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Engineering Properties of Palmyrah Palm Jaggery *(Borassus flabellifer L.)*

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ABSTRACT

Disintegration of the raw jaggery is one of the important unit operations in the palmyrah palm jaggery processing. The important engineering properties of palmyrah palm jaggery were studied. Three different grades of jaggery were obtained and classified based on the fineness modulus values. The values range from 5.5-6.5 (coarse), 4.5-6.5 (medium), 4.5-6.5 (fine) respectively. Result was revealed that the mean values of size, true volume, true density, moisture content, porosity, bulk density, coefficient of frictions against various surfaces was found to vary from 4.11±0.69 mm in height, 93.0± 0.49 mm diameter, 0.00014 ± 1.2 m^3, 1344.65 ± 2.4 kg/m^3 respectively. While the moisture content on different size of palmyrah palm jaggery was found to be in the range of coarse (3.23), medium (3.1) and fine (2.9). Bulk density and porosity of jaggery before and after disintegration obtained 687.08 ± 12, 765.85±31 and 48.83±2.3,42.77 ±9.3 respectively.

Key words *Palmyrah palm jaggery, disintegration, fineness modulus*

Palmyrah, widely called as Toddy palm tree"belongs to the family *Palmae* and the sub-family *Boracidae*. It is the one of the most common trees in India. The palm tree is considered as "karpagavirutcha "in Tamil Nadu and treated as the State tree. Out of the estimated 8.59 crores of palmyrah in India, about 5.10 crores of Palmyrah is in Tamil Nadu. It is a potential centre for the growth and development of Palm products industry to a greater extent attracting foreign exchange by way of export of palm products.

Gur (Palmyrah Jaggery) is a natural, traditional sweetener made by the concentration of palm sap or juice. It is an unrefined non-centrifugal sugar consumed in Asia. Palm sap is manually collected from each inflorescence of the Palmyrah palm tree. Traditionally, Palm sugar concentrate is produced by evaporating the palm sap in a large open pan (approximately 60-80 litres/pan). Heating is stopped when desired consistency and colour is reached. The product would be taken out from the pan to cool down and kept in containers for moulding. The shape of the solid jaggery may vary from small round balls to large lumps. The differences are based on personal hygiene, sanitary facilities, harvesting condition, heating temperature, heating time and storage conditions.

In recent times, different forms of jaggery are available in the market viz., solid, liquid and powder or granular forms. Price of palm jaggery is determined by its quality, colour, flavour and texture. The demand of palmyrah palm jaggery granules is growing rapidly due to ease in use, handling, packaging and storage. Raw jaggery which is large and solid at room temperature gains the moisture after three to four months and reduces the market value of the jaggery. The jaggery granules have same characteristics of taste, sweetness and molecular structure as that of raw jaggery. The overall life and quality of powdered jaggery is much better when compared to the available raw jaggery.

MATERIALS AND METHOD

Size

The size of palm jaggery such as height, diameter was measured using a digital vernier calliper, the horizontal and vertical height and diameter measured and average values noted.

True volume

The volume of palm jaggery was measured using water displacement method. First dip the jaggery by using sink rod in few seconds. The difference between the final volume of water displaced and the initial volume gives the volume of the jaggery

True density

The samples were first weighed to get its mass and the volume was determined for each sample by immersing it in water, in order to get the volume of displaced water. It is important to note that the readings were taken immediately after the sample was immersing into the jar.

$$\text{Volume } (m^3) = \frac{\text{weight of displaced water (kg)}}{\text{weight density of water } (kg/m^3)}$$

Moisture content of palmyrah palm jaggery

Moisture content of jaggery was determined by using a hot air oven method. Five gram of jaggery with few drops of absolute alcohol was dried to constant weight at 70°C The jaggery was dried for 7 h till it reached bone dry condition (constant weight).

$$MC_{(wb)} = \frac{\text{Initial weight of sample} - \text{Final weight of sample}}{\text{Total weight of sample}} \times 100$$

Where,

W_w - weight of water evaporated, (g)

W_d - weight of bone dry matter present, (g)

Bulk density

Bulk density is defined as the mass of the sample to its total volume (including its pore space). Filling a container of known volume with the jaggery from a height of 150 mm at a constant rate and then weighing the content. No separate manual compaction of jaggery was done.

Porosity

Porosity was calculated as the ratio of the difference between the true and bulk density, expressed in percentage.

$$P = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100$$

Where,

P - porosity, %

ρ_b - bulk density, kg/m^3

ρ_t - true density, kg/m^3

Co-efficient of friction

The co-efficient of friction for jaggery was determined by placing the samples on galvanized iron sheet with the help of a bottomless plastic cup. Then the cup was connected to the loading pan through a strong thread and the thread was allowed to move over a frictionless pulley. Weight was added gradually until the cup started dragging. Then the weight added on the pan was noted with different sheets.

$$\mu = \frac{F}{N}$$

Where,

ì - co-efficient of friction

F - lateral force, g

N - normal force, g

RESULT AND DISCUSSION

Results of physical properties like size, shape, true volume, moisture content, bulk density, true density, porosity, and coefficient of friction are determined before and after disintegration of jaggery are tabulated.

The study on size distribution of jaggery (average of three replications) is presented in Table 1.1 revealed that 88 per cent of the jaggery was in the range of 30-50 mm in height and 80-100 mm in diameter.

Coefficient of friction	
Stainless steel	0.476
Mild steel	0.773
Galvanized steel	0.424

Bulk density and true density of palm jaggery

The bulk density and true density of jaggery was determined to calculate the volume of feed hopper required and quantity of jaggery retained in the disintegrating unit during disintegration. The average value of bulk density and true density of the jaggery was found to be 687.08 kg per m^{3}and 1344.65 kg per m^3 .Similar results were reported by Jagannadha Rao et al. (2008). It was found that after disintegration bulk density of jaggery was varied from 628.93to 882.82 kg per m3 revealed that bulk density increased with increasing particle size. Similar studies reported by Horng Yuan Saw et.al.(2014) relationship between powder particle size and bulk density.

Moisture content of palm jaggery

Average moisture content of the jaggery was found to be 3.42 ± 0.66% wb Similar trend was observed by Velauthamurty et al.(2015) in palmyrah palm jaggery granules. Moisture content is varied before and after size reduction due to the hygroscopic nature of the jaggery it absorbs moisture from the atmosphere. Analogous results were reported by Mandal et al. (2006). Maximum moisture was observed in case of fine jaggery powder. On the basis of moisture it could be concluded that particle size is inversely related to the moisture absorption in jaggery similar results revealed by Unde et al. (2011).

Porosity of palm jaggery

The porosity of palm jaggery before disintegration varied from 34.35 to 52.87 per cent, average value of porosity was found to be 42.77 per cent. This clearly indicates that

Table 1. Important engineering properties of palmyrah palm jaggery

Particulars	Range	Mean	SD
Height , mm	31.2 – 44.2	41.1	0.69
Diameter , mm	83.6 – 101.3	93.0	0.49
True volume,m^3	0.00012- 0.00019	0.00014	1.2
True density , kg/m^3	1021.89 – 2242.021	1344.65	2.4
Bulk density , kg/m^3	**Before disintegration**		
	657.25 - 720.08	687.08	128.12
	After disintegration		
	628.93-882.82	765.87	31.5
Porosity (%)	**Before disintegration**		
	46.44- 51.12	48.89	2.3
	After disintegration		
	34.35-52.87	42.77	9.37

in a given volume of a container, volume occupied by jaggery is less i.e. 42.77 per cent as compared to air. It was found that after disintegration porosity of jaggery varied. Jagannadha Rao et al. (2008) revealed the porosity value of palmyrah palm jaggery granules was 65.4%. The porosity changed depending upon the shape of the material. It was evident from the study conducted by Chandrasekar and Visvanathan (1999) on determining the physical properties of coffee beans that the porosity increased with decrease in regularity in shape.

Coefficient of frictions

Coefficient of frictions is essential for the movement of jaggery through the disintegrating unit surface. The average values of static coefficient of friction on various test surfaces viz., Stainless Steel (SS), Mild Steel (MS) and Galvanized Iron (GI) are given in the Table1.1. The coefficient of friction of jaggery was high on MS surface (0.77) and was least (0.42) on GI surface. Among the test surfaces used, the mild steel surface recorded the highest static coefficient of friction of 0.773

CONCLUSION

Jaggery is highly priced due to its medicinal properties; there is a need for developing standard process as well as mechanisation for the same. These information will be very helpful to develop the process and machinery for Palmyrah palm jaggery production.

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