum milaceum*	Pearl millet	Africa, India
Eleusine coracana	Finger millet	Africa, India, China
Setaria italica	Foxtail millet	China, Near East, Europe
Digitaria exilis *D. iburua*	Fonio	West and North Africa
Panicum sumatrense *P. psilopdium*	Little millet	India, Nepal, Burma

Eragrostis tef *E. abyssinica*	Teff	East Africa, Ethiopia
Paspalum scrobiculatum *P. commersoni*	Kodo millet	Southern Asia
Echinochloa crusgalli *E. utilis* *E.frumentacea* *E. colona*	Japanese milllet	Asia

Table 8.2: Proximate Composition of millets

Millet	Protein(%)	Fat, Ether extract (%)	Crude fiber (%)	Ash (%)	NFE (%)	Starch (%)
Pearl millet	14.5	5.1	2.0	2.0	76.4	71.6
Finger millet	8.0	1.5	3.0	3.0	84.5	59.0
Proso	13.4	9.7	6.3	4.2	69.4	57.1
Japanese millet	11.8	4.9	14.3	4.9	64.1	60.3
Foxtail millet	11.7	3.9	7.0	3.0	74.2	55.1
Kodo	10.4	3.7	9.7	3.6	72.6	72.0
Tef	10.9	2.4	2.4	2.2	82.1	73.1
Fonio	8.7	2.8	8.0	3.8	76.7	61.0

All values are expressed on dry matter basis.

Protein conversion factor=N X 6.25.

NFE=Nitrogen-free extract.

8.4 Food utilization

Millets have been utilized for human food for prehistoric times. In India, virtually all of the pearl millet and most of the finger millet is directly consumed as human food. The most important use of pearl millet grain is in baking chapattis or rotis. Millet grain is also used for production of rice-like products and porridges. Pearl millet is also used to produce malt and alcoholic beverages. Millet flour has been successfully incorporated into cutlets, pakoras, weaning foods and biscuits.

8.5 Postharvest Processing

8.5.1 Storage

Millets are harvested, dried and stored intact in storage bins. Usually, the millet heads are pounded in a mortar and pestle, winnowed and the grains required for daily consumption is further processed (dehulled and ground) in the mortar and pestle as needed. Millets are traditionally stored in clay pots or raised huts. Millets have reputation of being less susceptible to the insect attack than other grains. This is due to small size of millet grains. The another reason id that they are commonly grown in semi arid areas of the world where the relative humidity is typically less than 40%, which is not optimum for many pests.

8.5.2 Milling

Milling separates the grain into three components, germ, endosperm and seed coat. Milling techniques practiced mostly depend on the end-use. Milling process starts with the cleaning of the grains, to remove unwanted impurities and broken grains, using vibratory sieves, aspirators and specific gravity separators. The cleaned grains are conditioned, by addition of water, to soften the endosperm. In developing countries, millets are normally decorticated and ground with mortar and pestle prior to use. Grinding stones are also used, followed by winnowing or washing at various stages of grinding to remove bran, coarse particles and fine particles. These milling techniques are labour intensive. In India, stone hand grinder, consisting of two round stones rotating horizontally against each other is used for grinding millets. Millets are also decorticated with abrasive discs in mechanical huller and ground into flour with attrition or hammer mills.

The endosperm is recovered in the form of grits, with the minimum production of flour. Yields of various fractions from the milling process are grit, 76.7; bran, 1.2; germ, 11; fiber, 10%.

Module 2. Cereal processing

Lesson 9

BREAKFAST CEREALS: CLASSIFICATION AND TECHNOLOGIES

9.1 Introduction

In this century, cereal grains have found a significant use as breakfast foods. Breakfast cereal technology has evolved from the simple procedure of milling grains for cereal products that require cooking to the manufacturing of highly sophisticated ready-to-eat products that are convenient and quickly prepared. Breakfast cereals are generally eaten cold and mixed with milk as opposed to hot cereals like oatmeal, grits, etc.

9.2 Definition and classification of Breakfast Cereals

9.2.1 Definition

Breakfast cereals have been defined as "processed grains for human consumption". One or more of the cereal grains or milled fractions therefore are indeed major constituents of all breakfast cereals, approaching 100% in the case of cereals for cooking. The proportion drops well below this in many ready-to-eat cereals, and to less than 50% in pre-sweetened products. They are made primarily from corn, wheat, oats, or rice and usually with added flavour and fortifying ingredients.

9.2.1 Classification

Ready-to-eat (RTE) cereals are made primarily from corn, wheat, oats or rice usually with added flavour and fortifying ingredients. Breakfast cereals are classified into two major categories: hot cereals and RTE cereals

Hot cereals are made primarily from oats or wheat nevertheless; hot cereals from corn or rice are produced in relatively small quantities. Hot cereals require cooking at home before they are ready for consumption with the addition of either hot water or milk.

The processing of RTE cereals involves first cooking the grains with flavouring material and sweeteners. Sometimes more heat stable nutritional fortifying agents are added before cooking. Most RTE cereals are grouped into eight general categories:

1. Flaked cereals

2. Gun-puffed cereals
3. Extruded gun puffed cereals
4. Shredded whole grains
5. Extruded and other shredded cereals
6. Oven puffed cereals
7. Granola cereals
8. Extruded expanded cereals

9.3 Manufacturing Processes for Breakfast Cereals

The proprietary nature of the breakfast cereal industry limits the information base to patent records and publications by individuals not directly associated with industry. In broad terms, breakfast cereal ingredients may be classified as grains or grain products, sweeteners, flavouring, texturizing ingredients, and micro-ingredients for nutritional fortification and preservation. The processing of ready-to-eat cereals typically involves first cooking the grains with flavouring material and sweeteners, followed by forming operation. Sometimes the heat stable nutritional fortifying agents are added before cooking. Two cooking methods are employed in the industry -direct steam injection into the grain mass and continuous extrusion cooking.

Various unit operations are involved in the manufacturing of the breakfast cereals such as tempering, cooking, puffing, flaking, shredding, baking and drying, etc. These unit operations yield breakfast cereals with certain forms such as puffed, cracked, flaked, cakes, pellets or definite shapes such as circular, cylindrical, rectangular, nuggets, oval, triangle; and irregular shapes such as chunks.

9.4 Processing Steps

9.4.1 Cooking

Flaked breakfast cereals can be made by cooking whole kernel cereals or legumes by pressure cooking followed by pressing through rollers. Alternatively it can be made by extrusion cooking of flour. Cooking helps in development of desirable flavour and nutritional benefits. It also assists in creation of desirable physical properties necessary for the development of desire texture – primarily by starch gelatinization.

9.4.1.1 Batch cooking

Corn flakes, wheat or bran flakes and shredded wheat are processed in batch pressure cook processes, where steam is injected into the pressure cooker. However, atmospheric cooking with steam injection especially in case of shredded wheat in steam jacketed mixing vessel is also used. Product from the batch pressure cooker forms lumps or individual grits, which are subsequently delumped before the next processing step, which is drying.

9.4.1.2 Extrusion cooking

The starting material for extrusion cooking is dough from which intermediates or half products are anticipated prior to puffing or flaking. Different types of extruders are employed in manufacture of breakfast cereals such as single screw, twin screw or kneading or forming – type extruder.

9.4.2 Tempering

Tempering is a physico-chemical effect that influences the quality of finished product. Tempering follows a drying or cooling step and is the period during which the cooked grain mass or cereal pellets are held to allow the equilibration of moisture within and among the particles. It assist in the development of desired flakability or shredability. During tempering the retrogradation of starch (firmness of grain due to starch crystallization) allows moisture equilibration.

9.4.3 Puffing

Puffing is a thermal process in which rapid heat transfer takes place in order to phase shift the water to a vapor. Two things are important for grain to puff – the grain must be steeped or cooked, and a large, sudden pressure drop must occur in atmosphere surrounding the grain. Rice and wheat are most widely used cereals for puffing. They are puffed as whole kernel grains.

In gun puffing, high temperatures are attained (600 – 800°F) followed by a pressure drop of 100 – 200 psi. A rotating gun is heated by means of gas burners with very hot flames; the moisture in the grain is converted into steam. When the lid is opened to fire the gun, the internal pressure is released, and the puffed grain is caught in a continuously vented bin.

9.4.4 Flaking

Flaked products are produced by passing tempered grits or pellets through two large counterrotating metal rolls, one of which is adjustable so that the distance between them or roll gap can be set to produce a flake of the desired thickness. These rolls are hollow and are internally cooled by passing water through the interior of the roll. A scraper knife on each roll removes the flakes, which are then conveyed to toasting oven.

9.4.5 Shredding

The grain used in whole kernel form for shredding is primarily wheat. Shredded wheat is made by cooking soft white wheat in an excess of water at atmospheric pressure. The drained wheat is cooled to ambient temperature and contains approximately 50% moisture. The next step is tempering for 24 hours to allow for moisture equilibration and firming of the kernel. Next, the wheat is squeezed between two counterrotating metal shredding rolls – one with a smooth surface, the other grooved. Shredding rolls are water cooled to control the roll surface temperature. The shreds are laid down on a conveyor under the rolls running parallel to the shredding grooves and subsequently conveyed to dryer for drying to a final moisture content of around 3 – 4%.

9.4.6 Baking

Cereal granules or granola cereals are usually produced using a modified bread baking process. A stiff dough is prepared from wheat flour, malted barley flour/rolled oats, salt, yeast and water. Other raw materials such as nut pieces, coconut, honey, malt extract, dried milk, dried fruits, vegetable oil, spices can also be added. The dough is mixed and allowed to ferment for 4 – 5 hours at 80°F and 80% relative humidity (RH). After fermentation the dough is baked at 300 - 425°F until the material is uniformly toasted to a light brown and moisture reduced to about 3%. The dried pieces are ground into small pieces and screened to obtain desired particle size. The final product has a notable crunchy texture.

9.4.7 Drying

Most ready-to-eat breakfast cereals require drying as an intermediate processing step. This drying is the controlled removal of water from the cooked grain and other ingredients to obtain appropriate physical properties for further processing such as flaking, puffing, forming, toasting or packaging. Cereals are dried at various stages of processing. Pellets for flake products have a moisture content of 30 – 33% prior to the drying and are dried down to 16 – 22% moisture. Pellets for gun puffing are dried from 30 – 32% to 10 – 12% moisture. This pre-drying prevents agglomeration of cooked cereals. Multipass dryer design for better control over residence time and humidity are widely used for drying of cereals.

9.5 Additives in breakfast cereals

Most breakfast cereal products contain large amounts of cereal grains and have small quantities of additives. Breakfast cereals available in market are manufactured from variety of cereals such as corn, wheat, oats, barley, rice, rye singly or in combination. Although breakfast cereals are usually eaten/mixed with milk, certain breakfast cereals contain milk solids as one of the ingredients. In broad terms, breakfast cereal ingredients may be classified as (1) grain or grain products, (2) sweeteners, (3) other flavouring or texturizing ingredients, (4) minor ingredients for flavour and colour and (5) minor ingredients for nutritional fortification and self-life preservation.

9.6 Additives in Breakfast Cereals

Some of the additives used in manufacture of breakfast cereals are listed in Table 9.1

Table 9.1 Ingredients found in breakfast cereals (Listed by function, some ingredients serve more than one function, as indicated by parenthetical notes)

Ingredient	Examples
Cereals	*Wheat:* Defatted wheat germ, Wheat bran, Wheat germ, Wheat gluten (protein source), Whole rolled wheat, Whole wheat, Whole wheat flour
	Corn: Corn flour, Degermed yellow corn meal, Milled yellow corn
	Oats: Oat bran, Oat flour, Rolled oats, Whole rolled oats, Whole oats, Whole oat flour
	Rice: Milled rice, Rice flour
	Barley: Malted barley (sugar source), Whole barley
Sweetening agents	Brown sugar, Brown sugar syrup, Cereal malt syrup, Dextrose, Fructose, High fructose corn syrup, Honey, Invert sugar, Malted barley (cereal), Malt extract, Molasses
Fruits (sugar source)	Strawberries, Apple juice, Dates, Dried apples, Strawberry juice concentrate, Apple juice concentrate, Grape juice concentrate, Raisins
Flavours	Malt flavouring, Salt, Cinnamon, Cinnamon extractives, Cocoa, Artificial flavours, Malic acid, Sodium citrate, Citric acid (stabilizer), Yeast (structural), Sodium bicarbonate (structural), Natural flavours

Structural additives	Gelatin (protein), Corn starch, Modified food starch, Wheat starch, Maltodextrin, Pectin, Sodium alginate, Sodium phosphate (dough conditioner and mineral), Glycerine, Trisodium phosphate, Calcium carbonate (mineral), Baking powder, Tricalcium and dicalcium phospahate, Wheat gluten, Cellulose gels and gums
Fats (Partially hydrogenated oils)	Coconut, Cottonseed, Soybean, Palm, Palm kernel, Groundnut
Dairy products	Dried whey, Calcium caseinate, Non fat dry milk, Whey protein concentrate
Protein sources	Nuts and legumes (flavour, fat), Peanut butter, Soy flour, Almond pieces, Coconut, Hazelnut, Pecan pieces, Walnut pieces
Vitamins	Vitamin A palmitate, Vitamin C, Sodium ascorbate, Ascorbic acid, Vitamin D, Vitamin E, DL – alpha tocopherol acetate, B vitamins, Niacin, Niacinamide, Folic acid, Thiamine mononitrate, Thiamine hydrochloride(B 1), Pyridoxine hydrochloride (B 6), Vitamin B 12
Minerals	Reduced iron, Tricalcium and dicalcium phospahate, Calcium pantothenate, Calcium carbonate (structural), Sodium phosphate (structural), Zinc oxide
Preservatives and stabilizers	Butylated hydroxyanisole (BHA) in packaging (antioxidant), Sulfur dioxide (in fruit), Citric acid (flavour), Mono- and di- glycerides, Soy lecithin
Colours	Artificial colour: Red 40, Yellow 5, Yellow 6, Blue 1 Natural colour: Caramel colour, Beet powder, Annatto extract

9.7 Functions of Additives

Within each listed items in Table 9.1 there are large number of subcategories. E.g. sugar includes sucrose, honey, glucose, invert sugar, corn syrup solids, etc. Sugar imparts sweetness to the product and it is sometimes used as coating material.

- Buffering salts such as mono-, di- or trisodium phosphates are added to adjust the pH of the cooked dough for browning and gelatinization.

- Salt is commonly added either to base mix or added to the surface in snacks for flavouring purpose.
- Emulsifiers like distilled mono- glycerides and distilled di-glycerides are added to reduce the stickiness of the product.
- Components like minerals and vitamins are also incorporated into the cereals as per Recommended Dietary Allowances (RDA) for a nutritional claim to be made.
- Fruits, dried fruits, milk products are also added to further improve the nutritional value as well as sensory characteristics of the breakfast cereals.
- Modified starches, specialty flours and stabilizers are added primarily as texturizing agent.
- Addition of oil, leavening agents and/or emulsifiers affects and contributes to shape, texture and eating quality of ready-to-eat cereals.
- Antioxidants either natural or synthetic are incorporated into the cereals to improve the shelf-life of the ready-to-eat cereals.
- Various flavourings (natural, nature-identical, synthetic) and colouring (natural, synthetic) are extensively used to improve the sensory and aesthetic quality of the ready-to-eat cereals.

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Module 2. Cereal processing

Lesson 10

MALTED MILK FOODS

10.1 Introduction

In the, Indian food market "Malted Milk Food" until recently, and "Malt Based Foods" at present are perhaps the only barley-based processed foods. Interestingly, this value-added food is most popular among children and therefore, it is no wonder these products represent among a rapidly growing milk-food market. Barley malt is major ingredient of malted milk foods and malt-based foods. Malted milk food is a product made by combining whole milk with the liquid separated from a mash of ground barley & wheat flour in such a manner as to secure full enzymic action of the malt extract, and reducing the mixture to dryness by desiccation. It may also contain added sodium chloride, sodium / potassium bicarbonate. India is among the world's biggest market for malt- milk based food products. Malted- milk food products' market in India has been growing in the range of 5 to 8 per cent for the last ten years.

10.2 Historical Background

Malted milk food was developed in 1883 by William Horlicks of Racine, Wisconsin, and the product was commercially marketed in 1887. William Horlicks who undertook the research at the request of some physicians for developing a baby food containing milk solids and cereal solids. This product received the attention of the medical professionals and the consumers due to its convenience, nutritive value, digestibility and palatability.

10.3 Definition of Malted Milk Food

10.3.1 FSSA definition

10.3.1.1 Malted milk food

According to FSSA (Food Standard Safety Act) malted milk food means the product obtained by mixing whole milk, partly skimmed milk or milk powder with the wort separated from a mash of ground barley malt, any other malted cereal grain and wheat flour or any other cereal flour or malt extract with or without addition of flavouring agents and spices, emulsifying agent, eggs, protein isolates, edible common salt, sodium or potassium bicarbonate, minerals and vitamins and without added sugar in such a manner as to secure complete hydrolysis of starchy material and prepared in a powder or granule or flake formed by roller drying, spray drying, vacuum drying or by any other process. It may contain cocoa powder. It shall be free from dirt and other extraneous matter. It shall not contain any added starch (except natural starch present in cocoa powder) and added non milk fat. It shall not contain any preservative or added colour. Malted milk food containing cocoa powder may contain added sugar. Malted milk food shall also conform to standards (Table 10.1).

10.3.1.2 Malt based food (Malt food)

Acording to FSSA (Food Standard Safety Act) malt based food (malt food) means the product obtained by mixing malt (wort or flour or malt extract) of any kind obtained by controlled germination of seeds (cereals and/or grain legumes), involving mainly steeping, germination and kiln drying processes with other cereal and legume flour with or without whole milk or milk powder, flavouring agents, spices, emulsifying agents, eggs, egg powder, protein isolates, protein hydrolysates, edible common salt, liquid glucose sodium or potassium bicarbonate, minerals, amino acids and vitamins. It may contain added sugar and / or cocoa powder and processed in such a manner to secure partial or complete hydrolysis of starchy material in the form of powder or granules or flakes by drying or by dry mixing of the ingredients. The grain legume and their products used in the preparation of malt shall be sound and uninfested and free from insect fragment, rat excreta, fungal infested grains or any other type of insect or fungal damage. It shall also conform to standards (Table 10.1).

10.3.2 BIS standard

India Standard Institution (ISI) have also prescribed specification (IS 1806: 1975) for malted milk (Table 10.1).

Table 10.1 FSSA and BIS requirements for malted milk food and malt-based foods

Characteristics	FSSA Requirements			BIS Requirement	
	Malted milk food without cocoa powder	***Malted milk food with cocoa powder***	***Malt-based foods (Malt food)***	***Type I***	***Type II***
Moisture	≤ 5.0 % by wt.	≤ 5.0 % by wt.	≤ 5.0 % by wt.	≤ 4.0 % by wt.	≤ 4.0% by wt.
Total protein (N x 6.25) (on dry basis)	≥ 12.5 % by wt.	≥ 11.25 % by wt.	≥ 7.0 % by wt.	≥ 13.0% by wt	≥ 11.5% by wt
Total fat (on dry basis)	≥ 7.5 % by wt.	≥ 6.0 % by wt.	-	≥ 7.5% by wt.	≥ 6.0% by wt.
Total ash (on dry basis)	≤ 5.0 % by wt.	≤ 5.0 % by wt.	≤ 5.0 % by wt.	≤ 5.0 % by wt.	≤ 5.0 % by wt.
Acid insoluble ash (on dry basis) (in dilute HCl)	≤ 0.1 % by wt.	≤ 0.1 % by wt.	≤ 0.1 % by wt.	≤ 0.1 % by wt.	≤ 0.1 % by wt.
Solubility	≥ 85 % by wt.	≥ 85% by wt.	-	≥ 85% by wt	≥ 80% by wt
Cocoa powder (on dry basis)	-	≥ 5.0 % by wt.	-	-	≥ 5.0% by wt
Test for starch	Negative	-	-	Negative	Negative
Alcoholic acidity (expressed as H_2SO_4) with 90 % alcohol on dry wt. basis	-	-	≤ 0.3 %	-	-
Bacterial count	≤ 50,000/g	≤ 50,000/g	≤ 50,000/g	≤ 50,000/g	≤ 50,000/g
Coliform count	≤ 10/g	≤ 10/g	≤ 10/g	≤ 10/g	≤ 10/g
Yeast and mould count	Absent in 0.1 g	Absent in 0.1 g	≤ 100/g	-	-
Salmonella and *Shigella*	Absent in 0.1 g	Absent in 0.1 g	Absent in 25 g	-	-
E.coli	Absent in 0.1 g	Absent in 0.1 g	Absent in 10 g	-	-
Vibrio cholera and *V .paraheamolyticus*	Absent in 0.1 g	Absent in 0.1 g	Absent in 0.1 g	-	-
Fecal *streptococci* and *Staphylococcus aureas*	Absent in 0.1 g	Absent in 0.1 g	Absent in 0.1 g	-	-

Type I: Malted milk foods containing no cocoa powder

Type II: Malted milk foods containing cocoa powder

10.4 Ingredients Used in Manufacture of Malted Milk Foods

Various ingredients are used in the manufacturing of malted milk foods. Newer formulations and manufacturing processes are developed to meet customers requirements for a quality product. Main ingredients and their functions, used in manufacturing of malted milk foods are described in Table 10.2.

Table 10.2 Ingredients used in manufacture of malted milk foods

Ingredient	Function
Wheat flour or any other source of starch	All the starch is fully converted to simple sugars during the mashing process and provides higher levels of simple sugars, proteins, and fat
Malted barley or Malted wheat	Provides an appropriate level of enzymes required to convert all the starch into simple sugars and also imparts typical malty flavour to the finished product
Malt extract	Provides desirable levels of colour and typical caramelized flavor
Milk solids	Increase nutritional value of the product by providing (high quality) fat, proteins, minerals, and vitamins. Milk fat enhances flavour and energy level of final product
Salts	Salts are added to optimize product pH to improve digestibility, enhances flavour, and to provide essential micronutrients, specially calcium
Microingredients	Improves nutritional value of the product and provide essential requirement of minerals and vitamins

10.5 Method of Manufacture of Malted Food

The preparation of malted milk combines the technique of dried milk manufacture with that of the brewing. The process consists of mixing milk solids with the liquid resulting from the mashing of barley malt, and wheat flour with certain minor ingredients. Hunziker in 1949 suggested a method for preparation of dried malted milk. The crushed malt after steeping at 90 °F should be mixed with cooked (at 200°F/2 h) wheat flour slurry in ratio of 0.4 pounds of wheat flour per pound of malt. Mashing should be done by holding malt- flour mixture at 113°F/30 min and then the temperature be raised gradually to 158°F and holding at this temperature for 2 h to complete the conversion of starch to sugar. After separation of the wort, milk should be mixed to have minimum statutory requirements of 7.5% fat. The mixture, after forewarming (at 150°F) and condensing (68-70% total solids) can be dried in a special vacuum pan or in drum drier or in a spray drier.

Sanyal (1980) prepared spray dried malted milk by using barley malt and wheat flour. Crushed barley malt and wheat flour (1.5:1) were steeped in 5-6 times of water of its total weight. The mashing process was performed under the following temperature-time regime; 32°±1°C for 30 min, 45°C for 15 min, 60°-70°C for 100 min, and 78°-80°C for 10 min, for the purpose of steeping, proteolysis, complete starch hydrolysis, and inactivation of enzymes, respectively. The mashing process was followed by filtration and washing of the husks with warm water. To this wort, standardized milk having 2% fat was added to have final product containing 7.5- 8.0% milk fat. The pH of the mix was adjusted to 7.0 with sodium bicarbonate. The mix was then forewarmed to 80°C for 15 min and then condensed to 30 and 40 per cent total solids in double effect evaporator. The mix was then spray dried at 190°±10°C and 95°±5°C, inlet and outlet air temperatures, respectively; with 25000 rpm speed of an atomizer.

Banerjee (1982) manufactured spray and roller dried malted milk using malt extract. Malted milk mix was prepared by mixing required quantities of malt extract, cream, concentrated skim milk and water. For the manufacture of spray dried malted milk, the ratio of malt solids to milk solids was 40:60, whereas for the roller dried malted milk the different ratio of malt solids to milk solids were tried, viz., 30:70, 20:80, 15:85,10:90, 7.5:92.5. The pH of the mix was adjusted to 6.8 to 7.0 with solution of sodium bicarbonate. The mix was then heated to 65°C and homogenized at a pressure of 2000 psi in the first stage and 500 psi in the second stage. The homogenized mix was heated to 85°C for 1 min before drying. The malted milk mix having 35, 40, and 45% total solids was spray dried at 200°±5°C inlet air temperature and 80°± 2°C outlet air temperature with speed of atomizer 20000 rpm. The roller drying of the malted milk mix was done at a steam pressure ranging from 65 to 70 psi and roller speed of 20 rpm.

Salooja (1983) obtained spray dried malted milk food by preparing wort through steeping of grains, mashing and filtration of spent grains. The mashing conditions were optimized for wheat flour and crushed barley malt in the ratio of 1:4 in 4-5 times its weight of water. Steeping of grist was performed at 35°C for 30 min with constant agitation. Mashing followed temperature-time regime of 45°C for 30 min (Protein hydrolysis), 55°C for 30 min (1st stage starch hydrolysis), 60°C for 60 min (2nd stage starch hydrolysis), 68°C for 60 min (complete starch hydrolysis). Inactivation of enzyme was carried out by heating the mashed mixture to 80°C for 10 min. Spent grains were then separated by filtration. The pH of the wort was adjusted to around 7.0 by the addition of sodium bicarbonate. Standardized milk was mixed with wort so as to have in the final product a fat content of not less than 7.5 per cent and protein not less than 13 per cent. The mixture of milk and barley malt wort was pre-heated to 85°C for 10 min and the mixture was then concentrated to 45 per cent total solids in vacuum pan. The concentrated product was spray dried at 25000 rpm speed of an atomizer, 195°±5°C inlet air temperature and 90°±2°C outlet air temperature. The spray dried product was packed and stored at 30°±2°C.

Cereal extract of malted barley and wheat flour is prepared by either batch or continuous method. Malted barley is sieved to remove dust and other foreign matter. It is then crushed using line roller mill and mixed with wheat flour. The mix is conveyed to mash tank, where water at 40°C is continuously added to prepare uniform slurry. The slurry is gradually heated to raise the temperature from 40°C to 70°C within about 40 min. The slurry is held at 70°C for about 35 min for complete the conversion of starch into maltose and dextrose. The slurry temperature is gradually raised to 78°C and held at this temperature for about 20 min to stop further activity of enzymes and also to achieve maximum cereal solids (28-30%). The slurry is then filtered to separate barley husk and obtain clear liquid, known as “wort”. The wort is then mixed with pre-determined quantities of milk, malt extract, sugar, salt, minerals and vitamins. The with about 26% solids is concentrated under vacuum, either in single stage calandria (50-58% solids) or in multiple stage evaporators (80% solids). The concentrate is then dried by using vacuum oven drying, band drying or spray drying.

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Module 3. Bakery and snack foods

Lesson 11
TECHNOLOGY OF BREAD MAKING

11.1 Introduction

Bread baking is one of the most important discoveries of mankind. Bread is made by baking dough which has for its main ingredients wheat flour, water, yeast and salt. Other ingredients which may be added include flours of other cereals, milk and milk products, fruits, gluten, etc. When these ingredients are mixed in correct proportions two processes commence: (i) the protein in flour begins to hydrate and forms a cohesive mass called as gluten (ii) evolution of carbon dioxide gas by action of the enzymes in the yeast upon the sugars. Three main requirements in making bread from wheat flour are formation of gluten network, aeration of the mixture by incorporation of gas, and coagulation of the material by heating it in the oven.

11.2 Principle of Bread Baking

There are three technological principles involved in baking of bread:

(i) Conversion of starch: Wheat flour starch is partly converted into the sugar, which is being used by yeast during fermentation producing alcohol with simultaneous release of CO_2 gas is responsible for porous, open honeycomb texture of the baked bread.

(ii) Mechanical stretching: The hydrated wheat protein forms gluten fibers, which are stretched mechanically to obtain a fine, silky structure. This structure remains permanent when the protein is denatured during baking. The stretching of gluten is partially achieved by development of CO_2 gas during yeast fermentation and partly by mechanical mixing.

(iii) Flavour development: Bread flavor is because of the alcohol and other compounds generated during yeast fermentation, together with flavor compounds formed during baking.

11.3 Ingredients and their Functions in Bread Making

11.3.1 Essential ingredients

11.3.1.1 Flour

Flour is essential to the structure of dough and subsequently the bread. Gluten (Gliadin and Glutenin) is the principle functional protein of wheat flour. Gluten forms fibrillar frame work when hydrated and mechanically worked. Thus the wheat flour is converted into cohesive, elastic, extensible dough. This viscoelastic three-dimensional gluten network retains gas formed by sugar fermentation and contributes to structure of dough and bread.

Starch plays important role in dough during baking. When heat is applied, gas cells expand gluten networks stretches, starch granules take up water and get partially gelatinized. This viscous paste sets to gel after baking. Satisfactory protein content for bread flour is 11 – 13% and moisture content not more than 14%.

11.3.1.2 Water

Water hydrates gluten proteins during mixing, gelatinizes starch during baking and serves as a dispersion medium for other ingredients such as yeast. Quality of water such as pH and hardness of water play important role in dough formation. Excessively alkaline water can retard the activity of yeast enzymes. Hard water containing calcium and magnesium ions, may have a “tightening” effect and soft water a “loosening” effect on dough.

11.3.1.3 Yeast

Yeast produces carbon dioxide and ethanol by fermentation of fermentable sugars. During fermentation it also helps in formation of flavour precursors. Rate of fermentation of dough by yeast is controlled by temperature, nutrient supply, water, pH, sugar concentration, salt and level and type of yeast. Generally two type of yeasts are used in baking: Compressed yeast and dried yeast. Both the types consist of living cells of *Saccharomyces cerevisiae*.

11.3.1.4 Salt

Salt acts as flavour enhancer and helps control the fermentation by yeast. It also toughens the gluten and gives less sticky dough.

11.3.2 Optional ingredients

The optional ingredients used in bread formulation are listed in Table 11.1 along with their functions.

Table 11.1 Functions of optional ingredients in the bread

S.N.	Ingredient	Example	Function
1.	**Mineral yeast food**		Controls fermentation
i.	Water conditioner (Calcium salts)	Calcium acid phosphate Calcium sulfate Calcium peroxide	
ii.	Yeast conditioners (Ammonium salts)	Ammonium chloride Ammonium phosphate Ammonium sulfate	
iii.	Dough conditioners (Oxidizing agents)	Potassium bromate Dehydro ascorbic acid Potassium iodate Dicalcium phosphate	
2.	**Sugar**	Sucrose High fructose corn syrup	Energy source for yeast Fermentable carbohydrate Flavour – Sweetness and flavour compounds generated during fermentation and baking

			□ Crust colour: Caramelization and non enzymatic browning □ Delays staling of bread by increasing hygroscopicity and thus tenderizing the crumb
3.	**Shortening**	Edible fats and oils containing dough conditioners and emulsifiers (Calcium stearoyl-2-lactylate, sodium stearoyl-2-lactylate, Mono and diglycerides, Polysorbate 60, Succinylated monoglycerides, Ethoxylated monoglycerides, Sucrose esters)	□ Facilitates dough handling and processing □ Eases gas cell expansion in dough □ Increases loaf volume □ Improves crumb grain uniformity and tenderness □ Lubricates slicing blades during slicing □ Extends shelf-life
4.	**Dairy products**	Skim milk powder Sweet cream butter milk Sweet dairy whey Caseinate Whey protein concentrate	□ Nutrition: high in lysine and calcium □ Flavour enhancement □ Improves crust colour (Maillard browning) □ Buffering effect in dough and liquid ferments
5.	**Mold inhibitors**	Sodium propionate Calcium propionate Sodium diacetate Potassium sorbate Vinegar	□ Retardation of spoilage due to mold growth □ Retards formation of "rope" by *B. subtilis*

6.	**Wheat gluten**	Wheat gluten	□ Enhances dough strength □ Increases water absorption □ Increases bread loaf volume □ Imparts greater stability to the dough during fermentation
7.	**Malt**	Malt flour Malt extract Dehydrated malt extract	□ Contributes fermentable sugar (maltose) □ Enhances flavour □ Contains amylases, which converts starch to sugar □ Improves crust colour □ Extends shelf-life because of improved water absorption
8.	**Enzyme supplements**		
i.	Amylases	Cereal amylase: barley malt Fungal amylase: *Aspergillus oryzae* Bacterial amylase: *B. subtilis*	□ Convert starch to sugar □ Aid crust colour □ Improve dough handling □ Extend shelf-life
ii.	Protease	Fungal protease: *Aspergillus spp.* Bacterial protease: *B. subtilis* Bromelain (Fruit)	□ Weaken dough due to cleavage of peptide bonds in wheat protein □ Reduce dough mixing time □ Increase pan flow
iii.	Lipoxygenase	Soya	□ Whiter bread crumb □ Improves shelf-life □ Increases dough strength and mixing dough tolerance

11.4 Bread Manufacturing

Production of bread consists of number of steps. The flow diagram for manufacture of bread is given in Fig. 11.1 and 11.2

The first step of bread making involves sifting of flour to remove any foreign matter and coarse particles, and to aerate and make the flour more homogeneous. The next step is dough mixing, which is accomplished by various methods of preparation of dough. Once the dough is formed, it is divided into pieces of requisite size. The divided dough is rounded to a ball shape and then passed through intermediate proofer, where the roughly stretched gluten fiber get time to recover their extensibility so that they can be moulded well without breaking the surface skin. After intermediate proving, the dough is passed through a set of pairs of roller to form a sheet. The sheeted dough is now passed through pressure board to get moulded into cylindrical shape.

The moulded dough pieces are then placed into greased individual bread baking tins. The panned dough pieces are then passed through final prover under controlled temperature and humidity. After complete proofing, the dough tins are transferred to the baking oven. Once baking is completed, the breads are de-panned, cooled and then sliced. Sliced breads are then packaged in suitable packaging material, generally polypropylene pouches.

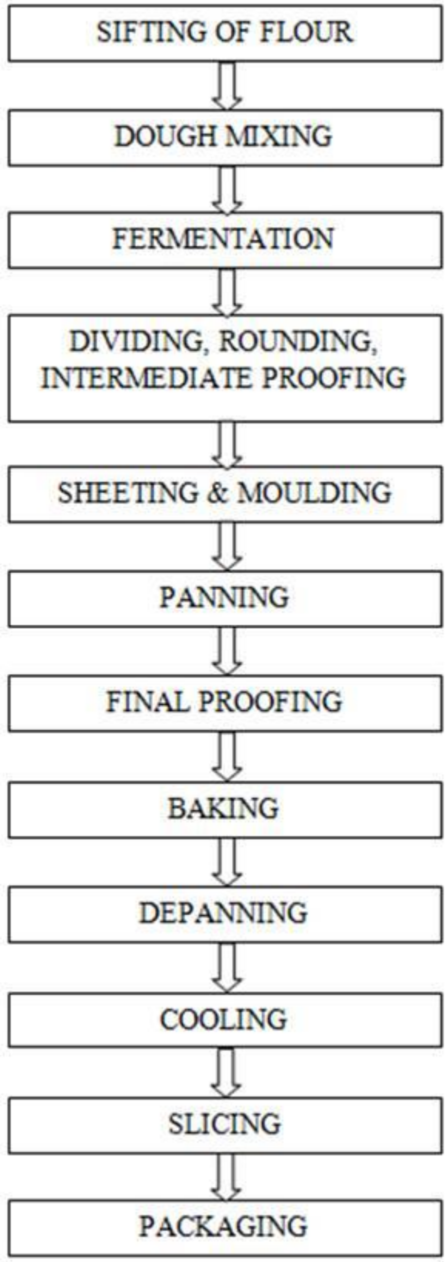

Fig. 11.1 Flow diagram for bread manufacture

11.5 Methods of Bread Making

Based on the way dough is prepared, different methods of bread making can be broadly grouped into three: Conventional (bulk fermentation) dough development methods, mechanical dough development methods, chemical dough development method.

The major production methods used in wholesale bread production are the sponge and dough method, liquid fermentation method, straight dough method, no-time dough method, frozen dough method, continuous bread manufacturing, Chorleywood bread process.

11.5.1 Sponge and dough process

This is the most common commercial method used to manufacture bread. Sponge is prepared by mixing flour with water and yeast and allowed to ferment for a certain period of time. Subsequently balance flour, water and other ingredients are added to sponge. The ratio of sponge to dough is maintained at 70:30. After through mixing, dough is allowed to ferment for 3 – 5 hours at 30°C. The dough is then divided into pieces to yield bread loaves of desired weights. The dough pieces are then rounded, given rest period of 7 min and then sheeted, shaped and panned. The proofing of dough is carried out for 55 min at 42°C and 85% relative humidity (RH). The bread loaves are subsequently baked at 230°C for 18 – 20 min, cooled, sliced and wrapped.

11.5.2 Liquid fermentation process

Principle of this method is same as sponge and dough method, except that it uses a liquid instead of plastic sponge.

11.5.3 Straight dough method

All formula ingredients are mixed in single step at the mixer. The dough is mixed to a full gluten development and then fermented. Fully fermented dough is then handled same as sponge and dough method. This procedure is used by retailers or for specialty breads.

11.5.4 No-time dough process

This method is same as straight dough method, except mixing is carried out mainly mechanically by the action of high-energy input of special mixers. This mixing step is further enhanced by addition of various ingredients such as L – cysteine, yeast foods and proteolytic enzymes. The mixed dough is given short or no fermentation, then divide, rounded, moulded, proofed and baked. This method is suited for frozen dough manufacturing and retail bakeries.

11.5.5 Frozen dough method

Frozen doughs are used for baking in in-store bakeries. Frozen doughs are generally manufactured by a straight dough method. The dough units are immediately frozen using fast freezers to a core temperature of – 7°C, then stored at – 15°C. In in-store bakeries the doughs are deposited in a retarder at 1 – 4°C, then proofed at 32 – 43°C for 75 – 90min and baked. The expected shelf-life of frozen dough is about 8 – 12 weeks.

11.5.6 Continuous bread process

In this method the dough is prepared continuously and automatically in enclosed chamber. This process introduced in United States is represented by two systems: Do-maker process developed by John C. Baker and Amflow process which was introduced by American Machine and Foundry Co. In both the methods high amounts of oxidants are required due to high mechanical dough abuse during mixing and extrusion operations.

11.5.7 Chorleywood process

This process is used widely world over. It was originated in United Kingdom. The basic principle is closed high-speed mixer with special mixer configuration blades. The mixing is generally accomplished under vacuum. Two types are mixers are widely used: Tweedy and Stephan. The oxidants used in this process are ascorbic acid and azodicarbonamide (ADA).

11.6 Staling of Bread

Bakery products undergo physic-chemical, sensory and microbial changes during storage. The generic term for this is ‘staling’. Staling means series of changes that causes a decrease in consumer acceptance other than that resulting from the action of spoilage microorganisms. The typical characteristics of staling of bread are that, the crust looses crispness and crumb becomes firm. Other associated changes are loss of flavour and emergence of stale flavor. The main cause for staling of bread is moisture migration from crumb to crust. The complete mechanism of staling of bread is not yet understood. But the theory given by Schoch and French is the most accepted one. According to this theory, retrogradation of starch is the underlying reaction of staling.

Starch gelatinizes during baking and amylose is leached out. Amylose component crystallizes upon cooling and impart firmness to the bread, which is an indication of freshness of the bread. During storage amylopectin retrogradation proceeds slowly and causes firming of the bread. This process is heat-reversible because retrograded amylopectin can be reverted to its amorphous state, which reduces firmness. Zobel and Kulp have described physico-chemical changes of the starch granule which is shown in Fig. 11.3

11.7 Ropy Bread

Bread ropiness is caused if the bread dough is contaminated with *B. mesentericus*. The spores of the bacteria are not killed during baking. A sticky, gummy material which can be pulled into threads develops in the centre of the loaf within 1 to 3 days after baking. The bread also develops an off-flavour.

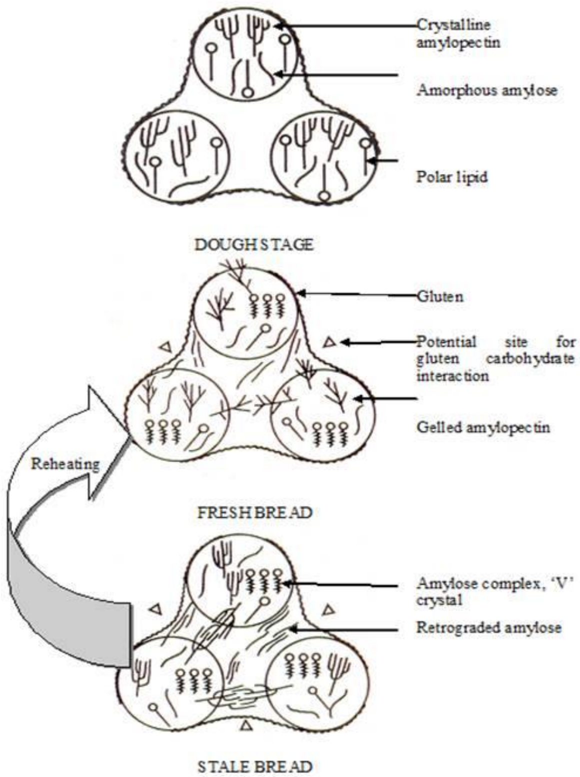

Fig. 11.3 Mechanism of bread staling

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Module 3. Bakery and snack foods

Lesson 12
TECHNOLOGY OF BISCUIT MAKING

12.1 Introduction

Baking industry is the most stable sector in the food manufacturing industries. The principal basis for most products in this range is wheat flour. Addition of water and various other ingredients give us variety of products like cookies, crackers, cakes, pastries and biscuits. Biscuits are flat, crisp, baked good, whereas cookies are softer and thicker. Cracker means biscuits of a low sugar and fat content, frequently bland or savory. These types of flour confections are palatable, easy to carry and don't require further preparation before consumption and thus they are considered as staple snacks.

12.2 Product Characteristics

Biscuit is a low moisture bakery product. Moisture content of biscuit is typically below 4% depending upon its weight, thickness and shape. Biscuit dough can be made from soft wheat flour with a high amount of sugar (25-55%) and shortening (20-60%). They are classified based on the way the dough is placed on the baking band e.g. rotary molded, wire-cut, cutting machine, etc.

12.3 Ingredients

12.3.1 Flour

Soft wheat flour is the main component in most recipes. Wheat flour consists of 65 – 75% starch and 7- 16% protein. When water is added, during the makeup of dough, starch absorbs a significant amount of water and may act as filler in the continuous protein network with the proteins. During baking, starch granules get gelatinized, which is a major part of the dough. Cookies, crackers flours are normally not treated with additives. For cookies to be premium quality, soft wheat flour containing 8 to 10% protein and less than 0.4% ash content is ideally suited.

12.3.2 Water

Water affects textural properties of baked products. Water acts as a plasticizer, and the amount of water used is adjusted to produce a batter or dough of acceptable consistency for processing. Water is needed for hydrating the proteins, gelatinizing the starch, making leavening agent function, activating the enzymes, dissolving sugar and salt, as well as acting as major heat transfer mechanism during baking through evaporation and condensation.

12.3.3 Fat

Fat provides shortness character to the products, like soft, pleasant and crumbly texture. Fats and oils are used in dough and batters, in surface sprays and in cream fillings and coatings such as chocolates. Bakery fats are often premixed with or used in conjunction with emulsifiers. The function of emulsifier is to promote formation and stabilization of water/fat/air emulsions.

12.3.4 Sugar

Sugar is most important ingredient after flour in soft wheat products such as biscuits, cookies, cakes, etc. Apart from providing sweetness to the product, sweeteners provide one or more of the following functions: tenderizing, texture, yeast nutrient and fermentation control, stabilizing, bulking agent, humactancy, flavour, crust colour and shelf-life extension. Sucrose, corn syrup solids, invert sugar, honey, glucose syrup and certain permitted intense sweeteners are used in manufacture of soft wheat products.

12.3.5 Salt

Salt is added to dough as a seasoning or as flavour enhancer. Salt also inhibits yeast growth and thus help in controlling the fermentation.

12.3.6 Other ingredients

- Various other ingredients are used in the manufacture of biscuits such as leavening agents, emulsifiers, chocolates, egg products, dairy products, fat replacers, spices, flavours, colours, icing, etc.
- Baking powder is widely used for leavening of the cookies and biscuits mixture. It controls the spread and imparts lightness to the product. Excess use of sodium bicarbonate (baking

soda) than recommended may impart alkaline flavour to the end product. Ammonium bicarbonate should be used in products which are quite dry after baking, otherwise ammonium odour will be retained if the product is moist. Baking soda is combination of sodium bicarbonate and an acid salt. During baking, in presence of moisture, gas will evolve which helps in leavening of product.

- Baking powder are of three kinds:

1. *Fast acting*: Most of the CO_2 is released during bench operations and very little gas is released during baking.
2. *Slow acting*: All the gas is released during baking.
3. *Double acting*: This is most widely used baking powder by the bakers. This type of baking soda releases part of gas during bench operations and part of the gas during baking.

- Milk solids have a binding action on the flour proteins. When milk solids are used in large amount, they cause less spread of the cookies and biscuits.
- Eggs, if added, give structure, impart flavour and taste. If it is used in large amounts, it may result in giving biscuits and cookies a rise rather than spread. Egg yolk produces a tender cookies than whole egg.

12.4 Technology of Crackers

- Crackers contain little or no sugar and moderate levels of fat. They are usually made from strong flour and developed dough. They generally contain 100 percent flour, 5-20 per cent fat and 0-2 per cent sugar and low moisture content of 20-30 per cent in the dough.
- There are three types of crackers: saltine, chemically leavened (snack crackers) and savoury.
- Saltine crackers are produced from fermented dough. They are made by a sponge (flour 65%, water 25% and yeast 0.4%) and dough (Flour 35%, salt 11% and soda 0.45%) process. The

- Chemically leavened crackers are not fermented. They do not contain yeast, but are leavened by chemical baking leaveners. They contain more shortenings and much higher level of flavouring materials. The dough is mixed once with the ingredients, allowed to rest, sheeted and laminated, and cut and docked. The texture of snack crackers is denser than that of saltine.

- Savoury crackers are also produced from fermented dough. The intense savoury flavours are produced by adding the appropriate flavouring agents directly to the dough or to the surface of crackers after baking.
- Production flow chart for saltine crackers and chemically leavened crackers are shown in Figure 12.1 and 12.2, respectively. Saltine crackers are distinguished by their long fermentation time and they are particularly light and flaky in texture. During fermentation process, the pH drops from 6.0 to about 4.0.
- As compared to saltine crackers, chemically leavened crackers contain more shortening and much higher levels of flavouring materials. They generally do not contain yeast and are not given an extended fermentation period.

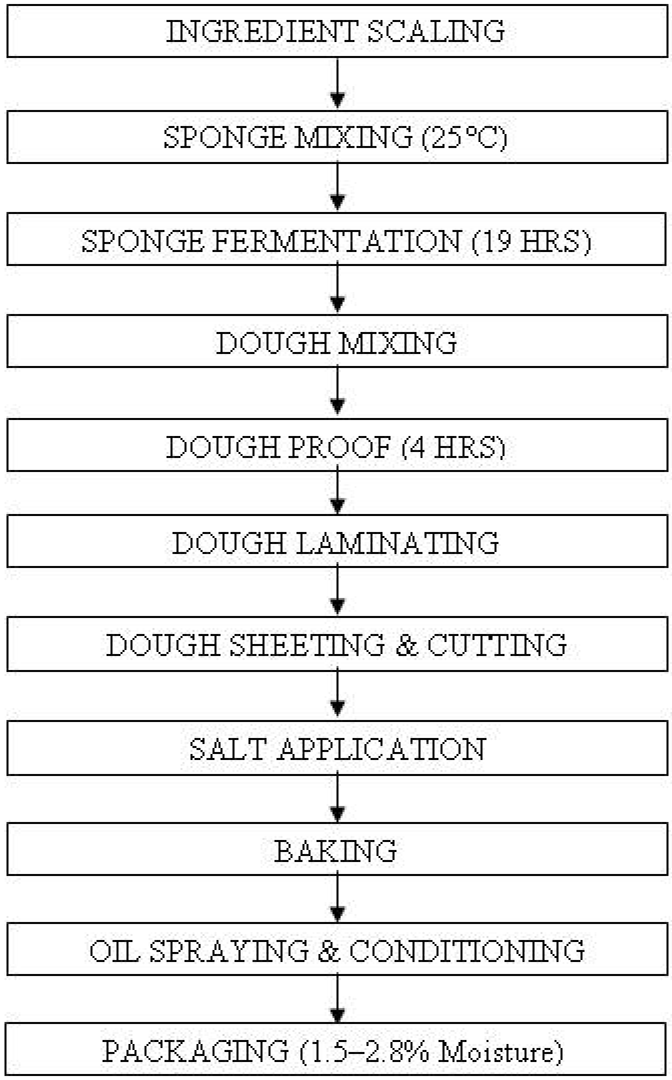

Fig. 12.1 Production flow chart for manufacture of saltine crackers

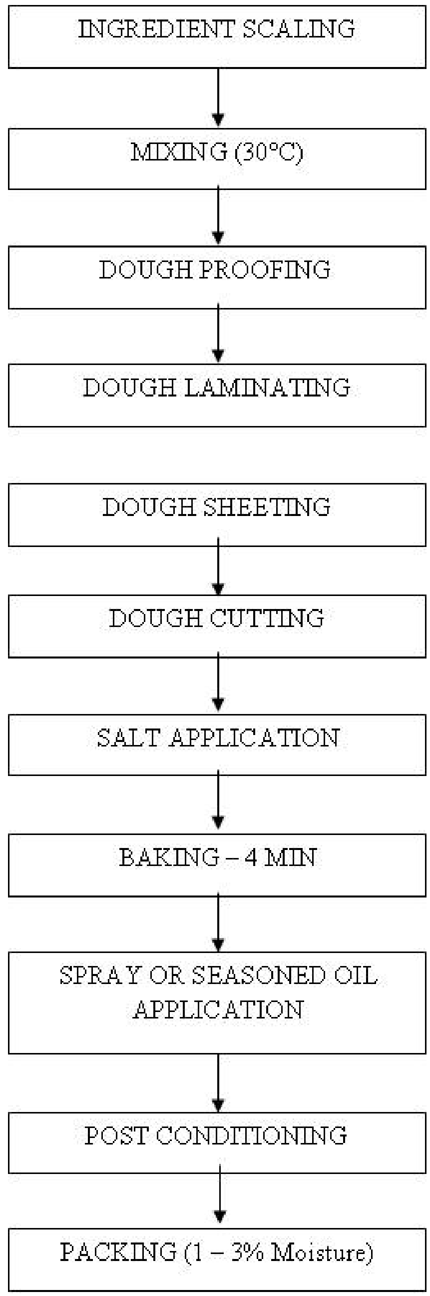

Fig. 12.2 Production flow chart for manufacture of chemically leavened crackers

12.5 Technology of Biscuits

- The name 'cookie' can be regarded as synonymous with biscuit but the cookies are more comprehensive in meaning in the USA and the latter in the UK. Groupings have been made in various ways based on

1. The method of forming dough and dough piece

- Fermented
- Developed
- Laminated
- Cut
- Moulded
- Extruded deposited
- Wire cut co-extruded

2. According to texture and hardness

- Biscuits
- Crackers
- Cookies

3. According to the recipe enrichments with ingredients like fat and sugar

- Another type of classification based on secondary processing are Cream sandwiched, chocolate coated, moulded in chocolate, iced (half coated with an icing that has been dried) and added jam or mallow (or both)
- The main raw materials for biscuits are flour, sugar and shortening. For protein enriched peanut flour or isolates, soy flour etc. can be added.
- Other ingredients include leavening agents, vitamins, minerals and flavours. In sweet biscuits, cane sugar is added while in salty biscuits, sodium chloride (0.5-1.0 percent is added).
- The main steps involved in biscuit making are (Figure 12.3)

1. Mixing and kneading: Weighed amount of sifted flour, sugar, shortening and flavouring agents are mixed in mechanical mixer. Water and baking powder are added during mixing to obtain a dough of desired consistency. Kneading for 10-20 min produces biscuits with fine structure, smooth crust and better appearance.
2. Sheeting and shaping: The dough is then rolled into sheets of desired thickness by passing it through pairs of rolls. The sheets are then cut by mechanically worked stamped dividers fitted with dies.

3. Baking and cooling: the cut biscuits are then transferred to plate sheet or wire mesh bands travelling through ovens. The biscuits are generally baked at 450°F for 15 min and cooled to ambient temperature after baking.
4. Packaging: the biscuits should be packed in moisture and grease proof cellophane or metalized laminated foils.

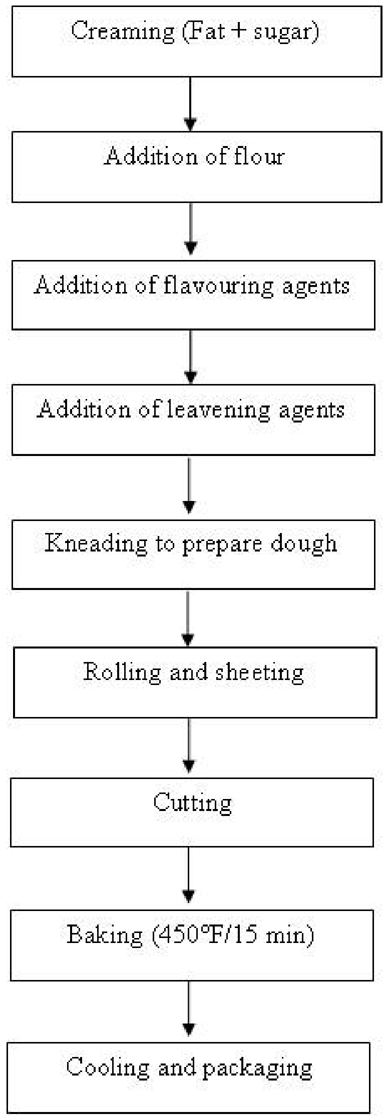

Fig. 12.3 Steps in involved in biscuit making

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Lesson 13
TECHNOLOGY OF CAKE MAKING

13.1 Introduction

Baking industry is the most stable sector in the food manufacturing industries. The principal basis for most products in this range is wheat flour. Addition of water and various other ingredients give us variety of products like cookies, crackers, cakes, pastries and biscuits. Biscuits are flat, crisp, baked good, whereas cookies are softer and thicker. Cookies and cakes are the some of the oldest snack foods known to the human. These types of flour confections are palatable, easy to carry and don't require further preparation before consumption and thus they are considered as staple snacks.

13.2 Product Characteristics

Cake is made by the formation of batter from soft/weak wheat flour. Cake is a traditional centerpiece of festivities and joyous celebrations. Cakes are relatively higher both in sugar and shortenings. Cake is a complex emulsion and foam system with appreciable amount of incorporated air as a small bubble into the batter.

Cakes are products leavened mainly by baking powders, sometimes by air incorporation, and occasionally by yeast. Although difficult to define, cakes can be divided into two categories.

First, cakes that are higher in fat and whose structure depends on fat-liquid emulsion created during batter mixing (e.g. fruit slab, Dundee, ginger cake). These types of cakes are characterized by high level of sugar in the formula in which starch gelatinizes during baking. Cakes set when baked giving a light product.

Second, those with less fat (un-shortened cake), or even none at all, but rich in eggs that can aerate to a foam during mixing and gives a characteristic spongy crumb to product such as angel food cake, Victoria sponge.

13.3 Ingredients

The Flour, sugar, shortening and eggs or skim milk powder are essential ingredients. Whereas baking powder, milk, fruits and flavouring substances are optional ingredients.

1. Flour: It builds the structure of cake and holds other ingredients together in an evenly distributed condition in the cake. Flour for cake making should have protein content of 7 to 9 per cent. Short patent flour with fine granule structure made from soft wheat is ideally suited for cake making. Cakes flours are bleached to a greater degree in order to brighten the colour. Bleaching also modifies the gluten forming properties (starch gelatinizes faster).
2. Sugar: Sucrose is most widely used sweetening agent in cake making. Finely granulated sugar ensure even grain and soft texture in cakes. Sugar has tenderizing action on flour proteins and makes the cake tender. It helps to retain moisture in cakes and improve its shelf-life. The golden crust colour of cake is due to caramelization of sugar.
3. Shortenings for cakes should have good creaming and emulsifying properties. Fats have a tenderizing action on flour proteins and thus make the cake tender by holding air cells incorporated during creaming process. It also acts as a moisture retainer and helps to keep the cake moist and thus improves the shelf-life of cakes. Fat used in cake making should be of plastic nature which could incorporate and hold minute air cells during creaming operation.
4. Eggs and flour form the necessary framework to support the cake structure. Eggs provide moisture to the cakes. Lecithin of egg yolk acts as emulsifier and later adds to colour. Egg improves taste, flavour and nutritional value.
5. Milk adds richness and structure to the cake. Milk proteins have binding action on flour protein which creates toughness in cakes. Milk sugar lactose improves the crust colour, moisture retention property and flavour. Milk solids also improve the nutritive value.
6. Water: formation of gluten, release of CO_2 gas from baking powder and formation of vapour pressure are made possible by presence of water. Water regulates the consistency of batter which affects the volume and texture of the cakes.
7. Salt enhances the natural flavour of other ingredients used in cake making. It also controls development of crust colour by lowering the caramelization temperature of sugar. It may be used at the rate of 0.7 to 1.2% depending upon flavour.

8. Baking powder of various types, when moistened with water and heated, evolve CO_2 gas which expands during baking and impart volume to cakes.

9. Flavourings: Cocoa, chocolate, vanilla etc are added as flavours.

13.4 Cake making methods

13.4.1 Sugar batter method

In this method fat is creamed and then sugar is added gradually. When adequate aeration is achieved, flour is added in the mixture along with raising agents. There should be minimum mixing action to avoid gluten formation. When all flour is mixed, remaining liquid is added to the batter to necessary consistency.

13.4.2 Flour batter method

In this method fat and quantity of flour not exceeding the weight of fat is creamed together. Eggs and an equal quantity of sugar are whipped to a stiff froth. Then remaining sugar is dissolved in water or milk and added to the mixture. Lastly remaining flour along with baking powder is added and mixed gently.

13.4.3 Blending method

This is used for formulations containing more sugar than quantity of flour. All ingredients except sugar and milk are mixed together. Sugar, milk, colour and flavours are mixed and added to previous mixture followed by eggs and mixed to form a smooth batter.

13.4.4 Boiled method

Flour (more than two third portions) is added to melted butter or margarine and mixed well. Eggs are whisked with sugar followed by addition of colour and flavor. This is added to flour- fat mixture in equal parts, mixing thoroughly at each stage. Remaining flour is also added at this stage.

13.4.5 Sugar water method

Initially sugar is dissolved in water followed by addition of all other ingredients except eggs. Finally eggs are added and whisked well.

13.4.6 All in process

In this method, all the ingredients are put into the mixing bowl together. Aeration of the mixture is achieved by controlling the speed of mixer as well as mixing time. The batter is then put in greased pan. Only 2/3rd height of mould should be filled. Load the batter containing pan into oven as soon as possible. Bake the cake at 375° - 400°F for 25-30 min.

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Lesson 14

TECHNOLOGY OF PASTA PRODUCTS

14.1 Introduction

Pasta is a generic term used in reference to the whole range of products commonly known as spaghetti, macaroni, vermicelli and noodles. Italy is generally regarded as the home of pasta products and it is the largest consumer of pasta products in the world. The Italians call these products *Pasta alimentare* (alimentary paste) since these products are made from alimentary dough of wheat semolina or flour and water. Pasta products are defined as a class of foods, each of which is prepared by drying formed units of dough made from semolina, durum flour, farina, flour, or any combination of two or more of these with water and with or without one or more of optional ingredients such as, egg white solids, quick cooking agents, seasonings, emulsifiers, milk solids, soya flour, vegetable solids, vitamins and minerals.

Pasta products in India are designated as Macaroni products. According to FSSA (Food Standards Safety Act), macaroni products means the product obtained from suji or maida with or without addition of ingredients like edible groundnut flour, tapioca flour, soya flour, milk powder, spices, vitamins and minerals. While as per BIS (Bureau of Indian Standards) other ingredients such as gluten, casein and vegetables are also permitted to be added in macaroni products.

14.2 Raw Materials for Pasta Products

14.2.1 Durum wheat

Durum wheat (*Triticum durum*) is the raw material of choice for the production of pasta products. Durum wheat is cultivated on about 8.8% of the total area of the world used for growing wheat, but it contributes only 4.5% of the world wheat production. Durum wheat is a tetraploid species and it is the hardest wheat amongst all the wheat. Durum millers generally prefer the following physico chemical characteristics during selection of wheat.

Table 14.1 Physico chemical characteristics of durum wheat

Characteristic	Value
Test weight (kg/hl)	82
Vitreous kernels (%)	77 – 96
1000 kernel weight (g)	30 – 55
Moisture (%)	10.5 – 12.5
Protein (%)	14 – 14.5

14.2.2 Semolina

Pasta products are manufactured principally from the three main milled products of durum wheat, namely semolina, durum granular and durum flour. Durum wheat is too hard to easily reduce to fine flour. First, durum wheat is cleaned to remove foreign matter, shrunken and broken kernels. Then it is tempered (conditioned) to a moisture content of approximately 16.5% to toughen the seed coat so that efficient separation of bran and endosperm can take place. The tempered wheat is ground on a series of corrugated break rolls to open up and scrape the wheat kernels to release the endosperm from the bran. A second set of reduction rolls having finer corrugation is used to grind the middlings (semolina) to proper size. Various vibrating sieves are used between grinding steps to allow for efficient reduction of the endosperm to proper granular size. Final step of milling involves purifying to separate as much as of small bran particles and flour from the semolina. A commercial durum wheat mill will produce 64% semolina and 9% flour from good grade of durum wheat. Semolina with more uniform particle size is preferred as less problems are encountered in mixing the semolina and water to form a uniform dough for extrusion.

The optimum size for the semolina particles for pasta is about 150µ. Durum granular is used usually used in short-cut pasta such as shells or elbows. Durum flour is used primarily in the manufacture of noodles, as it yields smoother and more homogeneous dough.

14.2.3 Water

Water used in pasta products should be pure, have no off flavours and be potable. Since, pasta can be processed below pasteurization temperature, the bacterial count of the water is directly related to the bacterial count of the finished product.

14.3 Pasta Processing

All pasta products were home-made until about 1800 AD. Around 1850 AD the first hand-operated mechanical press came into existence. At the beginning of twentieth century, equipments like mixer, kneader, hydraulic extrusion press and drying cabinets became available. Pasta extrusion and drying has evolved to the mark where as high as 7000kg pasta can be continuously produced within an hour; with different size and shape.

The typical steps for pasta processing include continuous press, shaker/spreader, pre-dryer, finish dryer, storage and packaging.

14.3.1 Extrusion

In the continuous press, the semolina and water are metered in a predetermined ratio to form uniform dough. A dough moisture content of 30-31% yields excellent quality of pasta. Uniform mixing of water and semolina is carried out in a counterrotating mixing chamber. Counterrotating mixing shaft prevents balling of the dough. Some mixing chambers operate under vacuum as it reduces formation of small air bubbles in the dough and limits oxidation of the xanthophyl/lutein pigments. Pigment oxidation otherwise reduces the attractive yellow appearance of the pasta and thus consumer acceptability. The presence of air bubbles in pasta reduces mechanical strength of pasta and gives chalky appearance to the pasta.

In the extrusion chamber, the hydrated semolina is passed through extrusion auger, which kneads the dough into homogeneous, cohesive plastic mass prior to extrusion through die. During extrusion, as heat generation due to friction is considerable, extrusion barrels are generally equipped with water-cooled jackets to maintain the pasta temperature near 40-45°C during extrusion process.

Pasta of various size and shapes can be made with change of dies and cutter knives. Generally bronze or stainless steel dies fitted with Teflon inserts are used. Teflon inserts extend the life of die and improve surface quality of the pasta.

14.3.2 Drying

Drying is most critical step in pasta processing. Pasta is dried from around 30-31% w/w moisture to 10-12% w/w moisture during drying process. Uniform drying of pasta is necessary to prevent moisture gradient. Uneven drying causes stresses, which can cause the product to crack or check (i.e. ruined by tiny hairline cracks). Checking can occur either during drying cycle or during storage.

Pasta drying is carried out in three or four discrete stages. The product is subjected to a blast of air for surface drying called “case-hardening”. The moisture in the pasta quickly reduced to 20-25% in about 1 hour in a pre-dryer at 65-66°C at 65% relative humidity (RH). At this moisture level, hard outer ‘skin’ is formed, which keeps the integrity of the pasta shape and flexibility. The pasta is equilibrated for 1.5 to 2 hours in the main dryer which is controlled at 55°C with RH at 95%. The temperature and RH maintained during the final stage of drying of pasta are 40°C and 70%, respectively. The moisture in pasta is reduced to 10-12% w/w at the end of drying. The dried pasta is allowed to cool to ambient temperature before being packed.

Drying is carried out in number of commercially available dryers. They can be divided into two classes. They employ either low or high temperature processes. In case of low temperature drying of pasta time required for drying of long goods is around 16 hours and for short goods it is approximately 8 hours. High temperature drying raised the drying temperature from 55°C to 75°C, which resulted in shorter drying times (10 hours for long goods, 4.5 hours for short goods), improved product and bacterial quality.

Recent pasta drying technology has increased drying temperature from 75°C to 100°C and above. These very high/ultra high temperature drying has many advantages like significant reduction in drying time (5.5 hours for long goods, 2.5 hours for short goods), improved bacterial and end-product quality and reduced investment and operating cost.

Microwave technology in conjunction with conventional hot air pre-dryers has been successfully employed for drying of pasta. Advantages associated with microwave drying are less floor space requirement (1/3rd to 1/4th of conventional dryer), reduced drying time (approximately 2 hours), improved product colour and cooking quality, reduced palte count, reduced sanitation and operation cost.

14.3.3 Packaging

There are many different sizes, shapes and types of packages in which pasta products are sold. The major considerations in choosing packaging material are: keeping the product free from contamination, sufficiently gentle mechanical handling to ensure minimal product breakage during shipment and storage, high degree of accuracy and precision in the weighing and filling of the packages and displaying the product favourably with consumer appeal.

Cellophane, low-density polythene bags and other types of flexible films are widely used for packaging of pasta products. Apart from this packaging, pasta is packaged into cardboard boxes, as they are easy to stack, provide good physical protection for the product and advertising is easier to print on boxes than on the plastic films. Modified-atmospheric-packaging (MAP) methods have also been used for packaging of fresh-pasta products, which are marketed in retail refrigerated cases.

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Lesson 15

METHODS OF PULSE MILLING – WET AND DRY METHOD, DOMESTIC AND COMMERCIAL MILLING

15.1 Introduction

Pulses are defined as dried edible seeds of cultivated legumes. Pulses occupy important place in human diet. They serve as major sources of dietary protein and energy. The production of pulses in India was 13.19 million tones in 2001-02, which was 27% of the World's production. Bengal gram/Chick pea (chana), pigeon pea (tur/arhar), cow pea (lobia), black gram (urad), green gram (moong), lentils (masur), peas (matar) are some of the major pulses grown in India.

Pulses are consumed in its dehusked and split form which is termed as dal. Pulse milling (dal milling) is accomplished in three major steps namely: loosening of husk, dehusking and splitting of pulses. Pulses are generally consumed in the form of Dal. Traditional methods for processing of pulses were labour intensive, time consuming and incurred losses. Modern technologies for processing of pulses have replaced old age methods and thus avoid losses and saves time. Processing of pulses involves two basic steps – (i) seed coat/husk loosening and its removal and (ii) conversion of seed grain into splits and grinding into flour depending upon its end-use. Various methods are employed for pulse/dal milling. Pulses undergo some basic unit operations during pulse milling such as cleaning and grading, drying, loosening of husk, dehusking, splitting and polishing.

15.2 Methods of Pulse Milling

15.2.1 Wet milling of pulses

Wet method of pulse processing (Fig. 15.1) involves cleaning to remove dust, dirt, chaff, stone pieces, immature grains and other seeds. The easy to dehusk pulses are then soaked into water for a period of 2 – 8 hrs whereas difficult to dehusk type of pulses (pigeonpea, black gram, green gram) are often treated with red earth. The pulses are subsequently dried and then subjected to dehusking and splitting to obtain Dal.

15.2.2 Dry method of pulse milling

In case of dry method of pulse milling (Fig. 15.2), the pulses after cleaning are fed into roller dehusker where a scratch, dent and crack is formed on the outer seed coat. Pitted pulses are then stored for ½ day to 3 days after applying oil on the surface. Generally 150 – 250 gm oil per 100 kg pulses is applied. The oil diffuses between husk and cotyledon and thus facilitates loosening of the husk. Water treatment (2.5 – 3.5 kg water/100 kg pulses for overnight period) helps in further loosening of the husk. Then the pulses are subjected to drying and cooling. Now, the dried pulses are dehusked and splited to obtain dal.

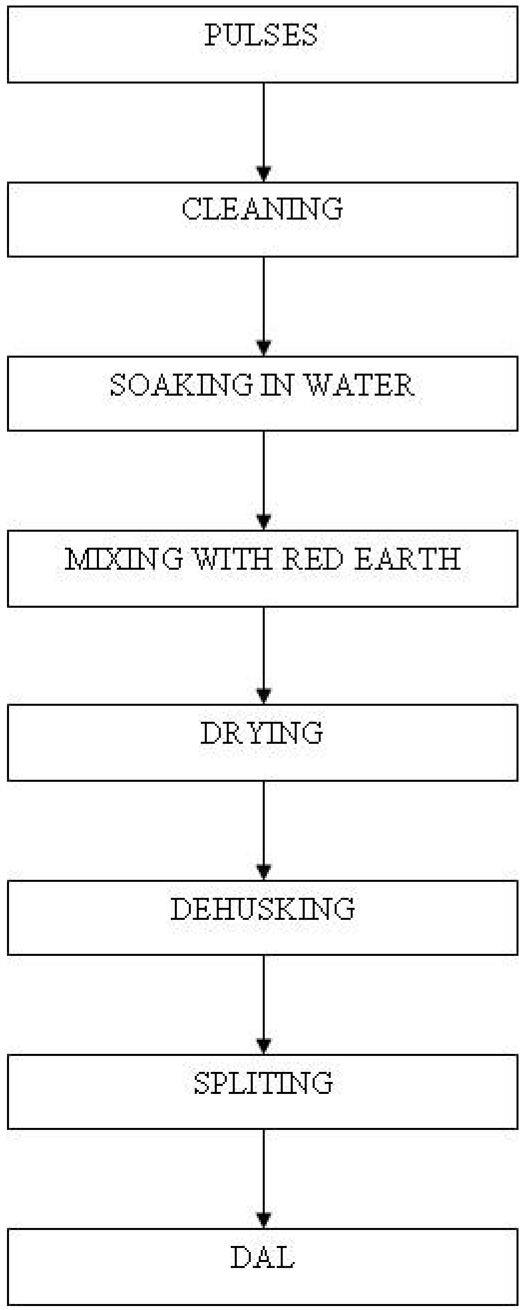

Fig. 15.1 Wet milling of pulses

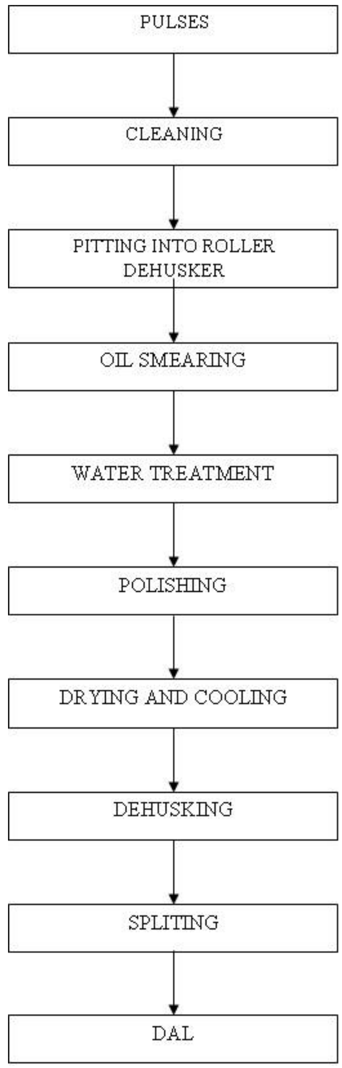

Fig. 15.2 Dry milling of pulses

15.3 Home Scale Milling of Pulses

The home scale method of processing of pulses involves pounding of pulses into mortar and pestle. Home scale method of pulse milling is different for different pulses and varies from region to region. In this method, the husk is loosen either by wet or dry method; treating the pulses with water and/or oil. The pulses are then generally stored overnight and the next day they are sun dried. The removal of husk is then carried out in pestle and mortar or by a hand operated stone mill. The husk then is separated by winnowing.

15.4 Commercial Scale Milling of Pulses

15.4.1 Cleaning and Grading

Pulses received at the mill needs to be cleaned and size graded for yielding good quality dal with higher recovery. Even during dehusking operation, pulses are subjected to sieving to separate out husk, brokens, splits, gota (dehusked pulse) and whole (unhusked) pulses. Usually two, types of cleaners are used: reciprocating air-screen cleaners and reel screen cleaners.

In reciprocating air screen cleaners air is blown through two screens (sieves) which separate out lighter material such as dust, stalk, dried leaves, husk etc. The upper screen has bigger perforations while second screen has smaller perforations. The reel screen cleaners consist of 2-4 cylindrical compartments. The frame of the machine is made of wooden or mild steel sheet. In these compartments different size perforation screens are fitted on a 5-7.5 mm diameter shaft. The machine is fitted at an inclination of 2-3°. The cylindrical screen drum rotates at 5-35 rpm.

15.4.2 Drying of Pulses

Drying of pulses is necessary to ensure safe storage before milling as pulses received at mill have generally higher moisture content. After steeping of pulses for loosening of husk, it is also necessary to dry pulses. During splitting operation too, it is very much essential to dry the pulses to separate cotyledons. Sun drying of pulses is economical option for drying of pulses. The sun drying is done for 1-6 days as per the requirement. The pulses are spread over floor/roof in 5 to 7.5 cm thick layer which are intermittently stirred manually with the help of rakes or turning by foot. At night, the drying pulses are collected in heaps and covered with canvass sheet to preserve the heat. Mechanically heated air dryers, either batch type or continuous flow type are also used by the millers. The temperature of heated air for drying varies from 60° to 120°C.

15.4.3 Loosening of Husk

This is very important step in pulses milling as it decides the total recovery and quality of milled dal. Loosening of husk is accomplished in two different ways: wet method and dry method.

15.4.3.1 Wet Method

Cleaned and graded pulses are soaked in water for 4-12 hours for steeping, mixed with red earth for 12-16 hours and then sun dried to keep the moisture content about 10-12 %. During steeping the husk becomes loose and thus facilitates easy dehusking and splitting. Yield is also increased due to lesser breakage. But cooking time increases when the dal is obtained by this method. Red earth is used as it impart a good yellow colour to the end product and also helps to remove small patches of adhering husk due to its mild abrasive quality.

15.4.3.2 Dry method

In this method, husk is loosened by sequence of operations such as: oil smearing, water application, tempering and sun-drying. Cleaned and graded pulses are passed through roller dehusker in which scratches, cracks and dents are created on hard seed coat of pulses. This is known as 'pitting' of pulses. The pitted pulse grains are then passed through the sieve cleaner to separate out the splits, husk and powder and later smeared with oil (100-500 gram per quintal of pulses) either manually or with auger mixer and stored for 1-5 days. During this tempering period oil diffuses in between the husk and cotyledons and weakens the bond and thus facilitates loosening of the adhering husk. At the end of storage period, water is applied to the grains (1-5 kg/q) and stored for further 12-14 h (overnight) and at last sun-dried for 1-3 days before subjecting to milling.

15.4.4 Dehusking

Roller dehuskers coated with carborandum are used to dehusk the pulses. Two types of rollers viz. cylindrical and tapered are available for dehusking. Tapered rollers are placed horizontally and the diameter of roller increase from feeding side to discharge side. The difference in diameter helps to gradually increase the pressure on pulse grains and thus helps in gradual dehusking. The cylindrical rollers are installed at an angle of 10-15° which enables forward movement of pulse grains inside the machine. Annular gap between rollers varies depending upon the type of pulses being dehusked. Inlet and outlet of the roller machine can be adjusted for regulation of grain flow and retention time respectively. Small dal mills use under run disc shellers or burr mills for dehusking operation in place of Roller mills.

Conditioned pulse grains subjected to mild abrasion inside the roller machine, removes 10-25% of husk in one pass. Shelled husk, cotyledon powder, brokens and splits are separated out by Air-screen cleaners after passing the grain lot once or twice through the roller machine. Depending upon adherence of husk to grain, the pulse grains are passed through mill for two to eight times.

For hard-to-dehusk pulses (arhar, moong, urad), the recovery is between 70-75% while for easy-to-dehusk pulses (bengal gram, lentil, kesari and peas), it varies in between 78-85%.

15.4.5 Splitting

Splitting operation involves loosening the bond between the cotyledons and splitting. For cotyledons loosening, water at the rate of 1-5 kg/quintal is applied to dehusked pulse grain (gota) and is stored for 2-12 hours and later sun-dried for 4-8 hours. For splitting, machines like under-run-disc sheller (URD), impact machine (Phatphatia), roller mill, and hitting the gota against the metal sheet at discharge side of bucket elevator are used. In this operation the embryo attached to two cotyledons breaks away, thereby, causing a loss in dal recovery by 1.5 to 2%.

15.4.6 Polishing

In this operation dal is imparted with a glazing appearance to improve its consumer's acceptance and market value. Depending upon the need, different materials like water, oil, soapstone powder and 'selkhari' powder are applied to dal surface. Sometimes removal of sticking powder from dal surface is considered sufficient to improve its surface glaze.

15.4.6.1 Removal of powder/dust

Cylindrical rollers mounted with the rubber mats, leather strips, emery rollers are used for the purpose. The dust particles sticking to dal surface are removed by gentle rubbing action on the roller surface.

15.4.6.2 Water polish

This is used for hard-to-dehusk pulses. In this method 1-1.5 kg of water per quintal of dal is applied while passing it through polisher.

15.4.6.3 Buff polish

In this method 2-2.5 kg of water and 200-250g of oil per quintal of dal is applied while passing it through polisher.

15.4.6.4 Nylon polish

Soapstone powder or '*selkhari*' powder (1-1.5kg/q) is applied to the surface along with water (1-1.5 kg/q) while passing through the polisher. Screw conveyors battery for repeated rubbings is used. The flights and shafts are covered with nylon rope to impart gentle rubbing.

15.4.6.5 Teliya dal

2.5 to 3.0 kg of castor oil is mixed per quintal of arhar dal to make it look glossy. The storage life of teliya dal is short.

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Module 4. Pulse processing

LESSON 16

ROASTED, GERMINATED, FERMENTED AND CANNED LEGUME PRODUCTS

16.1 Introduction

Pulses are consumed in its dehusked and split form which is termed as dal. Pulse milling (dal milling) is accomplished in three major steps namely: loosening of husk, dehusking and splitting of pulses. Pulses are generally consumed in the form of Dal. Processing of pulses is important in improving their nutritive value. The processing methods used are soaking, germination, decortications, cooking and fermentation.

16.2 Processing Methods

16.2.1 Soaking

Soaking in water is the first step in most methods of preparing pulses for consumption. Soaking reduces antinutritional factors present in pulses. Soaking reduces the oligosaccharides of the raffinose family, which are responsible for flatulence after pulse consumption. Soaking also reduces the amount of phytic acid in pulses.

16.2.2 Fermentation

The processing of food pulses by fermentation increases their digestibility, palatability, and nutritive value. Soybean is very valuable pulse whose protein approaches the quality of animal protein. However, it cannot be directly used as food because of the anti-nutritional factors present in it. The anti-nutritional factors can be eliminated by fermentation process. The common examples of fermented product are idli and dosa (blend of fermented black gram and rice). This fermentation process improves the availability of essential amino acids.

16.2.3 Germination

Germinated legumes are also occasionally used as traditional legume foods. Sprouting causes partial breakdown of starch and proteins and contributes to the better digestibility. Sprouting also improves flavour of the legume. Sprouted legumes can also be used as a ready-to-use marketable product. Sprouting causes hydrolysis of the oligosaccharides, also responsible for causing flatulence of legumes.

16.2.4 Puffing

Puffed legumes are cheap and popular food for the common man. Puffing and toasting of pulses is practiced all over the country. The flavour and light texture of the product makes it popular among all age groups. These products are traditionally used as snacks. Puffing is effected by manual or mechanical roasting of conditioned legumes in hot sand. The increase in size is 1.5 to 2 times of its original size. Bengal gram and peas are best suitable for puffing. The puffing expansion during roasting is maximum in Bengal gram which is most popular for puffing.

The grains are first soaked in water for short duration (1-3 minutes), mixed with sand heated to 250ºC and toasted for 15-25 seconds with agitation. After sieving off the sand, the grains are dehusked between a hot plate and a fast rotating rough roller. The yield of puffed product is about 65-70% by weight.

16.3 Legume Products

16.3.1 Canned legume products

Many pulses are required to be cooked soft for consumption. The cooking time needed for softening is long (15-45 min.). Instant or quick cooking pulses is necessary for modern urban consumers. Retort processed pulses in cans are now available in the super markets.

16.3.2 Besan manufacture

Besan is made from chana dal (Bengal gram). Its production involves three major steps namely size reduction, sieving and packaging. Besan is made in rural areas and at home scale level in burr mills (*atta chakki*). Capacities of such machines vary in between 50-100 kg per hour.

Some manufactures employ Pulverizers (hammer mill) along with reel sieves (recovery of besan is 98%). The reel sieve is generally fitted with a fine nylon cloth (112 mesh). It has a blower rotating on its axis at 350 rpm. This helps in blowing out the fine powder out of the reel which is collected at one end by auger. The coarse powder discharged at other end is fed back to hammer mill by a bucket elevator.

16.3.3 Papad manufacture

Papad is a thin round rolled sheet of dried papad flour. Papad flour is made by combining few pulses flours like urad, moong etc. In some papad flours, gram pulse is also added. Rolling papad is generally a manual operation done by women folks. The papad flour along with spices like black pepper, jeera, baking soda and salt is tightly kneaded with water and then rolled.

CFTRI has developed a papad mill where kneaded papad flour is pressed in round thin sheet by keeping the dough in between two polyethylene sheets and placing it in between two parallel discs. One disc is pressed against other with the help of foot through a lever. The capacity this machine is about 500 papad an hour.

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Module 5. Oilseed processing

Lesson 17

DEHULLING AND EXTRACTION OF OIL FROM OILSEEDS, PROCESSING OF VEGETABLE OIL, PROCESSING AND UTILIZATION OF OILSEED MEALS

17.1 Introduction

The major role of edible oils and fats in our diet is to supply energy. Fat provide 9 kilo calories for each gram consumed. Fat contain poly-unsaturated fatty acids (PUFA) which reduces blood cholesterol and is important in prevention of coronary heart diseases. They also contain essential fatty acids (EFA) which are required in the maintenance of normal growth, reproduction and skin permeability. Apart from these fatty acids, fats are the only source of fat soluble vitamins such as Vitamin A, D, E and K in our diet.

World's five major annual edible oilseeds are soybean (*Glycine max* (L.) Merr.), cottonseed (*Gossypium hirsutum* L.), rapseed/canola (*Brassica napus* L. *B.* rapa L. and *B. juncea* L.), sunflower seed (*Helianthus annuus* L. var. *marcocarpus* DC.) and peanut/groundnut (*Arachis hypogaea* L.) Almost all oilseeds are processed commercially by oil expellers. Oilseeds are made up of tinny particles called cells. Oil glands are embedded in each cell which liberates oil on rupturing. Thus, the primary object of oilseed processing is to rupture the gland and cell wall which gives more yield of oil during processing. Recovery of oil (primarily triglycerides and phospholipids) from oilseeds is facilitated by rupturing the cell wall by heat and pressure during flaking, and by optional extrusion with an expander, followed by pressing or solvent extraction.

17.2 Extraction of Oil from Oilseeds

Extraction of oil is typically done by following methods listed in Table 17.1. A general oil extraction flow diagram is shown in Figure 17.1

17.2.1 Cleaning

Oilseeds received at mill may contain certain impurities entering from field, during storage and transportation, or accidentally. Frequently encountered impurities include: straws, chaff, sticks, weed seeds, other grains, shrunken and broken seeds, infected seeds, mud, dust, stones, metal objects, etc. Cleaning of oilseeds comprises removal of all the impurities mentioned above.

17.2.2 Conditioning/Tempering

The ground or flaked oilseeds are heated with live steam to about 90°C. The purpose of tempering is to facilitate oil recovery. The heat treatment ruptures all the cells, partly denatures the proteins and inactivates most of the enzymes. It is very essential to maintain the optimum temperature to avoid formation of undesirable colouring compounds and aromas. After conditioning and moisture adjustment to about 3%, the oil is obtained by pressing and/or solvent extraction.

17.2.3 Pressing

The oil is removed by pressure from an expeller or screw press. The residual oil in the resultant oilseed meal is about 4–7%. It is, however, more economical to apply lower pressures and to leave 15–20% of the oil in the flakes, and then to remove this oil by a solvent extraction process ("prepress solvent extraction" process).

Table- 17.1: Oil extraction methods

S. No.	Method of oil extraction	Employed for	% residual oil in meal/cake	*Remarks*
1	Solvent extraction	Low oil seeds (less than 30% oil)	0.5 – 1.0%	*Oil is solubilized by solvent (n-hexane).*
2	Full/Hard pressing	High oil seeds (greater than 30% oil)	4.5 – 7.5%	*Seeds are passed through continuous screw press.*
3	Prepress-solvent extraction	High oil seeds (greater than 30% oil)	0.75 – 1.25%	*16 – 20% oil is extracted by screw press and the cake is then treated with solvent to achieve further extraction.*

17.2.4 Extraction

The ground seeds are rolled into thin flakes by passing them between smooth steel rollers. The extraction is then performed using non-polar solvents such as food grade hexane, as a solvent (boiling point 60–70°C). In addition to n-hexane, it contains 2- and 3-methylpentane and 2,3-dimethylbutane and is free of aromatic compounds. Solvent removal from the raw oil-solvent mixture, called miscella, is achieved by distillation. The maximum amount of solvent remaining in the oil is 0.1%. The oil-free flakes are then steamed to remove the solvent ("*desolventizing*") and, after dry heating ("*toasting*"), cooled and sold as protein-rich feed for cattle. The crude oil obtained either by pressing or solvent extraction contains suspended plant debris, protein and mucous substances. These impurities are removed by filtration.

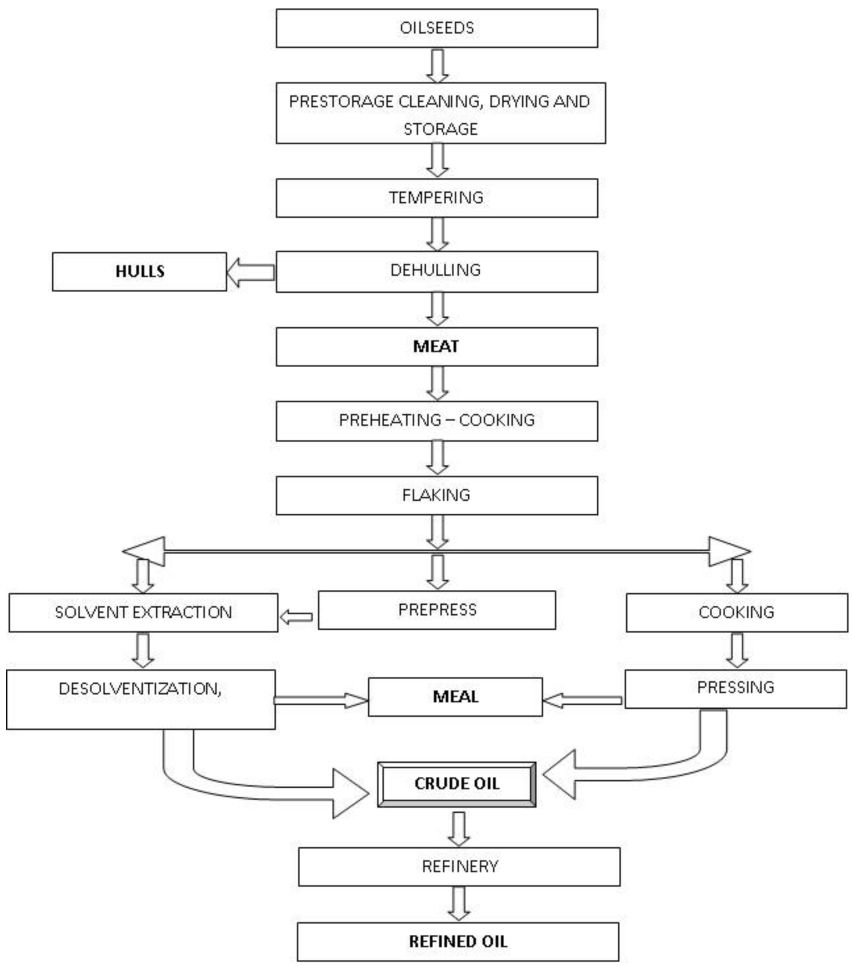

Figure 17.1 Flow diagram for oilseed extraction

17.3 Processing of vegetable oils

Many pathways exist for processing crude oil into various commercial oil and fat products (Fig. 17.2)

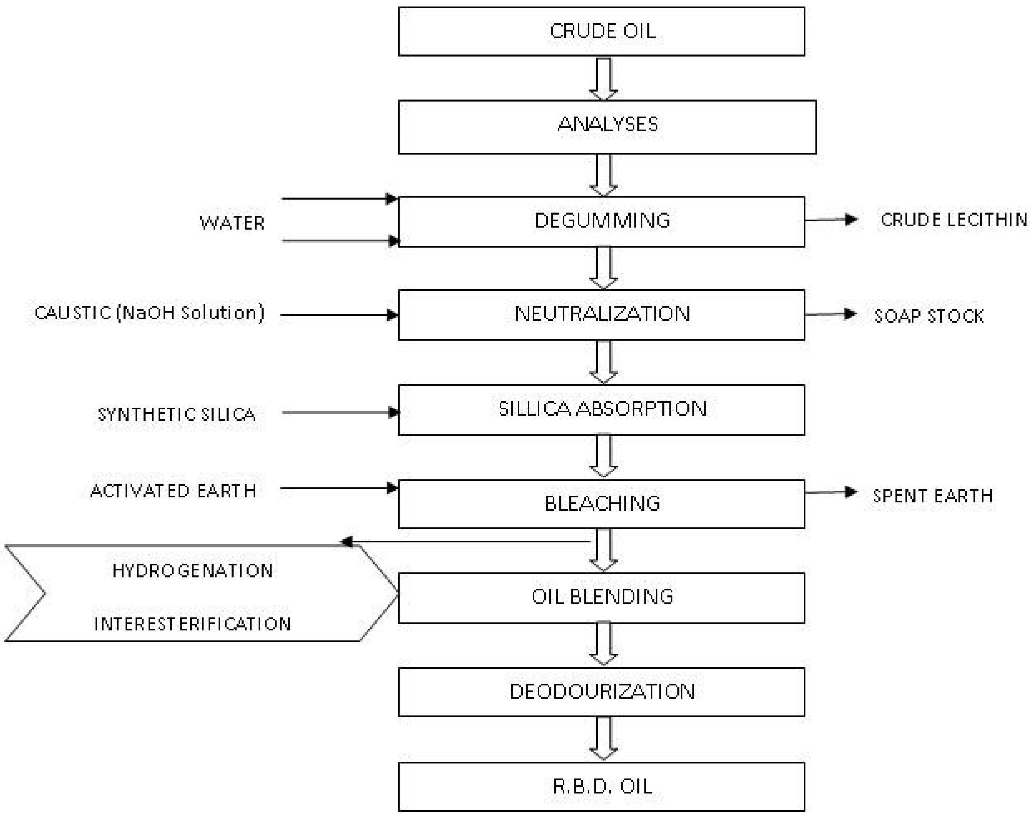

Figure 17.2 Flow diagram of vegetable oil processing

17.3.1 Analyses of crude oil

Before starting processing, oils are brought from storage tanks into a 'day tank', which is thoroughly mixed and sampled for analyses to determine the treatments to be applied. These tests include free fatty acids, phosphorous, moisture, insoluble impurities and colour.

17.3.2 Degumming

Degumming is the process of removing phosphatides by hydration with water. The phosphatides must be removed to prevent darkening of the oil during the high temperatures of deodourization and in later applications like frying and to extend oil shelf life. Degumming is practiced for recovering crude lecithin for later purification. Approximate phosphatides content of the major crude oils vary between 0.5 to 3.5%.

Crude oil is heated to 60-80°C and soft water at the rate of 75% of the weight of phosphatides is added into oil, and hydration allowed to occur with the mixing for 30-60 min. Although the hydrated gums will settle by gravity, in commercial installations, separation is accelerated by use of decanters and disc type centrifuges. Simple water degumming typically reduces phosphorus content of soybean oil from 500-800 ppm to well under 50 ppm. Levels of 0-5 ppm phosphorus are desired in oils going to be deodourized. To obtain this, it may be necessary to solubilise the nonhydratable phosphatides by acid degumming. Phosphoric and citric acids are used to chelate and withdraw the divalent cations and restore phosphatide solubility in water.

17.3.3 Neutralization

Neutralization is the step of converting the free fatty acids in crude oils to soaps. It is some times called 'alkali neutralization' or 'refining'. Sodium hydroxide is the most popular neutralizer used for refining of crude oils. Two continuous refining systems are used: long mix process and short mix process.

The long mix process uses a lower concentration of caustic and is conducted at ambient temperature 33°C with 8-15 minutes. Then the oil is heated to70°C, to assist breaking the emulsion and the mixture is passed through centrifuge.

The short mix process is conducted at 90°C, uses a more highly concentrated caustic, and a mixing and centrifuging time of less than 1 minute.

17.3.4 Silica absorption

In traditional refining, oil from primary centrifuge id washed with warm soft water to remove residual soap and passed through secondary centrifuge. In modern method degummed, caustic neutralized, partially vacuum dried oil is mixed with synthetic silica. Synthetic silica hydrogels, effective in removing 7-25 times more phosphatides and soaps than clay on a solid basis.

17.3.5 Bleaching

The objective of the bleaching is to remove various contaminants, pigments, metals and oxidation products before the oil is sent to the deodourizer. Types of bleaching material available include: natural earth, acid activated earth and activated carbon. A typical vacuum bleaching process is 20-30 minutes at 100-110°C and 50mmHg absolute.

17.3.6 Hydrogenation

Hydrogenation is the process of adding hydrogen to saturate carbon-to-carbon double bond. It is used to raise triglyceride melting points and to increase the stability against oxidation. Most of the catalysts that assist hydrogenation are nickel-based. Efficient hydrogenation requires cleanest possible feed stock and the purest, driest hydrogen gas possible. The catalyst must be completely removed by filtration before further processing of the oil.

17.3.7 Interesterification

Controversies exist about the healthfullness of trans fatty acids produced during hydrogenation. Interesterification is a technique for positioning or rearranging fatty acids on triglycerides. This technique is followed as a means of obtaining trans-free margarines, spreads and shortenings. Interesterification mainly uses sodium methylate, sodium ethylateor other catalysts ans is assisted by temperature manipulation. Position specific enzymes such as 2-glycerol and 1,3-glycerol position are also employed for interesterification. The catalyst must be deactivated and the resulting oil purified before further processing.

17.3.8 Chill fractionation

Chill fractionation is a process of chilling oil to a selected temperature to cause crystallization of a fraction. The crystals can be removed by vacuum belts or frame pressure filters equipped with inflatable air bladders.

Essentially all the palm oil is chill fractionated. The fraction seen most as palm oil is the olein.

17.3.9 Oil blending

Oil blending is an optional step, used primarily when oils with specific solid temperature profile are prepared. If blending does not occur, the oil may go directly from bleaching to deodourization.

17.3.10 Deodourization

The last treatment given to oil before leaving a refinery is deodourization to reduce its peroxide value to essentially zero. Deodourization is essentially steam distillation process for removing peroxides as well as flavours and odours from the oil. Soybean oil is deaerated, then deodourized in continuous deodourizers for 15-60 minutes at 252-266°C with an acsolute pressure of 1-6 mmHg, using stripping steam at the rate of 1-3% of the weight of oil.

17.3.11 RBD Oil

Some countries want characteristic flavours and colours left in their oils. In contrast, RBD (Refined, bleached, deodourized) oils are light coloured and bland regardless of the species. Supplier specifications generally are tighter than trade association specifications. Several suppliers offer soyben oil with <0.05% free fatty acids and 1.0 meq peroxide value.

17.4 Utilization of Oil Seed Meal in Food Formulations

Oil seed meal refers to coarse residue obtained after oil is removed from various oilseeds. It is relatively rich in protein and minerals and generally used as poultry and other animal feed. It may be broken up and sold or be ground into oil meal. Oil meal from certain seeds such as castor beans and tung nuts are toxic and are used as fertilizers rather than feed.

Oilseeds from which oil meal used as feed is produced include soybeans, peanuts, flaxseed (linseed), rapeseed, cottonseed, coconuts (copra), oil palm, and sunflower seeds. Cottonseed and peanuts have woody hulls and shells, which are generally removed before processing. The pressed cake from the production of cottonseed oil must also be processed to remove a toxic pigment called gossypol, before it can be used as feed for non-ruminants such as pigs and poultry.

17.4.1 Food uses of oil cakes

To cope up with protein deficiency malnutrition, cereal based products play a pivotal role as a vehicle for value-addition being consumed by masses. Defatted oil cake meal is widely used in various food formulations to improve quality characteristics and nutritional values.

The products in which oil cake meal are successfully used are shown in Table-17.2

Table 17.2 Uses of oil cake meal in food formulations

Sr. No.	Food Product	Results
1	Comminuted meat products	□ Improved sensory quality □ Improved yield
2	Frankfurters	□ Batter stabilizing effect □ Improved nutritional value

3	Macaroni	□ Longer dough mixing time □ Higher water absorption □ Improved protein content and amino acids profile
4	Bakery products	□ Improved the amino acid and mineral composition

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Lesson 18

PROCESSING OF SOYBEAN AND OTHER OILSEEDS; DAIRY ANALOGUES

Most of the unit operations involved in processing of oil seeds are discussed in the lesson no. 17 (Fig.17.1). In this lesson special requirements for processing of soybean and other oilseeds are discussed.

18.1 Soybean

Soybean can be processed at 12% moisture if not dehulled to make 44% protein content meal. In earlier years, in order to make high protein content soybean meal, hulls were loosened by drying the seeds from 13% moisture to 10% moisture at 65°C, cooling and holding for 1-5 days before dehulling. The hot dehulling process was developed to eliminate double heating of soybean. Soybean at 13% storage moisture are heated to 60°C during a period of 20-30 minutes to allow the moisture to migrate to the surface. Then they are rapidly heated to surface temperature as high as 85°C to loosen the hulls. During this process moisture is reduced by 1-3%. The soybeans are then cracked into six to eight pieces and flaked at 60-65°C and 10-11% moisture.

The phospholipase enzyme activity can be minimized by the following: drying seeds adequately before storage, avoiding breakage in handling, moving seed rapidly from dehulling to extraction with minimum addition of water, operating outside the optimum activity temperature range of the enzyme.

Soybean oil is the main source of commercial lecithin harvested by a degumming operation before alkali neutralization.

18.2 Rapeseed/Canola

The majority of rapeseed/canola oil recovery is by press-solvent extraction, with about 60% of the total oil removed in the first operation. Seed often is flaked at 7.0-9.5% moisture in two stages: to 0.4-0.7 mm thickness in the first and to 0.2-0.3 mm in the second.

Cooking reduces moisture content to 5-6% for hard pressing, denatures the protein and enhances coalescing of minute oil droplets into larger ones, inactivates the enzyme myrosinase (thus preventing hydrolysis of glucosinolates and reducing sulphur content of the oil), inactivates phospholipases and prevents development of monohydratable phosphatides in the oil.

18.3 Corn germ

The distribution of oil in corn is approximately as follows: germ,83%; endosperm, 15%; bran, 1.3%; tip cap, 0.7%. Most corn germ is a by-product of starch and corn sweeteners production by wet milling or alcohol fermentation, and contains 44-50% oil when dried to 2-4% moisture content. Dried wet milled germ is moistened to 8%, heated to 90-105°C to soften its intracellular structure, flaked to 0.10-0.13mm in thichness, prepressed and solvent extracted to 0.5% residual oil.

18.4 Cottonseed

Cottonseed requires special handling techniques. Flaked cottonseeds are extruded through an expander at 13% moisture and 100°C. The objective of flaking is to rupture both the spheresomes containing the oil and glands containing gossypol. The flaked cottonseed material is held hot for 20 minutes, retextured at 113°C, dried/cooled to 11% moisture at 57°C before solvent extraction.

The residual oil content in cake from a press is in the range of 4.0-6.5%. Solvent extracted meal contains 0.5-0.7% residual oil.

18.5 Peanut

The processing of peanut poses special problems. They mature in soil, and additional efforts are needed to remove small stones and sand to reduce wear on machines. Aflatoxin contamination is a potential and must be monitored constantly.

Shelled peanuts contain 50% oil. Generally peanuts are processed by full press or prepress solvent extraction. To provide traction in the screw press, peanuts are cooked to 5% moisture content. If only a prepressing is given, the cake is crumbled and solvent extracted.

Direct solvent extraction process uses two stages:

1. The kernel are cooked and sent to roll stand equipped with an upper set of corrugated rolls and a lower set of smooth rolls. They are cracked into quarters by the upper rolls, then given a light flaking in the lower rolls without production of fines.

2. After the first extraction stage, the flakes are rolled again and re-extracted.

18.6 Sunflower seed

Sunflower seed is the only major raw crop oilseed that does not have identified antinutritional factors requiring inactivation during processing. Oil type seeds are black in colour and consist of 20% hull and 40-45% oil. The seed clings to hull, which is thin, flexible and difficult to remove. Typically, oil-type sunflower seed are dehulled to the desired fiber content, heated, flaked, prepressed and than solvent extracted.

18.7 Vegetable Protein Concentrates and Isolates

Due to high protein content and ease of extraction, soybean is widely used to obtain protein for special food uses. Soy protein is made from dehulled, defatted soybean meal. Dehulled and defatted soybeans are processed into high protein commercial products such as soy protein concentrates and soy protein isolates. Soy protein is used in a variety of foods such as salad dressings, soups, imitation meats, beverage powders, cheeses, non-dairy creamer, frozen desserts, whipped topping, infant formulas, breads, breakfast cereals, pastas, and pet foods. Soy protein is used for emulsification and texturization in various products. Specific applications include as adhesives, asphalts, resins, cleaning materials, in cosmetics, inks, leather, paints, paper coatings, pesticides/fungicides, plastics, polyesters, and textile fibres.

18.7.1 Production methods

Edible soy protein isolate is derived from defatted soy flour with a higher solubility in water. The aqueous extraction is carried out at a pH below 9. The extract is clarified to remove the insoluble material and the supernatant is acidified to a pH range of 4-5. The precipitated protein-curd is collected and separated from the whey by centrifugation. The curd is usually neutralized with alkali to form the sodium proteinate salt before drying.

Soy protein concentrate is produced by immobilizing the soy globulin proteins while allowing the soluble carbohydrates, soy whey proteins, and salts to be leached from the defatted flakes or flour. The protein is retained by one or more of several treatments:

- Leaching with 20-80% aqueous alcohol/solvent
- Leaching with aqueous acids in the isoelectric zone of minimum protein solubility (pH 4-5)

- Leaching with chilled water (which may involve calcium or magnesium cations)
- Leaching with hot water of heat-treated defatted soy meal/flour.

All of these processes result in a product that contained ≥70% protein, 20% carbohydrates (2.7 to 5% crude fiber), 6% ash and about 1% residual fat, but the solubility may differ. One tonne of defatted soybean flakes will yield approximately 750 kg of soybean protein concentrate

18.7.2 Product types

18.7.2.1 Isolates

Soy protein isolate is a highly refined or purified form of soy protein with a minimum protein content of 90% on a moisture-free basis. It is made from defatted soy flour which has had most of the non-protein components, fats and carbohydrates removed. Because of this, it has a neutral flavour and will cause less flatulence due to bacterial fermentation.

Soy isolates are mainly used to improve the texture of meat products, but are also used to increase protein content, enhance moisture retention, and as an emulsifier. Pure soy protein isolate is used mainly by the food industry. It is available in health stores or in supermarket as pharma food. It is usually used in combination with other food ingredients.

18.7.2.2 Concentrates

Soy protein concentrate must contain not less than 70% soy protein and is basically defatted soy flour without the water soluble carbohydrates. Soy protein concentrate retains most of the fiber of the original soybean. It is widely used as functional or nutritional ingredient in a wide variety of food products, mainly in bakery products, breakfast cereals, and in meat products. Soy protein concentrate is used in meat and poultry products to increase water and fat emulsification and to improve nutritional values (more protein, less fat).

Soy protein concentrates are available in different forms: granules, flour and spray-dried. Because of their higher digestibility, they are well-suited for children, pregnant and lactating women, and the elderly. They are also used in pet foods, as milk replacer for infants (human and livestock), and even in some non-food applications.

18.8 Dairy Analogues

The rising demand by the consumers for healthy food has led to the alternative demand and development of dairy-like products, such as soy-based analogues. Soybean can be processed into many soy products which are analogous to dairy products such as soy beverage (soy milk), tofu (soy paneer), soy yoghurt.

18.8.1 Soy milk

Soy milk/soy beverage is a water soluble extract from whole soy beans. It is an off-white emulsion or suspension containing water soluble proteins, carbohydrates, and lipids. It resembles dairy milk in appearance. However, it is lactose free and represents an alternative to dairy milk.

Commercial soy beverages can be classified according to their composition such as: high solids soy milk (bean to water ratio of 1:5), dairy like soy extract (bean to water ratio of 1:7) and lower solids soy beverage (bean to water ratio of 1:20). Depending upon the processing parameters and water to soybean ratio, soymilk would have a typical solids content around 8-10%. Within this, protein is 3.6%, fat 2.0%, carbohydrates 19.9% and ash 0.5%.

Soy milk is healthy drink as it is cholesterol and lactose free. It also contains phytochemicals, which has proven health benefits.

18.8.2 Tofu

Tofu is a high protein food made from soybeans. It is used as meat or cheese substitute. It is sold as ready to eat cakes that resemble paneer or soft white cheese. The preparation of tofu involves extraction of soymilk and then coagulation of this extract to form curd. The curd is then pressed to form tofu cakes.

Typical wet composition of tofu is 85% moisture, 7.8% protein, 4.2% lipid. The remaining constituents are carbohydrates and minerals. The typical dry composition is made up of 50% protein, 27% fat and 23% carbohydrates and minerals.

Tofu can be categorised as silken or pressed tofu. Silken tofu production involves soy extract being finely filtered and heated before cooling to a temperature of 65-70°C. Calcium sulphate/magnesium chloride of low concentration is added to the extract. A fine, smooth and firm curd forms after 30-60 minutes. This curd is left unbroken.

In case of pressed tofu, coagulant is vigorously stirred into hot soy extract. The curd is broken and pressed. Pressed tofu contains about 22% protein and 61.6% moisture.

18.8.3 Soy yoghurt

While milk based yoghurt has long been consumed in many countries, soy yoghurt, also known as soghurt, is a relatively new product. It is produced through the fermrntation of soymilk by different cultures of bacteria to form soft, fragile, custard like texture, generally containing 12-14% total solids and possessing a clean tart flavour.

There are several types of soghurts. Soghurt can be produced in the form of a highly viscous texture, a softer gel or in frozen form as a dessert or drink. Generally they can be classified as: set type soy yoghurt, stirred type and drink type.

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Lesson 19

PRESENT STATUS OF MEAT, POULTRY AND FISH INDUSTRY IN INDIA

19.1 Current Status of Meat Industry in India

Animal food is considered as good source of quality nutrients viz. fat, protein, carbohydrates and minerals. Digestibility of animal source protein is 90-97% while vegetable origin proteins have 75-99%. However, proteins of animal origin are more completely digested and nutritionally superior than those of plant origin. Protein digestibility corrected amino acid score (PDCAAS), protein efficiency ratio (PER) and biological value (BV) of animal and plant proteins are 0.9-1.0 and 0.42-0.70; 3-4 and 1.5-2.6; 74-94 and 65-73 respectively. On the other hand, plant origin proteins are deficient in at least one of more essential amino-acids e.g. some cereals in lysine and some legumes in methionine but the animal proteins contain all essential amino acids.

India has the largest livestock population (485 million) which represent about 55% (96 million) and 16% of the world's buffalo and cattle populations respectively (17^{th} Census 2003). The country ranks second in goats, third in sheep and camels, and seventh in poultry populations in the world. Although India has been the top producer of milk (>115 MT, 15% global production) which is one of the primary produce of the livestock sector, the meat production is only 5 million tones annually representing mere 2% of the world production. Nearly three million tonnes of broiler meat and about 2.86 million tonnes of eggs are produced annually in India. Growing at about 20 per cent annually the domestic poultry market is currently estimated at about Rs. 49,000 crore.

The domestic market is mostly confined to fresh meat because of the eating habits of the Indians. Therefore hardly 40-50% of the total processing capacity of over 1 million tones per annum is utilized. Among processed meat, 6% of production of poultry meat is sold in the processed form of which only 1% is marketed as value added ready-to-eat/ready-to-cook types. Of the total meat produced, only about 1% is converted into value added products like sausages, ham, bacon, kababs, meatballs, etc.

Buffalo meat production was at 2.85 million tons in 2010 and is expected to increase marginally through 2012 (growing at 3%). The growth is primarily due to increasing domestic consumption, growing exports and a new trend of raising male buffalo calves for meat production. Spent buffalo cows are also used for meat purpose. Currently, the processing level of buffalo meat is estimated at 21%.

The buffalo meat share in total meat exports from India is more than 90 percent (in value terms), followed by 3% per cent share of goat and sheep meat and the rest comprising of poultry meat and animal casings. Exports of other types of meats such as from pork, poultry, and processed meat are almost negligible due to higher costs, inadequate meat processing facilities, and infrastructure constraints. For exports mostly deboned frozen buffalo meat is used. The demand for bovine meat has increased over the years in the global markets resulting in higher prices of cattle meat. This has opened new opportunities for us and led to increase in buffalo meat exports from India in recent years.

Beef exports are forecast to rise 5 percent in 2012 on robust global demand, particularly to Southeast Asia, the Middle East and North Africa. India accounts for nearly half of world growth in 2012 on increased supplies and price-competitive shipments to emerging markets. The export is restricted to very few products. The export from sheep and goat is very low. As per APEDA statistics (2010-11), the export of buffalo meat is 7, 09,437tonnes (Rs. 8412 crore), processed meat 1,19,08 tonnes (value Rs 253 crore), poultry products 6,19,150 tonnes (Rs 301 crore) while that of animal casings it is 1809 tonnes (Rs. 35 crores). Buffalo milk is not very remunerative because of competitive disadvantages and the export is largely restricted to few countries in the Middle East.

Slaughter rate for cattle as a whole is 20%, for buffaloes it is 41%, pigs 99%, sheep 30% and 40% for goats. In India there are about 3,900 licensed & authorized slaughter houses besides around 26,000 unauthorized slaughter houses. Furthermore, there are 13 export-oriented, modern, integrated abattoirs or meat processing plants registered with the Agricultural and Processed Food Export Development Authority (APEDA). In addition to these, there are 24 meat processing and packaging units, which receive dressed carcasses from approved municipal slaughter houses for the export of meat. According to the Ministry of Food Processing Industries (MFPI), about 70% of poultry processing is in the organised sector and 30% is in the unorganised sector. Nearly 60-70% of the broiler industry is located in the southern states, as is much of the layer industry.

Per capita consumption of meat from beef and veal put together in 2011 was only 1.6 kg. Mutton and lamb is relatively smaller segment where demand is outstripping supply, which explains the high prices in domestic market. The production levels have been almost constant at 950,000 MT with annual exports of less than 10,000 MT. This has restricted large processing companies from developing business interests in this sector. Production of meat is governed under local by-laws as slaughtering is a state subject. Processing of meat is licensed under the Meat Food Products Order (1973).

19.2 Status of Poultry Sector

India is the third largest producer of eggs and ninth largest producer of poultry meat in the world. The poultry industry has registered significant growth. In 2010-11, India's egg production reached 61.5 billion eggs, up 68% from 36.6 billion in 2000-01. As per FAOSTAT latest production data for the year 2010, India ranks 3rd in egg production in the world. Poultry exports are mostly to Maldives and Oman. Indian poultry meat products have good markets in Japan, Malaysia, Indonesia and Singapore. Among Indian states, Andhra Pradesh stands as the highest egg producer. Both public and private sector organizations have played important role in the poultry industry. India at present has only five egg powder plants which is inadequate considering the fact that export demand for different categories of powder viz., whole egg, yolk and albumen are increasing. There is a huge scope for the growth of poultry industry as the country's annual per capita consumption is only 2.4 kgs. Per capita consumption has grown from 1.22 kgs in 2001 to 2.26 kgs in 2010, an increase of 185%. The National Institute of Nutrition has recommended 180 eggs and 11 kg of meat per capita consumption for our country

India's poultry product exports are mainly confined to eggs and egg powder, which are growing due to cost competitiveness and logistical advantages. There are no restrictions on exports of poultry and poultry products. The government provides some transportation subsidies (Rs 3-15 per kg) for its exports. For the development of meat export from India the industry has demanded some immediate measures like financial assistance for upgradation of export oriented abattoirs/processing plants. Inclusion of buffalo meat under APEDA's Transport Assistance Scheme for new markets in Africa/CIS (Commonwealth of Independent States) where freight cost from India for refrigerated containers is much higher than from competing countries. Restoration of DEPB rates for frozen buffalo meat. Exemption from Service Tax on transportation of meat products processed for exports. This is presently applicable only for fruits, vegetables, eggs or milk even for domestic consumption.

19.3 Status of Fisheries Sector

India is the second largest producer of fish in the world, contributing about 5.54 percent of the global production. The total fish production during 2010-11 was 8.29 million tonnes with a contribution of 5.07 million tonnes from the inland sector and 3.22 million

tonnes from the marine sector. The value of output from the fisheries sector at current prices during 2009-10 was Rs. 67,913 crore which is 4.9 per cent of the total output of agriculture & allied sectors. India's marine product exports have for the first time crossed USD 2 billion. During 2010-11, the volume of fish and fish products exported was 8,13,091 tonnes worth Rs. 12,901 crore registering the highest growth rate of 10% in volume of fish exports in recent years.

19.4 Future Strategies for Sustainable Growth of Meat, Poultry and Fisheries Sectors

In view of the immense potential of the meat, poultry and fisheries sector, policymakers have recommended certain critical measures to support this vital segment of the Indian agriculture. Modernization of abattoirs, setting up of rural abattoirs and registration of all slaughter houses in cities/towns are essential for quality meat production. Besides, setting up of large commercial meat farms have been recommended to address the traceability issues necessary for stringent quality standards of CODEX. It has also been suggested that the goat sector has immense potential and needs to be supported in terms of higher investment, community approach and establishment of proper linkages between the processing industry and the market. Similar approach is needed for sheep sector which has remained almost static for a long time. Poultry sector in the country has now emerged as organized industry and important issues like breeding farms, hatchery, feed mills, equipment manufacture, feed supplements, drug and vaccine production, etc. have been addressed in a very satisfactory way. However marketing of the final product still remains mostly in the hands of traders which need to be addressed properly. The other important issues for the poultry sector are improved Feed Conversion Ratios (FCR) and quick control measures for tackling disease outbreaks.The overall growth rate in livestock sector is proposed to be revised to 5 per cent during the current Plan with a 4 per cent growth rate for milk sector and 6–8 per cent for poultry and meat sector.

The marine fisheries sector is expected to grow at the rate of 2.0 percent annually and it is estimated that 3.669 MMT of marine fish would be harvested by the year 2016-17. With

this production, the country will be exploiting about 83 percent of its potential harvest of 4.419 MMT. The developments and trends in fish production in the inland sector suggest that a growth rate of 8.0 percent can be achieved by the inland sector. With this growth rate, it is estimated to reach a fish production target of 7.910 MMT by the end of the Twelfth Plan Period (2016-17). The strategies adopted for achieving the targets are to include integrated approach for enhancing inland fish production and productivity with forward and backward linkages right from the production chain. This has to also include input requirements like quality fish seeds and fish feeds and creation of required infrastructure for harvesting, hygienic handling, value addition and marketing of fish. It is proposed to revamp the Existing Fish Farmers Development Authority (FFDAs) and cooperative sectors, besides actively involving the self help groups and youths in intensive aquaculture activities. Sustainable exploitation of marine fishery resources especially deep sea resources and enhancement of marine fish production through sea farming, mariculture, resource replenishment programme like setting up of artificial reefs etc are the other measures that could enhance marine fisheries sector.

Module 6. Meat and poultry processing

Lesson 20

PRE SLAUGHTER HANDLING AND INSPECTION OF ANIMALS

20.1 Introduction

Pre-slaughter handling of meat animals includes procedures adopted during transportation, pre-slaughter rest and ante mortem inspection.

20.2 Transportation of meat animals

Animals are taken to the slaughter house either on hoof or through road/rail/sea transport. Whatever the means, what is of paramount importance is that the animals must not be subjected to cruelty. There are legislations against cruelty to animals and procedures recommended need to be strictly adhered to. If the animals are carried by road or rail care needs to be taken to avoid overcrowding which may lead to suffocation and physical injuries in the form of bruises, fractures etc. Tying or chaining of the animals is to be avoided. There are specially designed trucks and wagons available to take care of such issues and should be used as far as possible.

20.3 Pre-slaughter rest

Pre-slaughter rest is the period before slaughter when animals are rested in order to improve the meat quality and reduce the chances of contamination with gastrointestinal bacteria.

- During pre-slaughter rest fatigue could have negative influence on protective functions of the animals (low immunity) allowing rapid penetration of the microorganisms especially E Coli through mucous membrane of the intestine to the blood stream and ultimately to the organs.
- Normal feeding and resting for 48 hours brings gradual freeing of muscles and other organs from microorganisms, improve bleeding and keeping quality of meat.
- Pre-slaughter rest also helps in preserving glycogen level in the muscles and during the later phase this glycogen undergoes anaerobic respiration and results in production of lactic acids which has mild preservation effect on meat quality.
- Under stressed conditions muscles do not receive enough oxygen which leads to higher lactic acid production often associated with comprised quality in terms of colour, texture and water holding capacity.

20.4 Ante-mortem inspection

It refers to inspection of food animals conducted prior to (12 to 24 hr) slaughter to ascertain fitness or otherwise of the animals for slaughter.

20.4.1 Objectives of ante-mortem inspection

1) To detect the animals suffering from infectious or scheduled diseases (communicable to animals or human beings) such as FMD, Rabies, Anthrax, etc.
2) To detect diseases causing toxic or infectious conditions and which may escape detection in post mortem examination.
3) To prevent outbreaks of food poisoning resulting from the consumption of meat from animals which were ill at slaughter
4) To make post-mortem inspection more efficient and less laborious.
5) To document information on animal diseases prevalent in the region.

To prevent the use of meat from animals suffering from febrile condition.

20.4.2 Facilities for conducting ante-mortem inspection

1. For successful ante-mortem examination, procedure for adequate identification of the animals to be slaughtered need to be followed.
2. The lairage should be properly designed, well lighted and ventilated
3. The lairage should have provision for isolation pens
4. There should be competent assistant staff for handling of livestock and above all a competent veterinary officer must be available.
5. A well designed code on veterinary ante-mortem inspection procedures, judgement principles and documentation of findings need to be maintained.

20.4.3 Procedure for ante-mortem inspection

Immediately after the animals arrive at the slaughterhouse, they are examined by qualified veterinary personnel before being sent to the lairage where ante-mortem inspection is carried out 12 to 24 hours before slaughter by the qualified veterinarians.

Ante-mortem inspection can be carried out in two stages:

20.4.3.1 Stage-I: General examination

The animals are to be examined collectively to assess the overall health status so as to segregate them into three groups:

1) Healthy
2) Unhealthy (diseased)
3) Apparently healthy (doubtful cases)

- The animals are examined while they are at rest and also in motion
- They are observed for the gait, posture, fatigueness and for their response to external stimuli.
- They are examined for abnormal behavior like walking in circles, state of alertness, symptoms of tiredness and agitation
- Animals are examined for abnormal discharge from natural orifices like eyes, nose, mouth, anus, vagina etc. and/or swellings on any part of the body.
- It is also important to observe for any evidence of cruelty to animals such as any sign of bruises, torn skin, and fractured bone indicating carelessness during transportation.

At the end of the first stage of examination, healthy **animals are cleared as "fit" for slaughter** whereas the other two groups are taken to the next stage of examination.

20.4.3.2 Stage-II. Detailed clinical examination

The animals classified as unhealthy (diseased) are subjected to further examination to correctly diagnose the illness while the animals placed in group three (Apparently healthy or doubtful cases) are examined to ascertain whether these animals are really sick and if so what could be the nature of illness.

Animals are subjected to the following investigations:

(i) Temperature, pulse and respiration rate should be recorded and animals suffering from fever must be retained for treatment preferably outside the meat plant.

(ii) The lymph nodes are palpated and examined for any swelling and abnormalities and on this basis the animals are either rejected or passed with clear instructions for careful post-mortem examination

(iii) Pregnant animals or animals having delivered a calf within the last 48 hours are not permitted for slaughter. Animals undergoing treatment or with a recent history of treatment as also experimental animals are not to be slaughtered unless a 'no objection certificate' has been issued by veterinarians.

(iv) Blood, urine and faeces samples to be drawn for laboratory tests

(v) Pathoganomonic clinical symptoms of the diseases for suspected animal to be carefully studied.

(vi) The species, class, age, condition, colour and markings re recorded in case of diseased or sick animals and in case of the animals in poor condition.

Table 20.1: Diseases and abnormalities encountered in ante-mortem inspection

General conditions	Specific infections			
	Cattle	**Calves**	**Sheep**	**Swine**
Moribund and exhausted status	Actinomycosis	Immaturity	Pneumonia	Arthritis,
Emaciation	Actinobacillosis	Calf diphtheria	Caseous lymphadenitis	Atrophic
Anasarca	Tuberculosis	Arthritis	Enterotoxaemia	Rhinitis
Poorness	Blackleg	Ringworm	FMD	Swine Fever
External injuries	FMD	White Scour		Swine
Localized swellings a) tumours b) abscesses c) oedema d) haematoma **e)** hernia	Anthrax	Salmonellosis		Erysipelas
Inflammatory conditions of skin a) urticaria b) eczema	Rinderpest			Swine
Pregnancy	Mastitis			Tuberculosis
Fractures	Ringworm Pneumonia			FMD
Dysnoea	Retained placenta			
Discharges from natural orifices				

20.4.4 Judgment decisions at ante-mortem inspection

Post anti-mortem inspections, the animals can be subjected to any of the following three decisions.

- **Passed/Accepted/ Fit for slaughter:** The animals free from any disease and normal can be directly sent for slaughter.
- **Rejected/ Condemned/ Unfit for slaughter:** Animals suffering from fever (106^{o}F or more), emaciated or dead animals, immature or pregnant animals are considered unfit and not passed for slaughter. Animals with established symptoms of diseases are not sent for slaughter.
- **Suspect:** Animals falling under this category are those for which decision regarding fitness for slaughter cannot be made at the ante-mortem inspection stage. The following possibilities exist under these circumstances.

(a) Slaughter under special precautions: Animals under suspect category if having symptoms of diseases.

(b) Delayed/Detained slaughter: If the animals require treatment, or have history of recent treatment/vaccination, animals in febrile condition, fatigued and exited state may require treatment before they are slaughtered.

(c) Segregated slaughter: Such decisions are made under special conditions such as dirty stock or animal suspected for some contagious diseases etc. Such animals are slaughtered at the end of the day's kill or separately slaughtered and a thorough post- mortem examination is performed.

(d) Casualty and emergency slaughter: Casualty slaughter is required when an animal is not in acute pain or immediate danger of death but affected with a more chronic condition like benign superficial tumors, obturator paralysis and post- partum paraplegia etc. When an animal is in acute pain or suffering from condition like, fractures, severe injuries, uterine prolapsed etc., where a delay in slaughter would be contrary to the animal welfare, then animals requires emergency slaughter. Prolonged recumbency in cows and sows after parturition, abscess formation in pigs due to *Corynaebacterium pyogenes*, pregnancy toxaemia and enterotoxaemia in sheep and injuries and affections of udder and uterus in cattle are the several other causes of emergency slaughter.

I. **"Fit"** for slaughter.

II. **"Unfit"** for slaughter and the animal is condemned at ante-mortem.

III. **"Suspect Animals"** which fall under 2 categories

(a) **"slaughter under strict supervision"**

(b) **"retain for a specified period"** enabling +he symptoms to develop or subside and thereupon take a final decision on slaughter (fit/unfit/slaughter under strict supervision).

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Lesson 21

SLAUGHTERING TECHNIQUES AND POST-MORTEM INSPECTIONS

21.1 Slaughtering Procedures

After the animals have been rested for sufficient time, they are quietly taken to the stunning area. Animals may be facilitated through mechanical means like canvass straps or rolled plastic or prodded to move forward. However tail twisting or beating is forbidden. Slaughter animals are properly restrained before stunning or bleeding. Different types of restraints are used for different species.

21.1.1 Stunning

It is a process to inactivate animals so that it is not able to move. It is an obligatory process with large animals. Stunning ensures that the animal is unconscious before it is slaughtered in order to eliminate pain, discomfort and stress from the procedure. Many countries have legislation that requires pre-slaughter stunning. Care should be taken not to affect the heart and it should function normally to ensure complete bleeding which ensures better meat quality. Stunning is done in special stunning pan (box with movable side wall).

21.1.1.1 Stunning methods

1. Most common method employed is **striking** on the head with a wooden hammer or captive bolt. However blow should not damage the frontal bones as it may cause brain hemorrhage.
2. Electrical stunning: An electric current of 75-120 volt is passed for 15-70 seconds through the hind part of the animal head in the regions of parietal boxes by puncturing the skin. This causes unconsciousness of the animals which may last for 5 min and it is enough to transfer the animal from stunning pan to bleeding runway.
3. Anesthetization: Anaesthetization may be carried out on swine using a mixture of CO_2 and air in equal volume with 0.18% chloroform and the inhalation period may last for one min.

21.1.2 Slaughter

The most common methods of slaughter practiced worldwide are the Halal (Islamic), the Kosher (Jewish) and the Jhakta (Sikh) methods.

Halal: Halal is one of the most popular method of slaughter. This method prescribes slaughtering of animals with a sharp knife to make a swift, deep incision that cuts the front of the throat, the carotid artery, wind pipe and jugular veins but leaves the spinal cord intact. The animal is then hung upside-down and left to exsanguinate i.e drainage of blood. The *Halal* slaughter requires that the name of Allah (or God) should be mentioned at the initiation of the operation. This method of slaughter ensures that the blood flows out completely from the animal.

Jhatka: It is an instant decapitation process limited mostly to sheep and goats and practiced in countries like India by few religious sects. The animals are killed by a single strike of a sword or axe by severing the head *Jewish Slaughter (Kosher):* "Kosher" is the term applied to the procedures and techniques of slaughter practiced under the Jewish faith. In Hebrew language, Kosher means fit to be used as food. Under this method of slaughter, the animals in fully conscious state are killed and bled thoroughly by one clean stroke of the knife. Animals are however hoisted and shackled first. A 16-inch (40.6 cm) razor-sharp steel knife called the chalaf is stuck into the throat by a trained slaughterer, the shohet, in an operation in which the animal is killed and bled at the same time. Skinning is made from the chest down to the level of the belly, and the chest is cut open first for inspection and later evisceration.

21.1.3 Bleeding

Bleeding is a procedure in the slaughter process which is performed by cutting jugular vein in the neck and carotid artery in order to allow blood to drain from the carcass, resulting in the death of the animal from cerebral anoxia. The bleeding knife should be continuously sharpened as a blunt knife may prolong the incision and damage the cut ends of the blood vessels. This may result in premature clotting and blockage of the vessels thus delaying the bleeding process. A prolonged delay in bleeding could result in the animal regaining consciousness. The delayed bleeding may also result in an increase in blood pressure causing the blood vessels to rupture and haemorrhage of muscle. The extra blood in the tissues may lead to meat getting decomposed quickly. Incisions should be therefore swift and precise. In poultry, sheep, goats and ostriches, the throat is cut behind the jaw.

21.1.4 Skinning

After successful bleeding, first the head is skinned, separated from the body, marked with the same number as the body and then hung on hook for post mortem examination. 'Skinning' is a term mostly used for small ruminants and the method of skinning is known as "case-on". The skinned materials are called as "skins". Skin is the most valuable byproduct economically. In sheep and goats, skin is first cut around the leg to expose and loosen the tendon of the hock and used for hanging the carcass. This process is called legging. The second step that follows is called skinning which involves removal of the entire skin and preparation of the animal body for evisceration. Skinning can be done either in the horizontal or hanging position depending on the convenience and available facilities. If animal body is in hanging position, legging is generally started at the back of the free leg by removing the skin around the hock and continued towards the toes. This exposes the tendon on the back leg and the foot is cut off at the joint above the toe. The body skin is removed by making an opening in the front legs, cutting towards the jaw and continuing over the brisket to the naval. Once the brisket has skinned, knife is seldom used to protect the "fell" (a fine membrane between the skin and the carcass). This helps in improving carcass appearance and reducing surface shrinkage. This is largely accomplished by using fist/hand. After the skin has been removed, the carcass is washed and placed on a hook. In horizontal skinning the animal is placed on its back on a flat raised surface and similar process repeated.

This operation is absent in pigs, because skin is a part of the carcass. In the case of large ruminants (cattle and buffaloes), cuts are made on the skin along the mid-ventral line and also on the medial side of the limbs connecting to the respective points (sternum and pelvis) in the mid-ventral line. Skinning of large ruminants is known as "flaying" and the incisions made on the skins are known as "ripping lines". The deskinned materials are called as "hides.

21.1.5 Evisceration

It should be carried out without damaging the internal organs or disturbing the internal surface of the carcass. Damage to the gastro-instestinal tract (GIT) may contaminate the carcass with the microorganisms. The first step in evisceration is to cut around the tied bung or rectum and free it completely from all attachments. The breastbone is then cut along the midline up to its tip. Another cut is made from the cod or udder down the midline into the breast cut. Then the ureter connections to the kidneys are severed and the intestines loosened. The stomach and intestinal mass are removed. The lever could be detached from its connecting tissues and then pulled out along with the contents of the abdominal cavity. The gall-bladder is carefully removed from the liver so that its content does not spill out and contaminate the carcass. The pluck consisting of heart, lungs, trachea and esophagus can be pulled out as a unit. The carcass is then washed and carried manually or mechanically to the inspection area.

21.1.6 Carcass splitting and sizing

In the slaughterhouses, carcasses of small ruminants are not split into sides or quarters; carcasses of large ruminants are split into four quarters; and carcasses of pigs are split into two sides. Therefore, at the retail meat stalls selling buffalo meat, pork and mutton, we find quarters, sides and whole carcasses of respective animals. Carcasses are sawed by electric or pneumatic saws starting from the hind part to the central vertebrae. This facilitates transport, storage and efficient refrigeration.

21.2 Post Mortem Examination

Postmortem examination/inspection refers to inspection of carcass and organs by qualified veterinarians to ensure that carcass and organs are fit for human consumption. During inspection, care should be taken not to contaminate the carcass and organs from diseased animals. The knives and other instruments used for cutting and examining organs, glands and tissues should be properly sterilized before and after use. The particular sequence should be followed during postmortem examination so that each carcass and thereof organs are checked thoroughly.

21.2.1 Objectives of postmortem examination

Carcasses should not be sent to the chilling section without inspection after dressing. Some of the diseases are not apparent during ante mortem examination can be detected easily in postmortem examination. Thus, post mortem inspection ensures safe meat to the consumers and also controls diseases right at the farm level itself. It also directs to adopt a proper disposal procedure for condemned meat and offal. Since postmortem inspection is performed for carcasses as well as their viscera, it ensures a systematic way of evisceration and handling of offals.

21.2.2 Facilities required for postmortem examination

- The area where the examination is being conducted should have sufficient and well distributed light. The natural light is considered better than artificial light. The intensity of light must be 540 lux
- The person carrying inspection need clean, sharp, stainless knives
- There must be provision for hot and cold water
- There should be a sterilizer to sterilize the knives, saws and cleavers. The postmortem examination should be carried out under hygienic conditions. The knives should be sterilized by dipping them in boiling water for 30 minutes or by autoclaving them for 10-15 minutes. (The sterilization of anthrax contaminated knives requires special consideration).
- To put a mark on carcass and its viscera, marking dyes should also be provided, which should be cheap, non-toxic and non-corrosive in nature. Marking indicates that the carcass has been inspected and guarantees the consumer about is wholesomeness. Marking of meat is done by (i) using a stamp (ii) branding or (iii) labeling. Common method – Metal stamp dipped in a stamping ink.
- There should be provision of detained room side by the inspection site.

21.2.3 General consideration

Following points should be considered during postmortem examination/ inspection:

- The examination must be done as soon as possible. Carcasses of beef and pork set rapidly and if the inspection is delayed especially in cold weather the examination of lymph nodes becomes difficult.
- Carcass and organs are to be examined methodically following a definite sequence. Healthy carcass should be examined before inspecting the diseased or suspected ones.
- Great care must be taken at the time of inspection particularly in cases suspected for zoonotic diseases.
- The identity of carcass and its viscera should be maintained.

- Inspector should avoid unnecessary cuts considering the value of high quality food. One should incise the carcass in such a way that the surface of the carcass appears clean and undistorted.

21.2.4 Postmortem principles

21.2.4.1 Visual perception

First the carcass and visceral organs should be examined visually for any visible abnormalities. Examination is done for any change of colour, atrophy, hypertrophy, neoplastic condition etc.

21.2.4.2 Palpation

The organs are palpated for any change in consistency, sliminess or gelation, cyst, etc.

21.2.4.3 Incisions

The organs are incised, if needed. This is done to examine any parasite inside organ, structural deformity etc.

21.2.4.4 Laboratory tests

These are done for confirmation and support the observation made by macroscopic examination. While examining the organs of carcass, lymph node of adjoining area must be examined.

21.2.5 Postmortem Examination of Carcasses

21.2.5.1 Large animals

In case of large animals like cattle, sequence of postmortem examination is as follows:

Head

- Verify the number, age and sex of the animal
- Inspect gums, lips and tongue for FMD, necrotic and other forms of stomatitis, actinomycosis and actinobacillosis (Palpate the tongue for the latter).
- Incise the internal and external masticatory muscles and tongue for *Cysticercus bovis.*
- Incise retropharyngeal, submaxillary and parotid lymph nodes for tuberculosis (TB) lesions.

- For sheep & goat, the lips, gums and nasal cavities should be examined for contagious ecthyma.

Lungs

- Examine visually and then palpate for the detection of pleurisy, pneumonia, tuberculosis, fascioliasis and hydatid cysts.
- Incise the bronchial and mediastinal lymph nodes and expose the lung by giving deep incision from the base to apex (for checking TB lesions).
- Check the tumors, abscesses etc. by palpation.

Heart

- Examine the pericardium for traumatic or tubercular pericarditis.
- Incise the ventricles of the heart and pay attention to look for petechial hemorrhages on the epicardium and endocardium and cuts in the myocardium. Flavy condition of the myocardium is indicative of septic conditions.

Liver

- A visual examination should be made for fatty changes, abscesses, hydatid cysts, actinobacillosis etc.
- For examination of fascioliasis, incise thin portion of left lobe of liver and examine the contents.
- For sheep and goat, lungs, heart and liver:

(i) Palpate lungs, heart and liver and accompanying lymph glands for abscesses.

(ii) Cut the bile duct for examining possible fluke infestation

Stomach and intestines

- Check the serous surface of the intestine for TB lesions and actinobacillosis.
- Palpate the mesenteric lymph node and if necessary incise and examine the same.

Spleen

- Examine the surface and substance for TB lesion, anthrax, hematoma and presence of infarcts.

Uterus

- Check for septic conditions by viewing, palpating and incising if necessary.

Udder

- Check the supramammary lymph nodes by incising for the evidence of TB lesions.
- Check for abscesses if any.

General inspection of carcass

- Look for the injuries and bruises. Bruises are dark colour after 24 hours and there is watery condition after 24 to 38 hours. After 3 days, the area becomes rusty orange colour and soapy to touch.
- Look for inflammation, abscesses and TB lesions in the thoracic and abdominal cavities.
- Examine the kidneys.
- Incise and examine renal lymph nodes.

21.2.6 Postmortem judgement

Similar to ante-mortem examination, a competent veterinarian has to submit its judgment report:

- Fit for human consumption
- Unfit for human consumption or total condemnation

- The affected organs must be condemned while rest can be passed for human consumption (partially condemned).
- The condemned carcass/ organs should be disposed off following scientific procedure.

21.2.7 Diseases and conditions for which carcass is totally or partially condemned

The carcass is totally condemned for rabies, anthrax, glanders, rinderpest, foot and mouth disease, acute enzootic meningoencephalitis, acute pleurisy, contagious bovine pleuropneumonia, ovine foot rot, sheep pox, swine fever, swine erysipelas, salmonellosis, fibrinous rhinitis, black leg, bovine viral diarrhea, haemorrhagic septicaemia, listeriosis, pasteurellosis, coccidiosis, calf diphtheria, calf diarrhoea, malignant oedema, tetanus etc.

The carcass in case of actinomycosis, actinobacillosis and Johne's disease, is totally condemned if accompanied with emaciation and in generalized form, otherwise the carcass is passed for human consumption after local condemnation. In case of corynebacterium infection, carcass is passed after removal of affected organs.

In case of heavy infestation (more than 10 cysts) with *Cysticercus bovis* and *Cysticercus cellulose*, carcass is totally condemned, otherwise the carcass is passed after removal of head, heart, diaphragm and esophagus. *Trichinella spiralis* infected carcass is totally condemned. If carcass show the sign of fascioliasis with emaciation then it is totally condemned, otherwise it is passed after trimming of liver.

Carcass is passed for consumption after removal of lung in case of emphysema and broncheolitis. If there is no fever, then carcass with sign of gastroenteritis is unconditionally passed.

The judgement of carcass suffered from tuberculosis depends on method of spread, extent of disease, character and age of lesion and general condition of the animal. Carcass is totally condemned when tuberculosis spreads through portal or pulmonary or systemic circulation. In case of localized tuberculosis, the carcass is passed after removal of the affected organs and associated lymph nodes.

21.2.7.1 Metabolic and nutritional disorders and intoxication

The carcasses are totally condemned if they show any of the following sign:
Anaemia with emaciation, (ii) grass tetany, (iii) haemoglobinuria, (iv) jaundice, (v) ketosis with chronic indigestion, (v) poisoning, (vii) bloat or (viii) impaction etc.

Abnormal conditions: Abnormal conditions like, abnormal colour, taste and smell, buck smell, bore smell etc. results in total condemnation of the carcass.

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Lesson 22

RIGOR MORTIS: BIOCHEMICAL AND HISTOLOGICAL CHANGES

22.1 Introduction

Meat is basically defined as the flesh of animals used as food. The term meat generally differs from the muscle in the sense its structural and physicochemical nature as it (muscle) has undergone certain chemical and biochemical changes following death of an animal which is a postmortem aspect. Thus, during the time elapsed between death of an animal and its processing, a series of biochemical and physico-chemical changes takes place which lead to conversion of muscle into meat.

22.2 Muscle: Structure, Composition & functioning

Muscle is made of number of fiber bundles (1.0 mm thick), comprised of a group of fibers, (0.1 mm thick) held together by a structure of connective tissues or perimysium (figure 22.1). Connective tissues which provide edible texture, structure and flexibility to the muscles, comprised of fibrous protein collagen, reticulin, and elastin. Muscle fiber, a unit of muscle contraction, is a multinucleate, cylindrical cell bounded by an outer membrane or sarcolemma and is consist of myfribils of 1-2 micron size. Myofibrils are separated by sarcoplasmic reticulum, a fine network of tubules. Each fiber is filled with sarcoplasm containing mitochondria, enzymes, glycogen, ATP, creatine, and myoglobin. The myofribrils are cross striated to give rise to understanding of physical structure of muscles (dark or A and light or I/Z bands). The unit of fibril is sacromere which lies between adjacent two Z- bands. Fibrils are consist of two set of filaments i.e. myosin and F-actin. Contraction and relaxation of striated muscles takes place due to interaction between actin, myosin and ATP. In the presence of magnesium and calcium ions, myosin liberates ATP which results in muscle contraction.

The composition of muscle is highly variable depending upon specie, type of muscle, animal's maturity and the treatments given to the animal before its slaughtering. Variation in the composition ultimately affects the nutritional and functional profile muscle tissues.

The lipid components of muscle tissue vary more widely than do the amino acid in fish muscle, the differences have been made in the concept of lean or white fish and fatty fish. In lean fish, storage fat is carried in the liver. Muscle of lean fish contains <1% lipid, mostly phospholipids, located in the membrane. In fatty fish, depot fat apparently occurs as extracellular droplets in the muscle tissue.

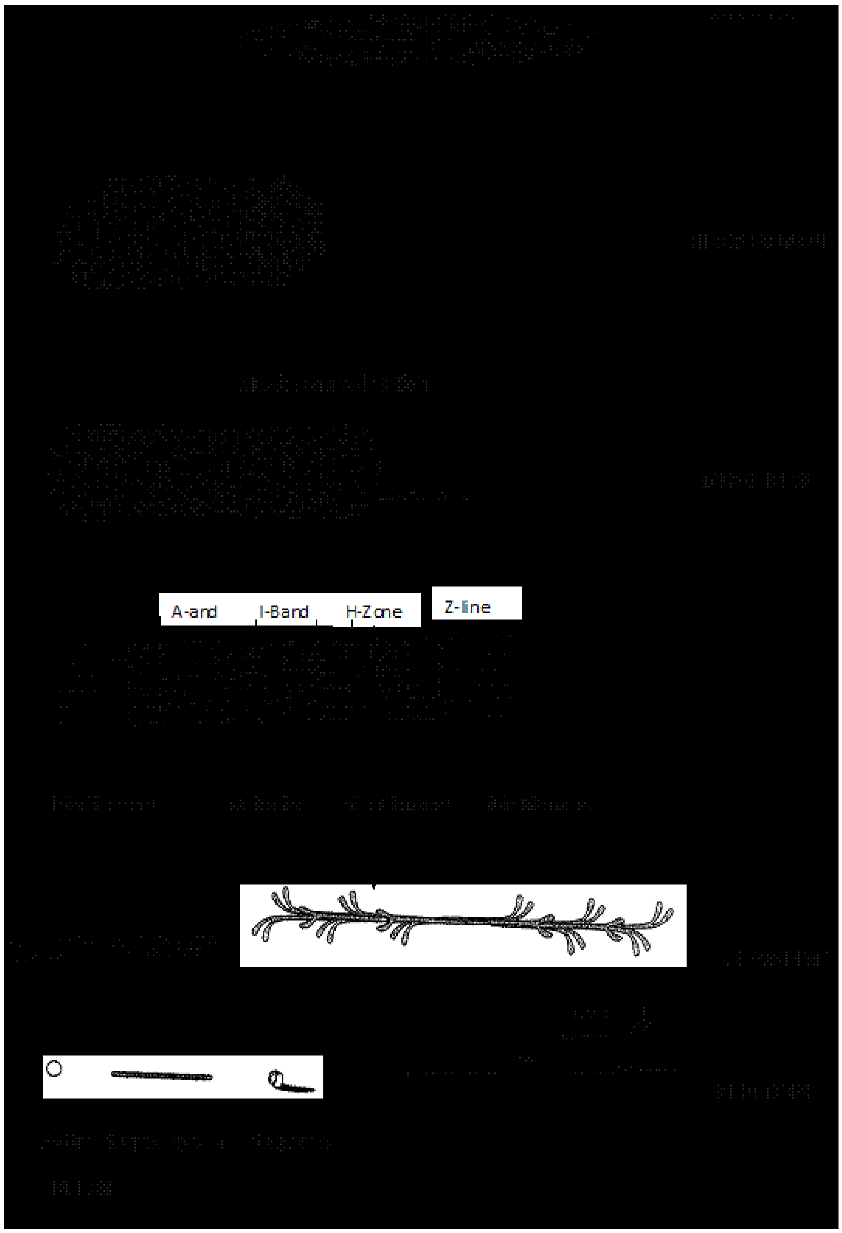

Fig. 22.1 Structure of Muscle (Redrawn and modified from the Greaser et al. 1999)

In mammals and birds, both the amount and type of collagen have important influence on textural properties of the muscle. In fish however, collagen is readily softened by normal cooking procedures.

Nature of muscle-

I) Striated or voluntary muscle –lean meat.

II) Unstriated or involuntary muscle- stomach wall.

III) Cardiac muscle- heart wall.

In white muscle, fat is apparently diffusely located among the muscle cells. Basically the lipid composition of meat of mammalian and avian muscles can be categorized into lipids from muscle tissue and lipids from adipose tissues lipid in the lean portion contains greater portions of phospholipids than lipids than lipids in adipose tissue lean muscle contains about 0.5-1.0% phospholipids and the fatty acids of phospholipids are more unsaturated than those of triglycerols. Consequently, lipid in the lean portion of meat has a higher degree of unsaturation than those in adipose tissue. The degree of unsaturation of fatty acids in cold blooded fish is much greater than that of fatty acids in avian and mammalian muscles. The much greater percentage of polyenoic fatty acids is found in avian and mammalian muscles. The much greater percentage of polyenoic fatty fish reflects differences in phospholipid – triacylglycerol ratios. Poultry fat is more unsaturated than pork fat, beef and mutton.

Table 22.1. Composition (%) of muscle tissue

SPECIES	WATER (%)	PROTEIN (%)	LIPID (%)	ASH (%)
Beef	70-73	20-22	4-8	1.0
Pork	68-70	19-20	9-11	1.4
Chicken	73.7	20-23	1.0	-
Lamb	73.0	20.0	5-6	1.6
Cod	81.2	17.6	0.3	1.2
Salmon	64.0	20-22	13-15	1.3

22.3 General Consequences Following Death of an Animal (Post Mortem Changes)

Following the death of animal, circulation of the blood ceases resulting in the complex series of changes within the muscle (Fig.22.2). As much as possible blood is removed from the animal carcass to increase the edibility and keeping qualities of the meat, since blood is an ideal medium for the growth of spoilage microorganisms. Failure of blood circulation and its removal from the muscle tissue results in depletion of oxygen supply to the tissue leading to depletion of ATP and creatine phosphate levels (due to stoppage of electron transport chain and oxidative phosphorylation) and most importantly to onset of anaerobic metabolisms of glycogen. Anaerobic metabolism of glucose and breakdown of ATPs by the continuing action of sarcoplasmic ATPase leads to depletion of ATP and creatine phosphate results in onset of rigor mortis on the other hand breakdown of glycogen in the absence of oxygen leads to production of lactic acid thus decrease in pH. Other postmortem physical changes in muscle are:

22.3.1 Change in pH

Decrease in pH due to lactic acid formation is accompanied by various exothermic reactions such as anaerobic glycolysis. pH changes from physiological pH i.e 7.2-7.4 to ultimately post-mortem pH i.e 5.3-5.5 in 24 hrs. This has profound effect on muscle portion of meat. Usually glycolysis ceases even before the glycogen is depleted.

22.3.2 Change in temperature

Temperature of animal increases from 37.6-39.0°C. This is the reason why animal cools slowly during refrigeration as a result of continuous production of heat. This phenomenon is known as "animal heat". Removal of "animal heat" by chilling or refrigeration is essential to ensure longer shelf-life of meat.

22.3.3 Change in proteins

Due to the change in pH and high temperature, colour of meat changes and water holding capacity (WHC) also decreases. Sarcoplasmic proteins get denatured and attached to the surface of myofilament, which produces change in meat colour which becomes light. Water holding capacity of myofibril proteins decreases resulting in exudation of fluid.

Sarcoplasmic proteins are more lable with respect to physiological conditions prevailing in the post- mortem muscles. These proteins are highly susceptible to disruption as compared with myofribrilar proteins. Sarcoplasmic proteins during rigor mortis denatured below pH 6.0 and at 37°c.

22.3.4 Change in water holding capacity

Water holding capacity is the function of respective proteins which binds with water. In pre-rigor stage meat possesses a high water holding capacity but later it decreases during first hour following death of animals. Lowest water holding capacity is found at its iso-electric pH i.e. 5.3-5.5. After post-rigor aging water holding capacity. is found to be increased because of increase in osmotic.

During post mortem movement of Na. K, Mg, and Ca in muscles takes place. But during aging there is continuous release of of Na & Ca. and uptake of K ions continued up to 6-8 days. The movement of cations produces an increased electrical charge on muscle protein which facilitated the formation of hydrated ions. This is believed to be the reason of increased water holding capacity during aging of meat.

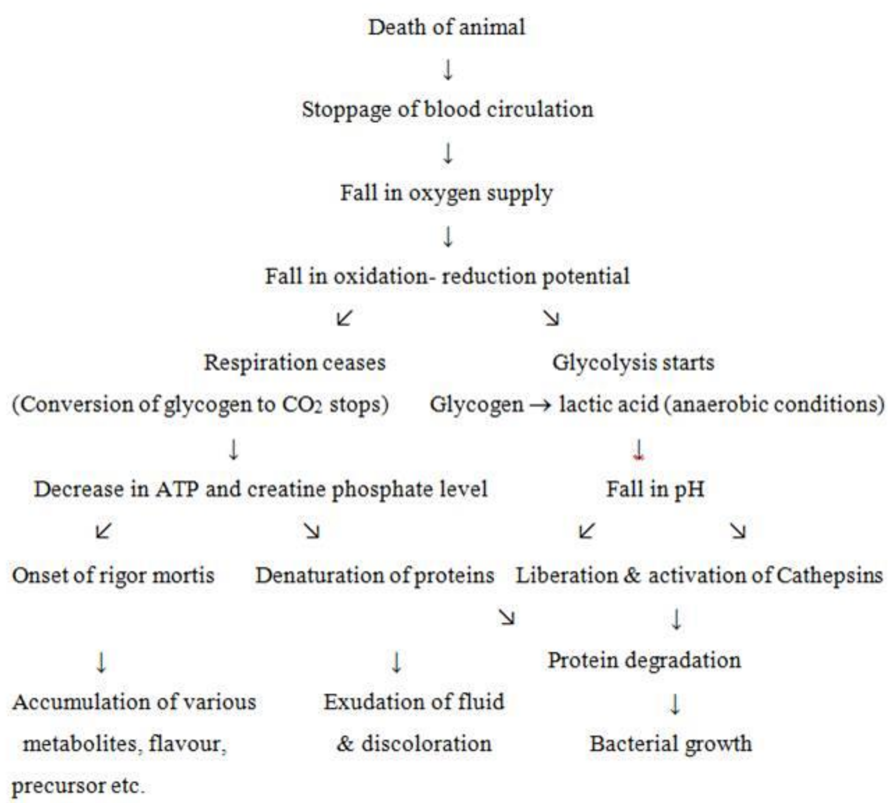

Fig. 22.2 Generation consequences following death of an animal (adapted from Lawrie, 1966 and Eskin et al., 1971)

22.3.5 Post mortem glycolysis

After the death of animal, blood circulation stops, thus oxygen supply to muscles tissues decreases hence anaerobic conditions prevails in the muscle. The glycogen present in tissues is no longer converted into CO_2 and water instead, converted in to lactic acid through anaerobic glycolysis. The conversion of glycogen takes place through two different pathways.

(a) Amyloytic pathway i.e. hydrolytic
(b) Phosphorolytic pathway

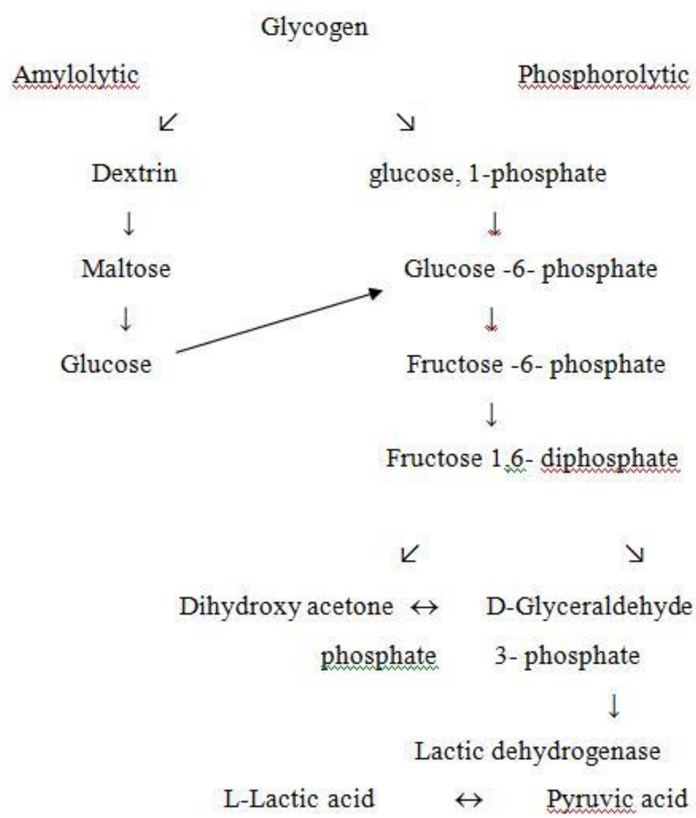

Fig. 22.3 Post mortem glycolysis

Due to this glycolysis pH changes from physiological pH i.e. 7.2-7.4 to ultimately post- mortem pH i.e. 5.3-5.5. This pH is attained within 24 hours and being related to ATP production, which falls in this pathway. The net fall in ATP is responsible for onset of rigor mortis. The pH 5.3-5.5 is ideal pH which can be obtained by well rested and well fed animal before slaughter (fig. 22.3).

22.4 Conversion of Muscle into Meat (Rigor Mortis)

The most important change that occurs in postmortem muscle is the development of rigor mortis, means stiffness of the muscle. The primary cause of onset of rigor is post mortem decline in the level of ATP. The process takes from 7-24 hrs depending on the species; however it is linked with the rate of depletion of ATP in muscle. The entire process of conversion of muscle into meat is broadly divided into three stages:

22.4.1 Pre-rigor stage

During early stages of postmortem or pre-rigor stage, the concentration of ATP more or less remains constant as the muscle tries to maintain ATP levels by an active creatine kinase. However it will lead to liberation of creatine from muscle. Thus, in this state creatine phosphate levels fall more rapidly than that of ATPs. ATPs are providing cushioning effect for the filaments of two proteins i.e. actin and myosin. This results in a meat which is soft and pliable. In pre-rigor stage, myosin dissociates from actin and can be extracted in solution of high ionic strength. Water holding capacity of the muscle proteins remains high during this stage.

22.4.2 Rigor mortis

This period is very important as meat becomes rigid and stiff. Onset of rigor mortis may be 8-10 hours postmortem and it may last in 15-20 hours in meat. Onset of rigor is demonstrated by fall in ATP, loss of extensibility of muscles and contraction of tissues. Time difference between death of an animal and onset of rigor state is termed as ‘delay phase’. This period depend upon number of factors such as age, health, size of carcass, the amount of fat cover, nutritional status of animal, pH and glycogen level, temperature as well. ATP plays very important role in this stage. As ATP level falls two muscle proteins gradually forms an associated actomyosin complex which is inextensible and is responsible for contraction. This is the necessary criterion for development of rigor mortis. The extent of contraction of the muscles is determined by estimation of length of the sacromere within the myofibril. Meat which is cooked in this state is very tough in texture. The water holding capacity of the muscle protein remains minimum during this stage due to drop in pH as it comes closer to their iso-electric point i.e. pH 5.3-5.5. If the ultimate pH (5.60) falls too quickly, carcass would still be warm adversely affecting water holding capacity and prevailing partial denaturation of protein resulting into pale, soft and exudative (PSE) muscle ultimately leading to lower yield of the meat. This is often encountered in pigs having sufficient reserves of glycogen. On the other hand if inadequately feed or fasting animal having minimum reserve of glycogen is subjected for slaughtering; dark, firm and dry (DFD) meat conditions. DFD meat is having pH not below 6.0 and is darker in colour and susceptible for microbial growth.

22.4.3 Post rigor (conditioning/ageing)

During post rigor stage meat become tenderizes and organoleptically acceptable when it is kept cold for sometime after rigor mortis. The muscle again becomes soft and pliable with improved flavour and juiciness. The post rigor meat provides lesser problems in toughness, when cooked compared to with that cooked in rigor. Meat gradually reaches to an optimum tenderness period after an ageing period of 10-18 days stored at 0°- 5°C following the dissolution of rigor. However, prolonged storage of meat in some species may results in some problems viz. microbial spoilage, desiccation of proteins, and development of off flavours. Thus it is recommended to consume meat before it gets spoiled. The ageing which also called as conditioning or ripening of meat is sometime accelerated by raising storage temperature for e.g. holding meat at 15° for 3 days period in UV to control the microbial growth at surface. While in the case of pork, ageing is not recommended rather to eat fresh as it develops rapid onset of fat rancidity even at low temperature. On the other hand beef is generally aged and lamb & mutton are occasionally aged.

Ageing is considered as very important aspect of meat processing as it imparts desirable flavour, textural and other sensory attributes to the finished product. The responsible factors for this desirable changes are still been researchable issue, however it is now a fact that in post- rigor state actomyosin complex does not dissociate but other subtle changes occur like, increase in the water holding capacity due to increase osmotic pressure in the muscle fibre due to net inside movement of cations and breakdown of proteins by liberated proteolytic enzymes, the cathepsins may lead to tenderness. While cooking of meat tenderizing agents such as enzyme calpain etc are added which breaks down the stiff muscle protein to yield a soft and orgnoleptically acceptable meat.

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Module 2. Meat and poultry processing

Lesson 23

PROCESSING OF MEAT AND MEAT PRODUCTS

23.1 Introduction

The meat processing involves the slaughter of animals and fowl, processing of the carcasses into cured, canned, and other meat products, and the rendering of inedible and discarded remains into useful by-products such as lards and oils. Meat is exposed to a series of wide range of processes viz. curing or preserving processes such as salting, wet pickling, drying, cooking and canning, sausage manufacture, ham curing. All these processing techniques are aimed at inhibiting the microbial spoilage and increasing the shelf life of the meat. Major principles involved in meat processing are use of heat, low temperature, smoking, modified atmosphere packaging and ionizing radiations. The methods of preservation are mainly grouped in three categories i.e. control by temperature, by moisture and by lethal agents (bactericidal, fungicidal etc.)

23.2 Preservation of Meat

23.2.1 Use of low temperatures

Chilling and freezing are most commonly used preservation system for meat and meat products.

a. Chilling

Chilling is most widely used technique to preserve raw and processed meat. Chilling preserves muscle tissue by retarding the growth of microorganisms and by slowing many chemical and enzymatic reactions. Storage temperature may vary from - 1.4 to 2.2 ˚C for storage of beef for 30 days depending upon the number of microorganisms. Carcass should go to the cooler as soon as possible and its inner most part should be able attain below 10^{o}C within 12 hrs of slaughter in order prevent undesirable off-flavours and bone taints due bacterial growth. An ideal temperature of storage for meat should 1^{o}C above its freezing point.

During post mortem cooling and subsequent refrigerated storage, control of relative humidity (around 90%) is very important. The undesirable moisture is lost from the surface, the weight reduction becomes of economic important and meat pigments myoglobin might get oxidized to brown metamyoglobin. However, a small amount of moisture loss from the surface is desirable since this tends to retard growth of microorganisms.

b. Freezing

Freezing is an excellent process for preserving the quality of meat for long periods. Freezing is often used to preserve meats during shipment over long distances or for holding until long times of storage. Its effectiveness depends on ice crystal formation and rate of lowering of temperature. When the temperature of storage is below - 18˚C, changes occur at a very slow rate in the muscle of warm blooded animals. Quality of frozen meat depends on various factors such as rate of freezing, packaging etc. When muscle tissue is frozen rapidly, small both intra – and extra – cellular ice crystals are formed which cause little damage to the meat structure. While large ice crystals are formed in slow rate of freezing causing compactness of muscle fiber. The process of denaturation can be accelerated with a resulting decrease in water holding capacity of tissue. Loss of water holding capacity of the muscle along with mechanical damage to cells by ice crystals is responsible in large parts of thaw exudates. To protect quality loss due to changes in protein, anti-freezing compounds or cryoprotectants i.e. polydextrose, polyphosphate are added to meat formulations. Rapid freezing can be obtained by using air blast freezers either on batch or continuous basis which employs -20 to -40^{o}C cold air. Large size meat cuts are vacuum packaged to prevent lipid oxidation and discoloration due to formation of metmyoglobin. Retail meat is packed in low permeability films with better mechanical strength e.g. Sarlyn.

23.2.2 Use of heat

The canning of meat is a very specialized technique in that the procedure varies considerably with the meat product to be preserved. Since meat products are low acid foods so the rate of heat penetration is fairly low. Commercially canned meats can be divided into two groups on the basis of heat processing used –

(a) Meats that are heat processed in an attempt to make the can contents sterile.

(b) Meats that are heated enough to kill part of spoilage organisms but must be kept refrigerated to prevent spoilage.

Processing temperature for shelf stable canned cured meat is 98˚C. Treatment of meat surfaces with hot water to prolong the storage time has been suggested. Although this may result in loss in nutrients and damage in colour. Actin is the most heat labile muscle protein becoming insoluble at 50˚C. Denaturation of muscle proteins decreases their water holding capacity. This decrease in water holding capacity may produce desirable juiciness, Provided free water is not expelled from the tissue. During heating, fat is melted. Adipose tissue cells are ruptured and there is a significant redistribution of the fat. When meat is eaten warm, the melted fat serves to increase palatability of the product by giving desirable mouth feel, especially at the end of chewing period, when most of the aqueous juices are lost. Myoglobin also undergoes denaturation. The red pigment heme is oxidized to brown pigment hemin. Canned meat loaf can be manufactured substituting a part of the meat with high calcium coprecipitate. It is observed that 20% meat can be replaced with high calcium milk protein coprecipitate in chicken meat loaf without affecting the quality of the end product.

23.2.3 Dehydration

Deprivation of available moisture (reduction of water activity) for microbes not only prevent their growth but also kills them, thus results in increased shelf life and better quality product. Water may be made unavailable either by dehydration, freeze drying or by increasing exrtacellular osmotic pressure as is done in curing. Drying meats can be successfully employed for both raw and cooked meat. However, the quality of the final reconstituted product is superior when meat is cooked prior to dehydration. There is a loss in native structure of protein as measured by loss of water holding capacity during temperature from 0 to 20 ˚C. This is caused by denaturation of sarcoplasmic proteins. The next major loss in water holding capacity begins in the temperature range of 40 – 50 ˚C due to denaturation of contractile proteins. Collagen is rapidly converted to gelatin at around 100˚C. Texture is most severely altered by dehydration. The tough texture of dehydrated meat can be overcome by preparing products of intermediate levels of water.

23.2.4 Smoking

Smoking is often used with salting and curing. It gives desired flavour, aroma and aids in preservation. It was noted that preservative substances added to the meat together with the action of heat during smoking have a germicidal effect and that drying of the meat together with chemicals from the smoke inhibit microbial growth during storage. Smoke consists of phenols, alcohols, organic acids, carbonyl compounds and hydrocarbons. The desirable effects of smoking of meat can be listed as below:

- Meat preservation through aldehydes, phenols and acids (anti-microbial effect)
- Antioxidant impact through phenols and aldehydes (retarding fat oxidation)
- Smoke flavour through phenols, carbonyls and others (smoking taste)
- Smoke colour formation through carbonyls and aldehydes (attractive colour)
- Surface hardening of sausages/casings through aldehydes (in particular for more rigid structure of the casing)

Production of smoke

Smoke is produced by burning of wood or its saw dust which consist of 40-60% cellulose, 20-30% hemicelluloses, 20-30% lignin. A temperature gradient exists during thermal decomposition of wood. Outer surface temperature is generally above 212^{o}F during dehydration process. Co, CO_2 and volatile medium chain organic acids e.g. acetic acid are released during dehydration and distillation process. When internal moisture level reaches to zero, the temperature rapidly rises to 570-750 ^{o}F. Once the temperature falls within this range thermal decomposition occurs and smoke is given off.

Nature of smoke

Although the smoke at the point of generation exists in a gaseous state, it rapidly goes into a vapor & particle phase. The vapor phase contains the more volatile component & is largely responsible for the characteristic flavor & aroma of smoke. As soon as smoke is generated numerous reactions and condensation occurs. Aldehyde & phenol condense to form resins which represent about 50% of the smoke component & are believed to provide most of color is smoked meats. Polyphenols are also formed by condensation.

The amount and ratio of smoke deposition on the product is influenced by smoke density, smoke house air velocity and its RH, and surface of product being smoked

Cooking during smoking

Cooking is often done simultaneously with smoking of meat. In fact cooking is often more important than smoking in meat processing. Cooking equines careful control of the smoking and heating process to give best results.

Liquid smoke preparations

Liquid smoke is used by some processors. It is sprayed on the product before cooking. It has some positive effects over natural wood smoke.

(1) It doesn't require the installation of a smoke generator and which usually requires a major financial outlay.

(2) Process is more repeatable, as the composition of liquid smoke is mane constant.

(3) Liquid smoke can be prepared so the particle phase is removed and thereby possible problems from the carcinogens can be alleviated.

Liquid smoke is generally prepared from hardwoods; The final product is composed primarily of the vapor phase & contains mainly phenols, organic acids, alcohols & corbonyl compounds. They don't contain poly hydro carbons (PHC).

The there are two types of smoking cold at 15 to 18°C (up to 26°C) and hot temperatures of +60 to 80°C. Cold smoking is used for fermented meat products (raw-cured ham, raw-fermented sausage) and precooked-cooked sausage (liver and blood sausages). Hot smoking is used for a range of raw-cooked sausages, bacon and cooked ham products.

23.2.5 Modified Atmospheric Storage

Fresh meat held at refrigerated temperature has a limited shelf life because of microbial growth. Modified atmosphere refers to the adjustment in the composition of the atmosphere surrounding the product. At higher concentration of CO_2 surface browning of meat occurs due to the oxidation of myoglobin and hemoglobin pigments to ferric state. The most desirable concentration of CO_2 to use in a modified atmosphere is a compromise between bacterial inhibition and product discoloration.

23.2.6 Ionising radiation

Ionising radiation constitutes the potentially useful form of preservation. Besides from its desirable ability to inactivate micro – organisms, it also has the undesirable effect of altering meat pigments. Sterilizing doses of ionizing radiation results in the breakdown of various lipids and proteins to often undesirable odours. Tenderization of muscle may also occur during this treatment. Temperature of ≤ 80 ˚ C or below greatly reduces undesirable effect without affecting lethal effect on microorganisms. Generally enzymes are not inactivated by irradiation treatment, it is necessary to heat approximately 70 ˚C prior to irradiation and storage.

23.3 Processing of Meat Products

23.3.1 Comminuted meat products

Comminution is the mechanical process of reducing raw materials to small particles called as minced meat. Depending upon the final use of the communited meat the degree of comminution is done which differs among various processed products and is often a unique characteristic of a particular product ranging from very coarsely comminuted (to produce non-emulsified sausages like salamis and summer sausages), to finely comminuted, (to produce emulsified sausages like frankfurters, bologna, etc). Sausages are usually defined as comminuted seasoned meats, stuffed into casings; they may be smoked, cured, fermented and heated. They are made from any edible part of the slaughtered, veterinary-inspected animal, and a series of nonmeat ingredients.

a. Sausages

Sausages are meat products that are salted & usually seasoned or spiced and are an example of comminuted meet products that are generally recognized as emulsified, stuffed, linked, smoked, and cooked meat products. Based on the product characteristics and processing methods, they are broadly divided into three categories: **fresh sausages, cured sausages and fermented sausages**. In all cases meat is communited to reduce meat and fat particle size (grinding, mincing, chopping, or flaking), mixing with ingredients, stuffing into specific casing, linking to obtain specific lengths and finally, packaging. Sausages might be of ground and emulsion type. In the ground variety of sausages discrete particles of meat are seen on the other hand, in emulsion type sausages fat is emulsified & stabilized by lean component. Sausages were developed to utilize low- quality meats such as trimmings head, shoulder & by- products of the meat. The processing of sausages is a continuous sequence of steps (Fig 23.1), which are all equally important.

Selection of ingredients
↓
Grinding
↓
Mixing
↓
Chopping and emulsifying
↓
Stuffing
↓
Linking or tie
↓
Hanging
↓
Smoking
↓
Cooking
↓
Showering with Chilling
↓
Peeling or slicing
↓
Packaging

Fig. 23.1 Process flow diagram of sausages manufacture

i. Selection of Ingredients

Sausage ingredients include:

- Meat - based on consideration of fat/protein; moisture/protein and myoglobin concentration
- Moisture - added as ice at time of chopping in a number of fresh and smoked sausages
- Curing ingredients - salt, sodiuim nitrite and/or nitrate and sugar
- Seasonings - may include spices, such as black peper, paprika, mace and cinamon; herbs that may include thyme and savory; vegetables such as garlic and onion and other substances, such as flavor enhancers

- Fillers and binders - occasionally used to improve color, binding properties, slicing characteristics, altering flavor or reducing costs
- Ascorbic acid - used to improve color in smoked sausages
- Other additives - may include liquid smoke

Milk protein have been utilized as fillers, binders and extenders in cooked, comminuted meat products to reduce cook shrink and formulation cost, as well as to improve emulsifying capacity, emulsion stability, water binding, potential nutritive value and slicing characteristics. These proteins significantly increase the gel strength of meat proteins and it has been shown that there has a synergistic effect between milk proteins and salt soluble meat proteins, through covalent cross linkages.

Addition of caseinate stabilizes the meat emulsion as required in the sausage mix. It thickens the gravy during frying and prevents it running out, but excess incorporation of caseinate may result in drying up of the sausages. Further addition of water absorbent materials becomes essential when sodium caseinate concentration in sausages exceeds 5%. The greater water holding capacity, lower viscosity and lower cooking losses of sausage batters containing 2% sodium caseinate in comparison to all meat control were observed.

The coprecipitates have good potential in various meat products such as frankfurters, sausage batter and luncheon meats as meat replacers or extenders. Sausage acts as a good medium for the use of coprecipitates. The finely, dispersed dairy protein matrix in sausages also can act as a moisture binding agent, thus, developing the desirable chewy texture besides controlling shrinkage during storage and deformation while slicing. Addition of milk coprecipitate in combined boiled sausages resulted in increased pH, reduced nitroso pigments and increased residual nitrites content in the end product. It is found that both high and low calcium coprecipititates improved the emulsifying capacity, emulsion stability and water holding capacity of meat emulsion in fresh sausages at the 20% replacement level. Supplementation with dairy coprecipitates into boiled beef pork sausage batters up to 30% of meat protein yields emulsion with increased pH, enhanced water binding ability and improved adhesion properties.

ii. Grinding

Meat chunks of variable size and shape with variable fat contents are ground to form uniform cylinders of fat and lean. The screw feed in the barrel of the grinder conveys the meat & presses it in to holes of the grinder plate. The rotating blade cut the compressed meat and aids in filling the grinder plate holes.

iii. Mixing

Cylinders of fat and lean obtained by grinding are tumbled in a mixer to give a uniform distribution of fat and lean particles. This can be used for coarse ground sausages or for emulsion type sausages by utilizing a chopper or emulsifier and with suitable additions of required ingredient to obtain the desired texture & uniformity of composition.

iv. Chopping

It is often used as a means of batching the sausage mix, the mixed batch being transferred to an emulsifier or acquiring the desired texture.

v. Emulsifying

This machine combines the principle of grinding and chopping. Emulsifier machine handles large volumes of meat rapidly to produce a desired texture. Speed of handling material and high degree of disintegration of meat tissue help in obtaining desired textures. In the preparation of sausage, the protein and water of the meat mixture form a matrix than encapsulates the fat portion. In a meat emulsion the protein myosin acts as the primary emulsifying agent. The addition of salt to the product is to release the myosin from the muscle fiber. The emulsion is generally formed by mixing the meat with salt and other ingredients in a chopper, which aids in disrupting the fibers and facilitates the release of myosin.

vi. Stuffing

Sausage emulsion also known in the trade as mix sausage dough or batter is transferred to stuffers for extending the mix or emulsion into **casings**. At this point, the size and shape of the product is determined. Generally three type of stuffing devices are used.

- Piston
- Pump
- Combination of piston & pump

In the past, the casing of the sausages were made from animal casings, however this was a limiting factor for the production of sausages. Today, the casings are made of cellulosic and regenerated collagen. The limiting factor now, is the supply of meat and the cost of it. Fermented sausages are further subjected for the fermentation and maturation. Fermentation of meat constituents results in flavor development, improvement of shelf life and improved quality and food safety. Sausage batter is inoculated with the started bacteria composed of **selected lactic acid bacteria (LAB)** i.e. homofermentative lactobacilli *(Lb pentosus, Lb plantarum, Lb sake, Lb curvatus)*, pediococci (*Pediococcus acidilactici*, *Pediococcus cerevisiae*) and gram positive catalase positive cocci (GCC) i.e. non-pathogenic, coagulase-negative staphylococci (*Staphylococcus carnosus, Staphylococcus xylosus, Staphylococcus piscifermentans)* . Small manufacturers use spontaneous fermentation without adding starter culture.

vii. Linking and tying

After the emulsion is stuffed in to casings, the encased mass is tied with thread of fastened with metal clips. In the case of small sausages such as Frankfurters stuffed casing are twisted or drawn together to produces links either by hand or with mechanical devices.

Large sausages items are tied or slipped on one end with a hanging tie and suspended from a smoke stick or hook so the entire surface is free from contact with the equipment. This permits a good flow of air around the sausage in the smoke house and prevents touch marks and spotting due to contact with adjacently hanging product.

viii. Smoking & cooking

The draped smoker picks are placed on smoke trees or trolleys with 12-18 specs per tree. The smoke house operation is essentially a specialized drying and cooking operation in which sausage emulsion is coagulated. Encased sausage at the time of introduction in to the smoke house usually has an internal temp of 60-70ºF. During cooking this rises to 155 to 160ºF.

ix. Chilling

After smoking and cooking the product is showered with cold water and than chilled by refrigeration chilling is frequently done with a brine solution by dipping or spraying the products. (a 6% salt brine) balanced within leaching of salt from the sausage and imbibing of water by the sausage.

x. Peeling & packaging

After properly chilling the product usually to an ultimate temp of 35 to 40ºF, the cellulosic casings on frankfurter and slicing bologna are removed. This is known as the peeling operation.

b. Semi dry sausages

Semi dry sausages are usually made from pork or beef or a mixture of the two and are characterized by a moisture content ranging from 40- 45%, e.g. summer sausage, Göteborg Sausage, Cerevelat, Thuringian, Holsteiner. They have excellent keeping quality with need of little refrigeration because

(1) Some reduction in microbiogical contamination is achieved in the cooking process
(2) A high salt to moisture ratio contributes to retarding bacterial growth
(3) A low pH (5.3 or less) provides the tangy flavor and serves a protective food and good keeping quality is achieved with a pH of 4.8 to 5.0 and with a total acidity of 0.75 to 1% lactic acid.

Grind pork trimmings
↓
Place the trimmings in a mixer; add the salt sugar spices, cure and starter culture and mix for 2 to 3 minute.
↓
Regrind the mix
↓
Hold the mix for 12- 72 hr at 40°F
↓ stuff
Warm water shower for 2 min to wash the sausage surface free of any adhering particles
↓
Smoke the encased sausage for 16 hr at 110°F
↓ Shower with cold water /15 min
Allows to stand at room temp so the surface dies and then chill to 40°F

Fig. 23.2 Manufacturing method of semi-dry sausages

c. Dry sausages

Semi-dried sausages are smoked and cooked to varying degrees, whereas dry sausages are not cooked and only with some products smoke is applied. The manufacture of dry sausages is more difficult to control than that of semidried sausages. Overall processing time may require up to 90 days. As a result of this prolonged holding the sausages are vulnerable to chemical, microbiological degradation. However, when prepared properly the finished sausages are usually stable and can be held with little or no refrigeration. Examples of dry sausages are Geneva salami, Pepperoni, mortadella etc.

23.3.2 Cured meat products

Curing of meat involves the essentially addition of **sodium chloride, sodium nitrite or sodium nitrate** and adjuncts to meat for increasing shelf-life and to obtain desirable colour and flavour. Sugar may or may not be added along with other ingredient to improve flavour. Curing can be done for both raw/cooked meats cut products as well for comminuted meat products e.g. sausages and similar preparations. Most popular raw cured meat includes ham and bacon which are pork products. However, the technique can be applied to any meat group.

23.3.2.1 Ingredients used in curing

(i)	Salt	Essential curing ingredients
(ii)	Sugar	
(iii)	Nitrate or nitrite	
(iv)	Phosphates	Optional ingredients/curing adjuncts
(v)	Spices	
(vi)	Baking Soda	
(ii)	Sodium erythroborate	
(iii)	Ascorbic acid	
(iv)	Mono sodium glutamate	
(v)	Hydrolysed vegetable proteins,	
(vi)	vinegar	

Commonly used salt sodium chloride (occasionally KCl) is most essential ingredients and it significantly inhibits growth of microorganism including *Clostridium botulinum* due to increase in the osmotic pressure of the medium and dehydration of the muscle. Salt if used alone results in dark coloured, unpalatable dry harsh and salty product. Therefore, it is recommended to be used in combination with sugar and nitrite and nitrate. Salt should be of good quality. Generally dry salting utilizes higher levels of salts; however, acceptable level of salt is about 3% for most of the meats and about 2% for bacon. Nitrite/nitrate has as well a small inhibitory effect on *C. botulinum*. However, it plays very important role in colour fixation of the cured meat. On the other hand sugar contributes to flavour and colour development due to mailard browning and also helps in increasing shelf life by controlling of bacterial growth. Endogenous low molecular weight components in the sarcoplasma of the meat promote the formation of nitric oxide, myoglobin and nitrite decomposition.

23.3.2.2 Chemistry of curing process and meat colour development

During the dry curing process salt in dry form is rubbed on the surface of the meat whereas in meat wet curing meat portion is immersed in the curing solution. The latest techniques of curing includes use of artery pumping, multiple needle injection, thermal or hot cures, tumbling, massaging, are employed to accelerate the curing the processes. In all cases, salt diffuses into the meat, causing some of the expelled protein to diffuse back in and the meat to swell. The salt – protein complex binds the water well thus the water holding capacity of proteins generally increases during curing. The final meat contains increased ash due to the absorbed salts. Generally salting results in darkening of the colour. To counteract the effect of salt nitrite/nitrates are added to salt which fix the desirable pink colour of the meat. In the curing, nitrite reacts with muscle pigment myoglobin to give purple-red coloured nitroso-myoglobin. On the cooking this is further converted into nitrosomyochrome which gives typical pink clour to the meat. It is further claimed that nitrite has a significant beneficial effect on the flavour of cured meats by preventing oxidation through the antioxidative activity of nitric oxide-myoglobin and s – nitrocysteine, a component found during the curing process.

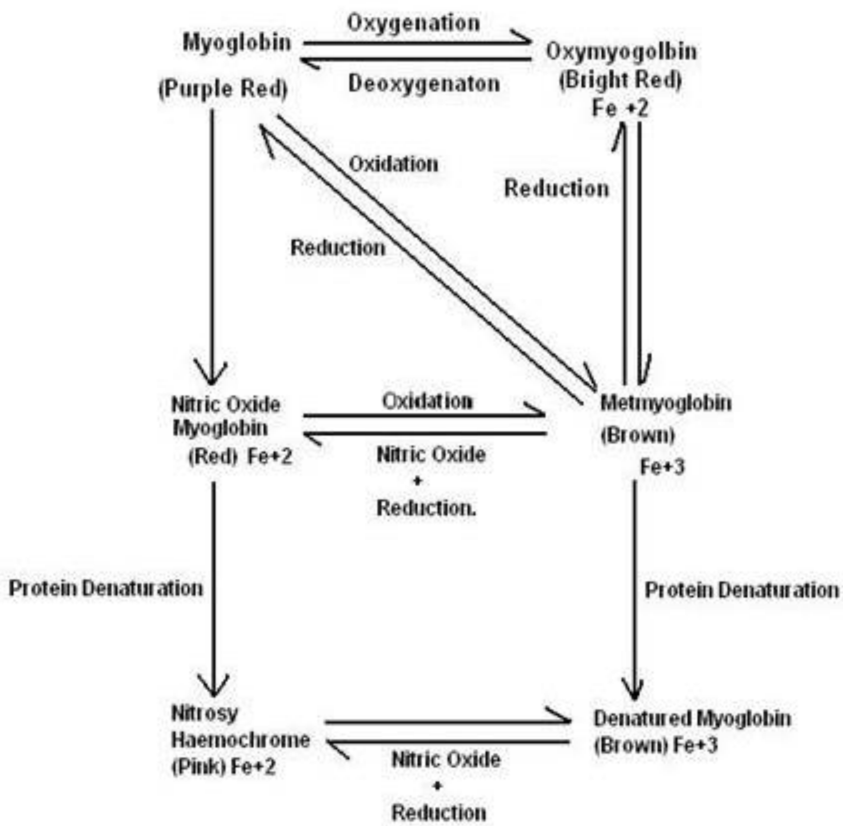

Fig. 23.3 Colour fixation in meat

A major detrimental change that can occur in cured meat during storage is the oxidation of nitric oxide hemochromagen (pink) or nitric oxide myoglobin (red) to brown metamyoglobin (Fig. 23.1). The rate of oxidation increases with increasing oxygen content, therefore cured meat should be preferably packaged in a container from which oxygen is excluded.

Acceptable levels of nitrite used in meat and meat products are 100-200 ppm. The use of nitrite in cured meat may be hazardous if it is used at higher concentration with improper mixing, as it reacts with amines, especially secondary amines, to form N – nitrosamines, which may be carcinogenic. High temperature may also induce nitrosamine formation.

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Module 6. Meat and poultry processing

Lesson 24

POULTRY MEAT AND ITS PROCESSING

24.1 Introduction

In global meat production poultry meat is taking the second place after pork. Due to its widespread availability and popularity and its mostly very competitive production cost, poultry meat has an increasing share as a raw material in processed meat. Turkey and chicken meat is very suitable for further processing purposes. Poultry meat is of higher nutritive value than that of other red meats, because of its higher protein content and better digestibility.

24.2 Characteristics of poultry meat

Muscle to bone ratio in the case of poultry is 1.8 thus the carcass yield is less as compared to other warm blooded animals (Table 24.1).

Table 24.1 Composition of carcass

Species	Meat %	Fat %	Bone %	Skin %
Broilers	52	6	30	12
Hen	37	12	40	11
Duck	34	18	38	10

Chicken meat is pinkish white in breast and wings and in other parts pink to light red. In general poultry meat is described as white meat while meat from other animals is called red meats. Total fat in chicken/broiler is 7.4g per 100 g portion of lean meat, of which is 27.53% saturated, 35.90% Mono-unsaturated and 22.81% Polyunsaturated fatty acids. The total conjugated linoleic acid (CLA) content of chicken and fresh ground turkey is 0.9 and 2.5 mg/g of fat respectively. On the other hand, typical composition chicken is moisture 73.7 %, protein 20-23% and fat 1.0%.

24.3 Processing of Poultry Meat

Either the entire carcass meat is used for further processing, or some of the cuts go in fresh meat sales and the remaining into the manufacture. Chicken carcasses are usually cut in **wings**, **legs** and **breast**. Legs can be further subdivided into *thighs* and *drumsticks***.** The breast consists of the larger *superficial breast muscle* and the smaller profound breast muscle, the latter is also called "*filet*". Primary objective of poultry meat processing is to inhibit microbial growth and to stop deteriorative quality changes in the meat. Poultry meat processing utilises, the same principles viz. refrigeration, freezing, smoking, curing, dehydration, freeze drying, canning and ionising radiations as applied in the beef and pork sector. Sometime antibiotics are also added to preserve raw poultry meat.

24.4 Slaughter and Dressing of Poultry

Poultry birds are generally not fed for 12 hrs before their slaughter and are killed by the method which utilizes minimum efforts/struggle. The poultry animal is stunned and made unconscious by attacking on the head. Larger poultry houses make use of electrical stunning devices. Jugular vein is cut in such a way that bleeding completes in 2-3 min of slaughter. Bird is then dipped scalding water (temp. 60ºC for 45 sec or at 52ºC for 2 min). Scalding results in loosening of feathers, thus easy removal of them. Evisceration of bird follows the defeathering, where in various parts of the birds are removed for subsequent processing e.g. chilling, freezing etc. Dressed chicken and other fowls may be canned whole or dissected in their own juice. Use of low temperatures may be applied to improve the shelf life of dressed chicken:

a) Chilling – Chilling storage of poultry is for only less than a month. Birds to be stored longer should be frozen. The lower the temperature of storage, the longer the birds stored without undesirable changes. Compared to room temperature, the storage life was extended 2 days at 10˚C, 6 days at 4.4˚C and 14 days at 0˚C. However, the rapid chilling is always advisable in the cases of poultry meat as the onset and outset of rigor takes at early.

b) Freezing - Poultry can be kept in good conditions for months if freezing is prompt and rapid and storage temperature is low enough. Fairly rapid freezing is desirable since it produces a light golden colour because fine ice crystals are formed within the fiber while slow freezing causes the flesh to be darker. The storage temperature should be below – 17.8 ˚C and RH above 95% to reduce surface drying. Rapid freezing of poultry is desirable since it causes tissues to become very pale, which is desirable since it cause tissues to become very pale, which is desirable. However, most poultry is sharp frozen at about – 29 ˚C or less in circulating air or on a moving belt in a freezing tunnel.

c) Modified atmospheric storage – Increasing carbon dioxide concentration to 10 – 20%in the atmosphere of store chickens inhibits the growth of psychrotrophs. The use of store chicken inhibits the growth of psychrotrophs. The use of films of both high and low gas permeability in combination with Co_2 atmosphere shows that the Co_2 atmosphere is the significant factor in reducing microbial counts.

d) Ionising radiation – It is a potentially useful form of preservation. Besides from its desirable ability to inactivate micro – organisms, it also results in the breakdown of various lipids and proteins to often undesirable odours.

24.5 Preparation of Carcasses for Cooking

Chicken is available either chilled or frozen state. Chilled Poultry should be kept uncooked, loosely wrapped and unfrozen in the refrigerator. It is good practice to wash the residues from the surface of the carcass before using.

24.5.1 Frozen poultry

For freezing poultry should be tightly wrapped in moisture vapor proof film and then it should be frozen as soon as possible. Its undesirable to unfreeze poultry for a second time because freezing and thawing releases fluid which is called drip. And at that stage chances of bacterial contamination increase.

24.5.2 Thawing of poultry

For the thawing of chicken is **p**laced in refrigerator for 12-24 hours, or place it in a pan under running cook water in its original wrapping for about ½- than. **A**ll frozen turkey should be thawed slowly and never at room temp or in warm water. Turkey should be thawed in the following manners.

a. Place the bird skill in its original wrapping under running cold water for about 2-6 hours depending upon size of birds.
b. Leave the bird in its original body wrapping. Poultry a refrigerator of allow 1-3 days for thawing.

24.6 Cooking of Poultry

Raw chicken meat has no flavour, it is developed during cooking and sometime due to addition of spices. For the cooking of tough poultry meat moist heat is preferred on the other hand for soft variety of meat dry heat methods are recommended. Major physico-chemical changes taking place due to Cooking are listed as below:

1. Heat causes coagulation of proteins ,
2. Melting of fat
3. Change in colour of red meat to pink & finally brown or grey. In the presence of moisture when is present naturally in the meat
4. Collagen is hydrolyzed to gelatin when the meat is heated.
5. Heat affects the tenderness of meat is coagulation of protein causes to toughening in meat tissues & hydrolysis of collagen to gelatin makes it tender.
6. The change on flavor due to heat is caused partly due to volatiles, decomposition of protein or fats and/or caramelization of carbohydrates & coagulation of protein
7. The shrinkage of meat is due to loss of the moisture and fat which are released from the meat and collect at the bottom of cooking pan.

24.7 Methods of Cooking

Poultry meat processing utilizes same principles (e.g. frying, roasting, broiling etc.) as are use in other meat processing. It is necessary part of improving taste and flavour of the finished products. Sometime marination is done of the chicken portions to improve flavor and texture of the product. In marination meat is soaked in the acidic seasoned liquid (known as marinade) before the cooking. Marinade contains vinegar, lemon juice, or wine or enzymes and oils, herbs and spices to add further taste and tenderize the meat. Before cooking sometime chicken is coated with flavoured batter to improve flavor. Breading of chicken is done prior to coating to provide crisp outer layer of beaten egg covered later with flour.

The cooking method includes both moist heat which are applied for older and tougher birds and dry heat methods which are given to young birds which improve their palatability.

Two general rules should be followed in cooking of poultry-1. First cook at a moderate heat so that the meat cooks evenly up to the bone and such meat will be tender and juicy. The poultry meat which is cooked intense heat has a high cooking shrinkage and is less juicy, flavour is lost and has hard and sogi flesh as compared to poultry which is cooked at moderate temperature. 2. The age and fattiness of the bird are considered to be main criteria to determine which cooking method should be used. Broiling, frying and open pan roasting are best for younger tender birds with a good covering of fat. For carcasses those are lean, braising in a covered roaster, produces tender and flavor full meat. Carcasses from older birds require long and slow cooking in water or stream to make them tender.

24.7.1 Frying

Only young tender & low fat poultry meat should be cooked by frying. They can be fried by general methods such as frying cooking, deep fat frying, pan frying, oven frying, and deep fat frying under pressure. Generally carcasses are use into portions suitable for serving and then they are seasoned, salts, pepper and other spices as required are added, chicken should be rolled in floor or dipped in a batter generally containing eggs, milk, flour, and seasoning. Another medium sometime used for dipping of poultry meat pieces is the egg. & milk batter. Coated meat pieces are then dipped into the cooking medium i.e. oil/fat heated to 358°F. Generally temp of fats/oils between 300-325°F during frying. When the meat is to be preserved, the parts of the meat are first to be deep fried for a short period to ensure browning and then they are cooked under pressure for about 5-8 minutes. A thick pan should be used which contain about ½” hot fat. The coated parts are added to fat and then pan as covered with a lid. Moderate heat should be used and process should be turned when they brown. Generally the boiled fried chicken cooked by this method taken about 20-25 minutes after frying the piece should be kept in absorbent paper in order to remove excess oil.

24.7.2 Broiling

Broiling, is a type of cooking which involves exposing food to direct radiant heat, either on a grill over live coals or below a gas burner or electric coil. Broiling differs from roasting and baking in that the food is turned during the process so as to cook one side at a time. Temperatures are higher for broiling than for roasting; the broil indicator of a household range is typically set around 550° F (288° C), whereas larger commercial appliances broil between 700° and 1,000° F (371° and 538° C). Fish, fowl, and most red meats are suitable for broiling. Young tender poultry e.g. chicken, turkeys & duckling can be cooked by broiling at 400ºF. Before cooking the meat is brushed with fat, seasoned with salt and pepper and some sauce instead of adding fat. Then portion is placed in a shallow pan with a skin side down and pan of meat is placed in preheated broiling. After cooking for about 30 minutes the pieces are turned and again basted. Generally broiler is placed 10 cm away from the flame and cooked till the internal temperature of breast reaches to 95ºC which takes around 45-60 minutes. Low fat content of the broiled chicken and basting of melted fat results in improved flavour and texture and palatability of the chicken. The chicken is considered to cook when the drum stick or the wings twist out of their poultry.

24.7.3 Roasting

Young broiler pieces of any weight may be used for the purpose of roasting. A plump chicken of at least 2.5 lb are desirable. It may be stuffed or unstuffed. While roasting whole birds, tender parts e.g. breast may be overcooked before the legs and thighs are cooked to the desirable state. In order to avoid any food poisoning the temperature of the internal parts of the stuffed chicken must reach to 74^{o}C. if the poultry is roasted without stuffing, it is cooked to temperature of 163^{o}C till the temperature of the interior side reaches to 85 ^{o}C. However the exact time temperature combination of the roasting depends upon the size of the carcass.

24.7.4 Tandoor chicken

This product is always tagged with typical Indian chicken dish and widely accepted worldwide. It is a kind of barbecued chicken wherein cooking is done on a clay oven called as tandoor. Charcoal is used inside the tandoor to produce the heat and increase the temperature. The combination of heat and the smoke generated due to charcoal gives typical savory flavour, taste and texture to the finished product. Chicken cooked this way is really found to be very delicious.

24.7.5 Braising and stewing

Braising is a combination cooking method using both moist and dry heat. This is the technique which is used to cook older and tougher birds. Disjointed pieces of chicken are generally cooked this way. Initially frying is done to darken the colour to the brown which is then followed by addition of water and simmering of the meat until it gets tender.

In the **stewing** the frying step is eliminated and the bird whole or its pieces are cooked in water with seasoing and some vegetables till they get tenderize. A stew is a combination of solid food ingredients that have been cooked in liquid and served in the resultant gravy. Ingredients in a stew can include any combination of vegetables (such as carrots, potatoes, beans, peppers and tomatoes, etc.), meat, especially tougher meats suitable for slow-cooking, such as beef. Poultry, sausages, and seafood are also used. While water can be used as the stew-cooking liquid, wine, stock, and beer are also common. Seasoning and flavourings may also be added.

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Module 6. Meat and poultry processing

Lesson 25

MEAT HYGIENE AND SANITATION IN MEAT AND POULTRY INDUSTRY

25.1 Meat Hygiene

Meat Hygiene refers to a set of activities that require the implementation of specific standards, codes of practices and regulatory action by the competent authority to ensure "safety and suitability" of the meat the consumers eat. Hygiene requirements are to be met at different stages of production, processing and transportation and must include hygiene of personnel, slaughter & meat processing equipments and environment. To ensure this, proper cleaning and sanitization practices are to be followed by plant personnel and should include disinfection of meat plant premises, equipments and storage area. Failure in maintaining meat hygiene may pose serious public health hazards and therefore evaluation of meat for meat borne pathogens which can cause diseases of public health importance is very important. Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011 also warrant that every product being sold in the Indian market must meet/conform to legal standards of quality.

25.1.1 Principles of meat hygiene

There are three principles of meat hygiene, which are crucial for meat processing operations.

- Prevention of microbial contamination during meat product manufacture by adopting proper cleaning and sanitation practices.
- Minimization of microbial growth in meat products by storing them at a low temperature.
- Reduction or elimination of the risk of microbial contamination by applying suitable heat treatment and packaging systems at the final processing stage.

25.1.2 Possible source of contamination

Failures in maintaining slaughter hygiene, meat cutting and meat handling/transportation and in the hygiene of by-products and additives contribute to quality losses and deterioration of the final processed meat products (Table 25.1).

Table 25.1 Microbiological contamination in the meat processing chain

Carcass contamination during slaughtering	Unavoidable – keep as low as possible.
Meat cutting	No reduction of contamination possible, but further contamination should be prevented.
Further processing	No reduction of contamination possible, but prevent further Contamination and create challenges / hurdles for microbial growth and survival (aw, preservatives).
Heat treatment of final product	Pasteurization (approx. 80°C): Substantial reduction of contamination, but products need refrigeration. Sterilization (above 100°C): Total elimination of contamination, products can be stored without refrigeration (in sealed food containers).

25.1.3 Control measures

Two useful schemes are usually adapted at various levels of meat production:

- Good Hygienic Practices (GHP) and
- Hazard Analysis and Critical Control Point (HACCP) Scheme.

25.1.3.1 Good hygienic practices in meat processing

Microbial meat spoilage or food poisoning through meat can be prevented if the microbial load/bacterial contamination, which occurs during slaughtering and meat handling, is kept as low as possible. The key for achieving this is strict meat hygiene including an uninterrupted cold chain throughout the entire meat production and handling chain through the following interventions.

Personnel hygiene

- Wear clean protective clothes
- Washing hands before starting work and repeatedly washing hands during work
- No finger rings, watches, bracelets
- Access to production areas with working clothes only
- Cleaning/disinfection of hands/tools/clothes if there was contact with highly contaminated subjects or abnormal animal parts likely to contain pathogens.
- Fresh wounds through knife cuts etc. must be covered by a water tight bandage. Workers with purulent wounds are not allowed to work with meat. (Risk of spread of *Staph. aureus* bacteria).
- Strict toilet hygiene must be observed (removal of apron, hand washing and hand disinfection). Toilets must be kept clean and must not have direct access to production areas. (Risk of spread of Salmonella).
- Periodic medical examinations of staff

Hygiene during meat processing

- Ideally meat cutting/deboning should be carried out in climatized rooms (approx. + 10°C) with low air humidity.
- If visual contamination of meat has occurred during manufacturing, do not try to wash it off but remove it with knives by cutting off superficial meat parts in the case of minor contamination. Discard the meat in case of heavy contamination.
- Do not hose down floor and wall areas or equipment next to meat processing operations or final products with a power hose. (Risk of contamination by aerosol/droplets).

- Never take meat pieces, which accidentally had contact with the floor or other contaminated surfaces, back onto working tables or into meat processing machines.
- Containers for meat, fat, or semi–or fully processed meat products must not be placed directly on the floor but on hygienic stands, pallets etc.).

Hygiene of meat processing premises (design and construction)

Meat processing facilities must meet the basic hygienic standards in order to ensure and maintain clean and hygienic working conditions:

- Provision of change room for duty staff.
- Wall windows must be positioned at least 2 m high over floor level in order to allow profound washing and disinfection of floors and walls. Window frames should be of non-corrosive material e.g. aluminium or similar materials and must not be painted.
- Walls in all rooms, where meat and by-products are handled, must have smooth and easily washable surfaces up to a minimum height of 2 m in processing plants. Walls should preferably be covered with wall tiles or at least with washable paint.
- Floors in the mentioned sections must be impermeable for water and reasonably smooth for good cleaning, but anti-slip for workers safety.
- In order to facilitate proper cleaning, the junction between floor and walls must be rounded (not rectangular)
- Rooms for meat processing should have sufficient ventilation. Air conditioning is only required in meat cutting/deboning rooms (10 - 12°C).
- Supply systems for electrical wiring and pipes for hot and cold water as well as for compressed air should not hamper cleaning operations and be out of reach of possible dirt contamination. Insulations for hot water pipes must have smooth surfaces and be washable.
- Openings for ventilation must be bird- and insect-proof.

Equipment hygiene

- Equipment should have proper sanitary design and construction. Designs must allow easy and profound cleaning and avoid any accumulation of difficult to remove organic matters. They should make use of food grade construction material in designing food contact surfaces and equipments and should allow easy cleaning after processing operations.
- Stainless steel must be used for all food contact surfaces e.g. working tables, meat hooks (at least their parts contact in meat), blades of knives, saws, cleavers and axes etc.
- Food grade synthetic materials should be used for meat containers and other utensils

25.1.3.2 Hazard analysis and critical control point scheme (HACCP)

HACCP are ***factory* and *product specific*** strictly sanitary control schemes that shall prevent, detect, control and/or reduce to safe levels of ***accidentally occurring hazards*** to consumers' health. Despite GHP in place, accidental hazards cannot be ruled out and may occur at any processing step of the individual meat product. Specifically for ***meat processing plants***, such hazards may be provoked by failures such as: batches of incoming raw meat materials with abnormal tissues or heavy contamination, breakdowns in refrigeration, failure in cooking/sterilization operations, abnormal pH or a_w in raw or finished products, errors in levels of application of curing salts and other additives, technical problems in sealing of vacuum packages or cans with the risk of recontamination. HACCP schemes serve as additional **alarm systems** in the interest of consumer protection to prevent such problems occurring. In case potential hazards should occur, they can be **detected, contained or eliminated at any stage**.

25.1.4 Food poisoning through micro-organisms present in the meat

Food poisoning sets alarming situation for consumers. After consumption of meat contaminated with food poisoning bacteria, food poisoning results in severe illness with consumers needing intensive and costly medical treatments. Type of food poisoning observed due to bacteria are of two types, ie.

- food borne infection or
- food borne intoxication.

Bacteria that cause **food borne infections**, cause sickness through microbial metabolic substances i.e. toxic substances released by the living microorganisms inside the human digestive tract. The best known examples of food borne infections are those caused by Salmonella bacteria and entero-pathogenic form, mostly type O157: H7 residing in faecal material, *Listeria monocytogenes, Campylobacter jejun and, Yersinia enterolytica*. The **Norovirus** group can be responsible for food infections with similar, mainly gastro-intestinal symptoms, as bacterial food infection agents.

Microorganisms causing **food borne intoxications** produce and release the poison during their multiplication in the food. Upon ingestion by consumers of such food, which was heavily intoxicated outside the human body, severe gastro-intestinal food poisoning symptoms occur. Food borne intoxications are frequently caused by *Staphylococcus aureus, and Cl. botulinum*. **Moulds** are sometimes found on the surface of meat products after prolonged storage. Mold produce two types of toxins i.e. **Aflatoxins** (toxin of *Aspergillus flavus)* and **Ochratoxin (**toxin of *Penicillium vividicatum*)**.**

25.2 Cleaning and sanitation

Generally cleaning refers to removal of visible, physical/chemical dirt and to some extent bacteria from the equipment surfaces, sometime from products itself and from the processing environment. On the contrary, sanitization term is used with disinfection of the product or product contact surfaces by all killing spoilage and pathogenic microorganisms in order to avoid all possible risks of microbial contamination. Inactivation of microorganisms requires antimicrobial treatments, carried out in food industries through hot water or steam or through the application of disinfectants or sanitizers.

25.2.1 Cleaning procedures

The first step in floor and equipment cleaning is to physically remove scrap, i.e. coarse solid particles, with a dry brush or broom and shovel. This is usually referred to as "**dry cleaning**". **Wet cleaning** is followed after removal of physical scrap material. Wet cleaning could be done manually or by using high pressure nozzles. However, this would require water in sufficient quantities.

Cleaning with equipment producing a **pressurized steam/water-mix** is even more efficient as impact temperatures of approx. 100°C can be achieved. The disadvantage of this method is the intense fog and aerosol formation, which may not only cause unwanted microbial spreading by water droplets (aerosol) but also affect installations and equipment through high humidity and excessive condensation. For these reasons a steam/water-mix is not suitable for meat processing facilities and cold or hot pressurized water cleaning is preferred.

A relatively new cleaning method for the food industry, in particular the larger-scale plants, is **foam cleaning**. Water foam containing detergents and other cleaning agents is sprayed on wetted walls, floors and surfaces of equipment. The foam does not immediately run off but clings to the surfaces. This allows a longer term contact on the surfaces to be cleaned. After a sufficient impact period (min. 15 minutes) the foam is washed down with water (water hose or low-pressure water spray). As no high pressure water spraying is needed for washing off the foam, the spreading of water droplets (aerosol) in the room to be cleaned is minimized.

25.2.2 Cleaning agents

Traditional cleaning substances/detergents for manual use are alkalines, such as sodium carbonates (Na_2CO_3, washing soda). These substances are efficient in dissolving proteins and fats, but may cause corrosion in tools and equipment, if their pH is 11 and above.

Ideal detergents should have the following desirable properties:

- Wetting and penetrating power-must wet, penetrate and dispose soil and remove it from walls of equipments.
- Emulsifying power
- Saponifying power
- Deflocculating power
- Sequestering and chelating power
- Quick and complete solubility
- Should be non-corrosive to metal surface
- Economical
- Stability during storage
- Should be mild on hands
- Should possess germicidal action

In Meat industry, various types of detergents and cleaners are used and each one has one or more limitations. These are presented in table 25.2:

Table 25.2 Common detergents & sanitizers used in meat industry

Detergent	Functions	Limitations
1. Alkalies: a) Sodium hydroxide b) Sodium carbonate c) Sodium bicarbonate d) Sodium silicates e) Sodium phosphates	Digest, disrupt or dissolve soil especially protein, act as emulsifier, bactericidal agents, generally used at 0.2 - 2% (NaOH)	i) Some of these have poor solubility and wetting power ii) NaOH corrosive towards AI, Tin and Zn especially at higher concentration. (>2.0%)
2. Acids: a) Nitric Acid b) Sulphuric Acid c) Hydrochloric Acid d) Phosphoric Acid e) Acetic Acid	Remove hard deposits such as water stones, such deposits do not dissolve in alkalies, generally HNO_3 (0.5%) Phosphoric acid (2.0%) used	Strong acids are corrosive to metal surface and dangerous also
3. Complex Phosphates: a) Tetra sod. pyrophosphate b) Sod. tripolyphosphate c) Sod. tetraphosphate d) Sod. hexametaphosphate	Water softening, soil displacement by emulsification, peptization prevention of redeposition of soil	Excellent but unstable in hot solution and in presence of strong alkalies.
4. Chelating Agents: EDTA (Ethylene diamine tetra acetic acid)	Sequestering, water softening, removal of mineral deposition.	--

5. Wetting Agents: a) Anionic (sod. salt of various complex organic materials b) Non ionic e.g. teepol	-- Wetting and penetrating properties in soil -- Stable dispersion -- Emulsion formation	QAC are expensive.

Alkaline cleaning agents are generally suitable for removing organic dirt, protein residues and fat, while a**cid cleaning agents are u**sed particularly for removal of encrusted residues of dirt or protein or of inorganic deposits ("scaling") such as waterstone, milkstone, lime etc. On the other hand, **Neutral cleaning agents** have much less effect than alkaline or acid cleaning agents, but have mild impact on skin and materials and are useful for manual cleaning of smooth surfaces without encrusted dirt. In practice alkaline and acid cleaning substances should be used **alternatively**.

25.2.3 Disinfection techniques

The elimination of microorganisms is achieved through **disinfection**, either by using

- hot water (or better steam) or
- chemical disinfectants.

Chemical disinfectants are preferred for most applications in the meat industries as they are easy to use and do not involve the risk of accidents or other negative side effects such as damage to equipment by generating high humidity or water condensation, which may occur when using steam. Best results are achieved when chemical disinfection is preceded by intensive dry/wet cleaning.

25.2.4 Disinfectants for the meat industry

Disinfectants should be effective and rapidly acting in killing microorganisms. In principle the following groups of substances are generally used as disinfectants:

(i) Chlorine containing compounds e.g. Na/Ca hypochlorite or chlorine gas, has a corroding effect on equipment.

(ii) Aldehydes (used in animal production, e.g. Formaldedyde) Phenoles / Kresols (used in medicine, households Alcohols (used in medicine, e.g. skin) Alkalines (pH 10 or higher) (e.g. NaOH, used in animal production) Acids (some organic acids used in food industries). Quaternary ammonium compounds Amphotensids (used in food industries, as not corrosive) Low efficiency on spores. They have effect on cell walls, not corrosive, odourless, additional cleaning properties (surfactant)

(iii) Oxygen releasing compounds e.g. Peroxide compounds (H_2O_2) Per-acetic acid (use in food industries). Penetrate into cells, good effect on all microorganisms including on spores and virus, odourless, may be corrosive in concentrations >1%

An example of the optimal combination of disinfectant commercially used is

- organic acids
- surfactants (= surface active agents)
- peroxide compounds

The **organic acids**, apart from their sanitizing effect, decrease the pH as some disinfectants are more efficient at lower pH. The **surfactants** assist in penetrating organic material. The **peroxide compounds** have the direct antimicrobial effect by coagulation and denaturation of proteins (virus) and penetration through cell walls causing cell destruction (bacteria).

25.2.5 Cleaning and disinfection (sanitation) schemes

- Several daily disinfections (by hot water or chemicals) are necessary for hand tools, meat saws and cutting boards.
- Daily disinfection is useful for dismantled equipment such as parts of grinders, fillers, stuffers, etc.
- Disinfection once a week is recommended for other equipment and floors and walls of processing and chilling rooms.

25.2.5.1 Cleaning and disinfection plans

Specific cleaning and sanitization plans should be developed for specific processing areas eg. Meat storage, processing etc. An example of such plan is given in table 25.2 for disinfection of meat processing equipment, in this case for a meat grinder. This type of equipment is an integral part of almost every meat processing line. Meat grinders require particular careful and frequent cleaning and sanitation, as the output product **minced meat** is hygienically very sensitive.

Table 25.3 Cleaning and disinfection plan

Equipment: Meat grinder

Pre-cleaning	Potable water Temp.: 40-50°C Pressure: 20-30 bars	
Cleaning	Daily Agent: A Concentr.: 1.0% Temp.: 40-50°C Time: 20-30 min pH: approx. 12	1 x monthly Agent: B Concentr.: 1.5% Temp.: 40-50°C Time: 20-30 min pH: approx. 1.8
Rinsing	Potable water Temp.: 30-50°C Pressure: 5-10 bars	
Drying		
Disinfection	2 x weekly Agent: C Concentration.: 0.5%	3 x weekly Agent: D Concentr.: 1.0%

	Temp.: 30-40°C Time: 30 min pH: approx. 5.7	Temp.: 30-40°C Time: 30 min pH: approx. 10.2
Rinsing	Potable water Temp.: 30-50°C Pressure: 5-10 bars	

Agent **A**: Alkaline cleaning
substance

(Source:Heinz and Hautzinger, 2007)

Agent **B**: Acid cleaning substance

Agent **C**: Disinfectant

Agent **D**: Disinfectant chemically different from C and supplementing impact of C

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Module 7. Egg and egg processing

Lesson 26

EGG: STRUCTURE, COMPOSITION AND QUALITY

26.1 Introduction

Egg is a complete food consumed throughout the world. Eggs of various birds may be eaten however eggs of hen and duck are most commonly consumed. Egg protein contains all the essential amino acid and has got highest biological value. Thus egg proteins are considered by the WHO to be the reference protein, to which all other proteins are compared. An average weight of hen egg is about 2 ounce i.e. 57g

26.2 Structure and Composition of the Egg

Whole Egg can be divided into three major components

1. Shell

2. Egg white

3. Egg yolk

26.3 Composition of Egg

Table 28.1 Composition of Egg

Component	%	Water %	Protein %	Fat %	Ash %
Whole egg	100	65.5	11.8	11	11.7
Egg white	58-60%	88	11	0.2	0.8
Egg yolk	31-33%	48	17.5	32.5	2
Shell	9 – 12%				

26.3.1 Shell

It is the Outer covering of Egg, contributes to 9 – 11% of the whole egg weight. 94% of the egg shell is composed of calcium carbonate. It Acts as a barrier against harmful bacteria and other contaminants. Shell has got numerous pores on its surface, permitting moisture and carbon dioxide to move out and oxygen to move in as egg ages. Strength of the shell indicates the quality of the egg and strength is influenced by mineral and vitamin content of the hen's diet, mainly calcium, phosphorous and Vitamin D. Inside surface of the Shell is lined by a mucous layer also known as protective layer called cuticle or bloom. Cuticle preserves the freshness of the egg by blocking the pores on the shell.

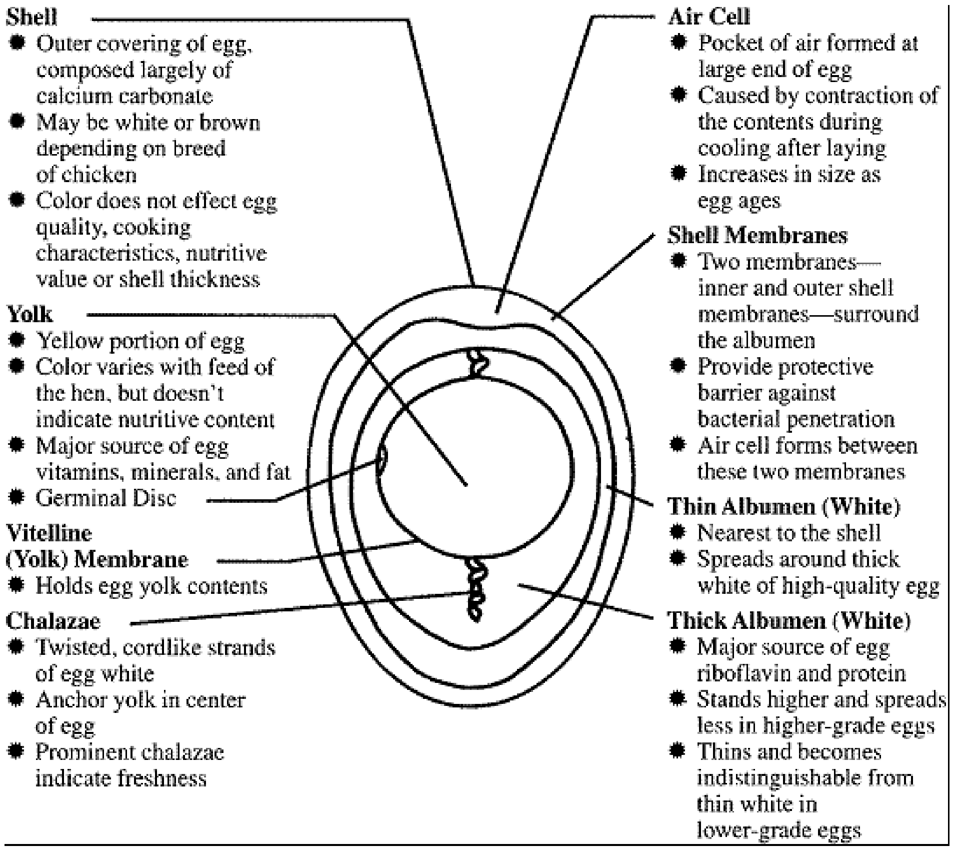
26.3.2 Egg white

It is also known as Egg albumin, it contributes to about 65% of the egg's liquid weight. It contains more than half of the egg's total protein. Egg white becomes thin as an egg ages because protein changes in character. Hence fresh eggs sit up tall and firm in the pan while older ones tend to spread out. As the egg ages, carbon dioxide escapes out, so the albumin becomes more transparent than the fresh ones

26.3.3 Egg yolk

The yolk or yellow portion makes upto about 33% of the liquid weight of the egg. It contains all of the fat in the egg and about 45% of total egg proteins.

26.4 Structure of the Egg



Source: USDA

Fig. 28.1 Structure of the egg

26.4.1 Factors affecting quality of egg

1. Age of the egg
2. Storage atmosphere
3. Temperature of storage
4. Relative humidity
5. Pre-treatments given before storage

26.4.2 Testing the quality of egg

1. **Water test**: this test is based on the principle of density. Eggs are simply dropped into water. Good quality eggs sink to bottom and poor quality ones float. Loss in weight is due to dehydration and thus increased air cell size.

2. **Sensory test**: Cracked, smelly, rough surface indicates poor quality

3. **Candling test**: This is the most commonly used test to determine the spoilage of egg. The egg shell is porous and allows the light to pass through. The eggs to be tested are placed in front of sharp, bright light and assessed for following factors

   a. Cracks on the shell

   b. Air cell size and position

   c. Albumin and yolk position and firmness

   d. Presence of any blood clot or foreign elements in the egg

26.4.3 Nutritional qualities of egg

Eggs are nutritionally rich and one of the nature's most complete food. They provide 173Kcals/100g.

26.4.4 Proteins

Egg contains high quality complete protein with all the essential amino acid in well balanced proportion. Biological value of egg protein is 100, indicating all of the protein consumed is retained by the body. Egg white, also known as Albumin, contributes to the 60% of total proteins present in Egg and the rest is from Egg yolk. Nearly 50% of the protein in egg white is **Ovalbumin**, followed by **Conalbumin** (13%), **Ovomucoid** (10%), **Lysozymes** (3.5%), **Ovomucin** (2%), **Avidin**, **Ovoglobulin** and **Ovoinhibitor**.

Vitellin is the protein present in Egg yolk, which is present in a lipoprotein complex as lipovitellin and lipovitellinin. **Phosvitin** phosphorus-containing and **Livetin** sulfur-containing protein are also present in egg yolk. **Avidin** is protein present in the egg while which binds the vitamin biotin thus makes it unavailable to the body.

26.4.5 Fat

Fat is concentrated in the Egg yolk. Yolk fat can be divided into 3 major parts i.e. Triglycerides, phospholipids and lipoproteins. Lipoproteins are present in conjugation with phospholipids. The primary phospholipid present in egg is **lecithin** and major sterol is **cholesterol.**

The major Triglycerides present in egg yolk are

Oleic acid	38.45%
Palmetic acid	23.50%
Linoleic acid	16.4%
Stearic acid	14.0% of total fatty acids

26.4.6 Carbohydrate

Glucose, Mannose and galactose are present in small amounts. This will take part in maillard reaction producing an undesirable brown discoloration in both dried and cooked egg whites.

26.4.7 Micronutrients

The major micronutrients present in egg are vitamins and minerals. Egg is the rich source of all known vitamins except vitamin C. All the fat soluble vitamins A, D, E are concentrated in yolk. Minerals such as iron, phosphorus, zinc, iodine, potassium, sodium, chlorine and sulphur are present in good amounts. Iron present in egg is bound to conalbumin and therefore its absorption is poor while Zinc is present in the most abundant biologically active form.

Module 7. Egg and egg processing

Lesson 27

PROCESSING OF EGG

27.1 Introduction

Egg products are processed and convenience forms of eggs for commercial, foodservice and home use. These are refrigerated liquid products, frozen products, dried and specialty products. When shell eggs are delivered to the breaking plant, they are put into refrigerated holding rooms. Before breaking, they are washed in water at least 20 degrees warmer than that of the egg and spray-rinsed with a sanitizing agent. They may be moist, but not wet, when they are broken.

27.2 Classification of Egg Products

Egg is processed to produce convenience forms of eggs for commercial, food service and home uses. Egg products can be classified as follows

1. Refrigerated Liquid products

Egg whites, Egg yolk, various blends of Yolk and white

2. Frozen products

Egg white, Egg yolk, Salted yolks, Sugared yolks, Whole eggs, Salted whole egg

3. Dried/Dehydrated products

Spray dried egg white solids, Instant egg white solids, whole egg or yolk solids, free flowing whole egg or Yolk solids (sodium silicoaluminate added as a free flowing agent).

4. Specialty Products

Freeze dried scrambled eggs, Frozen precooked products like Egg patties, Fried eggs, crepes, Egg pizza etc.

Egg products are preferred to shell eggs by commercial bakers, food manufacturers and the foodservice industry because they have many advantages including convenience, labor savings, minimal storage requirements, ease of portion control, and product quality, stability and uniformity.

As per egg product inspection act all egg processing plants must follow below conditions:

- Pasteurization of all egg products is mandatory.
- Shell eggs used for egg products must be clean and of edible interior quality.

27.3 Frozen Egg Products

These include separated whites and yolks, whole eggs, blends of whole eggs and yolks or whole eggs and milk and these same blends with sugar, corn syrup or salt added.

27.3.1 Production of frozen egg

Shell egg
↓
Candling
↓
Removal of egg content
↓
Inspection of egg meat
↓
Separation of yolks and whites when desired
↓
Mixing and churning of Yolks and whites when desired
↓
Straining to remove chalazas and pieces of shell and membrane
↓
Addition of sugar, salt and other ingredients
↓
Pasteurization (60-62°C/3-4 min)
↓
Freezing and drying of the product (-30°C)

Fig. 27.1 Process flow chart for frozen eggs

Eggs are frozen to preserve them for use in food manufacturing. Before freezing, egg contents are separated from the shell and which may be frozen as whole egg, Egg yolk, Egg white or various mixtures of yolk and white.

Freezing plants are generally combined with egg breaking facilities where eggs are received, washed and dried. Then the eggs are broken to remove the egg content this could be done by hand or with the help of machines. While breaking the spoiled eggs are rejected as this could spoil the good product. The whole or separated eggs are mixed for uniformity, filtered to remove chalazae, membranes or bits of shell. Thus prepared egg contents are pasteurized at 60-62°C/3-4 min and filled into suitable container for freezing. Freezing generally is done in a sharp freezer room with circulating air at -30°C. Freezing may take about 48-72h.

Egg white and whole egg can be frozen as such without any additives but it is difficult in case of egg yolk. While freezing egg yolk becomes gummy and thick due to gelation. This can be prevented by the addition of 10% sugar or salt or glycerin 5%. Sugar yolk will be used by bakers, confectioners and salted yolk may be used by mayonnaise manufacturers. These ingredients should be dissolved in the yolk during mixing and prior to screening.

27.3.2 Production of spray dried whole egg

Fresh eggs

↓

Cold storage (maintained at 4-5°C)

↓

Candling and Inspection (Candling room maintained at 15°C)

↓

Cleaning using Detergent-sanitizer solution (2% sodium hydrochloride solution, at 40°C/7min)

↓

Removal of egg content

↓

Churning and Filtration (without beating air into egg mass)

↓

Pasteurization – 62.5°C/3-5min

↓

Desugaring (0.5% yeast, fermentation at 30°C for 90min)

↓

Repasteurization - 62.5°C/3-5min to kill yeast

↓

Spray drying (inlet air temperature 185°C and outlet air temperature 85°C, moisture content 1.5% in the dried powder)

↓

Packing (in tin container with inert gas)

↓

Storage

Fig. 27.2 Process flow gram for spray dried whole egg

The whites, Yolks and whole eggs may be dried by several methods, like spray drying, tray drying, foam drying or freeze drying. Egg white contains traces of glucose and galactose which react with egg protein leading to maillard browning. This discolors the dried egg white. Browning can be prevented by removing glucose through fermentation by yeast or with commercial enzymes. This is known as desugaring and this is practiced prior to the drying of all egg white.

27.4 Functional Properties of Egg content

Eggs provide many desirable attributes as a food ingredient. The functional properties derived by egg contents are Coagulation, Emulsification and Foam formation.

27.4.1 Coagulation

The egg protein coagulates upon heating accompanied by binding of moisture and increase in viscosity. Heating causes denaturation of egg protein and gradually aggregates to form a three dimensional gel network. Thus eggs can be used as **thickening agent** in many food formulations mainly custards, cakes, pie fillings, cream puddings etc. The coagulation temperature is influenced by pH, salts, other ingredients and duration of heating. Egg white coagulates at 62 – 65^{o}C and egg yolk at 65-70^{o}C.

Heat coagulated protein helps to hold the shape of the product in which these are used. Thus eggs are used as binding agent in cutlets, chops etc.

27.4.2 Emulsification

The phospholipids i.e. lecithin and certain proteins present in egg acts as an excellent emulsifying agent. In mayonnaise egg yolk acts as an emulsifier to keep oil suspended in vinegar.

27.4.3 Foaming

Eggs when beaten form elastic films, which can trap air. Egg and egg products are good foaming agents. They produce large foam volume and relatively stable for cooking. Thus entrapped air expands during baking and gives fluffy and spongy product. Thus eggs are extensively used as leavening agent in baked products such as cakes and muffins.

27.4.4 Quality checks and storage of egg

Like any other food product, Eggs start deteriorating soon after it is laid. So it is very important to check the quality of the egg before its consumption. Good quality egg should possess following qualities once it is broken.

1. Yolk is firm and stands up in the centre of white
2. Egg white forms a definite ring around the yolk and thick white holds its shape
3. No blood spots are present
4. No bad odour

27.4.5 Changes occur in egg during storage

1. Increase in the size of air cell due to loss of moisture
2. Increased pH due to escape of carbon dioxide. pH increases from 7.6 to 9.7
3. Percentage of thin white increases, thus egg white loses its shape and runs easily.
4. Water passes from white to yolk, thus fluid content of yolk increases.

27.5 Indicators to Determine Spoilage in Eggs

1. White index:

White index = Height of thickest egg white portion/Egg diameter

Range: 0.08 – 0.1

2. Yolk Index

Yolk index = Height of Yolk/Yolk width

Range: 0.35 – 0.45

3. Hough's Unit (HU)

Commonly used index to check the egg quality

HU = Height of thick white/weight of Egg

For good quality egg HU is 72 and above and HU about 30 to 60 indicates poor quality.

4. Air cell size should be 2-3cm

27.6 Preservation of the Shell Eggs

Eggs can be preserved by 4 different methods

27.6.1 Wet immersion method

In this method only infertile, fresh, good quality eggs should be used

27.6.1.1 Lime sealing method

In this method saturated solution of lime water is used. Eggs are held in lime water for 14 -16hr, during immersion CO_2 released from the egg combined with lime to form calcium carbonate which deposits and seals shell pores. Then it is removed and stored at room temperature. Such eggs can be stored for 3 -4 weeks at room temperature

27.6.1.2 Water glass method

10% solution of sodium silicate is commonly called water glass. In this method Water should be boiled and cooled to 24 – 26^oC, to remove the dissolved CO_2, before the addition of calculated amount of sodium silicate. Eggs are kept overnight and then removed and stored at room temperature.

27.6.2 Dry methods

27.6.2.1 Oiling

In this method the quality of eggs is preserved by sealing the shell pores using suitable oil and thus preventing evaporation of water, CO_2 and other changes. Oiling can be done by Dip method or Spray method. Oiled eggs can be preserved upto 3 weeks at room temperature.

27.6.2.2 Gaseous atmosphere

Modified atmosphere packing of eggs proved to improve its shelf life. Maintenance of higher CO_2 pressure surrounding the eggs prevent CO_2 loss from the egg thus improves the egg quality.

27.6.3 Thermization or heat treatment methods

Fertile, fresh eggs can be preserved by this method. Eggs are thermo- stabilized by immersing it in boiling water for 3 to 5 min while keeping the water stirred constantly. This heat treatment coagulates the albumin very close to the shell and thus prevents CO_2 loss. Thermized eggs can be stored at room temperature for 3-4 weeks.

27.6.4 Cold storage or refrigeration:

Eggs can be stored well for a long time up to 5 – 6 months at -1.1ºC and 85-90% relative humidity. For storage up to 3 – 4 weeks a temperature of -12.8ºC and relative humidity of 60-70% is sufficient.

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Module 8. Fish and its processing

Lesson 28

FISH HARVESTING, HANDLING AND TRANSPORTATION; CLASSIFICATION

28.1 Introduction

Fish is a source of valuable animal protein and is now considered as a health food. This has resulted in increased consumer demand. Indian fisheries and aquaculture provides nutritional security to the human food and contributes to the agricultural exports and engages very large number of people in different activities. India is the 3rd largest fish producing nations (after Chine and Indonesia) in the world with the production of 7.3 million MT (FAO 2007). Presently, fisheries and aquaculture contribute 1.10 % to the national GDP, and 5.30 % to agriculture and allied activities, while the average annual value of output during the Tenth Five Year Plan (2002-2007) was Rs31, 682.50 crores.

28.1.1 Classification of fisheries

Fisheries can be broadly categorized into two types - **fin fisheries and non-fin fisheries.** Fin fisheries means fisheries of true fishes, whereas non-fin fisheries is the fisheries of organisms other than true fish like prawn, crab, lobster, mussel, oyster, sea cucumbers, frog, sea weeds, etc.

Fin fisheries can be further categorized into two types – **capture fisheries** and **culture fisheries**.

28.1.1.1 Capture fisheries

It is the exploitation of aquatic organisms without stocking the seed. Recruitment of the species occurs naturally. Capture fisheries is carried out in the sea, rivers, reservoirs, etc. Fish yield decreases gradually in capture fisheries due to indiscriminate catching of fish. Capture fisheries practiced in the sea is referred as **marine fisheries** and **Inland capture fisheries** if it is in the rivers or reservoirs.

28.1.1.2 Culture fisheries

It is the cultivation of selected fishes in confined areas with utmost care to get maximum yield. The seed is stocked, nursed and reared in confined waters and then the crop is harvested. Culture takes place in ponds, which are fertilized and supplementary feeds are provided to fish to get maximum yield.

28.1.2 Fishing techniques

Fishing techniques are methods for catching fish. Use of fishing methods varies, depending on the types of fisheries, and can range from as simple process as gathering of aquatic organisms by hand picking to highly sophisticated fish harvesting systems, viz. aimed mid-water trawling or purse seining conducted from large fishing vessels. The targets of capture fisheries can range from small invertebrates to large tunas and whales.

28.1.2.1 Principles of catching fish

The large diversity of targets in capture fisheries and their wide distribution requires a variety of fishing gears and methods for efficient harvest. These technologies have been developed around the world according to local traditions and technological advances in various disciplines like hydrodynamics, acoustics and electronics. Filtering the water, luring and outwitting the prey and hunting, are the basis for most of the fishing gears and methods used even today.

Harvest technologies, as they are practiced today generally fall into 3 main groups:

- Catching fish singly or in schools by use of nets or spears
- Trapping fish in stationary gears such as fish traps or set nets
- Attracting fish to get caught on hooks by use of bait, artificial lures or other means such as light.

28.1.2.2 Fish harvesting methods

Fish harvesting systems includes fishing vessels (craft) and fishing gear. The term fishing vessels is used to denote the mobile floating objects engaged in catching operations. Fishing gear is synonymous for 'fishing net' which is used to catch the fish in the water bodies.

Most significant among the technological developments which support the evolutions of fish harvest technology are

- Developments in craft technology and mechanization of propulsion, gear and catch handling,
- Introduction of synthetic gear materials
- Developments in acoustic fish detection and satellite based remote sensing techniques,
- Advances in electronic navigation and position fixing equipment,

28.1.2.3 The traditional methods of fish harvesting

Ring seine, Stake net, Chinese dip net, Cast net, Shore seine, Trammel net, Mini trawls, Gill nets, Hook and line, traps and pots

28.1.2.4 Modern methods of fish harvesting

Trawling, Purse seining, Hook and line mechanized Jigging and Trolling lines.

28.1.3 Handling of fishes

Since fish is highly perishable commodity, it is to be immediately processed into various products to preserve its quality and to increase the shelf life. Fish requires proper handling and preservation to increase its shelf life and retains its nutritional attributes. Fish are particularly prone to rapid pathogenic contamination. The main safety concerns are unhygienic handling during and after fish harvest, insufficient refrigeration, substandard processing and poor packaging. Maintaining the quality of the fish begins with harvest and carries through the harvest to consumption chain.

Handling of fish varies with type of the fish, the processing methods and the intended final product. The earliest practice of fish handling in many part of the world is to keep caught fish alive until cooking and consumption. Till today, this remains to be one of the common fish handling practices.

For harvested fish, the general handling practices after capture are

- Transferring catch from gear to vessel
- Washing/Sorting
- Bleeding/gutting
- Chilling
- Chilled storage and unloading

The most important factors to be considered in the initial handling and transport are the temperature, duration of storage/ transport and the hygiene in all respects including that of the handlers.

28.1.3.1 Washing and sorting of fish

The harvested fish should be washed well with potable water to free it from dirt and other extraneous matter. Slime accumulating on the skin surface of dying fish is a protection mechanism against harmful conditions. In some freshwater species slime constitutes 2-3% of body weight. Slime excretion stops before *rigor mortis*; it creates a perfect environment for the growth of micro-organism and should be removed by thorough washing. Water chlorinated at 10ppm level is ideal for initial cleaning.

After washing the catch should be sorted species wise and size wise. Bruised, damaged and decomposed fish shall be separated from the catch during sorting.

28.1.3.2 Dressing

Dressing operations of the catch include **deheading, bleeding and gutting.** This has to be carried out as fast as possible without significant bacterial contamination. Gills and viscera harbour several spoilage bacteria in large number. Therefore, where possible, it is advisable to remove the gills and viscera before the fish is preserved and stored.

28.1.3.3 Deheading

The head constitutes 10-20% of the total fish weight and it is cut off as an inedible part. Although many mechanized deheading machines had been developed for processing marine fish, freshwater fish are usually deheaded manually.

28.1.3.4 Bleeding

When fish dies, the blood in the fish can clot and turn black or brown in color adversely affecting the color and appearance of the meat. Therefore bleeding is done to preserve the quality of the meat. Slitting the throat followed by hanging the fish by tail or slitting the throat and immersing in cold water are the methods for bleeding.

28.1.3.5 Gutting

The purpose of gutting is to remove those fish body parts most likely to reduce product quality, as well as to remove gonads and sometimes the swim bladder. Gutting consists of cutting down the belly (fish may be deheaded or not), removal of internal organs, and, optionally, cleaning the body cavity of the peritoneum, kidney tissue and blood.

28.1.3.6 Chilling and storage

Decreasing the temperature of the fish to about 0°C slows down the microbiological, chemical and biochemical decomposition processes and extends fish stability. Thus when the raw material is cooled quickly, just after capture, and kept at low temperature during transport, processing and distribution, it meets the basic processing requirements. Its usefulness is extended and at the same time fish quality is maintained.

The most common means of chilling is by the use of ice. Ice is available is several forms such as blocks, plates, tubes, shells, soft and flakes. In modern fish processing plants, especially the small ones, flake ice generators dominate as flake ice ensures major contact surface with fish hence higher cooling capacity, low production cost, relatively dry and will not stick together to form clumps when stored.

Fish spoil more quickly if

- It has struggled for long in the net or inboard, than a fish, which is killed quickly.
- Its stomach is full while catching,
- It is bruised while catching or handling

28.1.4 Transportation of chilled fish

Fish is transported both through air and land. Land transportation of chilled fish is carried out in insulated or mechanically refrigerated vehicles with minimum inside temperature of 7^0C. Boxes for land transportation are made of wood, aluminum, high density polyethylene, expanded polystyrene or polyurethane. The ideal fish transpiration box should be light weight yet strong enough to withstand the combined weight of fish, ice and stacking and should have good insulating properties. Boxes are usually made of double bottom to collect the melt water.

Air shipment of chilled fish requires a lightweight and protective container. Modern insulated containers are made of high-density polypropylene with polyurethane insulation. Instead of ice, pads of nonwoven fabric encapsulating synthetic absorbent powder are used for chilling of air shipped fish. These pads could be soaked in water and deep frozen for use.

Plywood boxes insulated with 2.5cm thick foamed polystyrene slabs are found to be more useful to transport fish over longer distances involving duration of 60-80hrs.

28.1.5 Marketing practices

The fish marketing is normally done at the collection centers which are mainly situated in the area of fish landing. The fishermen visit the fishing grounds and tend to bring the

produce to the nearby market for sale as soon as possible. The fishermen who actually catch fish play only an insignificant role in the disposal of catches. Their role is only to hand over the fish catch to fish merchants at the landing centers for sale. The final distribution and marketing of catch is done by commission agents who step in at this stage.

28.1.5.1 Functions of the fish market

Fish markets are bridges between producers and consumers. The following are the functions of the market.

1. All types of fishes are brought together for selling.
2. Transportation of fishes
3. Storage of fishes
4. Business problems can be solved
5. Fishes can be graded here
6. Money transactions take place in markets
7. Time and distance is saved.

28.1.5.2 Types of markets

Based on the marketing place, production importance and products, the markets can be classified into the following types.

1. **Whole sale market**: More amounts of fish comes to this market, then distributed to other types of markets. Whole sale market can be grouped into two types,
   a. **Primary whole sale market:** More amount of sale of fish takes place in this market. Collection of the fishes from surrounding places and selling the fish to wholesalers takes place. These types of markets are found either in a village or a place covering a group of villages or towns or cities. These are known as shandies.
   b. **Secondary whole sale market:** These are also called as gunjs. The fishes are brought from the primary whole sale markets and sold to the wholesalers.
2. **Terminal markets:** The fishes are sold to the retailers or consumers or to the agents.

3. **Retail markets:** The fishes are sold to the consumers by the retailers or wholesalers.

4. **Fairs:** These are found temporarily during festival times or in fairs. The fishes are sold directly to consumers.

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Module 8. Fish and its processing

Lesson 29

PROCESSING AND PRESERVATION OF FISH; VALUE ADDED FISHERY PRODUCTS

29.1 Introduction

Fish, however, is more susceptible to spoilage than certain other animal protein foods, such as meat and eggs. To prevent spoilage of fish, some form of preservation is necessary. Preservation means keeping the fish, after it has landed, in a condition wholesome and fit for human consumption for a short period to few days or for longer periods of over few months. During the period of preservation the fish is kept as ‘fresh’ as possible, with minimum losses in flavour, taste, odor, form, nutritive value, weight and digestibility of flesh. This preservation should cover the entire period from the time of capture of fish to its sale at the retailer’s counter.

29.2 Methods of Preservation

Preservation can be done, both for short and long duration

29.2.1 Preservation for short duration

29.2.1.1 Chilling

This is obtained by covering the fish with layers of ice. Ice is effective for short term preservation such as is needed to transport landed fish to nearby markets or to canning factories, etc. Here autolytic enzyme activities are checked by lowering the temperature.

29.2.2 Preservation for long time

When the preservation is required for a long period of time, the fishes are passed through the cleaning, gutting and conservation and storage.

29.2.2.1 Cleaning and gutting

During cleaning, the caught first are fish washed thoroughly in cold, clean water to remove bacteria, slime, blood, faeces, and mud, etc. from the body surface of the fish. It is being done under proper sanitary conditions. Large fishes are gutted (i.e. all the internal organs or viscera are removed) and the body cavity is washed.

29.3 Conservation and storage

Conservation is necessary to keep the dead fish in fresh condition for quite a long time. This is achieved by employing any one of the methods like freezing, drying, salting, smoking and canning.

29.3.1 Freezing

Freezing means removal of heat from the body. To check the enzymal, bacterial action and putrefaction it is preferred to store the fish under lower temperatures. When fish is intended to be stored for a long period, quick freezing is preferred which inhibits bacterial action. During quick freezing every part of the product comes within the range of 0^{o} to $-5^{o}C$. Properly frozen fish at $-20^{o}C$ retains its physical properties and nutritive values for a year or more and is almost as good as fresh fish. There are three ways effecting quick freezing:

a) Direct immersion of fish in the refrigerating medium,

b) Indirect contact with the refrigerant through plates

c) Forced convection of refrigerated air directed at heat transfer surfaces.

In general different methods of freezing are adapted through sharp freezer, air blast freezer, contact plate freezer, immersion freezing, liquid freon freezing, liquid nitrogen freezing, fluidized bed freezer, cryogenic freezing, etc. Among the various types of quick freezing plants installed in India the carrier air blast type is widely used. The air blast freezer is in the form of a tunnel and heat transfer is affected rapidly by the circulation of air. The temperature used ranges from 0 to $-30^{o}C$ and air velocity varies from 30 to 1050 meters/min.

29.3.2 Freeze drying

This is modified deep freezing, completely eliminating all chances of denaturation. The deep frozen fish at $-20^{o}C$ is then dried by direct sublimation of ice to water vapour with any melting into liquid water. This is achieved by exposing the frozen fish to $140^{o}C$ in a vacuum chamber. The fish is then packed or canned in dried condition. The product is quite fresh looking in appearance, flavour, colour and quality.

29.3.3 Salting

Salting is a process where the common salt, sodium chloride, is used as a preservative which penetrates the tissues, thus checks the bacterial growth and inactivates the enzymes. Some of the factors involved in salting of fish which play an important role are purity of salt, quantify of salt used, method of salting and weather conditions like temperature, etc.

During the process the small fishes are directly salted without being cleaned. In the medium and large sized fish the head and viscera are removed and longitudinal cuts are made with the help of knives in the fleshy area of the body. Then the fish is washed and filled with salt for uniform penetration through flesh. Large fishes like sharks are cut into convenient sized pieces. Generally, sardines, mackerels, seer fishes, cat fishes, sharks and prawns are used for salting.

Dry salting and wet salting and are the methods employed in salting of fish.

a) Dry salting

In this process the fish is first rubbed in salt and packed in layers in the tubs and cemented tanks. The salt is applied in between the layers of fishes in the proportion of 1:3 to 1:8 salt to fish. The proportion of salt to fish varies with the fish since the oily fish require more salt. At the end of 10 - 24 hours the fishes are removed from the tubs and washed in salt brine and dried in the sun for 2 or 3 days.

b) Wet salting

The cleaned fish are put in the previously prepared concentrated salt solution. It is stirred daily till it is properly picked. With large sized fishes, longitudinal slits are made in the flesh to allow penetration of salt. After pickling for 7-10days, the salty water that oozes out from the fish is allowed to drain off. This can be stored upto 3-4months.

29.3.4 Smoking

In this method, landed fish is cleaned and brined. It is then exposed to cold or hot smoke treatment. In cold smoking, first a temperature of 38ºC is raised from a smokeless fire. After this heating, cold smoke at a temperature below 28ºC is allowed to circulate past the fish. In case of hot smoking, first a strong fire produces a temperature around 130ºC.This is followed by smoking at a temperature of 40ºC. The smoke has to be wet and dense. Good controls are necessary over density, temperature, humidity, speed of circulation, pattern of circulation and time of contact with fish of the smoke. The phenol content of the smoke acts as an antiseptic and it also imparts a characteristic colour and flavour. For making fire and smoke, only hard wood (Conifer wood, Saw dust etc.) are used.

29.3.5 Canning

Canning is a method of preservation in which spoilage can be averted by killing micro-organisms through heat. Oily fish are the most suitable for canning. Salmon, tuna, sardine, herring, lobster, shrimp, etc. are canned. The raw material should be processed properly since it contains most dangerous Clostridium botulinum which should be destroyed. There are some other heat resistant bacteria like Clostridium sporogenes which can be eliminated at a temperature of 5 - 6 times more than Clostridium botulinum. It needs a temperature of 120ºC for 4 minutes or at 115ºC for 10 minutes to kill them in large numbers.

Canning is done by putting cleaned dressed and cut fish into a saline solution. The cans holding the fish and the saline are then double seamed under vacuum. Thereafter, sterilization of cans takes place at 121ºC for 90min under steam pressure. Sterilization is followed by cooling of the cans under room temperature by running water.

29.3.6 Drying

Drying involves dehydration i.e. the removal of moisture contents of fish, so that the bacterial decomposition or enzymic autolysis does not occur. When moisture contents reduce upto 10%, the fishes are not spoiled provided they are stored in dry conditions. Fish drying is achieved either naturally or by artificial means. In natural drying the fishes after being caught are washed and dried in the sunshine. In artificial drying the killed fishes are cleaned, gutted and have their heads removed. They are then cut lengthwise to remove large parts of their spinal column, followed by washing and drying them mechanically.

29.4 Value Added Fisheries Products

Value addition is one of the most practical ways to increase the profitability in fish processing and sale in domestic as well as international markets. It is also becoming a market requirement as the wholesale traders, retail outlets and finally the consumers are on the lookout for fish products that require minimum preparation.

Some of the value added fish products are **Fish sausages, Fish fillets, Fish cutlets, dehydrated fish products, Fish pickles, Fish flakes/wafers, Fish noodles**. Some are described below.

29.4.1 Fish sausages

Fish sausage is the ground fish meat with various ingredients (additives) like salt, sugar, starch, spices, fat, chemicals, etc., packed in a synthetic casing, properly sealed, boiled and cooled product. In other words fish sausage is a ready to eat proteinacious food which is heat processed.

29.4.1.1 Recipe

Ingredients	Percentage
1. Minced fish meat	70.0%
2. Salt	2.0%
3. Sugar	1.5%
4. Polyphosphate	2.0%
5. Spices	1.0%
a) Coriander	0.3%
b) Chilli powder	0.3%
c) Pepper	0.2%
d) Garlic	0.1%
e) Ginger	0.1%
6. Mono Sodium Glutamate	0.2%
7. Preservatives	0.2%
8. 5% colour solution	0.13%
a) 2 % of carmosine	

b) 3% of ponceau – 4R

9. Starch 9.0%

10. Cold water 10.0%

11. Fat / Vegetable Oil 5.0%

29.4.1.2 Method of preparation

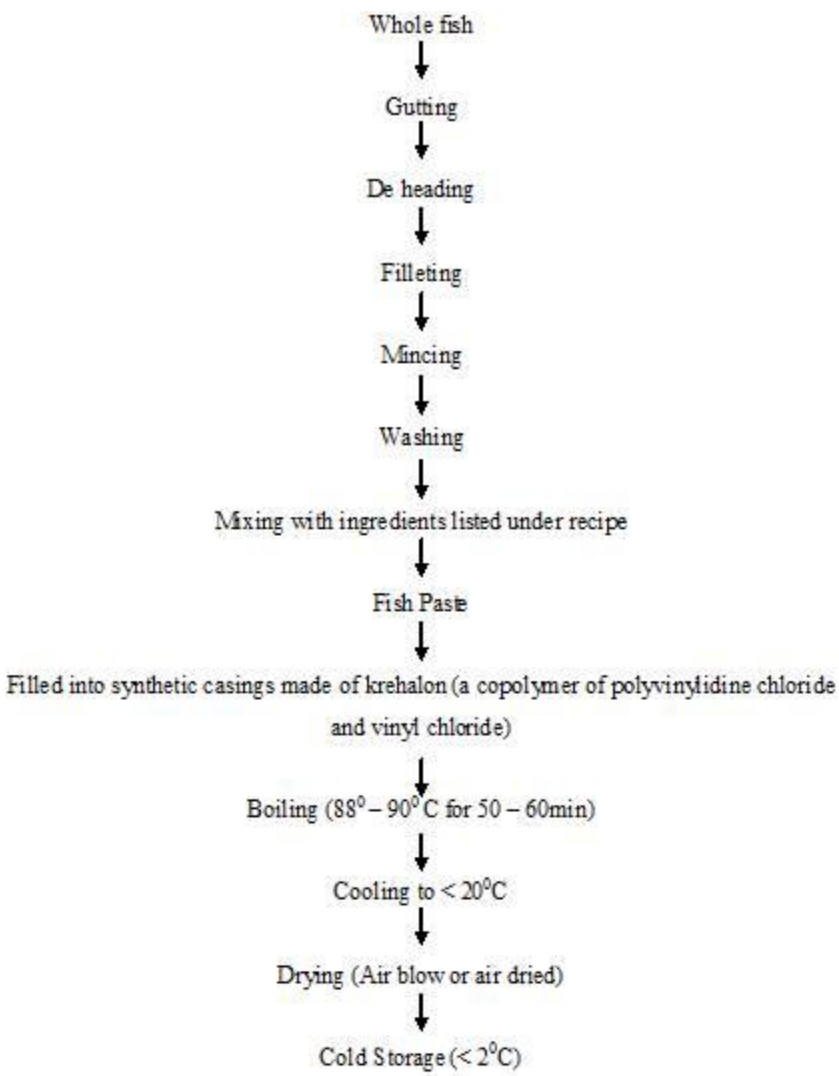

Fig. 29.1 Method of preparation

29.4.2 Dehydrated fish products

Value added dehydrated fish products available in the market are fish protein concentrate, fish soup powder, fish chutney powder etc.

29.4.3 Preparation of fish protein concentrate (FPC)

Fish protein concentrate (FPC) is collective term used for dried fish powders, which contain comparatively little fat.

Three grades of FPC available are:

1. FPC type C - fish meal (used for animal consumption).
2. FPC type B - fish meal of standard quality prepared mainly for human consumption. This has a strong taste and flavour of fish. Hence its use was restricted to countries where dried fish is common in their diet.
3. FPC type A - high quality FPC used for human consumption. Solvents are used to remove lipids. It has only 0.05 –0.75% lipid.

29.4.3.1 Method of preparation

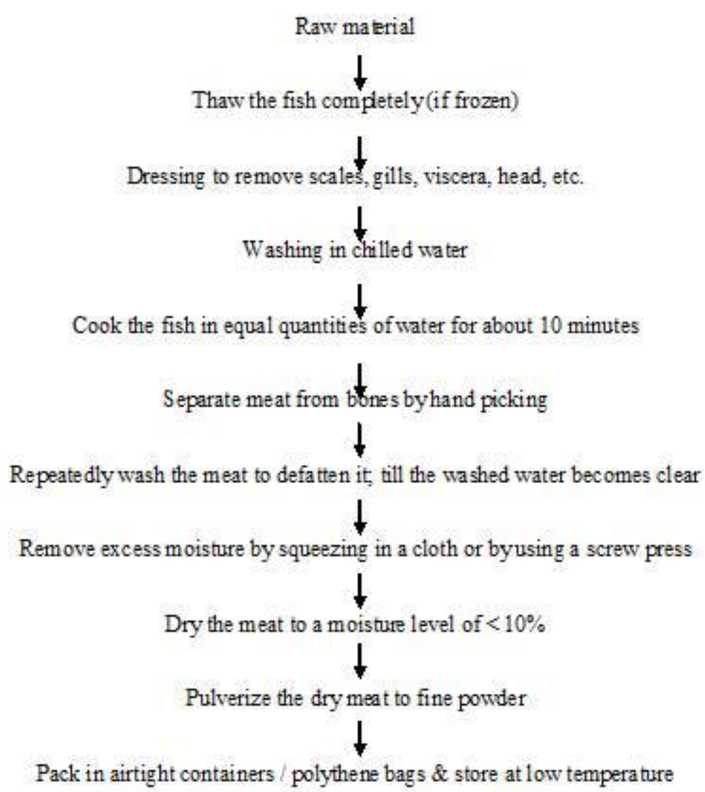

Fig. 29.2 Method of preparation

29.4.4 Preparation of fish pickle

'Pickling' is one of the safest means of preservation of fish. Pickles prepared from fish are gaining acceptance in recent days, since they add to the palatability to starch based bland tasting Asian dishes; besides being nutritious. Fish pickles are good appetizers too. At present there is an expanding export and domestic market for fish pickles.

It is prepared by cutting the edible portion of the fish into small pieces, followed by deep frying in vegetable oil and are subsequently mixed with vinegar and salt for preservation, along with fried condiments and species for flavour development. The material is then generally kept for a minimum of 24 hrs for maturing before packing. This is a traditional product of the country and is now gaining popularity.

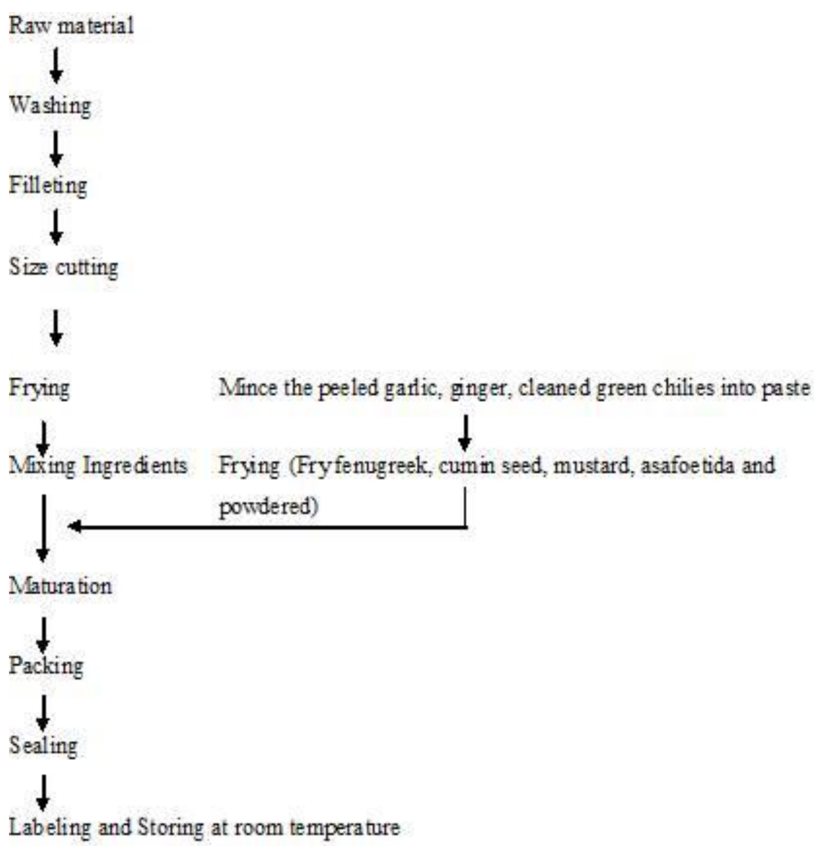

Fig. 29.3 Method of preparation

29.5 Other Value Added Fishery Products

29.5.1 Fish cakes

Tuna and mackerels are used commonly to prepare fish cakes. Fishes are cleaned and steam boiled, then separated in layers. Potatoes are boiled with salt, pepper and citric acid. Layered fish are mixed with the above mixture and packed in vacuum to prepare fish cakes.

29.5.2 Fish salads

The fishes are cleaned and pieces are boiled with steam. The boiled fish or prawns are mixed with tomatoes, salt, garlic, maida, pepper and oil to prepare fish salad. This can be used in fresh condition or can be stored.

29.5.3 Fish flakes/wafers

Thread fin breams and cat fishes are used in the preparation of flakes or wafers. Fish flesh is boiled, and then mixed with maida, salt, etc. to prepare flakes or wafers.

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