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# Physiochemical Properties of Cotton Stalk Biomass from Aricultural Residues

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**ABSTRACT**

The study was undertaken to investigate the properties of cotton stalk fuel from the agricultural residues. The whole cotton stalk plant is converted into shredded material with the help of cotton stalk shredder. The capacity of cotton stalk shredder machine is 218 kg/h. The proximate analysis of the shredded cotton stalk in terms of bulk density 34.92 kg / m$^3$ moisture content 13.63 %, volatile matter 74.52 %, ash content (4.95 %, fixed carbon 20.53 % and calorific value of cotton stalk biomass (3827 cal/g) respectively. were showed that agricultural residues are the most potential and their quantitative availability, Since the aim by using shredded cotton stalk as feedstock for energy conversion process of the developed gasifier.

**Key words:** Biomass, cotton stalk, proximate analysis, Gasification,

## INTRODUCTION

Progress and prosperity of nations depends mainly on energy. An availability and consumption level of energy is the best indicator of economic and social development. Use of crop residues for energy production has been propagated as a substitute for fossil fuels in industrialized countries. The available sources of fossil fuels are limited as well as the growing awareness of the unfavorable environmental consequences resulting from greenhouse gas emissions have reinforced the importance of crop residues as an alternate energy resource in developed and developing countries. Cropping intensity, productivity and crops grown in country causes large variability in crop residues generation and their uses. Pathak *et. Al.* attempted to assess the quantity of recoverable biomass from cropland, grassland, forest, roadsides, and agro-forestry (Pathak et al., 2006). They estimated total available crop residues in India as 523.4 Mt/year and surplus as 127.3 Mt/year. They also concluded that the surplus crop residues of cotton stalk, pigeon pea stalk, jute & mesta, groundnut shell, rapeseed & mustard, sunflower were 11.8, 9.0, 1.5, 5.0, 4.5, and 1.0 Mt/year, respectively on annual basis. The residues of most of the cereal crops and 50% of pulses are used for fodder. Stalks of rapeseed, Coconut shell, mustard, pigeon pea, jute & mesta, and sun flower are used as household fuel.

India has been an agrarian economy since much time as 70% of its GDP still comes from either agriculture or agro based industry (Singh, 1996). Any enrichment of returns from this sector is depends on adequate supply of basic inputs in this sector. Timely and enough power supply is one such input. Competition between industry and urban forfeit the agricultural use of electricity day-by-day in our country. Hence, there is a round the year deficiency of power in the agriculture sector. Consequently, Urgent need has been arises to produce more power, in order to accomplish the needs of agriculture sector efficiently. A rough estimation has putted agricultural and agro-industrial residues in huge quantities of about 350 million tones (mt) per year (Rao, 1996). It is also anticipated that the total cattle refuse generated is nearly 250 mt per year (Singh,1996). Further, 50 mt of fuel wood and with associated forest waste of about 5 mt produced from nearly 20% of the total land which is under forest cover. The total availability of agricultural waste, energy plantations and agro-industrial waste in the country is placed approximately 405 mt per year (Rao, 1996). Set up of agriwaste based captive power plants in agro-based industries and small capacity power generation plants in rural areas as decentralized power supply sources is the way of accomplishing use of such sources. Power need of a cluster of 30 to 40 nearby villages can be satisfied with such power plants. The biomass like rice straw, saw-dust, cotton-seed, sugarcane-trash, coir-pith,, peanut -shells, sorghum, wheat-stalks and straw, stalks and husk, soybean stalks, maize stalks and cobs, bagasse, waste wood, , sunflower seeds, shells, walnut shells, hulls and kernels and coconut husk can be prolifically utilized in power generation (Grover, 1996).

One third of primary energy sources are contributed by Biomass in India. Biomass fuels are predominantly used in domestic for cooking and water heating, as well as by conventional and artisan industries. Total biomass energy sources wood fuels contribute 56 percent (Sinha *et. al*, 1994). Since most biomass is not transacted on the market, estimation of biomass consumption remains highly variable (Ravindranath and Hall, 1995; Joshi et. al., 1992). Supply-side estimation (Ravindranath and Hall, 1995) of biomass energy are reported as: fuelwood for household sector- 218.5 million tons (dry), crop residue- 96 million tons (estimate for 1985), and cattle dung cake- 37 million tons.

The agriwaste, apart from being a disposal responsibility, obviously poses a serious environmental threat which in turn jeopardizes ecology and human health alike, because presently, some of the agri residues are being discarded at the fields and burnt in-situ, which results in environmental pollution and also affects the quality and fertility of soil. If these wastes are used for producing electric power it may help control the environment related problems. But this requires an elaborate collection process and economic conversion operation as well.

## MATERIALS AND METHODS

### Material preparation

The shredded cotton stalk biomass was used as feed material in the developed open core downdraft biomass gasifier. The whole cotton stalk biomass was difficult to use directly in the gasifier reactor so the shredded cotton stalk was used as feeding material. The whole cotton stalk plant was converted into shredded material with the help of cotton stalk shredder. Fig.1 shows the view of cotton stalk shredder used in the present study. It mainly consists of feeding trough, peg tooth beater, outlet section, electric motor and stand. The shredder was supplied by Bharat engineering works Jasdan (Gujarat). The shredder is operated with the help of 7.5 hp, 3 phase, 1400 rpm electric motor. The capacity of cotton stalk shredder machine is 218 kg/hr. The shredding operation was carried out at Cotton Research Farm, JAU, Junagadh. The machine was operated with the help of two persons, one person is required for supplying the material and another is required for feeding the material into the machine.

Physical properties of whole and shredded cotton stalk were determined in terms of average length, diameter and bulk density.

Average length of 15 pieces of randomly selected whole cotton plant stalks were measured with the help of measure tap. Average diameter of 15 pieces of randomly selected whole cotton plant stalks were measured with the help of vernier calliper. Bulk density of whole cotton stalk plant was also measured. Bulk density of whole cotton stalk plant was determined by tying the plant with the help of ropes with gentle rolling and pressing, so as to consider the bunch as cylinder. Weight of the bunch was measured with the help of spring balance. The bulk density is the weight of biomass bunch divided by the volume occupied by cotton stalk bunch.

### Physical properties of shredded cotton stalk biomass

Different size fractions of cotton stalk were analysed in terms of weight and length. Three samples of randomly selected, 2 kg shredded cotton stalk biomass were considered for the analyses. Each sample was dived into seven fractions i.e. thick, having diameter ranging from 13-18 mm, medium, having diameter 9-12 mm, thin, having diameter 4-8 mm, very thin, having diameter 2-3mm, very very thin, material passed through 2 mm sieve, cotton burrs (woody cover of cotton boll) and, bark. The diameter of each fraction of cotton stalk was measured with the help of vernier calliper. The maximum and minimum length of each fraction of shredded material was also measured with the help of scale. Five fractions i.e. thick, medium, thin, cotton burrs and bark were separated manually. The bulk density of shredded cotton stalk was determined by the weight of biomass placed in a container divided by the volume occupied.

### Proximate analysis

Proximate analysis was carried out for characterizes the moisture content, volatile matter, ash content and fixed carbon. Proximate analysis of the fuel defines its volatility and burning properties. ASTM standard (ASTM, 1983) recommended for coal, sparky fuels, etc., which meets the demand of the biomass material largely, was used for these analysis.

### Moisture content

Moisture content of most of the biomass depends on the type of fuel, its origin and treatment before it is used for gasification. Moisture content play important role in the combustion process. The moisture content below 15 per cent by weight is desirable for trouble free and economical operation of gasifier. Fuel moisture content (FMC) of cotton stalk was determined by drying the known weight of sample in hot air oven at 105 ºC for 24 hours while keeping the ground sample in petridish till constant weight..

### Volatile matter

Volatile matter and inherently bound water in the fuel were given up in pyrolysis zone forming a vapor consisting of water, tar, oils, and gases. Fuel with high volatile matter content produce more tar. Volatile matters in the fuel determine the design of gasifier for removal of tar. Volatile matter of cotton stalk biomass is the product, exclusive of moisture, given off by a material as a gas or vapor when solid biomass is heated out of contact with air under standardized conditions that may vary according to the nature of the material.

### Ash content

Mineral content of fuel which remains in oxidized form after combustion of fuel is called ash. In practice, ash also contains some unburned fuel. Ash content and ash composition have impact on smooth running of gasifier. Melting of ashes in reactor causes slagging and clinker formation. If no measure is taken, slagging or clinker formation leads to excessive tar formation or complete blocking of reactor.

### Fixed carbon

The fixed carbon represents the non-volatile combustible component of the fuel. The amount of fixed carbon present gives a rough indication of the charcoal yield. Also, a higher fixed carbon material is generally better suited for gasification then a lower fixed carbon material. After determining fuel moisture content (d.b.), volatile matter (d.b.) and fuel ash content (d.b.).

### Calorific value of biomass

Calorific value is the amount of heat generated by unit mass of the fuel on its complete combustion. It can be reported in two ways, namely HHV (higher heating value), and LHV (lower heating value). Calorific value of biomass feed stalk is determined for its suitability of gasification and gasifier efficiency.

Bomb calorimeter was used to determine the calorific value of cotton stalk biomass. One gm sample of the air dried ground sample was taken in the crucible. The fuse wire was attached across the electrodes of the bomb.

## RESULTS AND DISCUSSIONS

### Physical properties of whole cotton stalk biomass

Physical properties of whole cotton stalk plant in terms of length, diameter and bulk density were determined. The whole plant was randomly considered in three sections of lower, middle and upper part. The lower part was considered up to 500 mm, middle part was considered from 500 mm to 1000 mm and the remaining part considered as upper part. The diameter of each part of the randomly selected fifteen plants was measured at the middle of these sections. The average diameter of each section is given in Table 1. The average diameter of whole cotton plant i.e. lower section, middle section and upper section was found as 15.80mm, 11.33mm and 7.27mm respectively. The average length, average diameter and bulk density of the whole cotton stalk plant is shown in Table 2. that the average length, average diameter and bulk density were found as 1506.7 mm, 11.47 mm and 34.92 kg/$m^3$ respectively.

**Physical properties of shredded cotton stalk biomass**

Table 3 shows the different size fractions of shredded cotton stalk biomass in terms average weight, per cent weight and minimum-maximum length of shredded mass. The fractions of shredded mass was divided into seven different size fractions as thick, having diameter ranges from 13 to18 mm, medium having diameter from 9 to 12 mm, thin having diameter from 4 to 8 mm, very thin having diameter 2 to 3 mm, very very thin having diameter less than 2 mm, cotton burrs and bark. The average weight of thick, medium, thin, very thin, very very thin, cotton burrs and bark fractions of shredded cotton stalk were found as 198.20 g, 209.39 g, 749.10 g, 367.15 g, 49.96 g, 229.31 g and 195.31 g respectively. The percent of weight of thick, medium, thin, very thin, cotton burrs and bark fractions were found as 9.91 %, 10.47 %, 37.45 %, 18.36 %, 2.50 %, 11.50 % and 9.77 % respectively. It can be seen from the table that maximum and minimum per cent weight fractions were found as 37.45 % and 2.50 % having diameter ranging from 4 to 8 mm and less than 2 mm diameter respectively. It can be seen from the table that the minimum and maximum length of different size fractions of thick, medium, thin, very thin, very very thin, cotton burrs and bark were range from 23-112

**Table 1: Average diameter of each section of whole cotton stalk plant**

| Sr.No. | Average diameter of lower section up to 500mm | Average diameter of middle section 500mm-1000mm | Average diameter of upper section 1000mm-1500mm |
|---|---|---|---|
| 1 | 15.80 | 11.33 | 7.27 |

**Fig. 1: Cotton stalk shredder**

mm, 14-137 mm, 31-133 mm, 12-43 mm, 2-6 mm, 9-32 mm and 59-273 mm respectively.

The bulk density of shredded cotton stalk biomass was found as 157.30 kg/$m^3$. This bulk density and different size fractions represented the suitability of shredded cotton stalk as compared to whole cotton stalk for down draft gasifier because biomass with high density is advantageous for combustion systems as it represents a high energy value for smaller volumes and needs less storage space. Dubey and Gangil (2009) reported the bulk density of cotton sticks 160 kg/$m^3$.

**Proximate analysis of cotton stalk biomass**

Proximate analysis in terms moisture content, fixed carbon, volatile matter and ash content is determined and results of this analysis are presented below.

**Table 2: Average length, diameter and bulk density of whole cotton stalk**

| Sr. No. | Average length(mm) | Average diameter (mm) | Bulk density (kg / $m^3$) |
|---|---|---|---|
| 1 | 1505 | 11.47 | 34.92 |

Table 4 shows the proximate analysis of cotton stalk biomass. The moisture content of the cotton stalk biomass was found as 13.63 per cent on dry basis, which represented the suitability of fuel for gasification in down draft gasification systems, high moisture content not only gives rise to low gas heating values but also leads to low temperature in the reaction zone, which in turn to insufficient tar-converting capability, that is low grade gas, so moisture content should be less than 15 percent. Dogru et al. (2002) reported the moisture content of hazelnut shell was around 12 (%, d.b) and reviewed that the moisture content of most of the biomass varies between 11 and 18 (%, d.b). The fixed carbon, volatile matter and ash content were found as 20.53, 74.52, and 4.95 (%, d.b) respectively for cotton stalk as shown in Table 4. The result showed the feasibility of cotton stalk fuel for gasification because of high carbon content and low ash content. The results of proximate analysis of cotton stalk in the present study was in accordance with the results presented by Dubey and Gangil (2009) as fixed carbon, volatile matter and ash content of 15.30, 81.40 and 3.30 (% d.b) respectively for cotton stick. Vyas and Singh (2007) also found the fixed carbon, volatile matter and ash content as 24.99, 71.04 and 3.97 (%, d.b.) respectively for jatropha seed husk. Similarly, Jorapur and Rajvanshi (1997) also reported that fixed carbon,

**Table 3: Different size fractions of shredded cotton stalk biomass**

| Sr.No. | Size fractions | Average weight | | Length (mm) | |
|---|---|---|---|---|---|
| | | g | % | Minimum | Maximum |
| 1 | Thick,13-18 mm dia. | 198.20 | 9.91 | 23 | 112 |
| 2 | Medium,9-12 mm dia. | 209.39 | 10.47 | 14 | 137 |
| 3 | Thin,4-8 mm dia. | 749.10 | 37.45 | 31 | 133 |
| 4 | Very thin,2mm-3mm dia. | 367.15 | 18.36 | 12 | 43 |
| 5 | Very very thin,less than 2mm dia. | 49.96 | 2.50 | 2 | 6 |
| 6 | Cotton burrs | 229.31 | 11.47 | 9 | 32 |
| 7 | Bark | 195.31 | 9.77 | 59 | 273 |
| | Total | 2000 | 100.00 | | |

**Table 4: Proximate analysis of cotton stalk biomass**

| Sr. No. | Moisture Content (%, d.b) | Fixed carbon (%, d.b) | Volatile matter (%, d.b) | Ash content (%, d.b) |
|---|---|---|---|---|
| 1 | 13.63 | 20.53 | 74.52 | 4.95 |

**Table 5: Energy equivalent of the calorimeter and calorific value of cotton stalk**

| Sr. No. | Weight of water (ml) | Energy equivalent (cal / °C) | Weight of sample (g) | Temp. rise (°C) | Correction factor | | CV of cotton stalk (cal / g) |
|---|---|---|---|---|---|---|---|
| | | | | | Nichrome wire (E1) (cal) | Cotton thread (E2) (cal) | |
| 1 | 2000 | 398.26 | 1.02 | 1.75 | 1.40 | 213.8 | 3827 |

volatile matter and ash content as 14.9, 77.4, and 7.7 (%, d.b.) respectively for sugarcane leaves.

### Calorific value of cotton stalk biomass

Calorific value of the cotton stalk biomass was determined with the help of bomb calorimeter. The results of the energy equivalent of the calorimeter rise in temperature, correction factors for the nichrome wire and thread as well as calorific value of the biomass is given in Table 5.

It can reveled that energy equivalent of the bomb calorimeter was found to be 398.26 cal / °C. The temperature rise for burning of the 1.02 g biomass sample was observed as 1.75 °C in the bomb calorimeter. Calorific value of the biomass was obtained after using the correction factor of nichrome wire and cotton thread as 3827 cal / g.

The calorific value of cotton stalk was found as 16.01 MJ/kg indicated good characteristics for gasification because higher heat generated during combustion leads to high temperature in reaction zone. The results of calorific value of cotton stalk in the present study were in accordance with the results presented by Dubey and Gangil (2009) as LHV and HHV of cotton stick 16 and 17.40 MJ/kg. Vyas and Singh (2007) also determined the lower calorific value of jatropha seed husk was 16.92 MJ/ kg

Erol *et al*. (2010) analyzed 20 different biomass samples and determined net calorific value in the range of 15.41-19.52 MJ/kg.

## CONCLUSION

The results from this study have shown that characterization of the physical and chemical properties of cotton stalk agricultural residues to be used as feedstock for energy conversion process in open core downdraft gasifier, Average bulk density of shredded cotton stalk was found as 157.30 kg/ $m^3$.The proximate analysis of shredded cotton stalk biomass in terms of moisture content, fixed carbon, volatile matter and ash content were found as 13.34 %, 20.53 %, 74.52 %, and 4.95 % (d.b) respectively. The calorific value of cotton stalk biomass was obtained as 3827 cal /g. The shredded cotton stalk residues can be considered as an alternative for the woody biomass.

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