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A Note on Pyrolysis of Agricultural Residues: An Economic Analysis

K. K. BAVEJA and P. D. GROVER*

Introduction

The chemical stored energy in biomass is transformed either by combustion directly into heat energy or by other thermochemical processes into a variety of solid, liquid and gaseous fuels. These fuels, by their nature, are concentrated, storable forms of the original energy content of biomass.

Pyrolysis is the physical and chemical decomposition of organic matter brought about by heating it in the absence of air. In practice, many processes allow a restricted admission of air for partial combustion to achieve the temperature required for pyrolysis.

The puoducts of pyrolysis are char, liquid distillates containing oils and chemicals and a gaseous fraction containing hydrogen, carbon monoxide, carbon dioxide, methane and other hydrocarbons and nitrogen. The yields and composition of these products can be varied depending upon the operating parameters. These are: temperature of pyrolysis, rate of heating, retention time and physico-chemical composition of the original biomass. The slow rate of heating, low temperature and adequate retention time will tend to give high yields of char while rapid heating (flash phrolysis) shall yield higher amount of liquid distillates, which when subjected to further heating will thermally crack and give higher yields of pyrolysis gases.

Characteristics of the Biomass

The crop residues as energy sources resemble conventional fuels in many ways. The composition of certain residues is similar in many ways to coal, except that these residues have a higher moisture and oxygen contents and lower sulphur and ash levels.

The proximate analysis of typical biomass compared with conventional fuel (coal) are given in Table I.

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* *Dr. Baveja and Dr. Grover both are Professors at the Department of Chemical Engineering, Institute of Technology, New Delhi.*

TABLE I

Analysis & Heating Value of Biomass and Coal

	TYPICAL VALUES	
Proximate	Biomass wood	Coal
Moisture	24.0	2.5
Volatiles	65.5	37.9
Fixed Carbon	9.5	52.9
Ash	1.0	7.0
Ultimate		
C	51.5	76.9
H	6.9	5.1
O	40.9	6.9
N	0	1.5
S	0	2.4
Ash	1.0	7.2
H. A. V.	7,125 -4,000	13,000 BTU/1b - 7,000 Kal/kg
Variation	3,000–4,500	4000-7900

The higher heating value of the fuel is directly related to the total carbon content in the fuel.

Because of high oxygen in crop residues compared to coal, the pyrolysis/gasification of biomass tends to give more oxygenated compounds. Further, as biomass have similar C—H—O composition, the selction of these fuels for pyrolysis/gasification and choice of reactor systems are consequently highly influenced by the fuel's properties such as ash content, ash composition, ash fusion temperature and available fuel size.

Economic Aspects of Pyrolysis

The foremost aspect of selecting any pyrolysis system is to first identify the desired products. These can either be solid fuels (charcoal), liquid products or combustible gases. The main uses of these products are given in Table II.

TABLE II

Uses of Pyrolytic Products

Char	*Liquids*	*Gase (pyro and producer)*
1 Domestic fuel	1 Fuel	1 Industrial fuel
2 Industrial fuel	2 separation for phenol and other chemicals	2 Fuel for I.C. engines for mechanical and electrical power
3 Metallurgical fuel	3 Germicide	3 Synthetic liquid fuels and chemicals
4 Chemical feed stock for calcium carbide silicon carbide etc	4 Wood preservative	

As for any industrial venture, the economics underlying any appropriate pyrolytic conversion system requires that the final products be sold at a price that covers the entire cost of production and provides either convenience of usage or certain margin of profit or both. The cost in this case,includes cost of collection and transportation of agro-production, residues of labour,power,maintenance,capital investment and overhead cost of management and development expenses.

The price of biomass with its associated collection and transportation problems plays an important role. Since thermochemical processes that destroy the biomass fibres have to compete for the available methods of utilisation of their fibres and other uses, it is apparent that in the former process, only such agro-residues as are unsuitable for their use as food, fodder, fertilizer and for their structural needs should be considered. Some of these which fall into this category are coconut,coffee and rice husks.cotton stalks, corn cobs, cereal and pulses residues, coconut and bagasse pith; logging wastes and sawdust, leaves and pine needles; coconut and groundnut shells etc.

The development and utilisation of these technologies are most appropriate for developing countries, which like India have more than 50 percent contribution of energy from biomass resources in their overall-both commercial and non-commercial (domestic)-energy requirement. In comparison, the developed countries consume only 3 5 percent of energy derived from biomass resources.

It must be emphasised that due to the problems and expenses associated with collection and transportation of low energy and low bulk density of biomass, the conversion plants should invariably be in decentralised sector. The community and cottage level units can also be adopted to provide convenient fuels for rural population.

Of the three products available by pyrolysis of agro-wastes, the production of *solid* and *gaseous* fuels only need to be considered for specific situations. The solid fuels can be used for domestic and industrial applications and gases for either steam and heat, or *generation of mechanical and electrical power through I.C. engines*. Liquid fuels although more popular because of convenience suffer from problems of refining at moderately small scale. Large scale production of crude liquids from biomass by pyrolysis of liquefaction processes involves extensive collection and storage of biomass, which is definitely not economical, especially for most of the developing countries which have acute shortage of wood.

A further decisive criterion for the economy of an industry is the market price of the finished products. Since the chemical industry today can produce liquid by-products, obatin from wood or other biomass more cheaply than by the pyrolysis process, the main emphasis should be on the production of charcoal or combustible gases for captive utilisation.

Steam Gasification of Rice Husk

The husk generated by rice mills can be effectively utilised for captive power generation. A standard rice mill having capacity to dehusk 1 tonne/hour of paddy generates 250kg/hr.

of husk. The husk can be gasified at lower temperatures adopting the principle of pyrolysis with high partial pressure of steam. The gas after proper cleaning can be used to generate about 100 KW of power. The captive power so generated shall not only meet the demand of rice mill of the order 30–35 KW but shall have surplus power of about 50 KW after meeting the electrical reqirement of gasification. The additional power available can be utilised for either distribution to the surrounding rural areas or used for setting up ancillary industries.

The main advantages of steam pyrolysis/gasification are that no liquid products are obtained and gasification is carried out at lower temperature (700°C) below the critical fusion temperature of rice husk ash. Rice husk ash so obtained is in reactive form and can be used either as filler for rubber and plastic moulding industries or mixed with lime to yield pozzuolana cements. Because of comparatively longer setting time required for rice husk cement, it not suitable for R.C C. or plastesing blocks can be stored for about 3 months for maturing and then used for construction of buildings like bricks.

Thd yield data for steam gasificaton of rice husk is given in Table III.

TABLE III

Products from Rice Husk Gasification

Basis = 250 kg/hour of husk
Gas = 84 kg/hour (CV = 1207 KCal/kg)
Power = 100 KW
Ash = 50 kg. (equivalent to 100 kg rice husk cement)
Lime (required) = 50 kg.

A rotary steam gasifier plant for capacity 25 kg/hr has already been installed. The operating data so generated shall be useful for scaling up the design of commercial units. Once the data is obtained, the techno-economic analysis shall be carried out.

Charcoal Briquettes from Cotton Stalk – A Case Study

Cotton is one of the major cash crops of India. Associated with cotton growth, about 6 tonnes of cotton stalks per hectare are also generated. The cotton stalks, when stored invite growth of pests which propagate to the next crop. In order to avoid the damage to the crop and of land under cotton cultivation, it represtnts a colossal wastage of energy reduce cost on application of pesticide, the stalk are normally burnt "in situ" in the farms.

The present practice is highly wasteful. In terms of energy, with $7.8+10^6$ hectare of land under cotton cultivation, it represents a colossal wastage of energy of the magnitude of about 60 million tonnes of coal. Therefore, it becomes imperative that such a great source of energy should be properly exploited.

Further, cotton by and large is grown in India in areas which are remote from coal fields, hence utilisation of these local resources should not only meet local energy repuirements but also save energy required for long haulage of coal and other fuels.

The techno-economic analysis of a system for efficient utilisation of cotton stalks as fuel is presented as case study. The system is aimed at application of decentralised and appropriate technologies of conversion, suitable for rural environments and operable by unskilled farm labour. This will not only augment the rural and urban requirements of domestic fuel, but also provides gainful employment to farm labaur.

System Analysis

As far effective pest control, it is imperative to destroy the cotton stalk within two months of cotton harvesting, the system, therefore, aims at imparting same type of thermal treatment to stalks. However, instead of complete combustion, partial combustion of stalk is deployed, so that the stalk is not only subjected to high temperatures but also produces char-powder. This char is suitable for briquetting and its subsequent use as smokeless fuel.

In order to avoid the problems and cost of collection and transportation of cotton stalk, the charring (partial combustion) of stalk is carried out in the fields in small mobile kilns. In these kilns the air introduced for combustion is controlled and char yields of 40 to 50 percent based on sun dried stalk can be obtained.

About 2.5 tonnes of char valued at app. Rs. 1000/-can be obtained per hectare. A part of this car chan be manually briquetted and used as fuel by the farm workers and the remainder can be sold to centralised briquetting unit.

The flow sheet of the process and components and equipments involved for centralised briquetting plant are given in Fig.8.

The stalks are pyrolysed in mobile kilns which stalks having size 15-30 cms are fed manually and the char is obtained periodically The char is immediately quenched with water to avoid further combustion.

The char is then screened through 3mm screen and brought to centralised briquetting unit. The char is crushed and mixed with moist clay and molasses as binders and lime as binder cum energy extender. The mixture obtained containing 30-35 percent moisture is then briquetted either in extruder or briquetting machines which are commercially available in India. These briquettes are then dried in a tray drier using the rice husk or another similar biomass as fuel. To have complete and pollution free combustion of biomass and generate hot gas, appropriate unit, have been developed, known as "Paru" gas stoves and burners