Biomass Management for Fodder & Energy

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Biomass Management for Fodder & Energy

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Module 1. Introduction to biomass resource and management

Lesson 1. Introduction to biomass management

1.1. Introduction

With serious concern globally and in India on the use of fossil fuels, it is important for India to start using renewable energy sources. India is the seventh largest country in the world spanning **328 million hectares** and amply bestowed with renewable sources of energy. Among the renewable energy sources, biomass plays a vital role especially in rural areas, as it constitutes the major energy source to majority of households in India. India produces about 450-500 million tonnes of biomass per year. Biomass provides 32% of all the primary energy use in the country at present.

1.2. Biomass

Biomass is defined as the organic matter derived from biological materials such as plants, animals, microorganisms and municipal wastes. It is a renewable form of energy as it can be replenished within a short period. It can be used as a solid fuel, or converted into liquid or gaseous forms for the production of electric power, heat, chemicals or fuels.

As per the Energy Independence and Security Act of 2007, the term "renewable biomass" means each of the following:

(i) Planted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of this sentence that is either actively managed or fallow, and non-forested.

(ii) Planted trees and tree residue from actively managed tree plantations on non-federal land cleared at any time prior to enactment of this sentence, including land belonging to an Indian tribe or an Indian individual, that is held in trust by the United States or subject to a restriction against alienation imposed by the United States.

(iii) Animal waste material and animal byproducts.

(iv) Slash and pre-commercial thinning that are from non-federal forestlands, including forestlands belonging to an Indian tribe or an Indian individual, that are held in trust by the United States or subject to a restriction against alienation imposed by the United States, but not forests or forestlands that are ecological communities with a global or State ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest.

(v) Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire.

(vi) Algae.

(vii) Separated yard waste or food waste, including recycled cooking and trap grease.

1.3. Reasons for utilizing biomass

1. Readily available and renewable
2. Non-fossil forms of fixed carbon are not depletable, in contrast to fossil fuels such as coal, oil, petroleum fuels and natural gas.
3. Biomass is available in large quantities and provides a raw material for conversion to major supplies of synthetic fuels
4. Combining waste disposal and energy recovery processes offers recycling opportunities as well as improved disposal technology, often at low cost.
5. Clean and nearly pollution free combustion
6. Energy and capital requirement for production is low

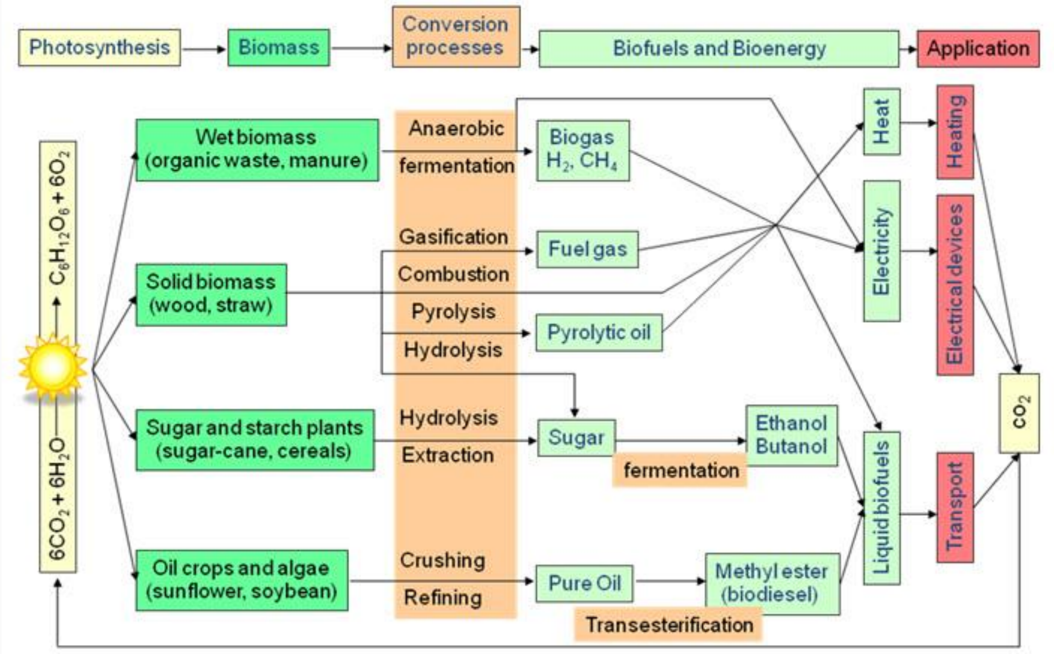
1.4. Biomass management

The biomass can be converted to useful secondary energy forms such as heat, gaseous fuels, solid fuels, organic chemical and liquid fuels. There are several alternative routes for producing useful secondary energies from biomass. Biomass conversion is surely the solution not only to reduce our dependence on fossil fuels but also to solve the problem of agricultural residues. It is important to say that biomass absorbs the same amount of CO_2 in growing that it releases when burned as a fuel in any form. This means that biomass contribution to global warming is zero.

1.5. Biomass management technologies

Biomass conversion may be carried on two broad pathways:

1. Thermo chemical conversion and
2. Biochemical conversion
3. Chemical conversion



Biomass conversion chart

1.6. Biomass characteristics

The ease and efficiency with which biomaterials can be converted to energy are largely determined by their physicochemical properties. There is no standardized method for the characterization of biomaterial with respect to its potential for conversion to energy for fuels. In the case of thermo-chemical conversion processes, proximate analysis, ultimate analysis and heating value are important parameters. In the case of biochemical conversion processes, the amount and chemical form of the carbohydrate constituents of the biomaterials are important parameters.

1.6.1. Proximate Analysis

The proximate analysis characterizes the material in terms of its moisture, volatile matter, ash, and by difference "fixed" carbon content. The proximate analysis gives the percentage of material burned in the gaseous state (volatile matter) and in the solid state (fixed carbon) as well as an indication of the amount of ash residue.

Proximate Analysis of some Biomass materials

Fuel type	Volatile matter %	Ash %	Fixed carbon %
Rice husk IR-3	68.60	17.40	14.00
Patnai-23	69.30	15.80	14.90

Padma	68.90	18.60	12.70
Arhar stalks	82.90	1.98	15.12
Pigeon pea	79.20	4.94	15.86
Cotton sticks	8140	3.30	15.30
Dhaincha stalks	82.70	2.98	14.32
Groundnut shell	83.90	4.43	11.67
Maize stalks	79.57	3.36	17.07
Maize cobes	83.01	1.83	15.16
Rice Straw	69.70	19.20	11.10
Wheat straw	73.60	8.47	17.93

1.6.2. Ultimate Analysis

The ultimate analysis involves elemental analyses for carbon, hydrogen, nitrogen, sulfur, and by difference, oxygen. The ultimate analysis is used to calculate the chemical balance of the combustion reactions as well as the quantity of combustion air and excess air required. Additionally, the ultimate analysis enables identification and quantification of the potential pollutants resulting from the thermo-conversion of fuels.

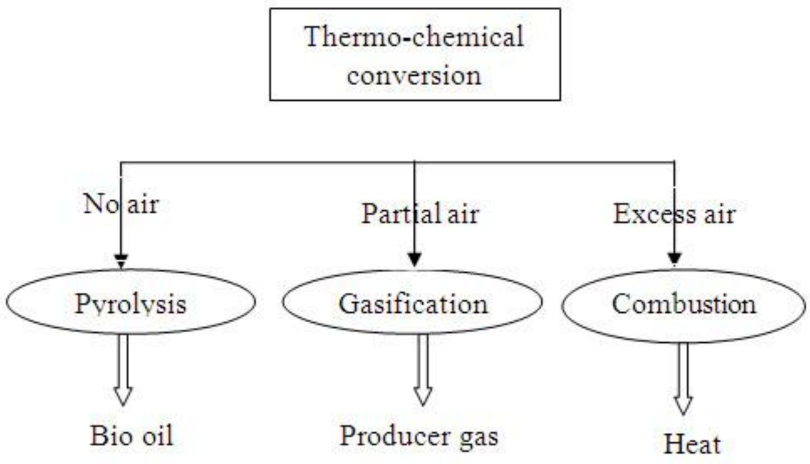
1.6.3. Heating value or energy Content

The energy content of biomass (heat of combustion) is usually determined by use of a bomb calorimeter, which measures the energy change for combustion to gaseous carbon dioxide and water vapour. This gives the "higher" or "gross" heating value of the biomass (HHV), including energy recovered from the condensation of the water.

1.7. Thermo chemical conversion technologies

Thermo-chemical conversion technologies can be utilized for energy conversion of low moisture herbaceous and woody biomass. The three routes of thermo chemical conversion of biomass are:

1. Pyrolysis
2. Gasification and
3. Combustion



1.7.1. Pyrolysis

Pyrolysis is the process of heating biomass in the absence of oxygen. The products of biomass pyrolysis are charcoal, oils and tars, water and permanent gases including methane, hydrogen, carbon-mono oxide and Carbon dioxide. The nature of the changes in pyrolysis depend on the material being pyrolyzed, the final temperature of the process and the rate at which it is heated up (slow or fast pyrolysis).

Typically the slow pyrolysis is conducted for hours to a maximum temperature of 400°C - 500°C. The charcoal yield is 35% to 40% by weight. The goal of fast pyrolysis is to produce liquid fuel (bio oil or pyrolytic oil) from biomass that can substitute for fuel oil in any application. Bio oil can also be used to produce a range of specialty and commodity chemicals. The essential features of a fast pyrolysis process are very high heating and heat transfer rates, which often require a finely ground biomass feed.

1.7.2. Combustion

Combustion is a process in which the fuel is burnt with oxygen from the air to release the stored chemical energy as heat in burners, boilers, internal combustion engines and turbines. It is the most direct process of biomass conversion into energy that can be used for a variety of applications such as cooking, process heating, power generation and cogeneration. In order to harness biomass energy to the maximum extent, it is important to understand biomass combustion. This includes understanding properties of biomass fuels and the fundamentals of numerous complex reactions associated with biomass combustion.

Combustion is a process whereby the carbon and hydrogen in the fuel react with oxygen ultimately to form carbon dioxide and water through a series of free radical reactions resulting in the liberation of heat. The overall combustion reaction can be written as

$$C_xH_yO_z + (x + 0.25y - 0.5z)O_2 \rightarrow xCO_2 + (0.5y).H_2O$$

The combustion efficiency is mainly determined by the completeness of the combustion process. The moisture content of biomass, excess air and the flame temperature plays an important role in deciding the overall efficiency of the combustion.

1.7.3. Gasification

Gasification is a thermo chemical transformation of a biomass by partial oxidation into a gaseous product. The reactions are carried out at elevated temperatures, 500-1400^{o}C, and atmospheric or elevated pressures up to 33 bar. The oxidant used can be air, pure oxygen, steam or a mixture of these gases.

Pyrolysis is only one of the steps in the conversion process. The other steps are combustion with air and reduction of the products of combustion (water vapour and carbon dioxide) into combustible gases (carbon monoxide, hydrogen, methane and some higher hydrocarbons) and inert gases (carbon dioxide and nitrogen). The end result is producer gas, having calorific value 950 -1200 kcal/m^3, which can be used in internal combustion engines with some fine dust and condensable compounds termed tar, both of which must be restricted to less than about 100 ppm each. The producer gas obtained by the process of gasification can have end use for thermal application or for mechanical /electrical power generation.

A few of the major reactions involved in gasification of biomass are:

Exothermic Reactions:

(1) $C + O_2 \rightarrow CO_2 + 393800$ kJ/kg mol (Combustion reaction)

(2) $C + 2H_2 \rightarrow CH_4 + 75000$ kJ/kg mol (Methanation reaction)

(3) $CO + H_2O \rightarrow CO_2 + H_2 + 41200$ kJ/kg mol (Water gas shift reaction)

Endothermic Reactions:

(4) $C + H_2O \rightarrow CO + H_2 - 131400$ kJ/kg mol (Water gas reaction)

(5) $C + CO_2 \rightarrow 2CO - 172600$ kJ/kg mol (Boudouard reaction)

(6) $C + 2H_2O \rightarrow CO_2 + 2H_2 - 78700$ kJ/kg mol

1.8. Biochemical conversion

The biochemical routes of conversion of biomass are essentially anaerobic digestion and fermentation.

1.8.1. Anaerobic digestion

Anaerobic digestion is a type of biochemical conversion involving the microbial digestion of biomass in the absence of air. An anaerobe is a microscopic organism that can live and grow without external oxygen or air. It extracts oxygen by decomposing the biomass at low temperatures up to 65°C, in presence of moisture (80%). It produces biogas which is a mixture of methane 55-65% and CO_2 35-45% and some impurities such as hydrogen sulphide in traces. The gas can be burned directly or upgraded to superior fuel gas (methane) by removing the CO_2 and impurities. The residue of the anaerobic digestion may consist of protein-rich sludge and liquid effluents. These can be used as animal feed or for soil treatment after certain processing.

In general, one kg of dry organic material will produce 0.036 m^3 of methane (at standard temperature and pressure) or 36 m^3 biogas/1000 kg biomass. The sizes of anaerobic digestion plants vary from 0.5 m^3/ day to 2000 m^3/day. In India anaerobic digestion plants are commonly known as biogas plants or gobar gas plants. In such plants slurry of cow dung and water is fed to the digester and is allowed to ferment for a few weeks. The biogas is released. The gas is being used in villages for cooking, lighting, running diesel engines and fuel for furnaces etc.

Anaerobic digestion technologies are being widened for using feedstocks such as

urban (municipal) waste, agricultural biomass (straw of rice, wheat, sugar cane bagasse etc.), forest biomass (trees, leaves), aquatic biomass (algae, water-plants) and human and animal excreta.

1.8.2. Fermentation

The fermentation is a process of decomposition of organic matter by microorganisms especially bacteria and. yeasts. Examples of fermentation include decomposition of grains, sugar to form ethyl alcohol (ethanol) and carbon dioxide by yeast (in making of wine) and ethyl alcohol forming acetic acid (in making vinegar). About 15% of ethanol produced in the world is through fermentation of grains and molasses.

Ethanol (Ethyl Alcohol) can be blended with gasoline (petrol) to produce gasohol (90% petrol and 10% ethanol). Processes have been developed to produce various fuels from various types of fermentations. Ethanol fermentation of biomass occurs at 20 to 30°C. The process takes about 50 hours. Yield is about 90% liquid. This contains about 10 to 20% of alcohol depending upon the tolerance of yeast to alcohol. Concentration of alcohol is increased by distillation.

OBJECTIVE TYPEQUESTIONS

1. Organic matter derived from biological material is called____________
2. The ultimate analysis involves_________________analysis
3. The process of heating biomass in the absence of oxygen______
4. Theprocessinwhichthefuelisburntinpresenceofoxygenfromtheairtoreleasethest oredchemical energy as heat is called__________________
5. Thermochemicaltransformationofabiomassbypartialoxidationintoagaseouspro ductis called____
6. The end product of gasification is ________________
7. Calorific value of producer gas is in the range of_______kcal/m^3
8. Biochemicalconversioninvolvingthemicrobialdigestionofbiomassintheabsenceof air is _______________________
9. At standardtemperatureandpressure,1kg of dry organic material will produce ____________$m^3$of methane
10. Gas produced during an aerobic digestion of biomass is _____
11. Methane content of biogas is__________%
12. Themixtureof90%petrol and 10%ethanol is known as____
13. The process of conversion of sugar to bio ethanol by microorganisms is called

 ____

14. Ethanolfermentationofbiomassoccurs at________°C
15. HHVrefers to ______________________________
16. Ethanolcan beblendedwith gasoline to produce___________
17. Theenergycontentofbiomass(heatofcombustion)isusuallydeterminedbyuseofa ____________________
18. The______________analysis characterizes the material in terms of its moisture, volatile matter, ash, and fixed carbon content.
19. The goal of fast pyrolysis is to produce__________________from biomass
20. The charcoal yield of pyrolysis is_______by weight.

QUESTIONS

1. What do you mean by the term biomass. What are the reasons for utilizing biomass.
2. Draw the flowchart depicting the biomass conversion technologies.
3. Explain the thermo-chemical conversion technologies of biomass.
4. Differentiate Pyrolysis and gasification.
5. Write down the major reactions involved in gasification of biomass

ANSWERSFOR OBJECTIVE TYPEQUESTIONS

1. Biomass
2. Elemental
3. Pyrolysis
4. Combustion
5. Gasification
6. Producerga7. 950 -1200
7. 8.Anaerobicdn
8. 0.036
9. 10.Biogas
10. 55-65
11. Gasohol
12. Fermentation
13. 20 to 30
14. HigherHeating Value
15. Gasohol
16. bomb calorimeter
17. proximate
18. bio oil or pyrolyticoil
19. 20.35 to 40%

Lesson 2. Biomass resource assessment management techniques/supply chains

2.1. Introduction

Biomass can be categorized broadly as woody, non-woody and animal wastes. Woody biomass comprises of forests, agro industrial plantations, bush trees, urban trees and farm trees. Wood, bark, branches and leaves constitute the above ground woody biomass. Woody biomass is generally a high valued commodity and has diverse use such as timber, raw material for pulp and paper, pencil and matchstick industries, and cooking fuel. Non-woody biomass comprises of crop residues like straw, leaves and plant stems (agro wastes), processing residues like saw dust, bagasse, nutshells and husks, and domestic wastes such as food, rubbish, sewage. They are harvested at the village level and are essentially used either as fodder or cooking fuel. Animal wastes constitute the wastes from the animal husbandry.

2.2. Biomass resource assessment

Assessment of available biomass resources is helpful in revealing its status and helps in taking conservation measures and ensures a sustained supply to meet the energy demand. Assessment of bioenergy potential can be theoretical, technical or economic. Natural conditions that favor the growth of biomass determine the theoretical potential. Technical potential depends on the available technologies that can be exploited for the conversion of biomass to more flexible forms and so is subjected to change with time. Of all the three potential estimates, the economic potential is subjected to high variability, as economic conditions fluctuate drastically over space and time.

2.3. Elements of an Assessment or Feasibility Study

<u>End-Use Market</u>

- Energy requirements (type of energy/fuel, quantities, projections...)
- Utilization pattern
- Distribution system
- By-products of bio-energy
- Competing energy sources (type, cost...)

<u>Resources</u>

- Biomass feedstock (nature, characteristics, production schedules, cost,)
- Land
- Water
- Others
- Present resources utilization

<u>Conversion Technologies</u>

- Selection of technology(s)
- State of development
- Availability and cost of equipment
- Maintenance and repair requirements
- Labor requirements

Environmental Factors

- Land and water impacts
- Air pollution
- Health hazards
- Safety hazards

Social Factors

- Regulatory aspects
- Employment (regional, national...)
- Training and skills
- Relation to development plans

Financing

- Options
- Financial analysis
- Comparison between bio-energy alternatives and competing sources of energy
- Risk and sensitivity

Economic Analysis

- Cost/benefits to region/nation
- Comparison of alternatives and
- Sensitivity to external factors

Recommendations

- Selection of a technology plan for implementation

2.4. Objectives of biomass resource assessment

- To identify the surplus biomass availability for power generation through the availability (biomass resource status) and consumption
- To analyze available technologies that can be exploited for the conversion of biomass
- Techno-economic analysis of feasible bio-energy technologies

2.5. Methodology

Data pertaining to the biomass availability in a particular village has to be collected by personal interaction with the local farmers and households.

2.5.1. Village Information

Information including the name of the village, list of the families in a village, geographical area, land details, agricultural activities, biomass generation and consumption, forest land details and livestock resources available are to be collected through village level survey.

2.5.2. Biomass resource status

Biomass resource status assessment is based on compilation and computation of biomass resource supply and sector wise bio-energy requirement. Bio-resource supply is based primarily on land use/ cropping pattern (agriculture and horticulture), plantation and forest biomass collection / productivities, live stock availability and the animal waste available. Sector wise biomass consumption/ requirement is computed based on the availability and the needs of the villagers.

2.5.2.1. Biomass resource from agricultural and residues

The cultivated area and the biomass yield of each crop for biomass potential from agriculture residues was collected from village. The yield of a crop and agro residues production across an area was obtained by averaging the yields of the previous years. Portion of the residues available are used as fuel, while some is used as fodder and the rest is left behind in the field for nutrient recycling. Apart from this, the actual availability of residues as energy supplements would also depend on other factors like efficiency of collection, mode of transportation and storage.

Bio-energy from agriculture residues (kcal) = Total agro residue production – consumption

2.5.2.2. Biomass resource from forestry

The biomass potential of the forests is dependent on the type of forest and its distribution cover. The biomass production varies with the type of forest. The forest wood fuel collected annually by the household from the adjoining forest area was taken with the energy equivalent.

Bio-energy from forest = Annual wood collected – consumption of wood in household activities

2.5.2.3. Biomass resource from live stock (animals)

The livestock population of cattle, buffalo, sheep and goat were collected from the personal interaction with the respondent. It was taken as 12-15 kg/animal/day for buffalo, 3-7.5 kg/animal/day for cattle, 0.1 kg/animal/day for sheep and goat. The total dung produced annually was calculated by multiplication of the animal dung production per year and the number of head of different animals. Assuming 0.036 m^3 – 0.042 m^3 of average 0.30 m^3 biogas yields per kg of cattle/buffalo dung, the total quantity of gas available was estimated.

Total bio-energy from livestock = Total cow dung collection- direct dung consumption through cake

2.5.2.4. Total biomass / bio-resources availability (surplus)

Total bio-resources available from various sector is computed by aggregating the energy computed from individual sectors.

Bio resources availability = Σ All above Bio-resources

2.5.3. Energy Consumption

The energy consumption pattern of the village such as use of energy in houses, irrigation pumping system, village lighting system, use of diesel tractor and allied machineries and use of petrol for two wheelers are to be computed using the village information study.

2.6. Technologies available for the conversion of biomass

Many technologies and options are available for generation of power from biomass. The options can be mainly classified as:

1. Combustion route, where there is direct combustion of biomass fuel such as wood wastes, bagasse, briquettes etc. in a boiler and power generation by expanding the steam in a steam turbine. For fuel particles of below 6mm in size, bubbling fluid bed combustion and circulating fluid bed combustion are some of the technologies used in the combustion route systems.
2. Gasification route, where biomass is gasified and power generated in a gas turbine or internal combustion engine. Fixed bed gasifiers like updraft, downdraft and cross draft gasifiers are available for power generation, each with its own advantages over the other technology.
3. Biochemical conversion routes viz., anaerobic digestion and fermentation, where microorganisms convert chemical energy in solid biomass material into an energy carrier, often with high efficiency relative to thermochemical conversion.

To help the entrepreneurs, TamilNadu Energy Development Agency (TEDA) has completed Biomass Resource Assessment Studies in 49 Taluks which assessed the potential of surplus biomass waste/materials to serve as a guide to private entrepreneurs willing to set up biomass based power projects, biomass gasifiers etc. Proposals were sent to MNRE, Government of India for sanction of financial assistance to conduct Biomass assessment studies in all the Districts of Tamil Nadu. Further to assist the entrepreneurs, TEDA forwards their application received after necessary scrutiny to MNRE, Government of India for the sanction and release of Government of India's financial assistance. The present installed Capacity of Biomass based Power Projects in Tamil Nadu is 116.15MW.

2.7. Techno-economic feasibility of suitable renewable energy generation system

The surplus biomass available in the particular village shall be utilized for the successful diffusion of the renewable energy technology in that village. Total crop residue and forest wood surplus in the village shall be utilized for the generation of electrical energy through gasification. The wood gasification mode of power generation is quite feasible and offers immense scope for rural development. Biogas has been promoted as an appropriate rural technology for utilization of local resources like cattle dung etc. Cooking energy accounts for about 80 percent of the total energy consumption, mainly derived from crop residue and forest wood. Fuel consumption can be reduced by employing improved stoves (20-25 percent efficient) instead of traditional wood based cooking stoves (8-10 percent efficient).

QUESTIONS

1. What do you mean by biomass and how will you categorize it?
2. Writeshortnotesonbiomassresourceassessmentandlistouttheobjectivesofbiomassresource assessment
3. Mention the elements of an assessment or feasibility study
4. Explain the methodology of biomass resource assessment
5. Write short notes on the technologies available for the conversion of biomass

Module 2. Densification Processes: Extrusion, briquetting and pelleting

Lesson 3. Processing of paddy straw, densification - extrusion process

3.1. Introduction

In the past, the principal form of biomass burned for energy was wood because of its relatively high density and availability. One of the major limitations of using biomass such as straw and woody resources like sawdust is its low bulk density, which typically ranges from 80–100 kg/m^3, cause major problem during storage, handling and transportation. One of the strategies to overcome this problem is to increase its density through densification. The process of densification, in which biomass residues such as saw dust, straw etc are compressed into pellets or briquettes promises to make other biomass forms, now wasted, equally attractive. These processes produce a fuel that has approximately three fourths of the energy of coal, both on a mass and volume basis and thus densified biomass could be called 'instant coal".

Densification enables several advantages including (i) improved handling and conveyance efficiencies throughout the supply system and biorefinery in feed, (ii) controlled particle size distribution for improved feedstock uniformity and density (iii) fractionated structural components for improved compositional quality and (iv) conformance to pre-determined conversion technology and supply system specifications.

Densification of paddy straw makes it available for commercial usage by increasing the energy content and reducing the transportation cost and storage space. The quality of the densified materials and energy required to densify them are influenced totally by the compaction process, physical characteristics and chemical composition of the biomass and process conditions. Hence, it is essential to know the physical and chemical properties of straw to understand the suitability of feed for densification.

3.2 Physical and chemical composition of paddy straw

Rice straw is composed of cellulose (about 40% of volume), hemi-cellulose (about 25% of volume) ash and other minor constituents mainly silicon dioxide (about 20% of volume) and lignin (about 15% of volume).

Proximate analysis	(% dry fuel)
Fixed carbon	15.86
Volatile matter	65.47
Ash	18.67
Ultimate analysis	**(% dry fuel)**
Carbon	38.24
Hydrogen	5.20
Oxygen	36.26
Nitrogen	0.87
Sulfur	0.18
Chlorine	0.58
Ash	18.67
Higher heating Value	15.09 MJ/kg

3.3. Process of densification

The densification of biomass may be defined as compression or compaction to remove inter and intra particle voids. It involves compression, deformation and self bonding between adjacent particles of biomass. The mechanical energy of the drive screw is converted into heat by means of friction and shear as the granular material is compressed and forced through an orifice. When heated above the plastic temperature range (165°C for wood), the agricultural wastes loose their elasticity and are relatively easily compressed, particle surfaces come into intimate contact and the thermally softened lignin and other phenolics allow the creation of adhesion between adjacent particles. Moisture plays an important role in densification. It may help in heat transfer and in enhancing the plasticity of the material. If the feedstock is either too dry or too wet, pressures required for densification increase drastically.

3.4. Preprocessing of Biomass

3.4.1. Grinding

Prior to densification, the biomass is ground to a certain particle size. This grinding partially breaks down the lignin, increases the specific area of the material and improves binding. Fine powders have more contact points, exposed surface area and surface energy per unit weight regardless of their physical and chemical characteristics.

3.4.2. Preheating

Preheating the biomass before densification is common because it results in a better quality product. Most commercial pellet or briquette producers use preheating to form stable and dense pellets or briquettes. Preheating biomass could significantly increase the throughput of the

pelletizing machine and reduce the energy requirement per kilogram of pellets formed.

3.4.3. Steam Conditioning and Explosion

Steam explosion is a technique that has been widely used and is an efficient method of pretreating lignocellulosic biomass prior to densification. In the steam explosion process, biomass is introduced into a reactor and heated under steam pressure for a short time producing significant physical, chemical, and structural changes and making more lignin sites available for binding during pelletization.

3.4.4. Torrefaction

Torrefaction is a method to improve the properties of the biomass for energy conversion. Torrefaction is a slow heating of biomass in an inert or reduced environment to a maximum temperature of 300°C. Thus, the process can also be called a mild pyrolysis as it occurs at the lower end in terms of temperature of the pyrolysis process. The treatment yields a solid uniform product with lower moisture content and higher energy content compared to raw biomass. The torrefaction process opens up a number of lignin active sites by breaking down the hemicelluloses matrix and forming fatty unsaturated structures that help in binding.

3.5. Various process of densification

The various processes being adopted for densification of biomass are:

1. Bailing
2. Extrusion
3. Pelleting
4. Briquetting
5. Cubing

3.5.1. Bailing

Compression bailing and roll- compression can reduce biomass volume to one fifth of its loose bulk. These processes are useful for agricultural residues like straw and certain type of forest biomass (energy plantation crops and logging residues).

3.5.2. Extrusion

During screw extrusion, the biomass material moves from the feed port through the barrel and compacts against a die with the help of a pressure building rotating screw. This process also causes friction from the shearing of biomass. The wall friction at the barrel, internal friction in the material and high rotational speeds (600 rpm) of the screw causes an increase in temperature of the biomass. This heated biomass when forced through the extrusion die forms briquettes or pellets with the required shape. If the die is tapered the biomass gets more compacted. If the heat generated within the system is not sufficient for the material to reach a pseudo plastic state for smooth extrusion, heat can be provided to the extruders from outside the system using either band or tape heaters.

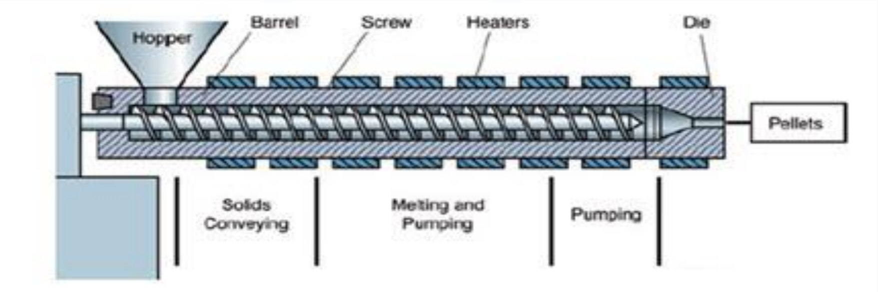


Fig. Extruder

Processing of biomass using screw extruder occurs in following stages:

1. Before reaching the solids conveying zone (a zone usually formed by tapering the barrel), the biomass gets partially compressed by the screw. This leads to closer packing and increased density. Energy is dissipated to overcome particle friction.

2. Once the biomass is in compression zone (melting and pumping zone), the material becomes relatively soft due to high temperatures (200–250°C) and the material loses its elastic nature, resulting in an increased area of inter-particle contact and local bridging. When the

particles come together they form local bridges which selectively support and dissipate the applied pressure. Interlocking of particles may also occur. The moisture gets evaporated to steam at this stage and helps in moistening the biomass.

3. When the biomass enters the tapering die (pumping zone), biomass gets further compressed due to the temperature of about 280 °C. In this section, removal of steam and compaction take place simultaneously. The pressure exerted transmits throughout the material giving uniform pressure, and therefore, uniform density throughout the briquette.

In the compression zone, the occluded air is pushed back to the feed section and thermal conductivity is improved due to compaction. During its passage through the compression zone the biomass absorbs energy from friction so that it may be heated and mixed uniformly through its mass. Brittleness, plasticity, and abrasivity are some of the important factors for pressure compaction.

The speed of densification determines the relative importance of the various binding mechanisms. The aim of compaction is to bring the smaller particles closer so that the forces acting between them become stronger which subsequenly provides more strength to the densified bulk material. The product should have sufficient strength to withstand rough handling. If uniform pressure is not applied throughout the entire volume of the material, it causes variations in compact density in the product.

3.5.3. Pellet mills

The process of pelleting involves the densification of agricultural residues like straws by means of a pellet mill or pelletizer. The pellet mill employs a hard steel die which is perforated frequently placed holes of 1.0 to 1.3 cm in diameter. By rotating the die or rollers, the feedstock is forced through the perforations to form densified pellets with a pressure of 700 kg/cm^2. As the straw is extruded through the die, smalle dense pellets are broken off at the specified length.

Fig. Pellet die

Prior to pelleting, the straw is chopped and hammered to the required size and then steam conditioned to 60 to 82^{o}C in a steam conditioner. Most mills have one or more steam conditioning units mounted above the main unit. The steam softens the feed and partially gelatinizes the starch to create more durable pellets.

When the ground material is introduced into the housing, the rollers press the material against the die opening and pellets are extruded through the die holes in a step wise fashion. A knife attached to the outside housing cut the extruded material to the required length.

OBJECTIVE TYPEQUESTIONS

1. Theprocessbywhichbiomassresiduesarecompressedintopelletsorbriquettesis called

   ____

2. The slow heating of biomass in an inert or reduced environment to a maximum temperature of 300°C is called______.
3. Grinding increases the______________of the material
4. Torre faction process is also called as___________
5. Compression bailing and roll-compression can reduce biomass volume to of its loose bulk.

QUESTIONS

1. What are the advantages of densification
2. Explain the process of densification
3. Detail the various processes adopted for densification of biomass
4. Discuss about the stages of biomass processing using screw extruder
5. Mention the physical and chemical composition of paddy straw
6. Explain the working principle of pellet mill

Lesson 4. Briquettes and cubes

4.1. Introduction

Briquetting is the process of densification of biomass to produce homogeneous, uniformly sized solid pieces of high bulk density which can be conveniently used as a fuel. In this process, the raw material is pressed together at an elevated temperature and forced through an orifice. In a pure briquetting process, the pressure and temperature make the material bond with the help of its own lignin which acts as a binder. In some process utilizing a lower pressure or a lignin poor raw material, a separate binding material may be added.

4.2. Advantages of briquettes

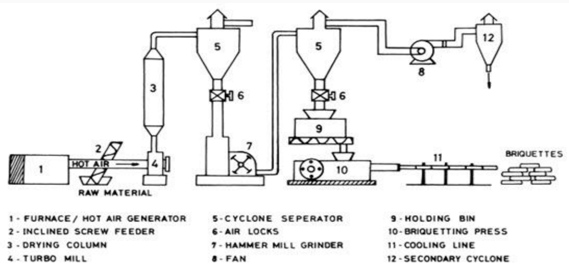
- better feed handling characteristics
- higher calorific value
- improved combustion characteristics
- reduced particulate emissions
- more uniform size

4.3. Binder less technologies

The compaction of loose biomass without any binding material is done using the technologies described below.

4.3.1. Die and punch technology

The piston presses are also known as ram and die technology. In this case the biomass is punched into a die by a reciprocating ram with a very high pressure thereby compressing the mass to obtain a briquette. The briquette produced is 60 mm in external diameter. This machine has a 700 kg/hr capacity and the power requirement is 25 kW. The ram moves approximately 270 times per minute in this process. Since the mechanical press is electric driven and not hydraulic driven, energy losses are reduced and throughput efficiency is increased.



The merits and demerits of piston press briquetting machine are:

- There is less relative motion between the ram and the biomass hence, the wear of the ram is considerably reduced.
- It is the most cost-effective technology currently offered by the Indian market.
- Some operational experience has now been gained using different types of biomass.
- The moisture content of the raw material should be less than 12% for the best results.
- The quality of the briquettes goes down with an increase in production for the same
- power.
- Carbonisation of the outer layer is not possible. Briquettes are somewhat brittle.

4.3.2. Screw technology

In this process, the biomass is extruded continuously by one or more screws through a taper die which is heated externally to reduce the friction. Here also, due to the application of high pressures, the temperature rises fluidizing the lignin present in the biomass which acts as a binder. The outer surface of the briquettes obtained through this process is carbonized and has a hole in the centre which promotes better combustion. Standard size of the briquette is 60 mm diameter.

The main merits and demerits of this technology are:

- The output from the machine is continuous and not in strokes, and is also uniform in size.
- The bulk density is higher (1500 kg/m^3 against 1200 kg/ m^3 for the die & punch technology).
- The outer surface of the briquette is carbonized facilitating easy ignition and combustion and also provides an impervious layer for protection against moisture ingress.
- The central core of the briquette is hollow which provides a passage for supplying the air necessary for combustion.
- The machine runs very smoothly with no shock loads.
- The machine is very light due to the absence of reciprocating parts and flywheel.
- There is no alternate suction and pressurization of machine thereby reducing the possibility of dust collection in the machine.

- The power consumed by this equipment is very high.
- The wear rate of the screw is very high.
- There is a limitation on the raw material that can be compacted.

The three types of screw presses used for briquetting are:

(i) conical screw press

(ii) screw press with heated die and

(iii) twin screw press.

4.3.2.1. Conical Screw Press

The raw material is compressed by a conical screw. The screw forces the material into the compression chamber. A rotating die head extrudes the material through a perforated matrix to produce briquettes of diameter about 2.5 cm. A knife cuts the densified product to a specified length. The conical screw press can also be used to produce briquettes with diameters of about 10 cm by using a single-die matrix.

4.3.2.2. Screw Press with Heated Die

The material is forced by a screw, having no taper or a small taper, through a die heated, usually electrically, from outside. The die has a number of ridges which serve to prevent the densified material from rotating with the screw. The briquettes are 5-10 cm in diameter. The die temperature is normally maintained at about 300^{o}C. The raw material gets heated up to about 200^{o}C during the process, most of the heating being caused by friction. The briquettes often get partially pyrolyzed at the surface, which causes quite a lot of smoking during briquetting. The design of the screw results in the formation of a central circular hole in the briquette, which acts as an escape route for steam formed during briquetting.

4.3.2.3. Twin Screw Press

In a twin screw two adjacent gripping shafts fitted with screw parts with varying leads, rotate closely and opposed to each other in "8" shaped casings. These casings are constructed as pressure casing boxes with cooling or heating section, as well as partly open sections with steam exhausts. Due to high pressure and friction, the temperature of the raw material could rise up to 250^{o}C. The steam produced during densification is extracted by steam removal units. The briquette is extruded axially. In this press raw material having a particle size 30-80 mm and moisture content up to 25% can be densified without pre-drying.

4.3.3. Comparison of a prison press and a screw extruder

	Piston press	Screw extruder
Optimum moisture content of raw material	10–15%	8–9%
Wear of contact parts	Low	High
Output from the machine	In strokes	Continuous
Power consumption	50 kWh/ton	60 kWh/ton
Density of briquette	1–1.2 gm/cm^3	1–1.4 gm/cm^3
Maintenance	High	Low
Combustion performance of briquettes	Not so good	Very good
Carbonization to charcoal	Not possible	Makes good charcoal
Suitability in gasifiers	Not suitable	Suitable
Homogeneity of briquettes	Non-homogeneous	Homogeneous

4.3.4. Hydraulic press based technology

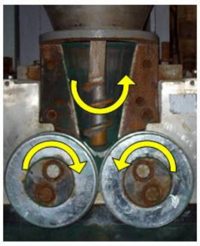
This process consists of first compacting the biomass in the vertical direction and then again in the horizontal direction. The standard briquette weight is 5 kg and its dimensions and 450 mm x 160 mm x 80 mm. The power required is 37 kW for 1800 kg/h of briquetting. This technology can accept raw material with moisture content up to 22%. The process of oil hydraulics allows a speed of 7 cycles/minute against 270 cycles/minute for the die and punch process. The slowness of operation helps to reduce the wear rate of the parts. Further, the relative movement of the material within the die is only for a limited length. The wear and tear of the machine will be lower than those currently available machines in the Indian market.

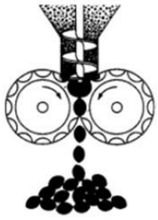
The merits/demerits of this technology are as follows:

- This technology can be used to compress any type of agro waste.
- Raw material with moisture content up to 22% can be briquetted.
- The power consumption is less compared to existing contemporary technologies.
- The output of the machine is uniform.
- The wear and tear of equipment will be less.
- The cost of the machine is high.
- The operational results are yet to be made available for Indian raw material.

4.3.5. Roller Press

Densification of biomass using a roller press works on the principle of pressure and agglomeration, where pressure is applied between two counter rotating rollers. The granular biomass, when forced through the gap between the two rollers, rotates with the rolls and is pressed in small dies or pockets. The rotation of the rollers causes the feed to be drawn in from one side and ejected from the other in the densified form. The final shape of the densified biomass depends on the type of die used. Design parameters, which play a major role on the quality of the biomass, are the diameter of the rollers, minimum gap size, roll force and shape of the die.





4.4. Cubes

The cubes can be made in a variety of densities and are extremely durable, stable and highly resistant to disintegration or breakage under normal conditions. Once in cube form, the densified organic material can be rapidly loaded with bulk loading and handling equipment for eventual storage, transport and consumption. Cubes might be suitable for use as industrial fuels.

The cuber die ring and press roller are similar to the die ring of a pelleter. An auger moves the chopped biomass uniformly toward the openings in the die ring. As the material leaves the auger flight, the heavy press wheel forces the feed through the die openings in the ring. The pressures in a cuber range from 24 to 34 MPa. The natural binders in chopped biomass, the high pressure of the press wheel, and heat generated by forcing biomass through dies help bond the cubes. An adjustable deflector around the outside of the die ring breaks the cubes in lengths of 50 to 75 mm. Cubing operators often find it necessary to add a binder to increase cube durability.

4.5. Binders used in biomass densification

Binders improve the cohesive characteristic of biomass by forming a gel with water, helping produce a more durable product. Binders also help reduce the wear on production equipment and increase the abrasion resistance of the fuel. In general, binders are allowed in a fuel feedstock but need to be specified as part of the final product. The most commonly used binders in pellet making are lignosulphonates (Wafolin), or sulfonate salts made from the lignin in pulp mill liquors. Lignosulfonates, considered the most effective binders, are used in animal feeds. The general quantity to include for effective binding ranges from 1–3%. Bentonite, or colloidal clay, is commonly used as a binder in feed pelleting and is made up of aluminum silicate composed of montmorillonite. As mentioned previously, proteins are natural binders that are activated through interactions with other biomass compositions, such as lipids and starches, and the heat produced in the dies. Some agricultural biomass, like alfalfa, has high protein content and can be used as a binder to improve the durability of pellets made from lower lignin content biomass materials.

4.6. Densification System Variables

Controlling the densification system variables is key for achieving the desired densified biomass quality. Specifically, the quality of the densified product can be managed by controlling conditions such the manufacturing process, changes in formulation, and the use of additives. In addition, process variables such as die thickness, die temperature, pressure, retention time, roller die ring gap, steam conditioning and feed rate affect the quality of densified biomass like density and durability. Feedstock variables (moisture content and particle size and shape) and feedstock composition (protein, fat, cellulose, hemicelluloses and lignin) also impact the quality of the densified biomass.

4.6.1. Moisture content

Moisture content plays an important role on pellet formation. Moisture in the biomass facilitates starch gelatinization, protein unfolding, and fiber solubilization processes during densification. Steam-treated biomass is superior to raw biomass because the additional heat modifies the physiochemical properties to the extent that binding between particles is enhanced, resulting in improved densification quality The effect of biomass moisture content on densification can be three-fold: (i) lowers the glass transition temperature; (ii) promotes solid bridge formation; and (iii) increases the contact area of particles by van der Waal's forces.

4.6.2. Particle size, shape, and distribution

In general, the density and durability of pellets is inversely proportional to the particle size because smaller particles have greater surface area during densification. However, very small particles can lead to jamming of pellet mills and affect production capacity. In the case of briquette presses, bigger particles sizes (>6 mm) are desirable, leading to better interlocking of the particles and increasing the durability.

4.6.3. Feedstock composition

Feedstock composition contributes significantly to the quality of densified materials. Raw biomass has both low molecular weight and macromolecular compositions. Low molecular weight substances include organic and inorganic matter, while macromolecular substances include cellulose, hemi-cellulose, and lignin Wood is shown to have higher lignin content than other biomass materials, and straws are shown to have a certain percentage of protein content, both of which can promote binding.

- Starch is a D-glucose polymer with branched (amylopectin) or unbranched (amylose) chains. Its behavior is mainly controlled by the gelatinization it undergoes at high processing temperatures. Starch granules at high temperatures and moistures influence the binding properties of many foods and feeds. Gelatinization of starch is an irreversible process and influenced by densification process variables like heat, water, shear, and residence time. During pelletization, starch not only acts as a binder but also as a lubricating agent, helping to ease the flow of materials through the die.

- Protein that is heated during the densification process undergoes denaturization, leading to the formation of new bonds and structures with other available proteins, lipids, and starches,helping to improve the binding capacity

- Fat content in biomass acts as a lubricant during pelletization, increasing throughput, and reducing pelleting pressure. However, higher fat content can hinder binding.

- Cellulose is an organic, polysaccharide compound forms crystalline microfibrils that are surrounded by amorphous cellulose inside plant cells. Semi-crystalline structure and highly hydrogen bonded cellulose itself is not a suitable adhesive, but this limitation can be overcome by heat treatment in the drying range, making the cellulose molecule more flexible.

- Lignin helps in building solid bridges at elevated temperatures and plays a signifi cant role in biomass densification. It is, in general, believed that highly lignified wood is more durable and therefore a good raw material for many applications. It is also an excellent fuel, because lignin yields more energy when burned than cellulose. The presence of lignin in plant materials allows pelletization without adding binders.

- Hemicellulose is any of several heteropolymers (matrix polysaccharides), such as arabinoxylans, present along with cellulose in almost all plant cell walls. Some researchers believe that natural bonding may occur due to the adhesive products produced by degradation of hemicelluloses

QUESTIONS

1. What are the advantages of briquettes?
2. What are the merits and demerits of piston press briquetting machine?
3. What are the merits and demerits of screw press briquetting technology?
4. Differentiate piston press and screw press briquetting technology
5. What are the merits and demerits of hydraulic press based technology?
6. Explain the working of hydraulic press based technology
7. Explain how a piston press briquetting machine works?
8. Mention the binders used in biomass densification
9. Discuss about the variables which affect the densification process
10. Explain the working of roller press with a neat schematic diagram.

Module 3. Bailing, surface mulch and soil incorporation

Lesson 5. Baling-classification, uses

5.1. Introduction

Off-field utilization of rice straw and other crop residues continues to attract increasing attention due to concerns associated with environmental impacts from open burning for disposal. Straw makes up about 40% to 60% of the dry weight of rice plants according to the cultivar and cultivation method. For every ton of grain harvested, about 1.35 tons of rice straw remains in the field. The proportion of straw recoverable depends on the technique of reaping and harvesting (manual or mechanical) and on the condition of the field or crop (flooded or lodged). About 2.5 to 3 tons per acre of dry straw is an average net production. After combine harvesting, the straw is left on the earth in swaths. The straw should be removed as quickly as possible so that the treatment of the soil preparation can begin thereby establishing next year's crop. The only method commonly used to handle rice straw is baling. Baling is a packaging operation performed to facilitate handling, transport and storing.

Optimum moisture for baling can range from 15% to 20% depending on size of bale being made. Baling at moisture levels lower than 15% will result in greater harvesting losses because straw losses increases as moisture content decreases. On the other hand, storing straw at moisture levels greater than 20% can result in molding and heating, which translate into discoloration and greater dry matter and nutrient losses.

5.2. Baler and its classification

A baler is a machine used to compress straw into bales for easy transport and storage. Balers are divided into stationary balers, movable and field balers. They are further classified into square balers, rectangular balers and round balers according to the bale shape produced. According to density of bale, they could be high (200-350 kg/m^3), medium (100-200 kg/m^3) or low density (<100 kg/m^3) balers. Based on the power used for operation, balers are classified as pull type balers and self propelled balers. Pull type models are available with either a PTO drive or a mounted engine.

5.2.1. Stationary baler

Stationary baler was grouted at one place and the material for baling was brought to its place.

5.2.2. Movable baler

Movable baler was transportable by attaching it through single point hitch of tractor. It was installed at one place for operation after carrying it to required place.

5.2.3. Field baler

Field baler was pulled by single point hitch of tractor and operated by power from tractor PTO shaft. Three hydraulic lines of the baler were connected to the three hydraulic secondary control valve of tractor. Hydraulic power was used for positioning of baler in rear offset and to adjust the height of finger reel mechanism while operation.

Functional components of field baler

A plunger type field baler includes the following components:

1. A unit to pick up straw from the windrow and elevate it.
2. A conveyor to move the straw to the bale chamber entry
3. Packers to place the straw in the chamber while the plunger is on its retracted stroke
4. A reciprocating plunger to compress the straw and move it through the bale chamber.
5. Means for applying forces to resist the movement of straw through the bale chamber and thus control the degree of straw compression and the resultant bale density.
6. An automatic metering device for controlling the bale length.
7. A means of separating consecutive bales and placing the wires or strings around each bale
8. Automatic tying devices that operate when the bale reaches the preselected length

5.2.4. Square balers

Square balers are classified as small square baler and large square baler based on the dimension of baler. In square balers, the straw enters the baler through the pickup, and the teeth gently rake the straw from the ground to prevent the loss of leaves and ingestion of rocks or debris into the baler. Directly behind the pickup is the compressor bar, which holds the straw in place so the auger can feed it into the bale chamber. The bale chamber contains a plunger that drives in and out, each time packing and compressing straw into the desired shape. The plunger also cuts the ends of the straw to make the bale a uniform size. The chamber feeds into a spring tension section that keeps the bale tightly compressed until enough straw has been processed to complete the bale. When the correct length of bale is achieved, a mechanism wraps the bale with two lengths of twine or wire and ties it securely. The twine is carried on spools and fed through two curved needles that are timed to miss the cycle of the plunger. After the twine is in place, a gear mechanism called a knotter ties the knot and cuts the twine free of the supply spool. After it is tied, the bale is pushed down the bale chute and falls to the ground. Some balers have "kickers," or bale ejectors, which throw the bale onto a straw rack pulled behind the baler.

Most of the small square balers operate to the right side of the tractor and the wagon follows behind the baler, usually in line with the tractor. However, the large square balers operate directly behind the tractor, requiring the operator to turn around even further than is necessary for the operation of a small square baler to view their operation.

5.2.5. Rectangular balers

Similar to square balers, rectangular balers are also classified as small rectangular baler and large rectangular baler based on the dimension of baler. Small rectangular bales of conventional type made by a variety of machines have dimensions close to 0.4 x 0.6 x 1.2 m (0.3 m^3) and weighing approximately 32 kg (dry matter) each (110 kg m^{-3}). Large rectangular bales have nominal dimensions of 1.2 x 1.2 x 2.4 m (3.5 m^3) weighing approximately 600 kg (175 kg /m^3) and nominal dimensions of 0.9 x 1.2 x 2.4 m (2.6 m^3) weighing 450 kg (170 kg/m^3).

In large rectangular balers, packer fingers above a windrow pickup cylinder push the straw through a tapered feeding chute into the bale chamber. The straw is compacted by the front wall of the chamber moving about 13mm into the chamber in a reciprocating motion. A gate on the chamber outlet remains closed while the bale is being formed. When the bale reaches desired density, the operator stops the forward motion and trips the knitters. Three ties are made around the bale, using special polypropylene twines. The rear gate opens automatically when the tying cycle is completed. The tied bale is subsequently pushed out by the next bale being formed, after which the gate closes.

5.2.6. Round balers

Based on the form of working unit, round balers can be classified into long-belt type, short-belt type, chain type and roller type. They are also classified into inside winding type and outside winding type by their working principle. Long-belt and chain types are inside winding; short-belt and roller types are outside winding. According to the chamber size adjustment, balers are classified as expandable chamber round pickup baler, ground roll baler and fixed volume round pickup baler.

5.3. Baler capacities

Baler capacities depend on machine characteristics and operating factors. Some of the machine characteristics that affect the capacity of the baler are (a) the size of the bale, (b) the number of plunger strokes per minute, (c) capacity limitations of the pickup and feed mechanisms, (d) the amount of power available, and (e) the durability and reliability of the machine. Important operating factors include (a) size and uniformity of the windrows, (b) the condition of the field surface, insofar as it limits the forward speed, (c) condition of the straw, (d) the density of the bales and (e) the skill of the operator.

5.4. Uses of baling

Baling can be applied to improve the characteristics of straw for transportation and storage. The bulk density of rice straw is around 75 kg for loose straw and 100 -180 kg in packed and baled form as energy feedstock. Transport of bailed straw can be up to 50% cheaper than transportation of loosed material.

QUESTIONS

1. What are the different types of balers available?
2. Discuss about the components of rectangular balers
3. Explain the working Rectangular pick up baler with a schematic diagram
4. Classifyroundbalersandexplainexpandablechamberroundpickupbalerwithanea tdiagram.
5. Detail the operation of inside wind in ground pick-up baler with a neat sketch

Lesson 6. Residue management for surface mulch and soil incorporation

6.1. Introduction

The recycling of crop residues has the advantage of converting the surplus farm waste into useful product for meeting nutrient requirement of crops. It also maintains the soil physical and chemical condition and improves the overall ecological balance of the crop production system. However, management of the rice straw is a major challenge as it is considered to be a poor feed for the animals owing to high silica content. Rice residue management is important in rice-wheat cropping system as machines are increasingly used for harvest. Several management options available to farmers for the management of rice residues are burning, incorporation, surface retention and mulching and removing the straw. Farmers use different straw management practices as per the situation. In some areas rice and wheat yields under these practices are similar.

6.2. Residue burning

Traditionally, rice straw is removed from the fields for use as cattle feed and for other purposes in India. Recently, with the advent of mechanised harvesting, farmers have been burning in-situ large quantities of crop residues left in the field as crop residues interfere with tillage and seeding operations for the subsequent crop, causing loss of nutrients and soil organic matter. When burnt, the residues instantly generate as much as 13 tonnes of CO_2 per ha, contaminating the air and killing of beneficial soil insects and microorganisms. This practice also kills soil borne deleterious pests and pathogens. One of the advantages of burning is that it clears the land quickly of residues before the next crop is established, thus facilitating seed germination and establishment. So there is a need to adopt ways and means to manage this valuable resource.

Nutrient content of rice straw and amounts removed with 1 tonne of straw residue

	N	P_2O_5	K_2O	S	Si
Content in straw, % dry matter	0.5-0.8	0.16-0.27	1.4-2.0	0.05-0.10	4-7
Removal with 1 tonne straw, kg/ha	5-8	1.6-2.7	14-20	0.5-1.0	40-70

6.3. Surface retention and mulching

Direct drilling in surface mulched residues is a practice that leaves straw residues from a previous crop on the soil surface without any form of incorporation. Surface retention of residues helps in protecting the fertile surface soil against wind and water erosion. The large volume of residues remaining on the surface often leads to machinery failures, thus affecting sowing of seeds of the following crop. Farmers usually follow this method where no till or conservation tillage practices are prevalent.

Surface retention of some or all of the residues may be the best option in many situations. Residues decompose slowly on the surface, increasing the organic carbon and total nitrogen in the top 5-15 cm of soil, while protecting the surface soil from erosion. Retention of residues on the surface increased soil nitrate concentration by 46%, nitrogen uptake by 29% and yield by 37% compared to burning. Retention, however, provides habitat for both harmful as well as useful organisms in one hand and also it provides carbon substrate for heterotrophic nitrogen fixation, increase microbial activity, soil carbon and nitrogen and reduce fertilizer nitrogen requirements for rice. The faster decomposition and release of nitrogen to soil is possible if it is treated with urea and applied during field preparation.

6.4. Straw incorporation

Crop residues may be incorporated partially or completely into the soil depending upon methods of cultivation. Ploughing is the most efficient residue incorporation method. Incorporation of the remaining stubble and straw into the soil returns most of the nutrients and helps to conserve soil nutrient reserves in the long term. Short-term effects on grain yield are often small (compared with straw removal or burning) but long-term benefits are significant. Where mineral fertilizers are used and straw is incorporated, reserves of soil N, P, K, and Si are maintained and may even be increased. Incorporation of straw and stubble into wet soil results in temporary immobilization of N and a significant increase in methane emission from rice paddy, a practice that contributes to greenhouse gases. Incorporation of large amounts of fresh straw is either labour-intensive or requires suitable machinery for land preparation and may result in the build-up of disease problems. Transplanting should be carried out two to three weeks after straw incorporation.

Recent research results from experimental farms indicate that early, dry shallow tillage at 5 to 10 cm depths to incorporate crop residues and enhance soil aeration during fallow periods has beneficial effects on soil fertility in intensive rice-rice systems. Shallow tillage of dry soil should be carried out up to two to three weeks after harvest in cropping systems where the dry-moist fallow period between two crops is at least 30 days.

Beneficial effects include:

- A more complete carbon turnover is achieved by aerobic decomposition of crop residues (about 50 percent of the C within 30 to 40 days), thereby minimizing negative effects (e.g., phytotoxicity) of the products of anaerobic decomposition on early rice growth.

- Improved soil aeration i.e., reoxidation of iron and other reduced substances that accumulate during the flooding period.
- Increased N mineralization and soil P release to the succeeding crop, up to the panicle initiation stage.
- Reduced weed growth during the fallow period.
- Reduced irrigation water requirement during land preparation (i.e., less soil cracking and bypass flow water losses in heavy clay soils).
- Easier wetland preparation (i.e., there is often no need for a second plowing operation).
- Smaller CH_4 emissions compared with straw incorporation during land preparation for the crop.

The major disadvantage of incorporation of cereal straw is the immobilization of inorganic nitrogen and its adverse effect due to nitrogen deficiency. Incorporation of rice straw into the soil after its harvest leads to slow down the decomposition and soil nitrate is immobilised, reducing the nitrogen uptake and yield of subsequent crops. Of course, proper fertilizer management practices can reduce N immobilization due to incorporation of crop residues into the soil.

These practices include appropriate method, time and rate of fertilizer (Nitrogen) application: i) placement of nitrogen fertilizer below the surface soil layer that is enriched with carbon after incorporation of crop residue, ii) application of nitrogen fertilizer at a higher rate than the recommended rate and iii) application of nitrogen 15-20 kg/ha as starter dose with straw incorporation increases yields of following crop compared to either burning of straw or its incorporation in the soil.

6.5. Residue Management Effects on Soil Properties

Soil physical, chemical and biological properties, though interrelated are affected by the residue management practices.

6.5.1. Soil physical properties

Residue management practices affect soil physical properties such as soil moisture content, temperature, aggregate formation, bulk density, soil porosity and hydraulic conductivity. Increasing amounts of rice residues on the soil surface reduce evaporation rates and increased duration of first-stage drying. Thus, residue-covered soils tend to have greater soil moisture content than bare soil except after extended drought. Soil temperature is affected through the mechanism of change in radiant energy balance and insulation. The radiation balance is influenced by heating of air and soil, evaporation of soil water and reflection of incoming radiation by surface residue. The insulation effect of residues is controlled by the amount and associated thickness of residue cover. Soil aggregation refers to the cementing or binding together of several primary soil particles into secondary units. The binding substances include oxides and hydroxides of iron, organic substances directly from plants, decomposition products of crop residues, microbial cells, excretory products of microorganisms and gelatinous substances secreted by earthworms. Decomposition of crop residues is controlled by the chemical composition of the residues, soil temperature, soil water, and associated macro and micro flora. The effect of residue management on soil bulk density and cone index has been found to be variable. Crop residues increase soil hydraulic conductivity and infiltration by modifying mainly soil structure, proportion of macropores, and aggregate stability. Hydraulic conductivity under straw-retained directly drilled treatments was around four times greater than that of straw-burnt conventional tillage treatments. The improvement in physical properties coupled with supply of nutrients from FYM and rice straw resulted in consistently greater grain yields than burning.

6.5.2. Soil chemical properties

One of the most important factors determining soil fertility is pH, which may however be influenced strongly by crop residue management. Research has shown that if these organic residues are returned to the soil, soil pH can be increased due to the decarboxylation of organic anions on decomposition by microorganisms. Silica rich plant material has the potential of transforming the electrochemical properties of acidic soils that reduces phosphorous fixation; improves base retention and increase the soil pH. Therefore, retention or incorporation of particularly the rice residues can manifest all the benefits of liming acidic soils. This is a common practice with most Indian farmers in the hills where acidic soils are found. Benefits of rice crop residues incorporation as soil amendments (as substitute for liming material) can also be tested in high rainfall regions of eastern India and Bangladesh, where acidic soils are commonly found and deficiencies of zinc, boron and phosphorous are at times quite acute. Silicates and organics (rice straw) improve iso-electric soils by way of improving the net negative charge, neutralizing acidity/detoxification of aluminium through manipulation of soil pH and point of zero charge of soil sediments having variable charge contributing materials; reduce phosphorous fixation and increase Si content in plants.

QUESTIONS

1. What are the drawbacks of burning of crop residue in the field?
2. How residue management practices affect soil physical properties?
3. How residue management practices affect soil chemical properties?
4. How residue management practices affect soil biological properties?
5. Write short notes on straw in corporation

Module 4. Paddy Straw choppers and spreaders

Lesson 7. Paddy Straw choppers and spreaders

7.1. Introduction

Although number of uses of paddy straw are available like as cattle feed, as packaging material for horticultural crops, as bedding for ruminants and in thermal power generation but still all these uses account up to 20 % of paddy straw and rest is considered as waste and is burnt in the fields. About 60-70 % farmers opt for burning of paddy straw. This practice needs to be discouraged because burning of paddy residue is not only a source of atmospheric pollution but it also leads to loss rich organic matter. The only solution to resolve this problem of paddy straw management is incorporation of paddy straw in soil. If the straw to be incorporated into the soil a straw chopper and spreader may be used. Chopper chops the straw and the spreader spreads the same. The chopped and spreaded stubbles can be buried easily in the soil with minimum tillage efforts by the use of traditional tillage implements like disc harrow and rotavator.

7.2. Classification

Straw choppers can be classified by size into small, medium and large. The small size chopper is mainly adapted for chopping dry straw or silage on small scale farms. The large chopper also called a silage chopper is mainly used for silage on cattle farms.
The medium chopper is normally suited to cutting dry straw and silage, so it is called a straw silage chopper. Choppers can be divided into cylinder or flywheel types, according to the mode of cutting. Large and medium size choppers are generally flywheel types, to facilitate throwing silage but the majority of small choppers are cylinder type. Large and medium choppers are usually equipped with road wheels for easy movement while small size choppers are normally stationary.

7.2.1. Cylinder choppers

There are many types of cylinder chopper. The machine consists primarily of mechanisms for feeding, chopping, and throwing, with a transmission, a clutch and a frame. The main parts of the feed mechanism are a chain conveyor, pressing rollers, and upper and lower feed rollers. For the upper feed roller, springs are used for pressure, with a cross-groove shaft coupled with a compact structure for driving. The chopping and throwing mechanism is in one unit, which consists of a main shaft, a blade rotor, rotating blades, a throwing vane and stationary blades. Gear teeth are 13, 22, 65 or 56. By changing the gear used, the speed can be adjusted to obtain various cutting lengths.

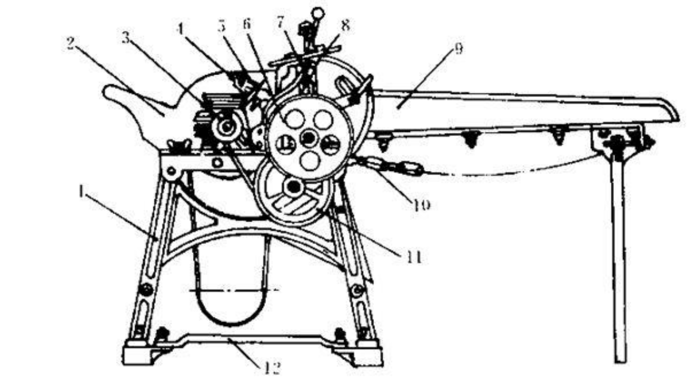
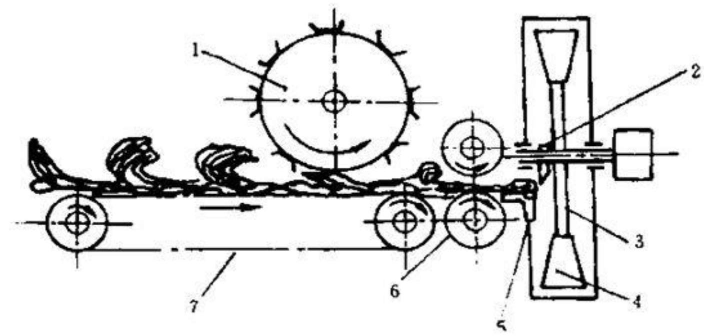


Fig. 7.1. Cylinder chopper

1. Frame	2. Throwing cover	3. Small single-groove sheave	4. Blades disk
5. Movable blade	6. Changeable gear	7. Wheel-tension clutch	8. Suspension bracket
9. Feeding groove	10. Chain	11. Large single-groove sheave	12. Supporting plate

7.2.2. Flywheel choppers

Flywheel chopper has a feed chain, upper and lower feed rollers, a stationary lower blade, a cutter and a throwing fan. The straw is fed via the feed chain into the feed rollers, pressed and moved forward by them, then cut into pieces by the combination of upper and lower blades, and it is finally blown by the fan to the storage site or silo.



1. Feed roller	2. Blade	3. Disk	4. Blower fan
5. Stationary bottom blade		6. Feed roller	7. Feed chain

7.3. Tractor-operated straw chopping machine

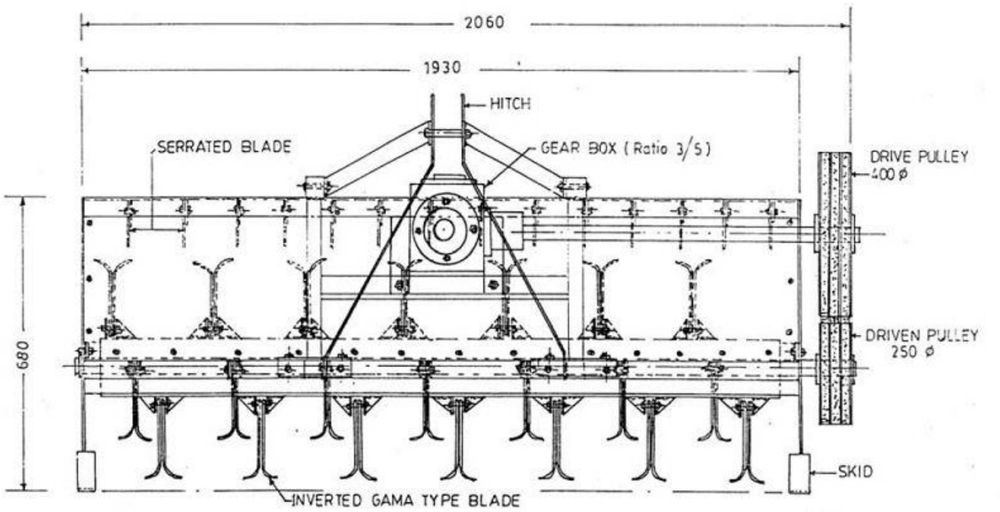
Tractor-operated straw chopping machine harvests the straw left after combining and chops it into pieces for spreading in the field in a single operation. The chopped and spreaded stubbles can be buried easily in the soil with minimum tillage efforts by the use of traditional tillage implements like disc harrow and rotavator. The two types of straw chopper cum spreader are: (1) flail type and (2) cutter bar type.

7.3.1. Flail type rice-straw chopper-cum-spreader

PAU, Ludhiana centre, in co-operation with a manufacturer has developed a tractor-operated straw chopper-cum-spreader. It harvests the straw left after combining and chops it into pieces for spreading in the field in a single operation. The machine consisted of a rotary shaft mounted with four rows of blades named as flail for harvesting and chopping the paddy straw. There were 14 number of flails on each row.

Specifications of flail type Straw Chopper cum Spreader

Parameter	Specification
Type of machine	Tractor operated mounted type
Power source	40 hp tractor or above
Overall machine dimensions, mm (LxWxH)	1090 x 2060 x 680
Working width, mm	1930
Diameter of rotary shaft, mm	137
No. of rows of flails on rotary shaft	4
No. of flails / row	14
Spacing of flails, mm	260
Shape of flails	Inverted gamma type
No. of rows of serrated blades	2
No. of serrated blades / row	14
Spacing of serrated blades, mm	130
Type of blade	Counter shear serrated knife
Gear ratio	3 : 5
Diameter of drive pulley, mm	400
Type of pulley	C-section, V-belt
Weight of the machine, kg	400



all dimensions in mm

The average field capacity (ha/h) of mounted type straw chopper cum spreader at forward speed of 2.00 km/h was 0.33 ha/h. At forward speed of 2.50 km/h, the field capacity was 0.39 ha/h and at 3.00 km/h the field capacity was 0.46 ha/h. The field efficiency at forward speed of 2.00, 2.50 and 3.00 km/h was 86.84 %, 82.10 % and 80.70 % respectively. Field efficiency decreased with increase in forward speed as at higher forward speed, the machinery is difficult to handle in the field.

7.3.2. Cutter bar type rice-straw chopper-cum-spreader

The cutter bar type machine has reel speed of 70 rpm and reel diameter of 457 mm.
A reel is attached in the front to feed the straw to the cutter. The cut stubbles are conveyed to the chopping cylinder with the help of feeding cylinder attached between the cutter bar and chopping mechanism. Field capacity of flail type machine varies from 0.35 to 0.38 ha/h at speed of operation of 2.72 km/h. The cutter bar type rice straw chopper cum spreader gave field capacity from 0.35 to 0.37 ha/h at speed of operation from 2.65 to 2.69 km/h. After chopping, the straw was incorporated by two passes of disc harrow.

Cutter-bar type rice straw chopper-cum-spreade

After chopping, the straw was incorporated by two passes of disc harrow. Then the field was irrigated and subsequent sowing of wheat was done with no-till drill. The machine is commercially available. Feed rate of the straw chopper cum spreader was dependent upon the crop density, forward speed, width of cut and stalk cut length.

Lesson 8. Paddy Straw choppers and spreaders as an attachment to combine Harvester

8.1. Introduction

The combine harvester or simply combine is a machine that harvests grain crops. The function of a combine harvester is to cut, thresh, winnow and clean grain/seed. Most Combine harvesters consist of several major components: the cutting section, the thresher, devices for separating the straw, a cleaner and a grain collection system.

The **cutting section** usually consists of straw lifters especially for lifting lodged crop, a cutter bar for cutting the straw above the ground, a reel for feeding the cut crop into the conveying system and conveyors for transporting the crop to the threshing components.

The **thresher** consists of one or more threshing cylinders and a concave. The threshing unit can be conventional but in most cases rice combines have **axial-flow** threshing and straw separation units, which are better in handling wet straw and do not require straw walkers for separating the straw. Other advantages of the axial flow concept are higher throughput and gentler treatment of fragile seeds like Basmati, which are often cracked by the faster rotational speeds of conventional combine threshing cylinders.

A conventional combine has a set of **straw walkers** for separation of the grain from the straw because the crop passes the concave very quickly and a lot of threshed grains are therefore still contained in the straw. On the straw walkers the remaining grains are separated from the straw by gravity.

All combines contain a **cleaner** in which chaff, immature grains and small straw particles are separated form the grains. The cleaner consists of a blower and several oscillating sieves. For **grain collection** the combine either has a grain tank or is equipped with a grain bagging station. For transporting the grain and other fractions inside the combine and for unloading the grain tank there are several conveyors, which can be bucket elevators or screw conveyors.

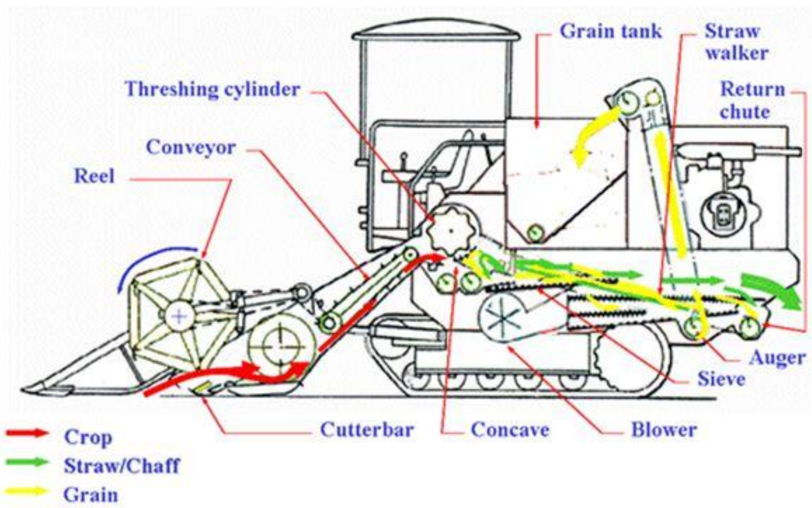


Fig. 8.1. Combine harvester

8.2. Classification

8.2.1. Self-Propelled Combine

A combine on which an engine of suitable power rating is mounted to serve as a source of power is called self-propelled combine. This may be wheeled type or track-laying type.
In wheel combine pneumatic wheels are used. Track-laying type combine fitted with full or half tracks instead of pneumatic wheels.

8.2.2. Tractor-Operated Combine

Tractor operated combine requires a tractor of suitable power rating to serve as a source of power for its working. It may be trailed type or side-mounted type.

8.3. Combine harvester with straw chopper

If the straw to be incorporated into the soil a straw chopper and attachment is used in combines. In many cases modern combines are equipped with straw-choppers. The chopper catches the straw falling from the straw walker and cuts this with high-speed rotating knives. For a good mulching of straw in the soil, the chopped straw is intentionally frayed and split by the design of the chopper hood. The straw chopper must be set in a way that all the straw and chaff is spread uniformly across the cutting width of the combine. The straw and the chaff should be redistributed over the whole cutting width by rotating distributors. Sheet metal shields are able to compensate for crosswinds.


Fig. 8.2. Combine harvester with straw chopper

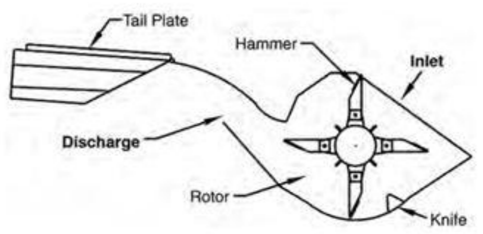
8.4. Combine harvester with straw spreader

Under Conservation Agriculture it is preferable even in the case of cereal straw not to chop but just to spread the straw behind the combine harvester. This saves energy and fuel, provides a longer lasting soil cover and reduces the danger of hair pinning – straw being push into the seed slot during planting. Straw spreaders for combine harvesters are commercially available.


Fig. 8.3. Straw spreader on combine

8.5. Combine with choppers and spreaders

In Combine with choppers and spreaders the straw falls directly into the chopper. Chaff is fed into the chopper by either a conveyor or a reciprocating chaff conveying pan. The unique design of the hammers enables the chopper to also act as a fan. Air and light chaff are drawn into the front of the chopper. The hammers pull in the straw and heavy chaff. The mechanical force of the hammers combines with the air to discharge the material. As material exits the chopper, the tail plate and the cupped vanes control the spread width and uniformity.



Chaff and straw spreading is a key part of good soil management. Heavy concentration or rows of chaff and/or straw can cause difficulty in subsequent tillage and seeding operations. Heavy concentrations may also cause slow soil warming, nitrogen depletion or toxic buildup. Ideally, all crop residues should be redistributed evenly over the field. This seldom happens. To get the most effective spread, it is necessary to match cutting and spreading widths closely. It is important that the spreader provide suitable spread uniformity over the spread width.

All combine choppers and spreaders are potentially dangerous. Material discharged can reach velocities that can cause serious injury or death. Extreme caution is required at all times when working near operating choppers or spreaders. It is especially important when working near choppers that discharge closer to head height.

QUESTIONS

1. Write short note on the components of a combine harvester
2. Give the classification of combines.
3. Explain the working principle of Combine harvester
4. How a Combine harvester with straw chopper chops the straw?
5. Discuss the working of combine with chopper cum spreader

Module 5. Mulch seeder, chopper-cum-Loader, Baler for collection of straw Paddy Straw

Lesson 9. Mulch seeder, Paddy Straw Chopper-cum-Loader

9.1. Introduction

Straw mulch reduces the amount of radiation reaching and leaving the soil surface, and therefore reduces the maximum soil temperature and increases the minimum temperature. Straw mulch also lowers soil evaporation leading to higher soil water content and/or crop water use. The magnitude of the reduction in evaporation depends on the straw load, soil water content and evaporative demand. Efforts are being used to develop simple machines capable of seeding under loose residue conditions after combine harvesting to use straw as mulch to conserve soil organic carbon and reduce pollution. The machines developed for seeding under loose conditions (mulch seeding) are detailed below.

9.2. Double disc coulters

It has double disc coulters in place of tines to place the seed and fertilizer in to the loose residues. Being light weight the seed and fertilizer are dropped on top of loose residues, part of which reach the soil surface. Irrigation is required immediately after seeding to facilitate germination. This machine works up to a load of about 4-5 t/ha.

Fig. 9.1. Double disc coulters

9.3. Happy Seeder

Punjab Agricultural University, Ludhiana in association with Australia has successfully developed Happy Seeder machines which facilitate sowing of wheat in the standing paddy stubble, while retaining the straw as surface mulch. Happy seeder is compact and lightweight and is tractor mounted. It consists of two separate units a straw management unit and a sowing unit. The straw management unit comprised a forage harvester with modified chute that would cut, lift and throw the standing stubble and loose straw. This was backed by a no-till seed drill with inverted T type furrow openers (the sowing unit), which followed the straw management unit and conducted the sowing activity concurrently.


Fig. 9.2. Happy Seeder

9.4. Combo Happy Seeder

To overcome the problems of poor maneuverability and visibility the seeding unit of happy seeder, the straw management and sowing units were combined into a single compact unit that could be lifted on the three-point linkage of a 45hp tractor. The machine has the same sowing configuration as the standard zero-till drill with 9 rows inverted T-tynes spaced 20 cm apart. This reduces the straw load on the germinating wheat seeds and power requirement of the tractor. The “Combo Happy Seeder” unit includes strip tillage in front of the inverted T-tynes to improve establishment and was tested and found that considerable dust generation and difficulty in lining up adjacent sowing passes accurately. The sown rows were difficult to see, especially with partial cutting of standing straw.


Fig. 9.3. Combo Happy Seeder

9.5. Turbo Happy Seeder

Turbo Happy Seeder has no chute that greatly reduces the amount of dust. Instead, the straw is chopped finely with the inclusion of fixed blades on the inside of the rotor volute and concave rotor blades in front of the improved design inverted-T sowing tynes. All the furrow openers (tynes) are now on the same bar and are curved so that there is only a very small clearance (15 mm) between the rotating flails and tynes, which are swept clean twice with every revolution of the rotor and the straw is fed between the tynes. As a result, the sowing lines are now more exposed, and visible. The rotor speed is only marginally higher than in Combo Happy Seeder (1300- 1500 rpm). Moreover, the Turbo Seeder does not have a strip-till mechanism and the tynes are on a single toolbar.

9.6. Rotary disc drill

This machine is based on the rotary-till mechanism. The rotor is a horizontal transverse shaft having six to nine flanges fitted with straight discs for a cutting effect similar to that of the wooden saw while rotating at 220 rpm. The rotary disc drill is mounted on a three point linkage system and is powered through the power take off shaft of the tractor. The rotating discs cut the residue and simultaneously make a narrow slit into the soil to facilitate placement of seed and fertilizer. The machine can be used for seeding under conditions of loose residues as well as anchored and residue free conditions.

If the machine is to be used under loose residue conditions, it is better to use an offset double disc assembly for placement of seed and fertilizer. Otherwise an inverted T-type or chisel type opener can be used. The rotary disc drill can also be easily converted in to a rotary till drill by replacing the discs with L- shaped or J shaped blades on the rotor. The rotor completely pulverizes the soil leading to a clean and fine tilth. Direct seeded rice using a rotary disc drill was successfully established in 6 t/ha of loose residues.

Fig. 9.4. Rotary disc drill

9.7. Flail mower cum loader

Flail mower cum loader is driven by a minimum 50 HP tractor. It has a pick-up swath width of about 150 cm. Straw recovery rate with this machine is about 1 to 1.50 tonne per hour depending on crop and swath. The machine has option of blowing back the straw into fields for sun drying. The machine can work on almost all types of biomass. Also an added advantage of this machine is the inbuilt chopper which is useful if the recovered biomass is used for silage or hay making.

About 10 tonnes of straw can be picked up in one day with this mower in loose form. In a year (say 50 days harvesting period) one flail mower can secure about 500 tonnes of straw. Mechanisms used in the machine and its operation are very simple. Therefore, low skill level worker and operator can run this type of straw recovery set. This type of operation may be popularised among the farmers through farmers' cooperatives, federations and service providing organizations, who could provide such services to farmers at nominal costs.

Fig. 9.5. Flail mower cum loader

9.8. Flail type chopper cum loader for paddy straw

Flail type chopper cum loader for paddy straw cuts straw from bottom, collects straw and loads into trailer. The width of the machine is 1.5m and power requirement is 35 hp. Flail type chopper cum loader were found to have application in effective management of cotton stalks. Field capacity of flail type chopper cum loader varied from 0.25 to 0.35 ha/h.

Fig. 9.6. Flail type chopper cum loader for paddy straw

QUESTIONS

1. Explain the working principle of Double disc coulters
2. Discuss the operation of Happy Seeder
3. Write short note on Combo Happy Seeder
4. Write short note on Turbo Happy Seeder
5. Write short note on Rotary disc drill
6. Write short note on Flail mower cum loader
7. Write short note on Flail type chopper cum loader for paddy straw

Lesson 10. Baler for collection of straw

10.1. Introduction

After combine harvesting, the straw is left on the earth in swaths. The straw should be removed as quickly as possible so that the treatment of the soil preparation can begin thereby establishing next year's crop.

A baler is a machine used to compress straw into bales for easy transport and storage.

Balers are divided into stationary balers, movable and field balers. They are further classified into square balers, rectangular balers and round balers according to the bale shape produced.

According to density of bale, they could be high (200-350 kg/m^3), medium (100-200 kg/m^3) or low density (<100 kg/m^3) balers.

Based on the power used for operation, balers are classified as pull type balers and self propelled balers. Pull type models are available with either a PTO drive or a mounted engine.

10.2. Rectangular balers for collection of straw

Field balers for making rectangular bales have been popular for many years. Smaller balers are powered by a tractor PTO and the larger balers are often equipped with auxiliary engines to drive the machine but may be pulled by a tractor.

10.3. Rectangular baler components

The basic functional components or units which make up a baler for rectangular bales are the pickup and elevating unit, feed conveyor, feeder, compression chamber and the tying mechanism. Each of these will be discussed individually.

10.3.1. Pickup and elevating unit

This unit takes the straw from the windrow and elevates it to the point where a feed conveyor can carry it to the bale chamber. The pickup consists of a series of spring loaded tines which gently lift the windrow and guide it along the stripper bars. At the top of the pickup, the tines retract downward to be ready to lift a new portion of the windrow. On many machines the pickup serves as the elevator but on older machines a separate elevator was used. Balers intended to pickup straw windrowed by mower conditioners may have pickup tines spaced much closer together.

10.3.2. Feed conveyor

This device moves the straw to the side of the bale chamber. Large diameter augers are common feed conveyors. However, on some machines several times extended from the feeder act to convey the material to the bale chamber side. On some older machines, rubber belts were used for this purpose.

10.3.3. Feeder

The feeder takes the straw from the end of the feed conveyor and actually places it into the bale chamber. In most cases the feeder enters the bale chamber when the plunger is forward, for this reason it must be timed accurately with respect to the plunger.

10.3.4. Compression chamber

Straw is compressed in the bale chamber by the plunger which is driven by a large crankshaft and connecting rod. Each new charge of straw is compressed against the previous charges. The partially formed bale moves slowly through the chamber by the plunger forcing new charges against it.

10.3.5. Tying mechanism

The tying mechanism consists of knotters, needles and metering wheel. These parts are responsible for tying each bale when it has reached its correct length. The fingers of the metering wheel extend part way into the bale chamber so the metering wheel turns slowly as the bales pass through the chamber. Rotation of the metering wheel, trip the knotter clutch to engage power to the needles and knotters to tie the bale. The relationship between the metering wheel and the knotter clutch can be adjusted to change the bale length. On most machines this can be done by sliding a collar on the trip arm at the metering wheel.

10.4. Rectangular pick up baler

It makes bales from the straw windrow left by the combine. The machine consists principally of a pick-up reel, a conveying and feeding system, a compressing chamber,
a bale density adjuster, a bale length controller, a needle and tying mechanism, a crank linkage mechanism and a power transmission and hauling system. It is powered from the power take-off of the hauling tractor. The straw windrow is lifted from the ground by a pick-up reel having spring teeth and transferred continuously to a conveying and feeding mechanism as the baler moves forward along the windrow.

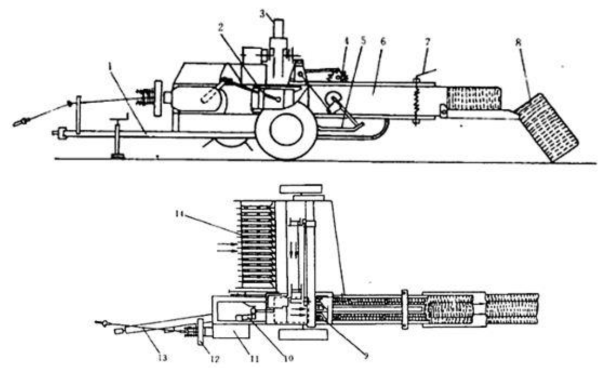


Fig. 10.1 Rectangular pick up baler

1. Tow beam	2. Piston
3. Conveying and feeding equipment	4. Bale length controller
5. Needles	6. Compression chamber
7. Bale density adjuster	8. Bale
9. Needle and tying system	10. Crank
11. Main gear box	12. Flywheel
13. Universal joint gearing axis	14. Pick-up reel

The conveying and feeding mechanism pushes individual charges of straw into the bale chamber from the side at intervals when the piston is withdrawn. The piston reciprocates under the function of the crank linkage mechanism to press the material into the bale. When the bale reaches the required length, the needle and tying mechanism is engaged automatically to bind the bale which is then pushed out from the chamber by successive bales and is discharged to the ground. Rectangular bales can be lifted and loaded either by hand or by a loading machine mounted on the side of a truck and driven by a ground wheel.

10.5. Round balers for collection of straw

Round balers are PTO operated and are pulled directly behind the tractor. It is desirable to use a tractor with a wide front axle to permit straddling the windrow. Large wide windrows are preferred to make round bales which are uniform in diameter. When small windrows are harvested, operators prefer to weave side to side as the bale is formed to avoid tapered bales. Based on the form of working unit, round balers can be classified into long-belt type, short-belt type, chain type and roller type. They are also classified into inside winding type and outside winding type by their working principle. Long-belt and chain types are inside winding; short-belt and roller types are outside winding. According to the chamber size adjustment, balers are classified as expandable chamber round pickup baler, ground roll baler and fixed volume round pickup baler.

10.5.1. Expandable Chamber Round Pickup Baler

The most common type of round baler is the Expandable Chamber Round Pickup Baler. This type of baler picks up the straw windrow with a conventional tooth pick up and moves the straw into the bale chamber using rollers and belts. The straw is then compressed using belts and rollers or apron chains. As the straw is fed into the bale chamber, it expands producing a bale of relatively uniform density. As the bale reaches the desired size, twine is fed into the chamber and wraps around the bale as it turns. After the bale has made approximately one revolution, forward travel is stopped, and twine continues to be fed in while the bale makes 6 to 10 more revolutions. After the wrapping is completed, the tailgate is raised, and the bale is ejected. The tailgate is then lowered, and a new bale is started. Bales produced by this type of baler usually have a high density and weigh from 0.5 to 1.0 tonne. This type of baler is usually easy to use and has overall capacity ranging from 2 to 12 t/h. Power requirements vary from 10 to 25 kW but a tractor with at least 48kW is recommended to fully utilize the baler's capacity.

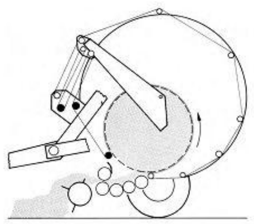


Fig. 10.2 Expandable chamber round pickup baler

10.5.2. Ground Roll Baler

Ground roll balers use the least amount of tractor horsepower of the three types of round balers. A pickup is used to roll the straw forward along the ground and belts, grids or cables are used to form the round bales. Bales made with a ground roll baler tend to be lighter and less dense than bales created by the other two types of round balers. This type of bale can experience significant losses during handling, transporting and storage. Overall capacity with these balers is very dependent on operator experience and can vary from 1 to 5 t/h. Power requirements usually do not exceed 20kW but a tractor with at least 34kW is recommended to fully utilize the baler's capacity.

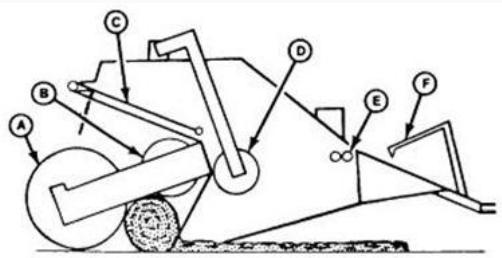


Fig. 10.3 Ground roll baler

A. pickup
B. bale forming roller
C. bale forming cables
D. bale forming roller
E. twine rollers
F. second bale starter

10.5.3. Fixed Volume Round Pickup Baler

In Fixed Volume Round Pickup Baler, the pickup lifts the straw into the bale chamber. The bale chamber, however, is of fixed volume and the bale does not take shape until the chamber is nearly full. Bales from this type of machine will have a lower density core than those produced by the expandable chamber balers. Although this type of machine has a capacity similar to the expandable chamber types, the power requirements appear to be higher. Overall capacity for this type of baler is the same as the Expandable Chamber Round Pickup Baler, but power requirements of up to 45 kW have been measured.

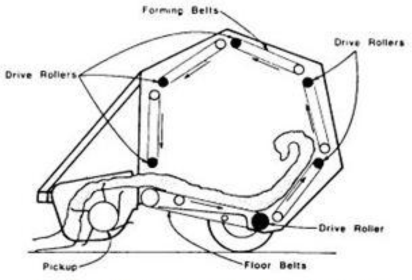


Fig. 10.4 Fixed volume round pickup baler

10.5.4. Inside winding Round pick-up baler

Figure 10.5 illustrates a belt, pick-up baler that consists of a pick-up reel, a conveying and feeding mechanism, a wrapping and pressing mechanism, a rear door for unloading, a transmission mechanism and a hydraulic operating mechanism. Its working process is shown in Figure 10.6. The windrow is lifted by a pickup reel and rolled up to double smooth rollers where it is pressed into a flat layer, then conveyed to the baler chamber. With the upper belt the straw moves upward by friction to a certain height, then rolls down to the lower belt by gravity to form the core of the bale, which continually rolls, increasing the diameter. When the bale reaches the desired size it is discharged from the lower belt. The springs fixed in the swing arms in the two sides of the bale chamber maintain the pressure of the belt on the bale's surface. The pressure increases with bale size, resulting in low density on the inside of the bale but high density on the outside. Inside wrapping means that the volume of the wrapping and pressing chamber enlarges during pressing to keep a constant pressure on the bale. The bales formed by inside wrapping have much higher density than by outside wrapping and keep their shape for longer during storage. However, the structure of an inside wrapping baler is more complicated. When the bale reaches the desired size, an indicator alerts the driver to engage the hydraulic distributor in order to activate the binding mechanism. The twine is passed by the tube and fed with straw to the chamber. The twine is wrapped around the circumference of the bale and then cut by a blade. The rear door is lifted hydraulically. The bale is then discharged to the ground.

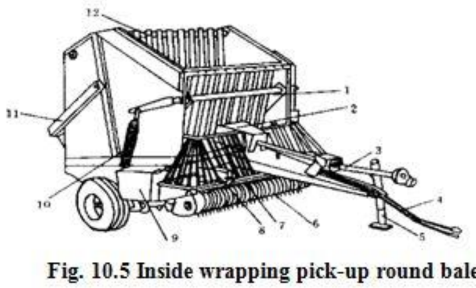


Fig. 10.5 Inside wrapping pick-up round baler

1. Swing arms	2. Gear box
3. Gearing shaft	4. Hydraulic power supply tube
5. Support frame	6. Pick-up reel
7. Tube for the twine	8. Twine cutter
9. Twine box	10. Tension spring
11. Rear discharge door	12. Belt of wrapping and pressing chamber

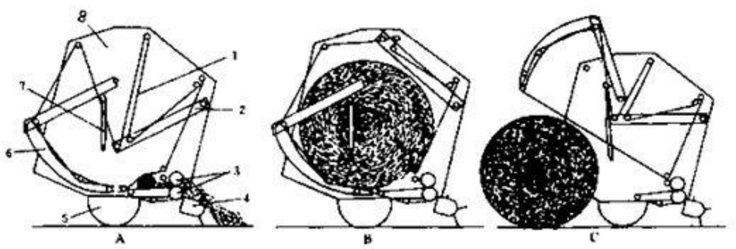


Fig.10.6. Operating principle of the wrapping and pressing mechanism

A. Forming of the core of the bale
B. Making the bale
C. Discharging the bale
1. Upper belt
2. Swing arms
3. Smooth rollers
4. Pick-up reel
5. Road wheels
6. Rear door for discharging
7. Hydraulic cylinder
8. Side walls

QUESTIONS

1. What are the functional components of rectangular balers?
2. Write short notes on baler tying mechanism
3. Explain the working principle of rectangular pickup baler with a schematic diagram
4. Explain the how an inside winding Round pick-up baler works
5. List out the types of round balers and explain anyone type with a neat diagram

Module 6. Processing and uses of straw for animal use and cushioning material

Lesson 11. Processing of straw/ fodder for animal use

11.1. Introduction

The livestock sector in India contributes about 32% of total agricultural output. India with 2.3% share of global geographical area supports nearly 20% of the livestock population of the World. The desired annual growth of agriculture sector about 4% can also be accomplished by enhancing productivity from the livestock sector. This would require a steady supply of fodder for supporting the livestock population. Many parts of the country face deficit of feed and fodder for millions of livestock. Harvesting, transportation, chaffing, handling and conservation of forage crops and crop residues are very important practices and are needed for effective utilization of fodder.

One of the most abundant lingo-cellulosic wastes on earth is paddy straw. Annual production of rice is about 136.5 MT. About 1 to 1.5 kg of straw is produced per kg of grain harvested and thus, 136.5 – 150 MT of paddy straw is estimated to be produced annually. In India, approximately 70-80 MT of paddy straw is disposed off by burning. Although burning leads to organic matter loss, it is quick and overcomes the many problems associated with slow decomposition of straw. It reduces the incidence of pests and diseases, facilitates soil preparation for a second rice crop or for other off-season crops, and it returns minerals to the soil.

11.2. Rice straw as an animal feed

Rice straw is traditionally fed during periods of feed shortage, but it does not provide adequate nutrients for maintenance. The use of straw for ruminant feeding is cellulose and physically make the structural fibers swollen constrained by its low digestibility due to high silica and lignin as well as low protein and energy contents when given as the only feed to animals. With straw, the level of intake is governed by the amount of material in the reticulo rumen, its rate of digestion and the rate of passage of digesta out of the reticulorumen. Thus, mechanical processes associated with digestion, namely, particle size reduction during eating and rumination and rates of microbial fermentation are important in relation to the level of intake. Where rice straw constitutes 100% of the diet, then all its limitations, in terms of physical characteristics, chemical characteristics and low contents of essential nutrients, will manifest themselves and the animals will lose weight. However, sometimes even small contributions from other feeds in a mixed diet can produce markedly improved results through effects at the rumen and/or tissue level.

11.3. Challenges in feeding rice straw

Palatability - Cattle are more likely to eat rice straw if the time between rice harvest and straw baling is short. In addition, rice straw has a slight pubescence (small hairs) that cows may take some time to adapt to.

Low digestibility - Rice straw has very high silica content (8 to 14%). Silica is indigestible and decreases digestibility of the feed. This high silica level combined with other mineral compounds produces an average ash content of 17%.

Low protein - The crude protein of 2 to 7% on a dry matter basis in rice straw requires protein supplementation to meet the nutritional requirements of most cattle.

High in oxalates - Oxalates in rice straw decrease the absorption of calcium.

11.4. Feeding value

The major components contribute to the feeding value or nutritive value of straw/forages are (a) chemical composition, representing the gross amounts of nutrients available; (b) level of voluntary intake, indicating the amounts of nutrients consumed; (c) digestibility, indicating the proportions of nutrients that are digested and absorbed and become available for metabolism; and (d) efficiency of metabolism at the tissue or cell level.

11.5. Improving the Feeding Value through Pretreatments

Pretreatment processes can improve the feeding value of straw by increasing its digestible energy content, by increasing feed intake or by a combination of these effects. Maximal increases in digestibility are only achieved with an adequate balance of energy and other essential nutrients, such as nitrogen and minerals. Further, limitations in the supply of these essential nutrients can limit the intake of straw independently of their effects on digestion and consequently, they are also necessary to allow expression of potential intake responses. In addition to the effects on feeding value, other factors are also important. Pretreatments can range from simple chopping and soaking procedures to elaborate chemical pulping operations or carefully controlled fermentation processes. Many of these processes are technologically feasible, but economic constraints limit their use to particular situations or in fact, rule out their use under practical conditions. Pollution effects of some of the pretreatments need to be considered and evaluated before promoting their use.

11.6. Physical pretreatments

Some physical processing methods such as chopping or grinding are unlikely to affect the chemical composition of straw. However, others such as soaking, steaming under pressure and gamma irradiation do have effects on the chemical composition of fibrous residues ranging from losses of cell soluble to alterations in the structural carbohydrates of the plant cell wall.

11.6.1. Soaking and wetting

Rice straw soaked for 3 days results in 8-14% dry matter losses, indicating removal of soluble cell contents and reduced feeding value.

11.6.2. Chopping

Straws are sometimes chopped to reduce wastage and to facilitate feeding, but this does not alter the cell wall structure in such feeds.

11.6.3. Grinding and pelleting

In the rumen, degradation of cellulose requires direct association of microbial cellulases with the substrate and, hence, the rate of hydrolysis would be expected to be affected by the cellulosic surface area accessible to the enzyme. The extent of any increase in cellulosic surface area is likely to be determined by the fineness of grinding. A process such as ball-milling results in extreme reduction in particle size to the point of the physical separation of cell wall components and this results in marked increases in in vitro digestibility.

11.6.4. Steaming under pressure

Steaming exerts physical effects through the separation of cell wall structures and chemical effects including the cleavage of bonds between cell wall constituents, the degradation of hemicellulose, and a hydrolytic action of the acids resulting from these processes.

11.6.5. Gamma irradiation

Ionizing radiation has been investigated as a means of increasing the availability of nutrients in plant cell walls for microbial digestion as this pretreatment may reduce the resistance of fibrous feeds to physical degradation without the necessity for fine grinding.

11.7. Chemical pretreatments

The objective of chemical pretreatments of fibrous feeds is to increase their digestibility and intake through solubilization of some of the cell wall components or disruption of complexes of lignin and cell wall carbohydrates. Some such treatments solubilize lignin, while others such as extreme pH conditions, whether acid (below pH 4) or alkaline (above pH 8) increase the solubility of hemicelluloses. The chemicals which have been most extensively used for the purpose of increasing cell wall degradation can be broadly classified into three groups: alkalis, oxidative reagents and acids. Of these alkalis have been the most commonly investigated chemicals for improving the feeding value of fibrous residues. Chemical treatment of straw with alkalis such as ammonia and sodium hydroxide, has been commonly used for improving both apparent digestibility, bacterial colonization on cellulose and voluntary intake of straws.

11.7.1. Alkali spray treatment

The alkali spray treatment of straws has been shown to improve digestibility and intake. Sodium hydroxide is generally regarded as the most effective alkali for improving digestibility. The straw is sprayed or sprinkled with a dilute solution of NaOH at the rate of 1 litre per kg and the moist straw is immediately fed to animals. The optimum concentration of the NaOH solution appears to be about 5 percent where straw is to be fed with limited supplements, although where treated straw forms only about 50 percent of the diet, 7 to 8 percent appears to be better.

11.7.2. Ammonization of rice straw

By processing rice straw with urea its quality and digestibility can be improved. It can also increase the protein content of rice straw. It would seem that with adequate moisture content and suitable temperature conditions, microbes which produce urease are capable of degrading urea with the formation of ammonium compounds such as ammonium carbonate, bicarbonate or hydroxide which then permeate through the straw.

Procedure for ammonization of rice straw

Two plastic bags are taken and one bag is put inside the other to make a double thickness. Then 15 kg of air-dried rice straw is put inside the bag. The rice straw is compacted by pressing it down with hands. 870 g urea dissolved in 5 liters of water is poured into the plastic bag of rice straw. The inner plastic bag is closed by binding the mouth and then the opening of the outer plastic bag is tied separately. The bag of straw is put in a safe place and can be opened after one month. The mouth of the bag should be left open to expose the straw to the air for two days. It can then be used as livestock feed. Sweet soy sauce or molasses may be added to increase the palatability. Once the cattle become used to the ammoniated rice straw, it can make up 60-100% of their feed intake.

11.7.3. Calcium hydroxide treatment

Calcium hydroxide is a relatively cheap chemical reagent for treating crop residues as its precursor lime is cheaper than sodium hydroxide. However, to be effective the calcium hydroxide needs to be used at reasonable concentrations to compensate for its low alkalinity and it needs to be applied by a soaking method to allow for its low solubility.

11.7.4. Pretreatment with oxidative reagents

Oxidative agents are known to reduce lignin content and to break bonds between lignin and carbohydrates of straw. However, pretreatment with oxidative chemicals, such as sulphur dioxide, ozone and chlorinated compounds involves the use of sealed reaction vessels and the processes are generally carried out under controlled conditions.

11.7.5. Pretreatment with acids

Acid pretreatment of fibrous feeds hydrolyses the hemicellulose in cell wall material thereby releasing sugars. Also some lignin-carbohydrate bonds are acid-labile and may be broken during this treatment and with concentrated acid cellulose can be hydrolysed. Treatment with hydrochloric or sulphuric acids followed by periods of storage was found to increase the rumen fluid digestibility of fibrous materials and this was associated with increases in water-solubility of the feeds.

11.8. Physico-chemical pretreatments

When physical and chemical pretreatment processes are used in combination they might be expected to be more effective in increasing the nutritive value of fibrous feeds. In this regard the effectiveness of alkali treatments might be increased if the surface area exposed to chemical action was increased by chopping or grinding or by steaming under pressure.

11.9. Biological treatment

The use of fungi and/or their enzymes that metabolize lignocelluloses is a potential biological treatment to improve the nutritional value of straw by selective delignification problems are considered and should be overcome as fungi may produce toxic substances. It is also difficult to control the optimal conditions for fungal growth, such as pH, temperature, pressure, O_2 and CO_2 concentration when treating the fodder. With recent developments in fermentation technology and alternative enzyme production system, the costs of these materials are expected to decline in the future. Hence, new commercial products could play important roles in future ruminant production systems.

11.9.1. White-Rot Fungi Treatment

White-rot fungi, belonging to the wood-decaying basidiomycetes, as lignocellulolytic microorganisms are able to decompose and metabolize all plant cell constituents (cellulose, hemicellulose and lignin) by their enzymes. Many species of white-rot fungi which are effective lignin degraders have been used to assess their ability to improve the nutritive value of fodder for ruminant nutrition but fungal metabolism can dissipate carbohydrate.

11.9.2. Treatment with Enzymes

Enzymatic hydrolysis of rice straw is an interesting way to produce sugars from cellulosic wastes because of its mild operating conditions, regarding pH and temperature and the absence of by products. Xylan-rich cell walls which contain significant amounts of lignin, are also generally resistant to enzymatic hydrolysis and require severe physic-chemical pretreatments such as steaming, radiation, acid hydrolysis and alkali digestion before the polysaccharides become accessible to enzymes and can be hydrolysed to monomeric sugars in high yield.

Although several treatments have been used to improve the degradability and voluntary intake of rice straw, such as physical or chemical treatments, the practical use of these treatments is still restricted in terms of safety concerns, costs and potentially negative environmental consequences. Moreover, the application of ligninolytic fungi or their enzymes combined with chemical pre-treatments to rice straw may be an alternative way to decrease the amount of chemicals affecting some synergy.

11.10. Forage value of rice straw

Rice straw varies greatly in its forage value with protein from 2 to 7 % and 44 to 56 % Acid Detergent Fiber (ADF). ADF is a laboratory method of determining the fiber content that can assist in predicting the digestibility of a feed. Crude protein is estimated by determining the total nitrogen and multiplying by 6.25. The lower the ADF per cent, the digestibility of the feed will be more.

Rice straw of 2 to 3 percent crude protein on a dry matter basis should not be used for cattle feed, as its forage value is generally less than the cost of baling and hauling, and it may cause poor animal health or death. The number of days that baling occurs after harvest will greatly impact palatability and forage quality. Forage that is baled 1 to 3 days after harvest maintain the best palatability (smell, flavor and colour) of the forage. Forage chemical quality starts to decrease at 6 to 10 days after harvest.

11.11. Supplementation of formulation of practical diets

11.11.1. Feeding rice straw with forage supplements

The most common feeds provided with rice straw are roadside grasses, while other important forages are cassava, gliricidia, leucaena and sesbania. In specific areas forages from many other trees, crops and water weeds including acacia, banana, jackfruit, pigeon pea, neem, sweet potato vines and water hyacinth are utilized. It is known that small quantities of green forage can improve the utilization of straw diets through increases in intake and digestion. These beneficial effects are apparently due to influences on rumen function. The leaves of these plants remain green during dry periods when the availability of and quality of roadside grasses are low and hence they can be valuable supplements. Within small farm systems these plants can have other beneficial effects in that they often provide fuel and in the case of leguminous types they may help to improve soil fertility by fixing atmospheric nitrogen. However, care should be taken to ensure they are palatable and that they do not contain toxic constituents. The value of forage supplements in feeding systems based on rice straw has advantages additional to their nutritional effects occur where they are available on the farm and hence are easily accessible and relatively cheap and in that they reduce requirements for other supplements.

11.11.2. Feeding rice straw with concentrate supplements

Concentrate supplements which are used may be home-grown or by-product feeds from mills, such as rice bran, coconut cake, cassava chips and palm kernel cake. Purchased concentrates from feed manufacturers have advantages in that they may be formulated feed mixtures designed to provide limiting nutrients in balanced amounts or they may be individual feeds required for specific purposes, like coconut cake, fish meal or molasses. Costs of the various formulated feeds have been increasing due to rising prices of ingredients and this has acted as a major deterrent to their use as the profit margin becomes small.

QUESTIONS

1. What are the challenges in feeding cattle with rice straw?
2. Mention the major components which contribute to the feeding value or nutritive value of straw
3. Classify the pre treatment processes to improve the feeding value of straw
4. Explain how physical pretreatments improve the feeding value of straw
5. Explain how chemical pretreatments improve the feeding value of straw
6. Explain the procedure for ammonization of rice straw
7. Explain how biological pretreatments improve the feeding value of straw.
8. Write short notes on forage value of rice straw
9. Write a brief note on Feeding rice straw with forage supplements
10. Write a brief note on Feeding rice straw with concentrate supplements

Lesson 12. Agricultural and horticultural use of paddy straw

12.1. Introduction

Agricultural and horticultural uses of paddy straw include mulching, manure through composting, and a source of natural herbicides. Paddy straw can be used for mulching, which benefits in preventing weed growth as well as supplies organic matter for nitrogen fixation by heterotrophic nitrogen fixing microorganisms, which could be absorbed by succeeding crop. Composting of rice-straw into a value added product is a highly promising alternative to its burning and can potentially increase the agricultural productivity and reduce the problem of environmental pollution. Mulching and composting of paddy straw were dealt in separate sections. The plant- derived compounds from rice straw could be serves as a renewed source of natural herbicides or probably as a good skeleton to build up new groups of synthetic herbicides. Production of paddy straw mushroom is dealt in this section.

12.2. Paddy straw mushroom

The mushroom defined as "a macro fungus with a distinctive fruiting body, large enough to be seen with the naked eye and to be picked up by hand" (Chang and Miles, 1991). In a narrow sense, the world mushroom also refers only to the fruit body. Unlike green plants, mushrooms are heterotrophs. Not having chlorophyll, they cannot generate nutrients by photosynthesis, but take nutrients from outer sources.

12.2.1. History of Paddy straw mushroom

Paddy straw mushroom (Volvariella volvacea) belongs to the family Pluteaceae. Chinese growers developed its cultivation more than 300 years ago. Therefore, it was named "Chinese Mushroom" (Zhanxi and Zhanhua, 2000). Paddy straw mushroom is a popular variety among people because of its distinct flavor, pleasant tastes, higher protein content and shorter cropping duration compared to other cultivated mushrooms. 2000). *Volvariella* requires a high temperature (35 ± 2 °C) for better and early hyphal growth. Also 32±2 °C and 80-90 % RH (relative humidity) are needed for the formation of fruiting bodies. Paddy straw Mushroom is quick growing fungus, which can be harvested on 12th or 13th day. Paddy straw mushroom was first cultivated in India in 1940 and is more popular in coastal states like Orissa, Andhra Pradesh, Tamil Nadu, Kerala and West Bengal, however, it can also be cultivated in most of the states, where agroclimatic conditions suit and agrowaste is available in plenty.

12.2.2. Cultivation of paddy straw mushroom

A small raised platform is prepared with bricks or wooden planks to drain the excess water that drips from the bed. Both indoor cultivation and the product of thatched sheds yield a good harvest all through the year. Paddy straw is tied in bundles of 500 g and soaked in water for 24 hours. The excess water is drained off. For a good yield of quality buttons, the bundles are preferably sterilized (under 13.5 kg/cm^2 steam pressure for 15 minutes) using a autoclave for large scale production or atleast by immersing in boiling water for about an hour. The sterilized straw is shade dried for about 30 minutes on a clean surface in order to cool it as well as to remove excess water. The stacks are kept inside a bamboo or wooden frame of 1 m^2 in 4 to 5 layers, each consisting of 6 to 8 bundles. The beds are arranged on a raised platform and the bundles are placed opposite to the first layer.

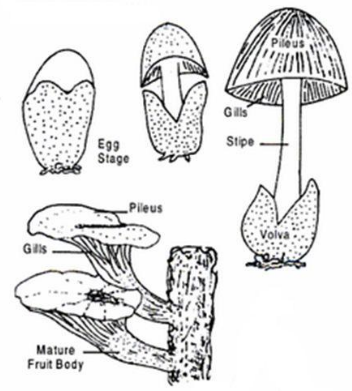
About 200g of chick pea or pigeon pea powder is added to enrich the bed except on the top layer. The grain spawn is shifted from the container on to a clean surface using a glass rod or stick and is laid over this bed. The beds are covered with perforated plastic bags and incubated at 20-30 ^oC under adequate humid conditions (relative humidity 70 – 85%) preferably in a dark room for about 15 – 20 days.

12.2.3. Spawn

Spawn is the preparation of the seedling material grown on substrates like sorghum seeds. The seeds (200-300g) are cooked under sterile conditions and usually milk bottles are used as containers. The sterilization can be done using a pressure cooker or an autoclave for large scale production. The fungus (inoculum) grown in test tubes can be transferred to the substrate under sterile conditions. One spawn bottle is used for preparing three mushroom beds under aseptic conditions. The spawn can be obtained ready made from the mushroom growers or from the mycology unit of any agricultural university.

12.2.4. Harvest

The bed is covered with a polythene sheet, which should not touch the straw, to create high humid conditions. After 12-15 days, the beds will be completely covered by a white cottony fungus. It is now time to remove the polythene bags. The beds are arranged on the raised platform are watered twice a day to ensure the presence of humidity. Wet gunny bags may be hung for the same purpose. Small button like growths (fruit formation) will appear within a week and are ready for harvest. Harvesting should start a day before the buttons open or after the volva ruptures and can be continued for a couple of weeks. Three to four flushes appear within a period of 4-5 weeks. The fruit bodies arise in clumps of variable sizes and shapes and should be harvested by cutting or plucking them at the stacking region in uniform size. The yield will be about 50% or more than the weight of the substrate.



12.2.5. Processing

Paddy straw mushroom is more perishable than other edible mushrooms and cannot be stored at 4 °C as it undergoes autolysis at this temperature. Paddy straw mushroom can be stored at a temperature of 10 to 15 °C for 3 days and little more at 20 °C or under controlled atmosphere storage. The loss of moisture in 4 days stored mushroom could be as high as 40-50% in unpacked mushroom, while it can be reduced to 10% on packaging in perforated polythene begs. Paddy straw mushroom can be processed by canning, pickling and drying.

12.2.6. Nutritional value

Mushrooms have been recognized as a source of protein rich food. In general, paddy straw mushroom contains 100 g of fresh mushroom contains 1-2 g of carbohydrates, 5 – 8 g of proteins, 0.2-1 g of fat, 5-15 mg of vitamins, 0.5-1g of minerals and rest is moisture. The straw mushroom is known to be rich in minerals such as potassium, sodium and phosphorus.

QUESTIONS

1. List out the agricultural and horticultural uses of paddy straw.
2. Explain the Cultivation of paddy straw mushroom.
3. What do you mean by Spawn?
4. At what stage paddy straw mushroom is harvested?
5. Write short notes on Nutritional value of paddy straw mushroom.
6. Write short notes on storage of paddy straw mushroom.

Lesson 13. Paddy straw - Cushioning material for fruits and vegetables

13.1. Introduction

India is a land of large varieties of fruits and vegetables due to its vast soil and climatic diversity. With 38 and 71 million tons of production of fruits and vegetables, India is the second largest producer of fruits and vegetables next to Brazil and China respectively. It is also a matter of concern that there is a wide gap between availability and the per capita nutritional requirement of fruits. The low availability of quality fruits and vegetables is mainly due to considerably high post harvest losses, poor transportation facilities, improper storage and low processing capacity coupled with the growing population.

Around 20-30 % losses take place during harvesting, grading, packaging, transportation and marketing of fruits. The fruits of increased production of fruits and vegetables and other agricultural produce will be realized only when they reach the consumer in good condition and at a reasonable price. The existing post harvest loss of fruits and vegetables could be considerably reduced by adopting improved packaging, handling and efficient system of transport. Packaging of fruits and vegetables is undertaken primarily to assemble the produce in convenient units for marketing and distribution.

13.2. Paddy straw as a cushioning material

Cushioning was done by keeping the cushioning materials between rows of fruits and layers of fruits inside the boxes. The function of cushioning materials is to fix the fruits and vegetables inside the packages and prevent them from damaging, when there is a vibration and impact.

For the cushioning materials to be useful it should, in addition to have resilient property the availability to dissipate the heat of respiration of the produce. It should be free from infection so that it does not pass on the same to the fruit and vegetables. The cushioning material used in wooden boxes for packaging of fruits mainly consists of paddy straw and newspaper. The compaction resistance and resiliency of paddy straw makes it a very good cushioning material.

13.3. Precautions during packing

- Containers should not be filled either too loosely or too tightly because loose products may vibrate against each other and cause bruising
- While over-packing results in compression bruising
- Proper filling along with cushioning material can minimize bruising damage

Module 7. Mulching and composting, paper and cardboard manufacturing from straw

Lesson 14. Mulching and Composting

14.1. Introduction

Paddy residue management is also important as machines are being increasingly used for harvesting of grains, and this mechanical harvesting leaves huge amount of residues in the field. There are several options for management of rice residues. In this chapter we shall study mulching and composting of rice straw.

14.2. Mulching

The practice of spreading plant residue or any other material like straw on the soil surface to reduce water evaporation losses is called mulching. Appropriate tillage and mulch practices are used to conserve soil moisture and increase the yield of crops. Mulches are designed to protect exposed soil or freshly seeded areas from erosion by eliminating direct impact of precipitation and slowing overland flows and to foster the growth of vegetation by increasing available moisture and act as shade. Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures and provide a suitable microclimate for seed germination leading to better root growth and higher grain yields.

14.3. Types of Mulches

14.3.1. Organic Mulches

1. Straw: The mulch most commonly used in conjunction with seeding. The straw should come from rice, wheat or oats (free of troublesome weed seeds) and may be spread by hand or machine. Straw can be windblown and must be anchored down by an acceptable method.

2. Hay: May be used in lieu of straw where volunteers will not present a problem, and may be spread by hand or machine. Hay can be windblown and must also be anchored or tacked down.

3. Corn Stalks: These should be shredded into 100 to 150 mm (4 to 6 inch) lengths. Stalks decompose slowly and are resistant to displacement.

4. Wood Chips: Suitable for areas that will not be closely mowed, and around ornamental plantings. Chips decompose slowly and do not require tacking. They must be treated with 6 kg of nitrogen per tonnes of chips to prevent

nutrient deficiency in plants; however, can be a very inexpensive mulch if chips are obtained from trees cleared on the site.

5. Bark Chips and Shredded Bark: These are by-products of timber processing which are used in landscaped plantings. Bark is also a suitable mulch for areas planted to grasses and not closely mowed. It may be applied by hand or mechanically and is not usually toxic to grasses or legumes; additional nitrogen fertilizer is not required.

14.3.2. Fiber Mulches

Fiber mulches are used in hydroseeding operations and applied as part of the slurry. It creates the best seed-soil contact when applied over top of newly seeded areas. These fibers do not require tacking, although tacking agents or binders are sometimes used in conjunction with the application of fiber mulch. This form of mulch does not provide sufficient protection to highly erodible soils. Additionally, fiber mulch will not be considered adequate mulch when used during the dry summer months or when used for late fall mulch cover. Use straw mulch during these periods. Fiber mulch may be used to tack straw mulch. This treatment is well suited for steep slopes, critical areas, and areas susceptible to displacement.

14.3.3. Chemical Mulches and Soil Binders

Chemical Mulches and Soil Binders make excellent mulches but are only use of these materials can reduce costs, a wide range of synthetic, spray-on materials are marketed to stabilize and protect the soil surface. These are emulsions or dispersions of vinyl compounds, rubber or other substances which are mixed with water and applied to the soil. They may be used alone in some cases as temporary stabilizers or in conjunction with fiber mulches or straw. When used alone, chemical mulches do not have the capability to insulate the soil or retain soil moisture that organic mulches have. This soil protection is also easily damaged by tratic. Application of these mulches is usually more expensive than organic mulching, and the mulches decompose in 60-90 days.

The type of mulch selected and the application rate will depend on conditions at the site, such as slope, erodibility, soil temperatures, moisture, wind, the potential for weed infestations, and the potential that wild animals might cause damage. The amount of mulch added to the soil should not suppress the growth of most plants. General mulch recommendations to protect disturbed soils from raindrop splash and sheet flow include: straw applied at 2-2.5 tons/acre, wood fiber or wood cellulose applied at 0.5-1 ton/acre and wood chips applied at 5-6 tons/acre. Early mulching proved advantageous, since the structure of soil improves progressively after the mulch is applied. Mulches increase soil moisture because they improve infiltration of rainfall and slow down evaporation from coil surface.

14.4. Paddy straw mulching

Previously a waste item, paddy straw helps to reduce weeds and increase soil moisture when used on its own or as a base layer for mulch. Rice straw is lightweight, so it is best used in a place that will not get heavy winds when used without heavier mulch as a top layer. The quality of mulch depends of the quality of the straw. Clean straw without any dampness or mold and free from weed seeds is to be used for effective mulching. Seedling establishment has been high with straw mulch. Straw decomposes within 1 to 3 years. Usually, about 2 – 2.5 tons of straw is applied per acre providing about 66 to 100 percent cover. For seedlings to germinate and become established soil needs to show through the straw. A heavier application of straw will help suppress weeds and keep the soil cooler.

14.5. Composting

Composting is an aerobic process in which microorganisms convert a mixed organic substrate into carbon dioxide, water, minerals and stabilized organic matter under controlled condition, particularly of moisture and aeration are required to yield temperatures conductive to the microorganisms involved in the composting process. The stabilized compost produced should benefit the plant growth and be suitable for agricultural applications. Compost is a mixture of decayed organic materials decomposed by microorganisms in a warm, moist and aerobic environment, releasing nutrients into readily available forms for plant use.

The technology used in composting facilities range from very simple windrow and mattress composting facilities to highly advanced composting in closed reactors with automated control of process parameters. Composting facilities typically consist of three stages; primary treatment, composting, and final treatment. The primary treatment usually involves some sort of separation and screening to remove unwanted materials and ensure a proper particle size. Primary treatment can also include mixing with structure materials or adjustment of the C/N ratio pH, or water content. The composting can take place in one process for instance in a reactor or in open windrows. The process may also be a combination of primary composting in a reactor for a short period (1 – 3 days) followed by composting in windrows for several months. The purpose of the final treatment is to make the compost ready for marketing or storage. This typically involves screening to 10-15 mm particle size, hygeinization and in certain cases mixing of different types of compost to adjust the nutrient (N, P, K) contents of the finished product.

14.6. Composting process

The composting process can be divided into four phases.

The initial phase is the first period after initiation of the compost process where the temperature rises to about 50°C over a period of a few days. During this phase the population of especially bacteria increases rapidly and compounds that are easily degradable, such as sugars, starch, proteins and fats are degraded. Due to the rapid rate of degradation and oxygen consumption it is often difficult to provide enough oxygen for the biological processes and the compost will have a tendency to develop anaerobic pockets. Modest decreases in pH may be observed due to the production of organic acids by anaerobic organisms. The organisms active during the initial phase are mesophilic (optimal temperature 35-45 °C) and thermophilic (optimal temperature (55 – 60 °C) bacteria.

If the conditions in the composting material are well maintained the composting material are well maintained the composting process will normally enter the **thermophilic phase** next. This phase involves especially thermophilic bacteria and also certain thermophilic actinomycetes and fungi. During this phase the temperature can exceed 70^{o}C and temperatures as high as 80-85 ^{o}C have been observed during composting o sewage sludge. The pH usually increases to about 7.5 due to the destruction of the organic acids. Near the end of the thermophilic phase when the readily degradable organic material has been removed by the microorganisms only organic materials such as hemicellulose, lignin, chitin, and similar compounds that are more difficult to degrade remain. The microbial activity especially concerning the bacteria begins to decrease and the temperature in the compost begins to fall. At this point the composting process is not yet finished and the compost is sometimes called raw compost.

Upon completion of the thermophilic phase the temperature decreases to levels where the mesophilic organisms have their optimum and the composting process enters **the mesophilic phase**. During this phase where the temperature ranges between 35 and 45 ^{o}C the more difficult to-degrade components such as cellulose and lignin are decomposed. During the mesophilic phase several types of bacteria are still very active but it is especially the actinomycetes and fungi that are important during this phase. Actinomycetes and fungi are better adapted to utilize the more difficult degradable compounds compared to most of the bacteria. Some fungi can even produce penicillin that will kill some of the bacteria. The mesophilic phase can take up to several weeks to complete. At the end of the mesophilic phase the compost is often called finished compost.

The final phase of the composting process is termed the cooling phase, during this phase the temperature slowly decreases to near ambient levels during a time span of several weeks, the microbial degradation of the organic material will be almost completed when entering the cooling phase and the rate of degradation will approach that of a natural soil. The organic matter remaining consists of very complex compounds with humus like structures that are difficult to degrade. The pH during this phase will normally stay relatively constant at about 8. Towards the end of the cooling phase higher organisms such as worms and insects will often colonize the compost. The compost is now termed mature compost and the structure of the organic matter in the compost will closely resemble that of humus.

14.7. Process parameters

14.7.1. Temperature:

The temperature controls the microbial activity and thus the rate of the composting process. The degradation rate usually increases strongly with temperature up to about 70-80 ^{o}C. Above this temperature most microorganisms will either be killed or form spores, which is a resting stage. This prevents further increases in degradation rte and temperature of the compost. It is often important to maintain a high temperature as long as possible to ensure rapid degradation and effective use of the compost facility.

14.7.2. Water content

The water content controls both the microbial activity and the oxygen transportation in the compost material. At low water contents oxygen will be transported faster and easier because a greater amount of the pores are filled with air. This makes it easier to ensure a high oxygen concentration in the compost. Low water contents, however, are inhibitory to microorganisms whose activity will cease at gravimetric water contents below 8-12 %. The optimal water content also depends on the structure of material being composted. Materials that are structurally strong can have higher permissible gravimetric water contents (70-80% for wood chips, straw, hay, etc.) because the structure of the materials ensure that there will be a sufficient amount of air-filled pores.

14.7.3. pH

Composting may proceed effectively over a range of pHs without seriously limiting the process. The optimum pH for microorganisms involved in composting lies between 6.5 and 7.5.

14.7.4. C/N ratio

A good C/N ratio to ensure efficient decomposition in 30 parts carbon to 1 part nitrogen by weight. When too little nitrogen is present, decomposition will occur more slowly; if too much nitrogen exists, it can be lost to atmosphere as ammonia gas.

14.7.5. Oxygen concentration

Oxygen concentration is the limiting factor for biological degradation especially in the early stages of the composting process. If the oxygen concentration is too low, the process will proceed at a much slower rate resulting in lower temperatures in the compost. Also low oxygen concentrations are usually the cause of foul odors originating from organic acids that are produced as a result of anaerobic conditions. Proper oxygen concentrations can be maintained by turning the compost more frequently. Frequent turning or high aeration rates can, however, lead to increased evaporation of water and decreased compost temperatures.

14.8. Composting methods

14.8.1. Turned windrow composting

The organic material that is to be composted is formed into piles that are roughly triangular or trapezoidal in cross section. If manual construction is used the piles should be about 2.5m wide, in case of mechanical turning they can be as wide as 3-4m. The piles are often 20-50m long depending on the amount of input to the facility. The piles are normally turned 7-10 times over a period of about 15 weeks to ensure aeration and to expose all material to the high temperatures in the center of the pile. Turning of the piles can be done either manual or mechanical to make proper exposure to high temperature. The course of the composting process is typically controlled based on temperature and moisture content. If the temperature decreases due to low moisture contents, the piles are watered. If temperature decreases due to lack of oxygen, the piles are turned more frequently to increase oxygen concentration and microbial turnover. After the active composting period, the compost is stored in piles for 2-3 months without turning to ensure proper stability, i.e., that the microbial activity in the compost material has reached a level corresponding to natural soils.

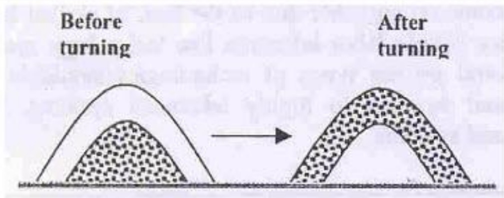


Fig. Process of turning windrows to ensure proper exposure to high temperatures Static pile composting

14.8.2. Static pile composting

The static pile composting process is closely related to turned windrow composting in that both technologies uses open piles during composting. In the static pile process oxygen supply is provided by means of forced aeration rather than natural convection. Perforated aeration pipes are installed under the piles and air is sucked in through the piles toward the pipes and is subsequently pumped to a bio filter where odor-causing compounds produced during the composting process are adsorbed and subsequently degraded. The filter can be made very simple from finished compost. Air may alternatively be pushed from the perforated pipe out through the compost pile. This approach has the advantage that moisture and dust will not accumulate in the piping system.

The static piles are usually not quite static, however, they are turned less frequently than the basic turned windrows usually 3-5 times during the first 15 weeks. Aerationequirements for static pile composting varies with the type of material being composted but is typically on the order of 20-30 m^3 air per ton of compost per hour.

14.8.3. Mattress composting

Mattress composting is a very simple technology that is especially suitable for yard and park waste, i.e., plant residues and tree branches etc. the mattress composting process usually takes significantly longer than both turned and static windrow composting due to the construction and operation of the mattress. The height of the mattress can be varied depending on the space available but a height of 2 to 6 m has been used widely. Phase 1, i.e., the mattress construction and pre-composting at 50^oC can take from 3 months up to approximately one year.

At the beginning of phase 2 the mattress is usually rebuilt using a tractor or bulldozer to ensure homogeneity of the materials. The mattress may actually be "turned" several times during the composting phase. During this phase the temperature can rise to approximately 70^oC. The phase 2 composting takes from 8 to 12 months typically. When the composting phase is nearing its end, the microbial activity and temperature will start to decrease and the temperature will reach about 40°C.At this point the composted material is typically screened (phase 3) and perhaps mixed with other types of compost to adjust nitrogen and phosphorous content and then stored for later marketing.

14.9. Rice Straw Composting

Rice straw is rich in carbon and poor in nitrogen, which limits the composting process. Microorganisms need carbon for cell structure formation and nitrogen for cellular protein synthesis. It was found that C:N ratio of 25 to 30:1 for raw material was desirable for efficient composting. Organic materials poor in nitrogen content (wide C:N ratio) decompose slowly, take more time and result in lower amount of compost formation. Under the situation, the biological activity diminishes and several successions of organisms may be required to degrade the carbonaceous materials. So, C:N ratio of organic materials poor in nitrogen should be made narrow by adding organic raw materials including farm yard manure and poultry droppings or nitrogen in the form of any nitrogenous fertilizer for better decomposition.

14.9.1. IBS Rapid Rice Straw Composting

Rapid composting requires carbon-rich materials such as rice straw, nitrogen-rich materials like animal manure and the activator Trichoderma harzianum. If animal manure is difficult to obtain, it may be replaced with leguminous plants such as azolla and sesbania. At harvest time, rice straw is heaped to one side of the paddy. It saves labor later to have one compost pile for each paddy instead of one central pile. The process steps are as below.

- Rice straw is soaked overnight in irrigation water or in the rain until saturated.
- A simple platform is made in the middle of the paddy (size is relative to the size of the paddy).
- A layer of saturated rice straw 10-15 cm thick is loosely piled on the platform.
- On top of the layer, one or two handfuls of the activator, Trichoderma harzianum is broadcast (25 kg /ha).
- Straw is alternately layered with the activator until all the straw has been used.
- Manure and nitrogenous plants are put on top of the straw layers. The nitrogen substrate is 15-25% of total composition.
- The compost is covered (with plastic, banana leaves, or coconut fronds) and heats up within 25 hours.
- The compost must be moistened frequently to compensate for evaporation.

- The compost is left unturned and matures within one month. It is ready for use when the pile has cooled and is 30% of its original size.

14.9.2. Vermicomposting using paddy straw

The term "vermicomposting" had recently been coined to mean the use of earthworms for composting organic residues. Vermicomposting is an appropriate technique for efficient recycling of animal wastes, crop residues and agro-industrial wastes. Paddy straw is a wide C:N (80:1) organic material, low in nitrogen and phosphorus but fairly rich in potassium. Superphosphate is generally added to fortify the phosphorous content of the compost. It also checks the volatilization loss of NH_3 from the decomposable mass during the process of compost formation.

In conventional method of composting, paddy straw takes 6-8 months for decomposition resulting in a poor quality of compost. The process of conversion of organic materials into manure is chiefly microbiological and greatly influenced by the proportion of carbonaceous and nitrogenous materials present in organic wastes.

Earthworm activities are important in aiding faster decomposition process mainly done by microbial actions. It grinds the organic waste materials in the gizzard and the actions of bacteria therein hasten the decomposition process. The number of bacteria and actinomycetes increased 1000 fold during passage of substrate through the gut.

Besides, aeration, mixing and turning over the materials are essential in decomposition process which are also done by earthworms. Jena et al, (2002) conducted an experiment in Orissa taking red earthworm (Eisenia foetida) for the decomposition of paddy straw in presence of fertilizer sources to add N and P. Dried and chopped (3-4 cm) paddy straw, after thorough mixing with fresh cowdung slurry was introduced into pots. Nitrogen in the form of Calcium Ammonium Nitrate (CAN) was applied to raise the N level of the straw to 2 per cent N and phosphorus as Single Super Phosphate (SSP) to raise the total P_2O_5 content to 0.2 per cent. In control, no such additional fertilizer N or P was added. Watering was done to pots to maintain the moisture content to 40-50 per cent.

After two week of preliminary decomposition, red earthworms were released at 10 adults per pot. The pots were covered with gunny bag to maintain moisture and temperature under shed. This prevents worms from crawling outside the waste material and also to prevent entry of other insects. Ten weeks after the initiation of the composting process, the compost masses were collected. The experimental results showed neutral reaction of the compost masses indicating their suitability for soil application. The straw decomposition was (91 per cent by vermiculture in presence of fertilizer N & P which was greater than the control. The C:N ratio decreased to 10:1 due to earthworm activity alone and further decreased to 8:1 when inoculated in presence of Nitrogen and Phosphorous, showing better influence for the decomposition of a wide C:N ratio material like paddy straw. The earthworm population was increased by 16-20 times.

14.10. Benefits of compost

- Improves the soil structure, porosity and density, thus creating a better plant root environment.
- Increases moisture infiltration and permeability of heavy soils, thus reducing erosion and runoff.
- Improves water-holding capacity, thus reducing water loss and leaching in sandy soils.
- Supplies beneficial micro-organisms to soils, a variety of macro and micronutrients in addition to significant quantities of organic matter.
- May control or suppress certain soil-borne plant pathogens.
- Improves Cation Exchange Capacity (CEC) of soils and growing media, thus improving their ability to hold nutrients for plant use.
- Improves and stabilizes soil pH.
- On practical agricultural level, the compost is an easy process; it saves money on disposal costs, in addition that reduces the need of the farmer for chemical fertilizers.
- On environmental level, the compost reduces the volume of garbage.

Composting of rice-straw into a value added product is thus highly promising alternative to its burning and can potentially increase the agricultural productivity and reduce the problem of environmental pollution.

OBJECTIVE TYPEQUESTIONS

1. The practiceofspreadingplantresidueoranyothermateriallikestrawonthesoilsurfaceto reduce water evaporation losses is called_______
2. Composting is an___________process
3. The optimal mesophilic temperature during the initial phase_^{o}C
4. The optimal thermophilic temperature during the initial phase_^{o}C.
5. The optimum pH for microorganisms involved in composting lies between and____.
6. A good C/N ratio to ensure efficient decomposition in By weight.

7. Vermicomposting mean the use of_______for composting organic residues.
8. CEC refers to ________________________
9. The activator used for rapid paddy straw composting is __________
10. At the end of the mesophilic phase the compost is called_____compost.

QUESTIONS

1. What do you mean by mulching?
2. What are the advantages of mulching?
3. Discuss the types of mulches
4. Write short notes on straw mulching
5. Define composting
6. Explain the composting processes.
7. How the process parameters affect the composting?
8. Write short notes on Turned windrow composting
9. Explain different methods of composting in detail
10. Give a brief note on rapid composting of paddy straw
11. How vermicompost is produced using paddy straw?
12. What are the Benefits of compost?

ANSWERSFOR OBJECTIVE TYPEQUESTIONS

1. Mulching
2. Aerobic3. 35-45oC
3. 55 – 60 oC
4. 6.5 and 7.5
5. 30:1
6. Earthworms
7. CationExchange Capacity
8. Trichodermaharzianum
9. finished

Lesson 15. Paper and cardboard manufacturing from paddy straw

15.1. Introduction

Paper and cardboard are made predominantly from natural fibre-based products bamboo, hemp, papyrus, wood, cotton and straw. Cardboard is the generic term for heavy duty paper and is often referred to as paperboard. In India, paper industry is broadly classified into three segments namely (i) Printing and Writing (P&W) (ii) Newsprint and Paperboard and (iii) Industrial Packaging (Paperboard). Paperboard is the largest segment, accounting for 45% of total domestic paper demand, followed by Printing and Writing (35%) and Newsprint (20%). The industry is further categorized on the basis of raw-material used for manufacturing paper into forest based (21%), agro-based (23%) and recycled fibre-based paper (56%).

15.2. Paper making process

Paper making essentially consists of following stages:

1. Raw material preparation
2. Pulp making
3. Bleaching
4. Stock preparation
5. Sheet formation & water removal

15.2.1. Raw material preparation

Natural fibre based raw materials are received and cut or chipped into small pieces of size 0.5-1" and then screened for further processing.

15.2.2. Pulp making

Pulping generally refers to various industrial processes used to convert raw plant materials or recycled paper into a fibrous raw material known as pulp, which is used primarily to make paper or paperboard products. Predominantly, pulp making is done either by mechanical or chemical means. In mechanical process, the raw material is reduced to small particles by rubbing against huge grindstones revolving at high speeds. In the chemical process, the cellulose fibers of the raw material are separated from the non-cellulose components by chemical action.

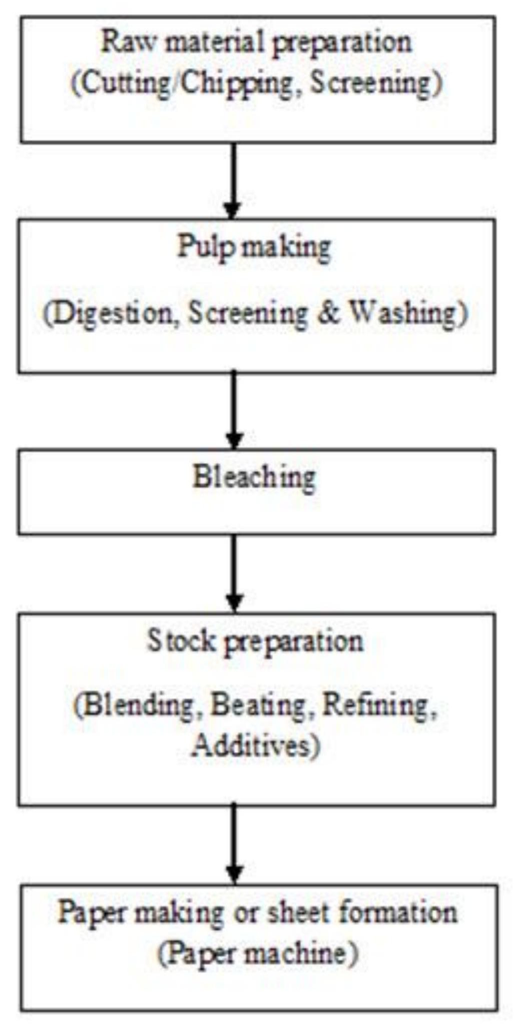


Fig 15.1. Paper manufacturing process flow chart

Three primary chemical processes are in use, viz., Kraft or sulphate (alkaline), sulphite (acidic) and Neutral Sulphite Semi Chemical (NSSC). All large Pulp & Paper mills in India use the Kraft/sulphate chemical process for pulping. In this process, the raw material is cut to 0.5-1" size. Then the raw materials are fed into digesters, reacted with white liquor (80:20 NaOH and NaS) and steamed for about two to three hours at high temperature and pressure (162 - 168^{o}C and 7-8 kg/cm^{2}). Digesters may be batch or continuous type, the latter offering advantages such as increased throughput, reduced labour and better energy utilization. Continuous digesters are also very useful in agro fiber pulping. The pulp is then washed to make the pulp free from soluble impurities and removal of black liquor through usual 3 or 4 stages of counter current washing using rotary drum filters. The washed pulp is then sent for bleaching to increase the brightness of the pulp and the dilute black liquor is sent to evaporators.

15.2.3. Bleaching Process

Pulp when it comes from digester contains residual coloring matter. This unbleached pulp may be used for making heavy wrapping paper or bags. However, paper to be used for printing, writing or paper which is to be dyed must first be bleached. The main object in bleaching is to remove residual lignin from the pulp fibers as well as to destroy or remove remaining colouring matter. Chemical pulps are bleached through the use of alternating treatments of oxidizing agents and alkali solutions. Mechanical pulps are treated with hydrogen peroxide or sodium hydrosulfite to reduce the light absorption of the lignin rather than remove it. Nowadays various bleaching agents are used to bleach the pulp like chlorine, chlorine dioxide, hydrogen peroxide, oxygen and calcium hypo chlorite.

15.2.4. Stock preparation

Stock preparation is undertaken to give the pulp various desired qualities through refining. It is mostly accomplished in either double disk or conical refiners. A more vigorous and special type of refiner known as Jordan is used in mechanical pulp preparation method in which a conical plug rotates in conical shell. The stock then undergoes addition of sizing, filling and coloring agents. A final screening & centri-cleaning is carried out prior to paper making for removing the contaminants as they may lead to defects in paper.

15.2.5. Sheet formation & water removal

The feed to the paper machine consists of combination of refined pulp together with additives such as fillers and wet end chemicals having requisite stock consistency. Either fourdrinier or cylindrical mould machines form the above feed into a sheet. Mills producing cultural and newsprint paper use high-speed fourdrinier and twin wire sheet formers. Mills producing packaging paper & board mainly use cylindrical mould machines. At wet end of paper machine, water is first removed by gravity then by suction and then by pressing the sheet and lastly by drying by steam heated cylinders.

15.3. Paper from paddy straw

15.3.1. Straw preparation

Paddy straw was initially cut to equal sizes of about 1.5 cm.

15.3.2. Pulping

Straw pulping is usually produced by the soda pulping process in batch rotary digesters with a four to six hour cycle comprising basic stages of delignification, cooking with 6% sodium hydroxide and bleaching which produce a strong black and a large volume of bleach washings.

15.3.3. Bleaching

The straw after digestion is washed in a multi stage washer with counter current system and usually bleached with a single stage or double stage hypochlorite treatment with 5% hypochlorite in first stage. The treatment is given in Decker washers or thickeners. It is customary to omit the chlorination stage since it causes degradation and yields poor quality product.

15.3.4. Stock preparation

A single pass refining treatment is sufficient for the pulp to attain the desired level of freeness usually 250° csf or 45° SR. Brightness levels are seldom higher than 70° PV and the pulp tends to discolour on storage.

15.3.5. Blending

Paddy straw pulps are blended with 10-15% of high strength bamboo or imported hardwood pulps for paper making.

15.4. Paperboard

Paperboard is made in a similar way to paper but is thicker to protect materials or products (foods) from mechanical damage. The main characteristics of board are thickness, stiffness, ability to crease without cracking, degree of whiteness, surface properties and suitability for printing.

Corrugated board is the most common form of secondary food packaging and is used by virtually every industry. Corrugated board has an outer and an inner lining of kraft paper (made from at least 80% sulfate pulp) with a central corrugating (or fluting) material. This is made by softening kraft paperboard with steam and passing it over corrugating rollers. The linear are then applied to each side using a suitable adhesive. The board is formed into "cut-outs" that are then assembled into cases at the filling line. There are four different flute sizes, A, B, C, and E flutes which vary in height and the number of flutes per unit length of board. They can be used alone or in combination with one another to produce single face, single wall, double wall and triple wall corrugated board constructions as shown in Fig. 15.2.

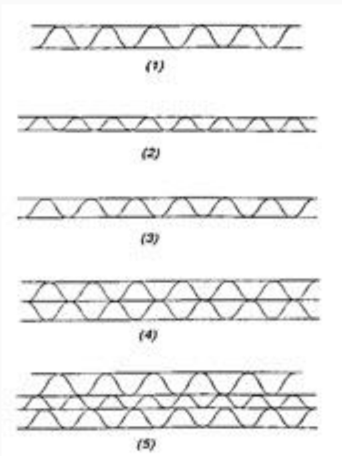


Fig 15.2. Various types of corrugated board construction

(1) "A" flute single wall, (2) "B" flute single wall, (3) "C" flute single wall

(4) "C" and "C"double wall and (5) "A," "B," and "C" triple wall

Corrugated board has good impact abrasion and compression strength and is mainly used in secondary packaging containers. The most standard type of secondary packaging material is single-wall C flute. High storage humidity that causes delamination of the corrugated material is prevented by lining with polyethylene or greaseproof paper to coating with microcrystalline wax and polyethylene.

15.5. Card stock

The thinnest type of cardboard, card stock is thicker than most traditional writing paper but still has the ability to bend. As a result of its flexibility, it is often used in post-cards, for catalog covers, and in some soft-cover books. Many kinds of business cards are also manufactured from card stock because it is strong enough to resist the basic wear and tear that would destroy traditional paper.

15.6. Major factors affecting energy efficiency in paper mills

Section-wise details of factors, which affect energy efficiency, are given below:

1. Type of raw material preparation section
    1. Type of chippers/ cutters and type of conveying system
2. Digesters system
    1. Type of pulping technology
    2. Installation of blow heat recovery
    3. Optimal bath liquor ratio
3. Washing section
    1. Utilisation of advanced washers, such as, flat belt wire washers, double wire press, DD washer and Twin drum washer
4. Screening section
    1. Installation of advanced screening equipment
5. Stock Preparation
    1. Type of refiners and type of centri-cleaners (use of low pressure drop centri-cleaners reduce the pumping power consumption)
6. Paper machine
    1. Type of press
    2. Percentage moisture after press section and on-line moisture control
    3. Type of hood system
    4. Type of siphon for condensate removal
7. Evaporation section
    1. Type of evaporator and number of stages

2. Steam economy achieved (minimum should be 6) and extent of condensate recovery

Apart from the above factors, optimized operation and proper maintenance are also very important for energy efficiency.

1. Classify Indian paper industry

Lesson 16. Straw as a fuel

16.1. Introduction

In India, annual production of rice is about 136.5 million tonnes and about 136.5-150 million tonnes of paddy straw is estimated to be produced. Disposal of paddy straw has been a big problem since time immemorial. Paddy straw burning can be commonly seen during the harvesting season which causes soil erosion and emission of pollutants. Little proportion of paddy straw is also used for composting, surface mulching, in situ incorporation, mushroom production, animal feed and like. Direct combustion of biomass for heat and power generation, Biogas generated via anaerobic digestion, producer gas generated through gasification, ethanol production are the common ways of utilizing paddy straw for energy.

16.2. Technologies for producing fuel from rice straw

In general, paddy straw can be converted into energy products via two processes:

1. Thermochemical processes

- Combustion
- Pyrolysis
- Gasification

2. Biochemical processes

- Anaerobic digestion
- Fermentation

16.3. Pre-treatment prior to thermo-chemical conversion

The typical pre-treatment technologies include sizing, leaching (commonly known as washing) and pelletisation. Sizing refers to the process of reducing the size of rice straw with the aim to improve boiler efficiencies. In general, fuel with small-sized particles provides higher burning rates as well as ignition front speeds, leading to better combustion efficiency. Looking from the perspective of chemical properties, the high alkali content of rice straw can ultimately lead to slagging and fouling problems in combustion equipment. Hence, pre-treatment of these paddy straw becomes an integral part of utilizing these resources as fuel. Leaching process can remove unwanted substances in the rice straw. It can reduce slagging, fouling as well as corrosion problems in furnaces system and subsequently extend the operating life of a boiler. Studies have shown that distilled water or tap water can efficiently reduce the quantity of potassium, sodium and chlorine in the rice straw.

16.4. Pre-treatment prior to bio-chemical conversion

In biochemical conversion, pretreatment of lignocellulosic biomass is an essential step that emphasizes on the removal of lignin network. The cellulose and hemicelluloses components of paddy straw are embedded within the lignin network consisting of polysaccharide layers that prevent the enzymatic hydrolysis. Hence, to expose the cellulose and hemicelluloses for enzymatic action, and subsequently increase the bioconversion efficiency, the lignin network must be removed with proper pretreatment.

Based on the application and type of pretreatment catalyst (liquid and steam water are not considered a catalyst in this paper), pretreatment techniques have generally been divided into three distinct categories, including physical, chemical, and biological pretreatment.

16.4.1. Physical pretreatment

Physical pretreatment does not use chemical agents, and typically includes uncatalyzed steam explosion, liquid hot water pretreatment (LHW), mechanical comminution, and high energy radiation. The former two pretreatment methods are more common than the later.

16.4.2. Chemical pretreatment

Chemical pretreatments were originally developed and have been extensively used in the paper industry for delignification of cellulosic materials to produce high quality paper products. The possibility of developing effective and inexpensive pretreatment techniques by modifying the pulping processes has been considered. Chemical pretreatments that have been studied to date have had the primary goal of improving the biodegradability of cellulose by removing lignin and/or hemicellulose, and to a lesser degree decreasing the degree of polymerization and crystallinity of the cellulose component. Chemical pretreatment is the most studied pretreatment technique among pretreatment categories. The seven common chemical pretreatment techniques include catalyzed steam-explosion, acid, alkaline, ammonia fiber/freeze explosion, organosolv, pH-controlled liquid hot water and ionic liquids pretreatments.

16.4.3. Biological pretreatment

Biological pretreatment employs wood degrading microorganisms, including white-, brown-, soft-rot fungi, and bacteria to modify the chemical composition and/or structure of the lignocellulosic biomass so that the modified biomass is more amenable to microbial action/enzyme digestion. Fungi have distinct degradation characteristics on lignocellulosic biomass. In general, brown and soft rots mainly attack cellulose while imparting minor modifications to lignin, and white-rot fungi are more actively degrade the lignin component.

16.5. Thermo-chemical process

Thermo-chemical processes can be divided into two categories. The first category involves direct utilisation of biomass as fuel for combustion, and subsequently for heat and electricity generation. The second category involves converting biomass into other useful forms of energy products prior to its utilisation as a source of energy.

16.5.1. Direct combustion

Rice straw could be used with the current heat and power technologies in many rice producing countries to replace fossil fuels to reduce sulphur dioxide and greenhouse emission.
In direct combustion, straw is utilised as a fuel in a combustion boiler to produce steam (a heat source) in the presence of sufficient air in the combustion chamber. Heat and electricity can be simultaneously generated (cogeneration) using turbines. Generally, biomass combustion technologies can be categorised into the fixed bed and fluidised bed combustion systems.

Co-firing is the simultaneous combustion of different fuels in the same boiler. Many coal and oil-fired boilers at power stations have been retrofitted to permit multi-fuel flexibility. Biomass such as paddy straw is a well-suited resource for co-firing with coal as an acid rain and greenhouse gas emission control strategy. Co-firing is a fuel-substitution option for existing capacity and is not a capacity expansion option.

Sizing is done to increase the energy conversion efficiency and combustion performance which involves the cutting of straw into smaller sizes to improve boiler efficiency. Rice straws are dried in the air for two weeks, the dried rice straws with length ranges from 70-140 cm are cut to 6.4 mm or smaller particle size. Equipment such as hoggers, hammer mills, spike rolls, and disc screens are required to properly size the feedstock. Unlike coal, paddy straw contains very small amounts of sulphur. Hence, substitution of paddy straw for coal can result in significant reductions in sulphur dioxide (SO_2) emissions. Co-firing of biomass residues, rather than crops grown for energy, brings additional greenhouse gas mitigation by avoiding CH_4 release from the otherwise landfilled biomass. It is believed that CH_4 is 21 times more potent than CO_2 in terms of global warming impact.

16.5.2. Pyrolysis

Pyrolysis is a decomposition process of biomass at high temperature in the absence of air. Pyrolysis occurs under pressure and suitable typical operating temperature range between 350 ^{o}C and 550^{o}C. The end products are in the form of gas and liquid as well as carbon-rich solid residue. The proportion of the products depends on the operating conditions.

16.5.3. Gasification

For electricity generation, two most competitive technologies are direct combustion and gasification. Gasification is the thermo-chemical process required to convert rice straw to producer gas, fuel that could replace natural gas and diesel. Fluidized bed gasification has been investigated since 1981 as a method to produce low Btu gas from rice straw. The system uses a bed of sand inside a refractory-lined cylinder reactor. The rice straw is fed into the sand bed which is fluidized by air supplied from below. The air provides only one-fifth to two-fifths of the amount needed for total combustion. Producer gas is a mixture of combustible gases carbon dioxide, hydrogen, methane, and a small amount of higher carbon gases. It also contains water vapor and nitrogen gas. The combustible gases range from 25 to 40 percent by volume of total gases. producer gas can be used in internal combustion (IC) engine to produce heat, or in a cogeneration system to produce heat and electricity.

In India gasifier technology has penetrated the applications such as village electrification, captive power generation and process heat generation in industries producing biomass waste such as rice straw, rice husk, bagasse, wood waste, wood, wild bushes and paper mill waste. Nearly 55 MW of grid connected biomass power capacity is commissioned and another 90 MW capacity is under construction.

16.6. Bio-chemical process

The bio-chemical process routes for biomass conversion into value-added products include the production of ethanol, hydrogen as well as methane.

16.6.1. Biogas generation via anaerobic digestion

Paddy straw has high content of cellulose (35-40%), hemi-cellulose (20%), lignin (12%) and silica (8%). But, the lignin complex and silica incrustation shields the microbial action and hence restricts paddy straw digestibility. So, the first step towards economical utilization of paddy straw is to remove/degrade lignin and silica to enable cellulose to be more accessible to the microbial/enzymatic attack. Pretreatment methods including alkali pretreatment, heat pretreatment, size reduction and seeding have been explored to increase the digestibility of straw. Among these methods alkali pretreatment is notably effective in treating straw for anaerobic digestion.

Biogas can be produced from paddy straw by anaerobic fermentation using cattle dung as a source of inoculum. Biogas generation involves consortium of microorganisms which is a group of hydrolytic, acidogenic and methanogenic bacteria. Hydrolytic bacteria degrade the complex organic matter (carbohydrates, proteins and fats) into simpler forms (sugars, amino acids, fatty acids and glycerol). Acidogenic bacteria breakdown these simpler forms (sugars, amino acids, fatty acids and glycerol) into CH_3COOH, H_2 and CO_2 which is further utilized by methanogenic bacteria to produce biogas. Biogas is mixture of CH_4 (50-60%), CO_2 (30-40%),

H_2 (1-5%), N_2 (0.5%), CO, H_2S and water vapors. The biogas is subsequently utilized as fuel to generate heat and energy.

16.6.2. Production of ethanol from fermentation of paddy straw

Production of ethanol from paddy straw contains three major processes, including pretreatment, enzymatic hydrolysis, and fermentation. Pretreatment is required to alter the biomass macroscopic and microscopic size and structure as well as its sub-microscopic structural and chemical composition to facilitate rapid and efficient hydrolysis of carbohydrates to fermentable sugars which has been discussed in the earlier section. Hydrolysis refers to the processes that convert the polysaccharides into monomeric sugars. The fermentable sugars obtained from hydrolysis process could be fermented into ethanol by ethanol producing microorganisms, which can be either naturally occurred or genetically modified.

After fermentation, ethanol can be recovered from the fermentation broth by distillation or distillation combined with adsorption or filtration, including drying using lime or a salt, addition of an entrainer, molecular sieves, membranes, and pressure reduction. The distillation residual solid, including lignin, ash, enzyme, organism debris, residue cellulose and hemicellulose, and other components may be recovered as solid fuel or converted to various value-added co-products.

16.6.3. Hydrogen production via fermentation

Hydrogen production from fermentation of agricultural wastes is a relatively new research area as compared to the well established anaerobic digestion. During fermentation, anaerobic bacteria ferment carbohydrates to produce hydrogen, volatile fatty acids and carbon dioxide. The fermentation process can be divided into photo-fermentation and dark fermentation where different types of bacteria function under different operating conditions. Biomass fermentation with carbohydrates such as rice or other agricultural wastes is a promising route to produce hydrogen. Further increase in the hydrogen production, yield to an economically feasible level, coupled with continuous development of industrial scale operations are however still needed.

In many countries paddy straw has great potential to be converted into energy in order to meet the countries' energy demands. India, China, Indonesia and other rice producing countries can enjoy the environmental and economic benefits from utilization of rice straw as a source of renewable energy. Heat and electricity from cogeneration systems could be used to meet the energy demands of local rice mills. Alternatively, excess electricity can be exported to the national grid. Other potential sources of energy from rice straw that can be used for heating and power generation include methane and hydrogen generated via various biomass conversion processes. Ethanol is another important source of energy derived particularly from rice straw. It is typically used for public transportations and has potential to reduce dependency on fossil fuels. Despite all the potential benefits, further research is still required on optimal allocation of rice straw resources in rice mills as well as on industrial commercialization of these technologies.

QUESTIONS

1. List out the technologies for producing fuel from rice straw
2. Write short note on pre-treatment given prior to thermo-chemical conversion
3. Write short note on pre-treatment given prior to bio-chemical conversion
4. Explain the different thermo-chemical processes
5. Define Co-firing
6. What do you mean by the term pyrolysis
7. Give a brief note on biogas generation via an aerobic digestion
8. Give the composition of biogas
9. How ethanol is produced from paddy straw?
10. Write short notes on Hydrogen production via fermentation