4.2. PRINCIPLES OF BIOMASS CONVERSION

Bioconversion, also known as biotransformation, is defined as the process of conversion of organic materials such as plant or animal waste into usable products or energy sources by biological processes or agents such as certain microorganisms.

4.2.1. Photosynthesis Process

Biomass energy is obtained by photosynthesis process. It means the synthesis process with light. Photosynthesis converts solar energy into biomass energy. It consists in building up of simple carbohydrates such as sugar in the green leaf in the presence of sunlight.

Solar radiation incident on green plants and other photosynthesis organisms perform two basic functions. They are given below.

1. Temperature control for chemical reactions to proceed and

2. Photosynthesis process.

The fundamental conversion process in green plants is photosynthesis. Photosynthesis is a complex process. It is the process of combining CO2, water and light energy to produce oxygen and carbohydrates (sugar, starches, celluloses and hemicelluloses). They are the main source of our foods and clothes (in the form of cotton), furniture etc. The net energy absorbed from solar radiation during photosynthesis can be measured from its combustion.

$$xCO2+y\ H2O+\text{Light energy} \xrightarrow{\text{Photosynthesis}} xO2+Cx\ (H2O)\ y$$

where the symbol Cx (H2O) y indicates the carbohydrates.

For example, the basic chemical reaction for the formation of hexose (glucose, fructose e) using photosynthesis is represented by the following chemical equation

$$6CO_2 + 6H_2O + \Delta Q \xrightarrow{\text{Photosynthesis}} 602 + 6\ C_6 H_{12} O_6$$

Where ΔQ is enthalpy change of the combustion process equal to the energy absorbed from

photons of solar radiation.

Necessary conditions for photosynthesis process:

1. Light: It is one of the important input for biomass production.

2. CO_2 concentration: It is the primary raw material for photosynthesis.

3. Temperature: Photosynthesis is restricted to the temperature range 0°C to 60°C.

4.2.2. BIOMASS CONVERSION TECHNOLOGIES/PROCESSES

There are many biomass conversion routes to prepare energy efficient biofuels. The conversion routes are broadly divided into four categories. These are outlined as follows:

1. Physical or mechanical conversion

2. Agrochemical conversion

3. Thermal gasification or Thermochemical conversion

a) Direct combustion

b) Carbonisation

c) Pyrolysis

d) Gasification

e) Liquefication

4. Biochemical conversion

a) Anaerobic digestion

b) Ethanol fermentation.

4.2.3. PHYSICAL OR MECHANICAL CONVERSION CLASSIFICATION OF BIOMASS AND ITS CLASSIFICATION

Mechanical conversion of biomass is an important method because it is a solid. Usually. agricultural residues and energy crops have irregular shapes and a low bulk density due to loose harvest formats. They also have high moisture content which can accelerate degradation during storage. Therefore, the low density of biomass materials makes a challenge for the handling transportation, storage and combustion processes. These problems can be reduced by proper processes called biomass densification and biomass upgrading.

Biomass densification is a process to increasing the bulk and energy densities of a biomass feedstock by reducing its bulk volume to obtain more uniform properties than raw biomass

Mechanical means are used to arrange biomass into predetermined smaller, uniform sizes to facilitate better handling, transportation and storage.

Biomass upgrading is the process of changing the properties of biomass to improve storage, transportation, pretreatment and conversion. For example, upgrading can reduce moisture content and increase hydrophobicity to reduce feedstock deterioration during storage. Upgrading also increases feedstock flow ability by improving the handling of feedstocks and their grindability. Also, it reduces energy requirements during the size-reduction process. Before doing of mechanical conversion biomass, it is necessary to pre-treatment of biomass.

4.2.3.1. Pre-treatment of Biomass

Pretreatment is a main tool for cellulose conversion processes which is essential to change the structure of cellulosic biomass to make cellulose more available to the enzymes. They convert the carbohydrate polymers into fermentable sugars. Some of the methods are listed in Table 4.2 below.

Table 4.2 Methods of pre-treatment of biomass residues materials

Pre-treatment methods	Procedures	Effects	Benefits

Steam explosion	It is method in which high pressure steam is applied for a short time and then released.	Due to this, there is a physical, chemical and structural changes in the biomass residues materials.	It helps in binding during palletization and briquetting.
Torrefaction	It is a process of slow heating of biomass residues materials to a temperature of near about 3000°C.	Due to this, volatile materials and smoke evolving products are reduces to make final product better.	It helps in binding during palletization and briquetting.
Ammonia fiber expansion	It is a process in which ammonia aqueous is used at high pressure and temperature to obtain more hydrolysis yields for several gramineous feedstocks.	Due to this process, recrystallizing of cellulose in the biomass residues material reduces hemicellulose and lignin.	It helps in binding during palletization and briquetting.
Grinding	It is a process of grinding of the biomass raw/residues material at specific size depends upon the densification technology selected.	Due to this, Conversion of the biomass raw or residues material in appropriate size and breakdown the lignin present in it.	It increases the surface area of the biomass raw or residues material which improves the binding process.
Pre-heating	It is a process of heating of biomass raw or residues material before densification or briquetting process to enhance the quality of the product.	Due to this, energy consumption of manufacturing the briquettes or pellets can be decreased.	Generate more lignin which help in binding during densification.

4.2.3.2. Methods of Biomass Densification and Upgrading

Various methods of biomass densification and upgrading techniques are used based on the type of feedstock, available equipment and desired final product such as

1. Baling:

(i) Baling

(ii) Briquetting

(iii) Pelletization

(iv) Torrefaction

(v) Chipping.

Baling is a traditional method of densification commonly used to harvest crops. A bale is formed using farm machinery called a baler to compress the chop. The shape of bales can be square, rectangular or round based on the type of baler used. The dimensions of round bales range from 1.2 m x 1.5m to 1.5 mx 1.5 m. Large rectangular bales are in the size of 0.9mx 0.9mx 1.8m in length. Round bales are less expensive to produce but large square bales are sally denser and easier to handle and transport.

Briquettings

Briquetting is one way to increase the energy density and overcome handling difficulties. as the simplest method of physical conversion of biomass by compressing the combustible material. In this method, feedstocks are compacted using a hydraulic, mechanical or roller press under high pressure by a piston press or screw press/extruder. Briquettes (66 mm diameter and 06 thick) made from paddy husk or sawdust is a cheap and effective fuel for the tobacco- caring industry. Also, briquettes can be made from feedstocks with a 6-18% range of moisture and may use binders such as starch, molasses and arabic gum. The addition of binders permits a considerable flexibility in the production method and type of feedstock. Briquettes are primarily used for heating purposes.

Screw compaction/extruder machine:

Screw extruder has a rotating screw which exerts a force on biomass residues coming from the feedstock for compression. A separate mechanical drive is used to operate a screw inside de machine. A significant amount of energy is needed to reduce the particle friction because biomass residues are moderately compressed and crammed. At high temperature and initial emperature, particles of biomass become softer. It causes interlinking of particles and local bends formation. When biomass enters in tapered die section, a remaining moisture is again evaporated because of high temperature of range 2800°C. This process helps to intensify the compression on biomass residues materials. The high temperature and heavy compression make the biomass material more appropriate for burning and co-firing process.

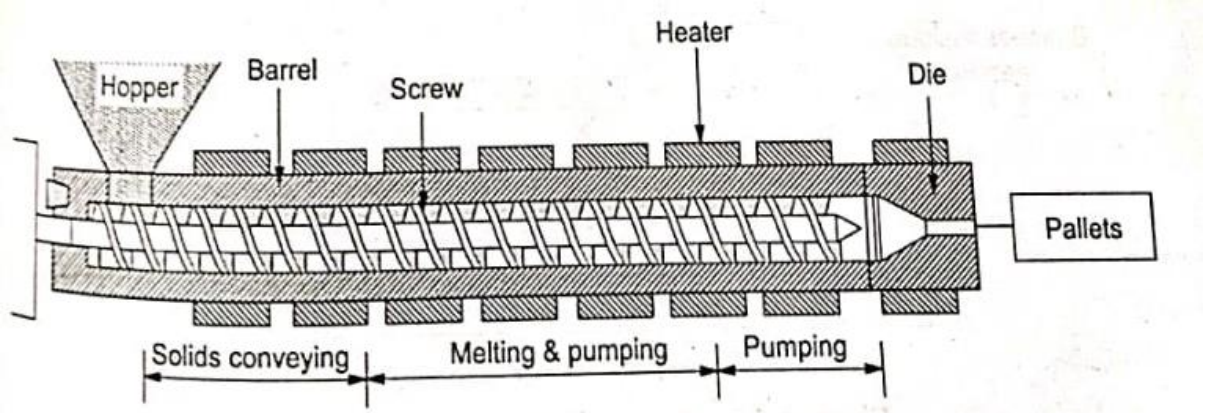

Figure 4.1 Biomass screw type extrude

Piston press/pump machine:

Piston press used piston which is driven by flywheel or some hydraulic mechanism for the production of densified biomass fuel such as briquettes/pellets. A biomass residues material

coming from feedstock unit into the cylindrical shaped piston drive which can be driven either mechanically or hydraulically. For heating of biomass residues material, temperature range lies between 15000°C to 30000°C during compression process. The incoming biomass residues material is compressed towards the conical shaped die by the piston and the briquettes is extrude from the opening face of the die.

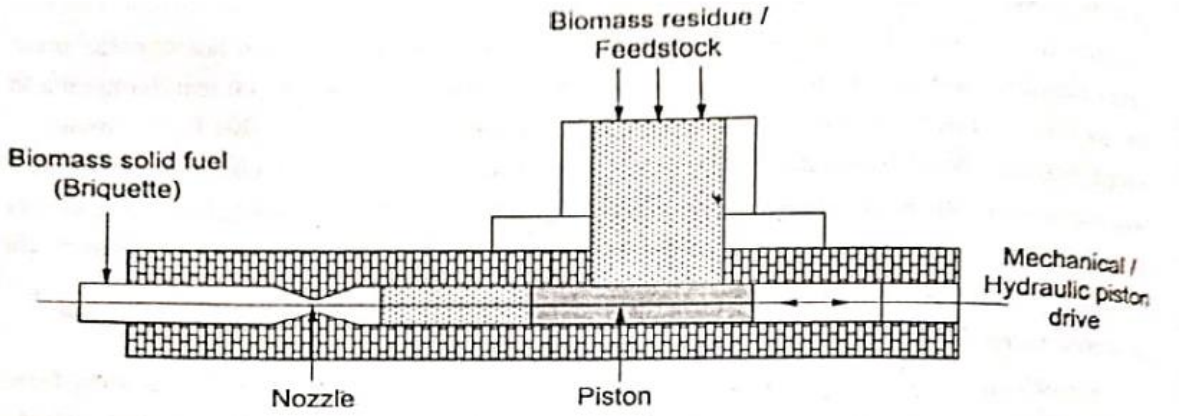

Figure 4.2 Biomass piston press/pump type machine

(iii) Roller press/mill machine:

A biomass roller press/mill type machine depicted in Figure 4.3. The main unit of roller mill is two rollers which rotate in the opposite direction with each other.

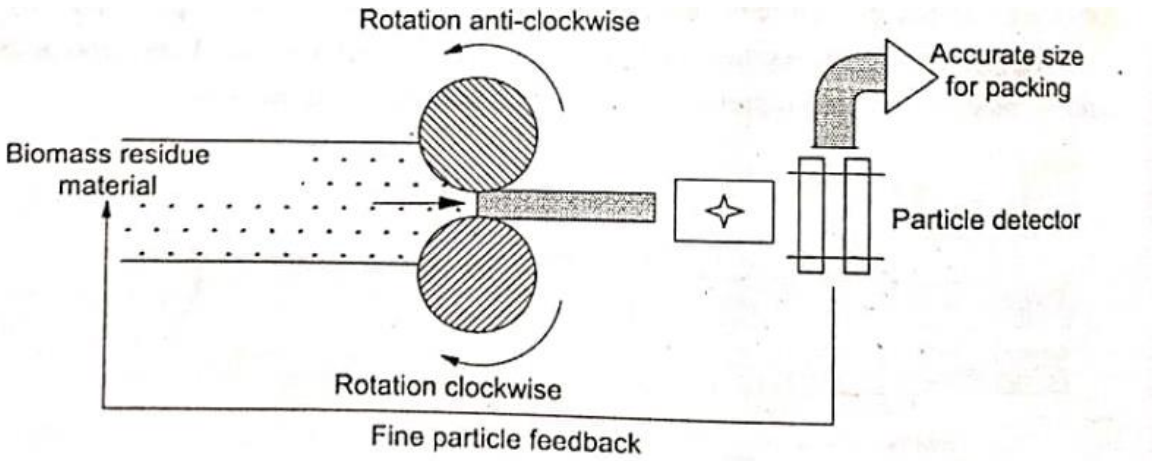

Figure 4.3 Biomass roller press/mill type machine

The biomass residues material is fed through the hopper. The flow of biomass residues material is controlled by control mechanism. The forces exerted on the predetermined quantity of pre-compressed biomass residues materials by two rollers which continuously rotate in

opposite direction. The biomass residues material is dragged out from one side and the densified product is extruded from other side. The gap between two rollers depends on type of biomass residues material used, content of moisture, size of particle, ratio of binders and several other factors.

3. Pelletization:

Pelletisation is a process in which wood is compressed and extracted in the form of rods (5-12 mm diameter and 12 mm long). It has applications in steam power plants and gasification systems. The purpose of pelletisation is to reduce the moisture contents and increase the energy density of wood for longer transportation haulage. A pellet mill is used to produce high-density pellets by compressing ground biomass between rollers and a die and then it is extruded through die holes. The most common pellet mills are flat die and ring die mills. The primary difference between briquettes and pellets are their bulk densities, the particle size of the biomass inputs and their final product size. For pelletization, the biomass is ground to 0.18-3 mm in diameter. The production of high-quality pellets is enhanced by using steam to soften the biomass and entrained lignin and by adding different binders. Usually, pellets have high bulk density and durability, good flowability and storability. Currently, pellets are used for domestic space heating. They also have the potential for supplying feedstock to biobased industries with improved processability.

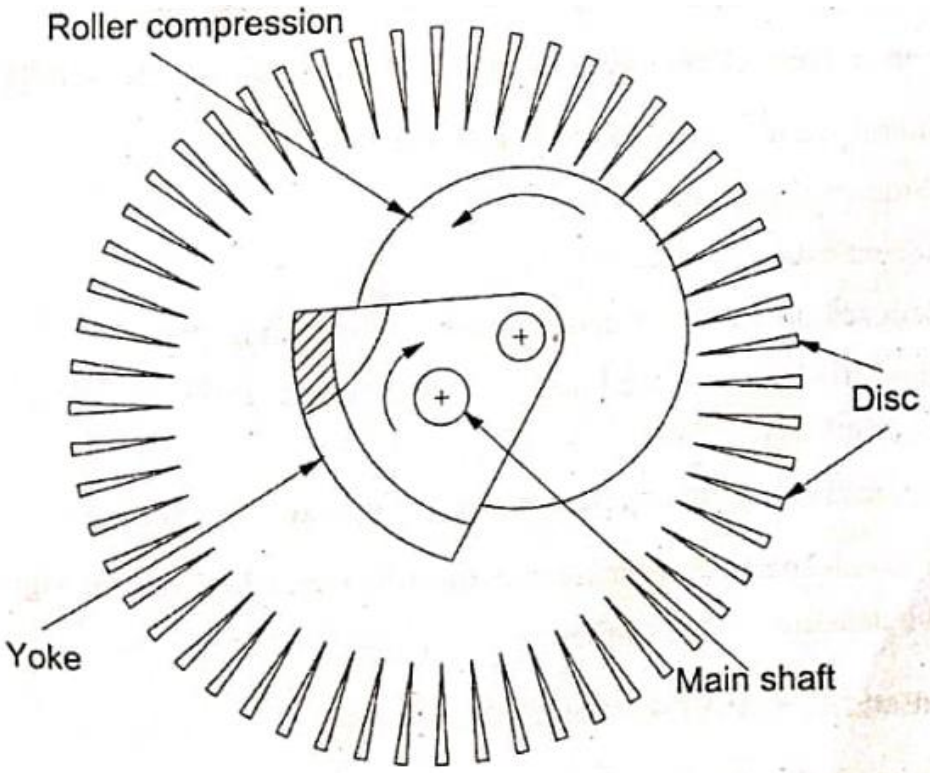

Figure 4.4 Biomass pellet press type machine

4. Torrefaction:

Torrefaction is a thermal biomass upgrading process carried out at 200-300°C under inert conditions which means in the absence of oxygen with a reactor residence time of 10-30 min and longer. Torrefied biomass has reduced moisture content, improved hydrophobicity, enhanced brittleness and greater energy content when compared to the raw biomass. It is also better-preserved during storage and its enhanced brittleness improves downstream grindability. Torrefied biomass is further densified by pelletization which increases its specific bulk and energy densities while enhancing its flowability by creating uniformity among the different biomass types and forms.

5. Chipping:

Chipping is a biomass upgrading method to reduce the size of woody biomass which includes forest residues and short rotation woody crops into smaller and more uniform wood chips. Usually, the bulk density of chipped biomass is higher than forest residue which is loosely piled but it is lower than stacked wood. It is cut to specific lengths and split or sorted by diameter before stacking. Chipping improves the handling, storage and transportation of irregular-sized and shaped woody biomass. It prepares it for use in biorefineries or combustion power plants. Wood chips used in biofuels plants and boilers are irregular in shape and size ranging from 3 to 80 mm.

Advantages and disadvantage of biomass densification

The main advantages of biomass densification for combustion are as follows.

(i) Simplified mechanical handling and feeding

(ii) Uniform combustion in boilers

(iii) Reduced dust production

(iv) Reduced possibility of spontaneous combustion in storage

(v) Simplified storage and handling infrastructure, lowering capital requirements at the combustion plant

(vi) Reduced cost of transportation due to increased energy density

The major disadvantage to biomass densification technologies is the high cost associated with some of the densification processes.

4.2.4. AGROCHEMICAL CONVERSION OF BIOMASS

Agrochemical fuel extraction describes the production of fuels from plants. The plant usually remains alive and unharmed. Generally, liquid or solid fuels may be obtained directly

fon living or freshly cut plants. The materials are called exudates. They are obtained by ating into stems and trunks of the living plant or by crushing freshly harvested material. A well-known similar process is the production of natural rubber latex.

Some of the plants form not only partly oxidised C-II bonds (cellulose or lignin) but also fem completely oxygen-free hydrocarbons. The oil of the plant itself can directly be used as energy source. Categories of suitable materials are as follows:

(i) Seeds (sunflower with 50% oil)

(ii) Nuts (oil palm; coconut copra to 50% by mass of oil) (ii) Fruits (olive)

(iv) Leaves (eucalyptus with 25% oil)

(v) Tapped exudates (rubber latex)

(vi) Harvested plants (oils and solvents to 15% of the tree dry mass, e.g. turpentine from pine trees; oil from Euphorbia).