

Role of Biorefining and Biomass Utilization in Environmental Control

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Abstract—The continuous decline of petroleum and natural gas reserves and non linear rise of oil price has brought about a realisation of the need for a change in our perpetual dependence on the fossil fuel. A day to day increased consumption of crude and petroleum products has made a considerable impact on our foreign exchange reserves. Hence, an alternate resource for the conversion of energy (both liquid and gas) is essential for the substitution of conventional fuels. Biomass is the alternate solution for the present scenario. Biomass can be converted into both liquid as well as gaseous fuels and other feedstocks for the industries.

Keywords—Bioenergy, Biomass conversion, Biorefining, Efficient utilisation of night soil.

I. INTRODUCTION

CURRENT prediction for the global energy and food/ feed supply has led to search for alternate resources. Utilization of biomass shows a possible long term solution to the problem of dwindling petroleum reserves [1]. Biomass is the overall plant material, produced by photosynthesis, where the Sun's energy converts carbon dioxide and water into organic matter, which is mainly consist of cellulose, hemicellulose and lignin and is expressed as lignocellulosics. Agricultural wastes, mainly lignocellulosic materials, are most abundant renewable resources produced by photosynthesis in the world. Usually aliphatic compounds are produced from cellulose and hemicellulose, while lignin can be degraded into almost every type of aromatic downstream products.

The entire organic content of the biomass can be converted into available forms of energy [2]. Ideal example is firewood which is still one of the most widely used fuels in developing countries. Fossil fuels were also derived from biomass since they are the fossilised remains of plants that grew some million years ago. Organic substances presents in agricultural wastes can be converted into almost every kind of useful chemicals and synthetic products. Such products include solid, liquid and gaseous fuels which are produced by both chemical and biological processes [3].

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II. BIOMASS CONVERSION

The most easy and cheapest way to obtain energy from biomass is by direct combustion. This is widely applied in the developing and industrialised countries.

Conversion of biomass into energy systems are of three types: a) direct combustion of biomass materials to generate heat/ electricity b) feeding animals or other livestock, and c) formation of special molecules those are richer in high energy elements (carbon and hydrogen) than the original biomass [4]. Conversion of biomass into high energy fuel usually depends on global location and the different processes of energy conversion. The potential for biomass production and its conversion are much more than its present level of fuel consumption in developing countries. A larger amount of energy in biomass is lost during its conversion to utility fuels. However, these losses of energy are much lesser than those of coal into synthetic oil and gas.

Energy from biodegradable wastes (organic in nature) can be recoverable by physical, chemical or microbiological means. Energy is physically recovered through incineration of sewage sludges, municipal refuse and the solid wastes of animals. Chemical processes involve the use of pyrolysis and gasification. The most eco-friendly method is biomethanation (biogas) production process [5], [6]. This process eliminates the waste disposal problem using microbial technology.

The various processes for conversion of biomass into commercial fuels will be discussed in details. These fuels are suitable for substitution of petroleum derivatives and other fossil fuels. In fact, all fossil fuels can be substituted by fuels derived from biomass. However, one must consider the real potential for such large – scale substitution.

Technologies to convert biomass into energy fall into two general categories – thermal conversion and bioconversion. Thermal conversion processes use high temperatures to convert biomass by direct combustion, pyrolysis, gasification, liquefaction, etc. By contrast, bioconversion processes involve, biomass refining, enzymatic/ microbial breakdown of biomass at comparatively lower temperatures and pressures. The thermal and bioconversion routes have certain comparative advantages. It has been found that the conversion in a single step bioconversion process is usually very high (90-95 per cent of the theoretical). On the other hand, a single step conversion in most thermal conversion routes is seriously affected by equilibrium limitation.

A. Bioconversion

In contrast to thermal conversion processes, bioconversion processes are less energy – intensive, and take place at near

atmospheric pressure and low temperatures (30 to 80°C). Biological conversion entails an energy-yielding enzymatic breakdown of biomass by selected species of micro-organisms. The product can be gaseous and liquid fuels, food, animal feed, fertilisers and other chemicals. In the short-run, however, sugar, cereals, grains and oil seeds seem to be most technologically feasible feedstocks for liquid fuels. There is a large scope for improvement in conversion efficiencies through the incorporation of modern processes and technologies such as continuous fermentation, cell and enzyme immobilization, vacuum distillation and so on.

B. Biomethanation

Biomethanation is an important biological conversion process yielding methane. It converts biomass in the absence of oxygen (by anaerobic digestion) to methane, popularly known as biogas, leaving a stabilised residue which makes an excellent organic manure [6].

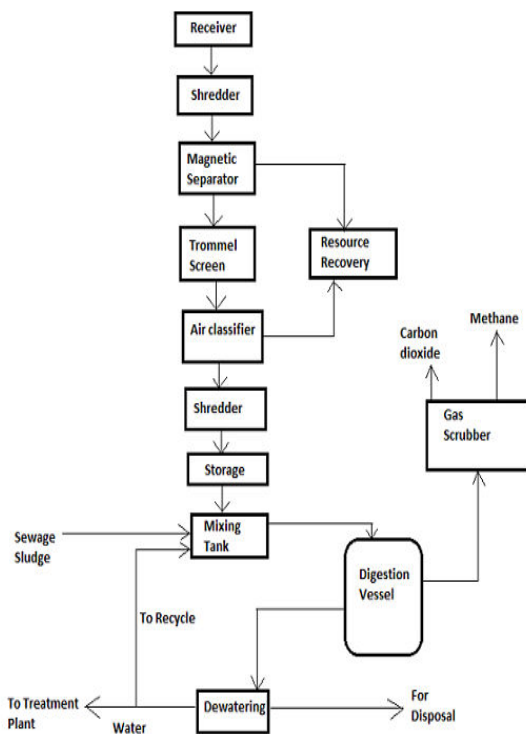


Fig. 1 Schematic diagram for Methane formation from Municipal Solid Waste

Traditionally in use for about a century, biomethanation is a very complex process which only recently is beginning to be understood. Basically anaerobic digestion consists of three phases; the enzymatic hydrolysis of biomass, organic acid formation, and methane generation. The total process requires a symbiosis of acid – forming and methane – forming micro-organisms. The reactions of the two groups must occur simultaneously; if these become unbalanced, the digestion process fails.

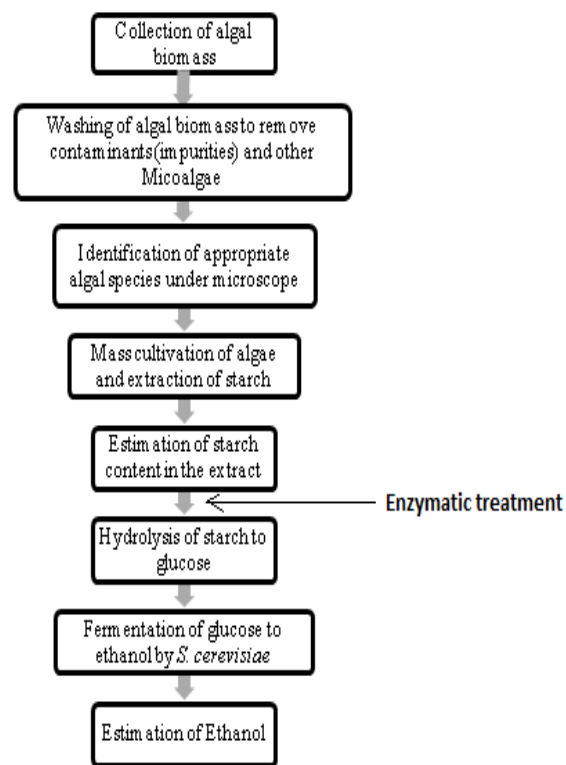


Fig. 2 Schematic diagram for Fermentation of algal starch to ethanol

Night soil, another renewable resource, that today largely goes waste. If, it is supplemented with nearly 25 per cent dung and 25 per cent aquatic biomass like water hyacinth and algae, and agro-residues, could become a massive renewable feedstock for a steady supply of biogas to the rural community. This can also become a radical way of solving our severe rural sanitation problem. However, handling of night soil is not an elite job and so this large and stable resource continues to remain unexploited in our country.

C. Bioethanol Fermentation

Besides biomethanation, the biomass can be transformed into ethanol by different fermentation processes by using yeast, bacteria etc. This process is termed as bioconversion. Different biomass may be classified as either starchy materials or cellulosic materials. Starchy materials like potato, cassava, barley, corn, sweet sorghum, and algae can also be transformed into reducing sugars either by acid/ enzymes or combination of acid and enzymes (amylolytic) action. After getting the reducing sugars, these substrates may be converted into ethanol by yeast (*Saccharomyces cerevisiae*, *Pichia stipitis*) [7] or bacteria (*Zymomonas mobilis*, *Clostridium thermocellum*). Another substrate, which is cellulosic biomass, may be refined (removal of lignin) by several chemical (NaOH treatment) and physical (solvent, steam treatment, etc). These refined materials will be used as feedstock for the production of simple sugars. This may be done either by acid hydrolysis or by enzymatic (cellulases) treatment.

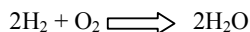
Different technologies were adopted to convert reducing sugars into ethanol. This may be done by several microorganisms similarly yeast, bacteria, etc using various modes of bioreactor including batch bioreactor, continuous bioreactor, fed batch bioreactor, immobilized bed bioreactor, etc.

Cane molasses, one of the byproduct of sugar cane industry is abundantly available in subcontinent of Asia. This biomass is mainly used as cattle feed in our country. These useful substrates may be converted into ethanol by *Saccharomyces cerevisiae* in the subcontinent of Asia. Free and immobilized cell culture technologies were adopted for the production of ethanol.

Mass cultivation of algae (by product/ site product of paddy cultivation, one of the important biomass) was adopted for the collection of important substrate for ethanol production. The algal species include *Spirogyra* sp (Carbohydrate content = > 50%) and *Chlorella* sp (Starch content = 37%) [8]. Simultaneous saccharification and fermentation (SSF) is an important mode of fermentation to convert algal starch to ethanol. Different technological approaches were made to get successful operation of this process (schematic diagram shown in Fig. 2).

D. Biohydrogen

Different types of biomasses may be converted into the green fuels, viz. hydrogen. The hydrogen gas is termed as clean fuel gas as it is non-polluting for the environment [9]. It is harmless to humans and environment as it is a non- carbon fuel and it produces only water on combustion.



The civilization of Indian subcontinent is greatly dependent on the Holy river 'Ganga'. This river is just like the life of living beings. There is a severe problem of pollution of this holy river. The people are disposing off the temple waste (the age old rituals of disposing off the temple waste of flowers, leaves, etc.) into river Ganga. The temple waste usually is Biomass in nature. The BOD value of the river Ganga thus increases to a dangerous level. This problem can be dealt with by treating the temple waste of flowers for some other purposes and not disposing them off into the rivers. Utilisation of this temple waste for the production of Biohydrogen can be a radical solution to this problem of pollution of our Holy river. Technologies were developed for the production of Biohydrogen from Temple waste [10]. The small scale production plants can be set up in the areas where these wastes are produced. This will avoid the energy expenditure and expenses on transport. The Schematic diagram of the whole process has been described in Fig. 3.

The major problem with the production of Hydrogen is the high cost. If the carbohydrate containing temple floral waste and wastes from food industry and other nitrogen containing agricultural wastes are utilised as raw material for the production of hydrogen, then the cost of production of hydrogen can be minimised to some extent as the raw

materials will be much cheaper. This production of Biohydrogen from the agricultural and food industry raw material can be of great significance. This process will drastically reduce the level of pollution to river 'Ganga'. On the other hand, the pollutants will also be utilised for the production of a non polluting clean fuel gas (hydrogen). Thus the pollution management of the river 'Ganga' will be handled most judiciously.

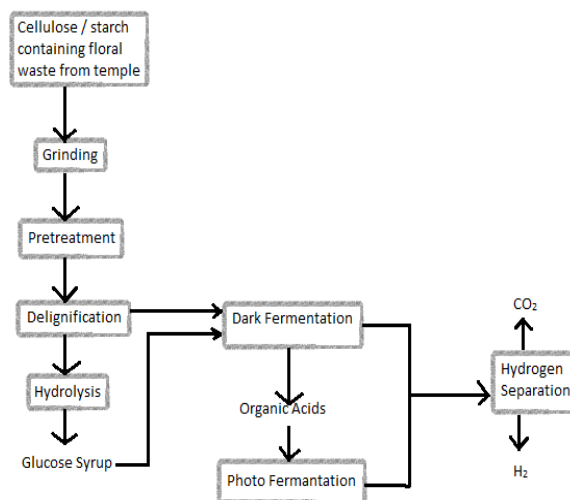


Fig. 3 Schematic diagram for biohydrogen production from temple waste containing cellulose/ starch

III. ENVIRONMENT AND SOCIO-ECONOMIC CONSIDERATION

The energy generation using biomass can change the quality of life in the rural areas. The production, harvesting and transportation of biomass provide opportunity for employment, and biomass energy cropping will also provide extra income for rural people, which in turn stopping the migration to the urban areas [11]. Night soil is another biomaterial that today largely goes waste. If supplemented with nearly 25 per cent cow-dung and 25 per cent aquatic biomass (water hyacinth, algae), and agro-residues (rice husk, straw etc.), could become a massive renewable feedstock for a steady supply of biogas and biofertilizer to the rural community [12]. This can also become a radical way of solving the severe rural sanitation problem.

IV. CONCLUSION

There are many drawbacks for the process of converting biomass into energy. These must be overcome before processes for the production of fuels (energy) from biomass can be commercialised. The lingo-cellulosic wastes are dispersed over wide areas and a major portion of their cost is associated with their collection and transportation to the plant of biomass processing technology. Development of efficient harvesting techniques and establishment of localised processing plant in close proximity to the biomass resource centre will help to minimise this cost.

Besides being a substantial source of energy, biomass can reduce environmental damage/pollution and provide feedstocks to the chemical industry. Therefore, the wider use of biomass for development would offer minimal ecological imbalance and provide the means to recycle nutrients and carbon dioxide from the atmosphere. Hence, different types/modes of biomass Utilization have the critical role to Control the Environmental abatement and hence it helps in maintaining Sustainable Developments.

The following specific suggestions are made in the areas of biomass resource – based energy programme:

- * Bioconversion of lignocellulosic biomass to ethanol in an integrated system incorporating the production of biogas, biofertiliser and sugars for industrial applications.
- * Exploitation of biomethanation technology based on domestic wastes (particularly night soil), agricultural residues and animals wastes. This will increase the improved sanitation for rural area.
- * Conversion of non-edible oils to diesel substitutes and large scale attempts of such possibilities.
- * Small as well as large scale chemical and thermochemical conversion of biomass into gaseous and liquid fuels (especially methanol) and bulk chemicals.
- * Adoption of massive afforestation and energy plantation projects in arid and semi-arid regions.
- * Ultimately genetic engineering impact in the solution of bioconversion routes for high productivities. Therefore, bioconversion processes are likely to be more economical than many synthetic processes for organic feedstock production till today.

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- [11] S. N. Mukhopadhyay and T. K. Ghose, "Integration of Bioconversion, Environmental and Genetic Engineering Concepts in Bioenergy System", *Proc. BESI Second Convention*, 1985, pp. 260-263.
- [12] Unpublished data of the author.

REFERENCES

- [1] T. K. Ghose, "Technoeconomic Feasibility of Liquid Fuels and Feedstocks through Biomass Refining", In *Bioconversion and Biochemical Engineering*, Vol 2 (Ed T. K. Ghose), IIT Delhi and SFIT Zurich, 1980, pp. 31-56.
- [2] C. Lewis, "Energy requirements for the bioconversion of cellulosic raw materials", In *Bioconversion and Biochemical Engineering*, Vol 2 (Ed T. K. Ghose), IIT Delhi and SFIT Zurich, 1980, pp. 57-72.
- [3] "Green Energy from Wastes", An UNDP/GEF assisted Project on "Development of High Rate Biomethanation Processes as means of Reducing Greenhouse Gases Emission" *Ministry of Non - Conventional Energy Sources Government of India, March 2006*.
- [4] T. K. Ghose and B. Ghosh, "Organic Feedstocks – Chemical versus Biochemical Routes", *Proc. VII International Biotechnology Symposium, New Delhi*, 1984, pp. 41-44.
- [5] W. E. Batch, G. E. Fox, L. G. Magrum, C. R. Woese and R. S. Wolfe, "Methanogens: Reevaluation of a Unique Biological Group", *Microbial Rev.*, 1979, pp. 43, 260-296.
- [6] J. G. Zeikus and V. G. Bowen, "Fine structure of Methanospirillum Hangati", *J. Bact.*, 1975, pp. 121, 373-380.
- [7] Z. P. A. Silva, S. I. Mussatto, I. C. Robarto and J. A. Teixeira, "Ethanol production from xylose by *Pichia stipitis* NRRL Y-7124 in a stirred tank bioreactor", *Braz. J. Chem. Eng.*, 2011, Vol 28, pp. 151-156.
- [8] M. Yoon, J. Choi, G. H. Kim, D. Kim and D. Park, "Proteomic analysis of *Spirogyra varians* mutant with high starch content and growth rate induced by gamma irradiation", *Bioprocess Biosyst Eng.*, 2013, Vol. 36 (6), pp. 765-774.
- [9] I. K. Kapdan and F. Kargi, "Bio-hydrogen production from waste materials", *Enzyme and Microbial Technology*, 2006, Vol 38, pp. 569-582.
- [10] I. C. Uttamrao, "Fermentative hydrogen Production from temple and food waste by batch mode using *Enterobacter aerogenes*", M. Tech.