RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 7 | Issue 1 | April, 2014 | 221–224

Bulk density of biomass and particle density of their briquettes

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Received : 23.01.2014; **Revised :** 11.03.2014; **Accepted :** 25.03.2014

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ABSTRACT : The direct burning of agricultural residues in domestic as well as industrial applications is found to be very inefficient. Moreover, some of the drawbacks like transportation, storage and handling problems are also associated with its use. One of the approaches, which are being actively pursued worldwide towards improved and efficient utilization of agricultural and other biomass residues, is their densification in order to produce pellets or briquettes. Bulk density is a major physical property in designing the logistic system for biomass handling. The size, shape, moisture content, particle density, and surface characteristics are the factors affecting the bulk density. Bulk density is an important characteristic of biomass that influences directly the cost of feedstock delivered to a bio-refinery and storage cost. Present study deals with the determination of gives the density of the powdered biomass such as Cotton Stalk(CS), Pigeon Pea Stalk(PPS), Cumbu Napier Grass(CNG), Ground Nut Shell(GNS) and Sunflower Stalk(SS) besides their various briquettes diameter. Among the biomass combu napier grass found higher bulk density and among the biomass briquettes Cotton Stalk briquettes has the highest and Pigeon Pea Stalk briquettes has the lowest value besides their diameter size of 40, 50 and 60 mm diameter.

KEY WORDS : Bulk density, Particle density, Biomass, Briquettes

HOW TO CITE THIS PAPER : Bhagwanrao, Shinde Vaibhavkumar and Singaravelu, M. (2014). Bulk density of biomass and particle density of their briquettes. *Internat. J. Agric. Engg.*, **7**(1) : 221-224.

In India about 46% of total energy consumption is estimated to be met from various biomass resources, *i.e.*, agricultural residues, animal dung, forest waste, firewood, etc. India produces nearly 350 million tons of agricultural wastes per year**.** A huge quantity of agricultural residues and a major part of it is consumed in traditional uses (such as fodder for cattle, domestic fuel for cooking, construction material for rural housing, industrial fuel for boilers, etc.). The direct burning of agricultural residues in domestic as well as industrial applications is very inefficient. Moreover, transportation, storage and handling problems are also associated with its use. Thus, efficient biomass technologies, that convert the chemical energy of biomass into a more useful form are required. One of the approaches, that is being actively pursued worldwide towards improved and efficient utilization of agricultural and other biomass residues is their densification in order to produce pellets or briquettes. Briquetting is the process of conversion of agricultural waste into uniformly shaped briquettes that are easy to use, transport and store. The briquetting of biomass improves its handling characteristics, increase the volumetric calorific value, reduces transportation costs and makes it available for a variety of applications.

Bulk density is a major physical property in designing the logistic system for biomass handling. The size, shape, moisture content, particle density, and surface characteristics are the factors affecting the bulk density. Bulk density is an important characteristic of biomass that influences directly the cost of feedstock delivered to a bio-refinery and storage cost (Sokhansanj and Fenton, 2006). It also affects the impacts storage requirements, the sizing of the material handling system and how the material behavior during the subsequent thermo-chemical and biological processes. (McKendry, 2002). The engineering design and operation of transport equipment, storages, and conversion processes depends on bulk density and flow characteristics of feedstock (Woodcock and Mason, 1987). Due to their heterogeneous nature, biomass material possesses inherently low bulk densities and thus it is difficult to efficiently handle large quantities of most feedstock. Therefore, large expenses are incurred during material handling, transportation, storage, etc. Transportation had the second highest cost by considering all factors, when the biomass power plant was run at full capacity (Kumar *et al.*, 2003). It is noted that transportation cost will increase with

increasing power plant size. In order to combat the negative handling aspects of bulk biomass, densification is often required. If such crop residues are converted into briquettes they can provide a huge and reliable source of feedstock for thermo chemical conversion (Anonymous, 2006).

Present study deals with the determination of gives the density of the powdered biomass such as cotton stalk (CS), pigeonpea stalk(PPS), Cumbu napier grass (CNG), Ground nut shell (GNS) and sunflower stalk (SS) besides their briquettes.

METHODOLOGY

Bulk density of biomass materials:

Yaning Zhang (2012) explained that an empty container was weighed using a digital balance to the nearest 0.0001/g. The container was filled with the sample and the material was slightly compacted to ensure the absence of large void spaces. The container and the sample were then weighed. Three replications were carried out. The wet bulk density of the sample was calculated from the following equation:

$$\rho_b = \frac{(W_2 - W_1)}{V}$$

where:

ρ_b = bulk density of the sample (g /cm^3)

W_2 = weight of the container and sample (g)

W_1 = weight of the container (g)

V = volume of the container (cm^3).

Bulk density of biomass briquettes by geometric measurements :

Rabiera *et al*. (2006) explained the briquettes which are already cylindrical in shape, whose volume was known by the formula *i.e.*(π/4) × (diameter of cylinder) × height. Then bulk density can be calculated by using the formula :

Bulk Density = (mass of briquette) / (volume of briquette)

Bulk density of biomass briquettes by wax method :

Sengar *et al*. (2012) explained that water displacement method was used to measure the volume of individual briquette. The briquettes were coated with wax, in order to prevent any water absorption during deeping. Each briquette was weighed and then coated with wax. The wax coated briquettes were weighed and then submerged into water in suspension position and weight of displaced water was measured and recorded as the volume of the wax briquettes. (since density of water is 1 g/cc) The volume of each briquette was calculated by subtracting the volume of coating wax from the volume of waxed briquettes. The bulk density of briquettes is obtained by the formula given below :

Bulk density of briquettes = (weight of the waxed briquettes – weight of the original briquette) / (volume of water displaced).

RESULTS AND DISCUSSION

Biomass density of briquettes depends on the initial density of biomass and binder (if used), briquetting process and pressure applied during the manufacture. Bulk density varies significantly with moisture content and particle size of the fuel.

In the determination of bulk density of biomass using measuring cylinders (Fig. 1), it is found that powdered biomass had bulk density in the range of 98.95 kg/m^3 to 131.50 kg/m^3 by rectangular container and from 90.127 kg/m^3 to 120.70 kg/m^3 by cylindrical container. Cumbu napier grass biomass had the highest bulk density of 131.50 kg/m^3 and 118.15 kg/m^3 by rectangular and circular container, respectively. Ground nut shells had lowest bulk density of 98.95 kg/m^3 and 90.127 kg/m^3, respectively. Ground nut shell was observed to posseses the lowest bulk density, because of larger particle size and shape, because ground nut shells were not powdered before briquetting (Table 1).

Table 1 : The measured values of biomass bulk density

Biomass	By using rectangular vessel (kg/m^3)	By cylindrical vessel (kg/m^3)
Cotton stalk	99.28	94.58
Sunflower stalk	116.05	111.78
Cumbu Napier Grass	131.50	118.15
Pigeon pea stalk	128.21	120.70
Ground nut shell	98.95	90.127

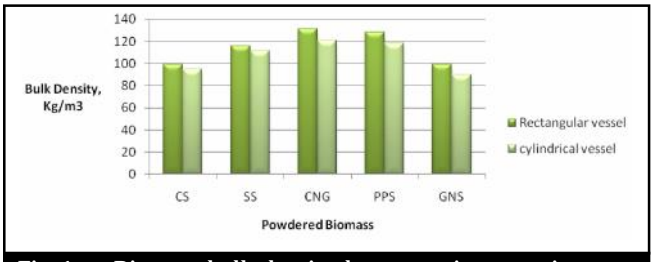

Fig. 1 : Biomass bulk density by measuring containers

From the Fig. 2 and 3, it can be observed that as the diameter of briquette decreased, the bulk density increased in the cases of bulk density by wax method and geometric measurement method. Hence, in the both the methods briquettes of 40 mm size had the highest value of bulk density as compared to 50 mm and 60 mm in all the biomass briquettes. 60 mm size briquettes had the lowest value. Because as the diameter is less then compaction will be more.

Bulk density by wax method of 40 mm sized briquettes was in the range of 1186 to 1406.90 kg/m^3. Among these cotton

Table 2 : Determination of bulk density of biomass briquettes by wax method

Feedstock for briquetting	Diameter (mm)	Bulk density (kg/m^3)
	40	1406.90
Cotton stalk	50	1288.30
	60	1204.68
	40	1246.93
Sunflower stalk	50	1119.60
	60	996.91
	40	1251.22
Cumbu Napier Grass	50	1183.50
	60	1034.13
	40	1237.12
Pigeon pea stalk	50	1102.28
	60	996.33
	40	1186.00
Ground nut shell	50	1159.90
	60	1005.57

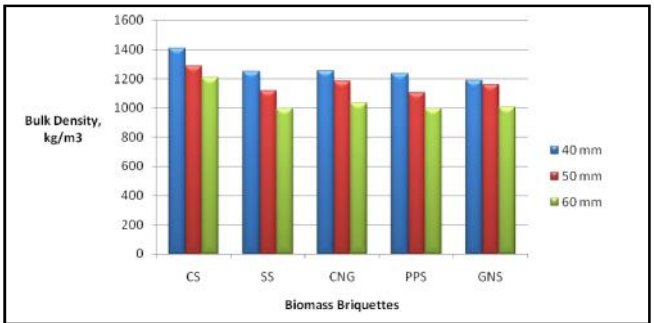

Fig. 2 : Bulk density of biomass briquettes by wax method

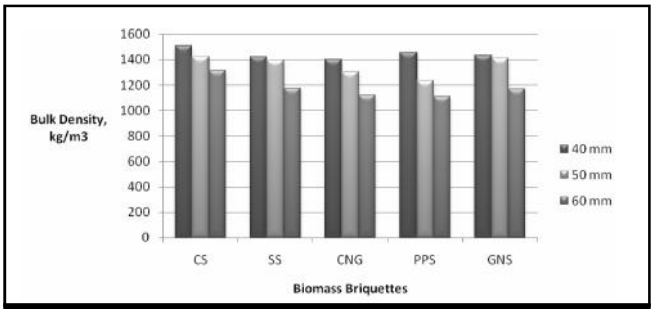

Fig. 3 : Bulk density of biomass briquettes by geometric measurements

Table 3 : Determination of bulk density of biomass briquettes by geometric measurements

Feedstock for briquetting	Diameter (mm)	Bulk density (kg/m^3)
	40	1508.80
Cotton stalk	50	1424.10
	60	1314.40
	40	1425.00
Sunflower stalk	50	1396.80
	60	1174.20
	40	1401.10
Cumbu Napier grass	50	1304.80
	60	1121.60
	40	1456.30
Pigeon pea stalk	50	1236.80
	60	1110.00
	40	1435.60
Ground nut shell	50	1411.90
	60	1167.10

stalk briquettes had the highest and ground nut shell briquettes had the lowest value. Bulk density by wax method of 50 mm sized briquettes was in the range of 1102.28 to 1288.30 kg/m^3. Among these cotton stalk briquettes had the highest and pigeonpea stalk briquettes had the lowest value. Bulk density by wax method of 60 mm sized briquettes is in the range of 996.33 to 1204.68 kg/m^3. Among these cotton stalk briquettes had the highest and pigeonpea stalk briquettes had the lowest value (Table 2).

Bulk density by geometric measurement method of 40 mm sized briquettes was in the range of 1401.10 to 1508.80 kg/m^3. Among these cotton stalk briquettes had the highest and Cumbu napier grass briquettes had the lowest value. Bulk density by geometric measurement method of 50 mm sized briquettes was in the range of 1236.80 to 1424.10 kg/m^3. Among these cotton stalk briquettes has the highest and pigeonpea stalk briquettes had the lowest value. Bulk density by geometric measurement method of 60 mm sized briquettes was in the range of 1110 to 1314.40 kg/m^3. Among these cotton stalk briquettes has the highest and pigeonpea stalk briquettes had the lowest value.

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