



Paper

FROM RAGS TO RICHES

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Abstract

Organic waste is extensively increasing with rising population, increased agriculture and industrialization. The disposal of waste has become important for a healthy quality of environment. Proper waste disposal is critical due to the fact that certain types of wastes can be hazardous and can contaminate the environment if not handled properly. These types of waste also have the potential to cause disease or get into water supplies. Wastes that are not properly disposed of can leak and contaminate soil and water, which can lead to issues with both the environment and human health. The conversion of waste into beneficial materials is an important aspect of resource through Biomass Conversion Routes which include Thermochemical Conversion and Biochemical Conversion methods which utilize techniques such as Combustion, Gasification, Pyrolysis Liquefaction and Fermentation. The review states how wastes can be converted in to usable matter not only contributing to economy but also reducing the problem of rising waste management.

Key words: Cellulosic Agricultural Biomass Waste, Pyrolysis, Combustion, Gasification and Fermentation.

INTRODUCTION

Waste management is fast becoming a nightmare for citizens and local authorities in cities across India. The future of waste management on this planet is highly overcrowded. Even the best waste management system in the world has shown that it cannot withstand the test of a global financial downturn; and with the global population, GDP per capita – and therefore the amount of waste – increasing globally we must become aware of the consequences and do something about it in a way where in it would contribute to economic status ensuring conversion of wastes to usable matter as well as optimum utilization of products.

Biomass Conversion Routes

Thermochemical Conversion

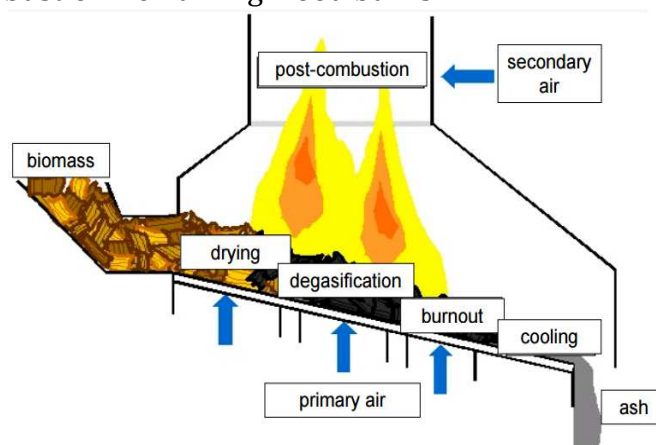
Significance of biomass combustion

- Biomass energy will not increase emissions like carbon dioxide in the atmosphere; hence will not add threat of climate change.

- On the other side growing plants will help in removing atmospheric carbon by the process of photosynthesis.
- Growing biomass balances the used biomass for energy thus resulting in neutral carbon dioxide from bioenergy.
- 14% of the world's energy is met by biomass, globally.
- Biomass origin process can be simply described through the following equation:
$$6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{(sunlight)}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

Direct combustion

- Biomass fuels can be converted into various useful forms of energy using combustion technologies which can be used either for commercial or industrial uses like, hot air, hot water, steam and electricity.
- The simplest combustion technology is a furnace. In a furnace biomass is converted into heat energy.
- Wood combustion is generally divided into four phases:
 - Drying: removing water from wood
 - Degassification: removal of gas content from wood
 - Gasification: released gases burn at a high temperature by mixing with atmospheric air.
 - Combustion: remaining wood burns.



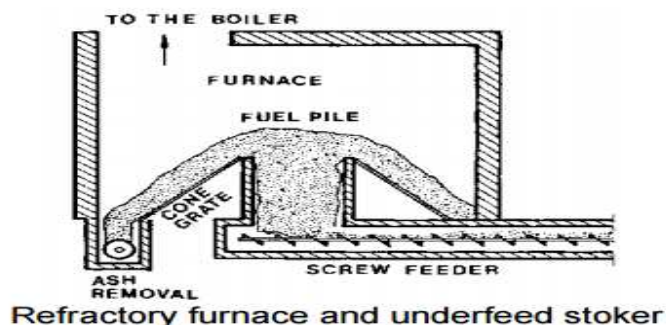
- Most adaptable combustion technology is a biomass – fired boiler which will convert the heat of combustion into steam, which can be used for heat, mechanical energy or electrical energy.
- 60 to 85% of potential energy is present in the boiler's steam output.

Combustion boilers:

- Pile burners, stationary or travelling grate combustors
- Fluidized-bed combustors

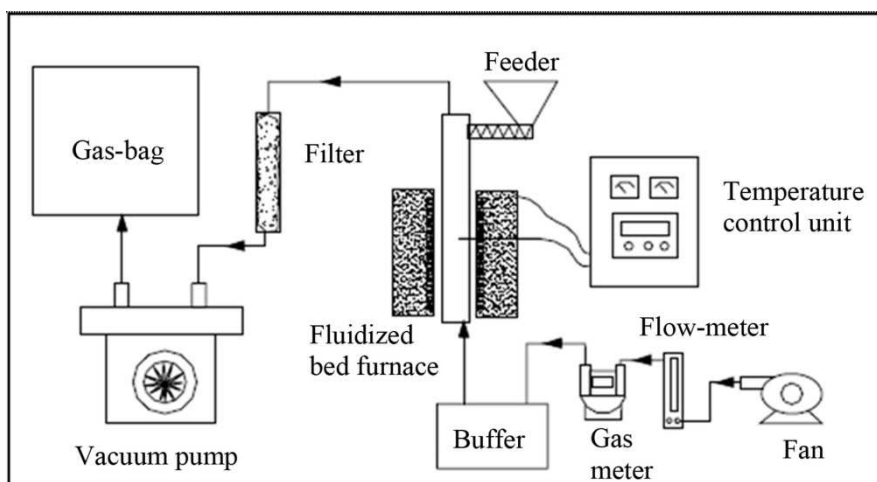
Pile burners:

- Essentially consists of two combustion chambers: upper and lower
- Biomass fuel is burnt in the lower chamber, where volatile gases are released, whereas in the upper chamber gases are burnt.
- Pile burners are to be shut down periodically for ash removal.



Fluidized-bed combustors:

- In this biomass fuel is burned in a hot bed granular material like sand.
- When air is injected into the bed it creates turbulences resembling a boiling liquid. This turbulence causes the distribution of fuel and keeps it suspended.
- Increase of heat transfer allowing operating temperatures below 950°C, reducing emissions of nitrogen oxides is possible with the design of a fluidized-bed reactor.
- High-ash fuels, agriculture residues and sewage sludge can be handled by fluidized – bed.



Source: AnkeBrems et al., 2013

Direct-Fired Gas Turbine Technology:

- Biomass particle size reduction to less than 2 mm with less than 25% moisture content is obtained in fuel pre-treatment.
- Process of electricity generation is given as compressed air → turbine → electricity.

Co-Firing:

Biomass from a sustainable source is used as secondary fuel in coal fired power plant which reduces emissions of oxides of sulphur and nitrogen. This in turn decreases net carbon dioxide emissions from the power plant.

Pyrolysis:

The process of thermal decomposition of volatile components of an organic substance, at temperature range of 400 – 1400°F (200 – 760°C) in the absence of oxygen resulting in syngas and liquids is pyrolysis. Heat used in the process comes from an indirect source. Residues obtained are a mixture of un-reacted carbon char (the non-volatile components) and ash.

Advantages: Liquid energy obtained is easily transportable and also contain high energy density.

Gasification:

This is the process that comes after pyrolysis. Temperature range at which the process takes place is 900 – 3000°F (480 – 1650°C) with traces of oxygen. Apart from thermal decomposition of volatile constituents, the non-volatile carbon char is also converted to additional syngas. Partial oxidation of carbon is done by direct supply of heat. Residue in the process is ash.

Advantages: Process results in reduced emissions as compared to combustion and is also ideal for energy recovery.

Disadvantages: Release of dust and organic compounds in the exhaust.

A glimpse of literature review on studies related thermal conversion:

Godbout et.al., 2011 have measured and compared the emissions and energy produced from the direct combustion of wood and biomasses from dried solid pig manure, switch grass and willow. The result from the study showed that agricultural biomass has potential to be used as a source for production of renewable energy.

Prince Yadav et.al., 2013. Production of producer gas was done using material like bagasse (sugarcane waste), coconut shells and wood particles in an updraft gasifier. Results of the analysis showed that coconut shell is best suitable for the tested gasifier.

Yao et.al., 2008, employed experimental as well as mathematical modelling approaches to study the combustion characteristics of a sole biomass particle ranging in size from 10 µm to 20 mm. Processes like moisture evaporation, devolatilization, tar cracking, gas-phase reactions, and char gasification were studied. Results obtained from their study were useful in assessing different combustion systems using biomass as fuel.

Timothy and Ashraf, 2011, investigated use of forage sorghum as potential biofuel for direct combustion. Planting densities of 12 and 18 kg/ha of seed were fertilized with either 90 or 135 kg/ha of nitrogen. The average yields in plots seeded at 12 and 18 kg/ha were 2.9 and 3.4 t/ha, respectively. Fertilizer application rate had no effect on the crop yield, with the average yields for the 90 and 135 kg/ha of nitrogen application resulting in 3.1 and 3.2 t/ha, respectively.

Biochemical Conversion

The process of breaking down biomass in order to make carbohydrates available for processing into sugars, which can further be converted into biofuels and bio-products by utilizing microorganisms and catalysts.

The process of biochemical conversion can be explained as follows:

- Raw material: Raw material for biochemical processes are selected to meet the need of optimum composition, quality and size.
- Pre-treatment: Raw material is pre-treatment with acid or base in order to break hard, fibrous cell walls of cellulose and hemicellulose to make them hydrolyse easily.
- Hydrolysis: Enzymes enable sugars present in the cellulose and hemicellulose in the pre-treated material which is to be separated and is released over a period of few days.
- Biological Conversion: Molecules suitable for use as fuels or building-rock chemicals are generated through the breakdown of sugar using micro-organisms.
- Chemical conversion: Sugars can be converted in to fuels or other useful products using chemical catalysis.

Fermentation

An anaerobic process that breaks down the glucose in the organic materials through chemical reactions that convert sugars to ethanol is called fermentation. Conversion of plant glucose into alcohol or acid is the basic fermentation process. Microbes like yeast and bacteria are added to biomass which will feed on sugars for producing ethanol and carbon dioxide. Higher concentration of alcohol is produced by distillation and dehydration of ethanol to the level of purity required for fuel in automobiles. Solid residue from the process is used as cattle-feed, baggase from sugar cane can be used as a fuel for boilers or for subsequent gasification.

Biochemical Conversion

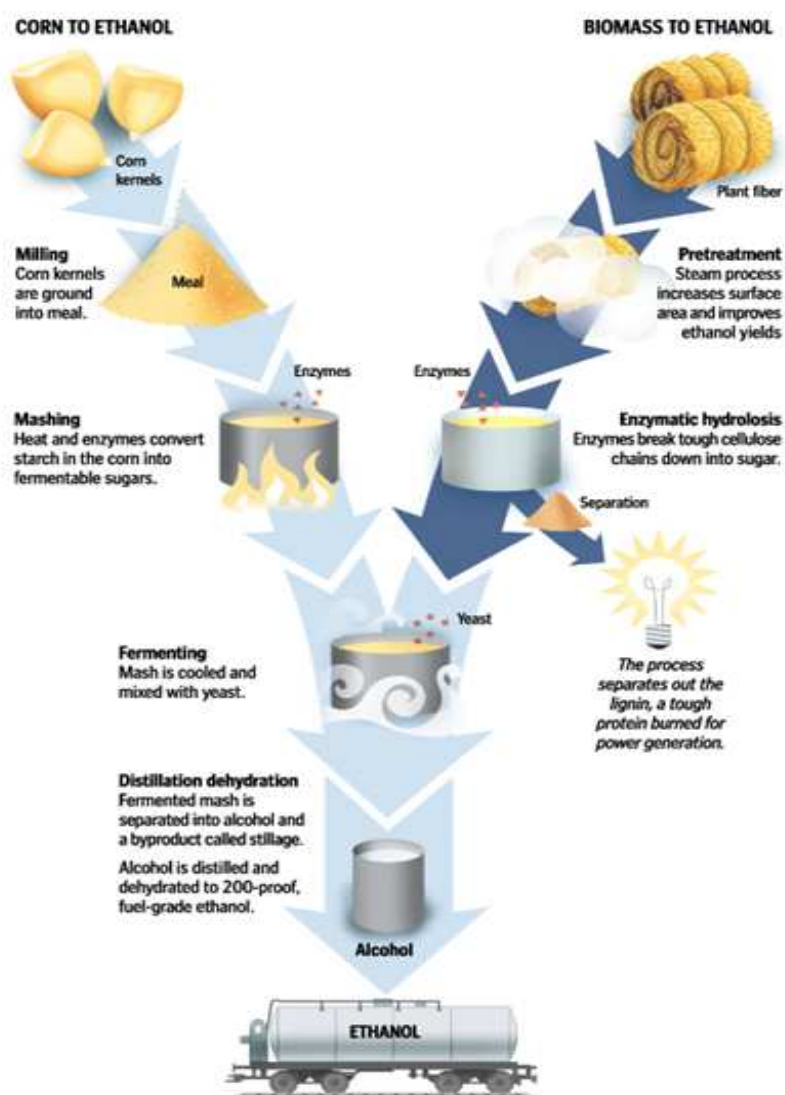


Image Source: International Eco-Endeavours Corp (endeavorscorp)

Mapping out both conversion processes down to energy products, the flowchart provides a useful guide to end-users on which technology to consider given their energy product requirement.

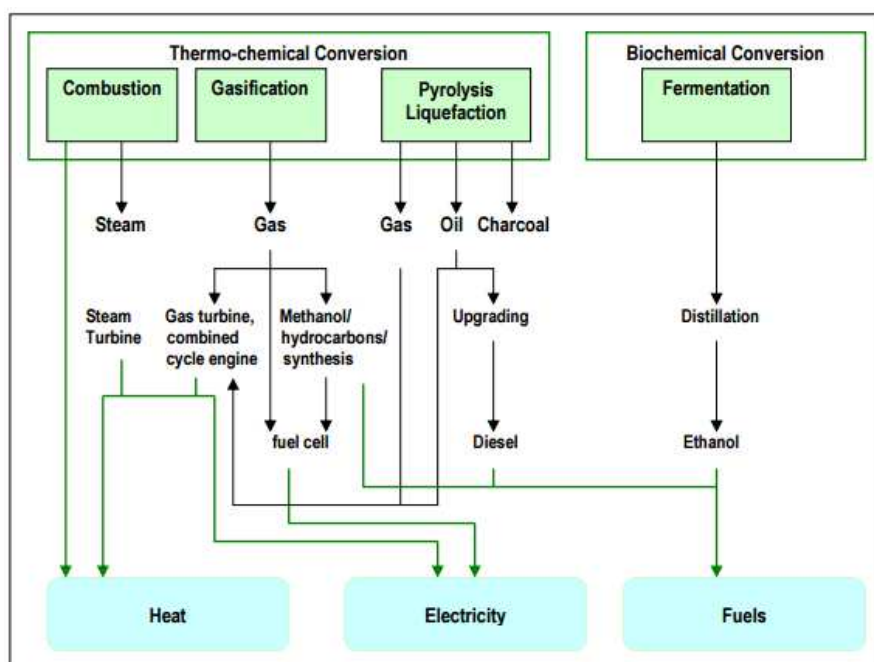


Image Source: UNEP Publications Waste Management; Waste Agricultural Biomass

Following are some of the research works carried in the area of biochemical conversion of biomass:

Seema Devi, et.al., 2012 have provided a review on the utilization of lignocellulosic biomass for the production of 2G bio-ethanol owing to the fact that these are abundantly available and are lower in cost. They have also stated that proper pre-treatment methods can increase concentrations of fermentable sugars proceeding enzymatic saccharification, which will improve the efficiency of the entire process. They have also presented various techniques available for bioethanol production from agricultural wastes.

Wanget.al., 2011 presented a review of the published research on modelling of pre-treatment process using leading technologies such as dilute acid, alkaline and steam explosion as well as the enzymatic hydrolysis process for converting lignocellulose to sugars. They have concluded that future prospects for research should concentration on in-depth understanding of the interactions between biomass reactants and chemicals/enzymes which is a key for developing refined models for the entire conversion process.

Anoop Singh and Stig Irving Olsen. 2011 provided life cycle assessment (LCA) of algal biofuels which suggested them to be ecofriendly over fossil fuels, with the only disadvantage of being economically not yet so attractive.

M. Ballesteros. 2010 have authored a chapter on the mechanisms of enzymatic cellulose hydrolysis and the synergistic interactions of cellulolytic enzyme components. He has also presented a review of factors affecting the hydrolysis efficiency and research efforts to enhance saccharification efficiencies.

CONCLUSION

Population explosion results in increase of demand for various resources especially food resources which in turn results in an increase of agriculture practices. Increase in agriculture practice will result in production of huge quantities of biomass. According to the UN, between now and 2025, the world population will increase by 20% to reach 8 billion inhabitants (from 6.5 today). Moreover, by 2050, the total population will be around 9.5 billion, unless specific control measures are broadly adopted. If this becomes a reality then a population of 8-8.5 billion in 2050 may be considered a successful stabilization of numbers.

Perceptibly, both the increase of the population and the remarkable growth of global GDP/c will drive an increase in waste volumes. Hence it becomes necessary to effectively manage the waste that is being produced. Dumping of wastes will not solve the problem but would in return give rise to several other consequences which need to be worked upon. Therefore it is best suggested to convert waste in to usable matter, which would not only help in waste management but also ensures optimum utilization of a product, by producing usable matter even from the waste generated which in turn would even add to the economic conditions of that particular area. Hence the above provided review offers means and methods of both conversion of waste to wealth and also an eco-friendly way of disposing/managing the waste.

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