Current Journal of Applied Science and Technology

40(24): 18-25, 2021; Article no.CJAST.73834
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Some Physical Properties of Palmyrah Palm (*Borassus flabellifer* L.) Fruits

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i2431498
Editor(s):
(1) Dr. Ahmed Fawzy Yousef, Desert Research Center, Egypt.
Reviewers:
(1) Rakesh Bhargava, India.
(2) G. Ravichandran, India.
Complete Peer review History: https://www.sdiarticle4.com/review-history/73834

Original Research Article

Received 06 July 2021
Accepted 16 September 2021
Published 18 September 2021

ABSTRACT

Some physical properties of palmyrah fruit were investigated in this study. The average values of major, medium, minor and geometric mean diameters of fresh whole palmyrah fruit were 11.54,10.45, 9.85 and 10.64 cm respectively at 47.34 % (w.b) moisture content whereas that of palmyrah nut were 8.59, 7.35, 4.99 and 6.79 cm respectively at 8% (w.b) moisture content. Sphericity, surface area and aspect ratio were found to be 91.94%, 359.17 cm2 and 0.90 for fruit and whereas that of nut were 79.19%, 145.16 cm^2 and 0.86 respectively. The average mass of the individual palmyrah fruit and nut was 927.78 and 248.10 g whereas bulk density was 525.92 and 693.0 kg/m^3 respectively. The coefficient of static friction on mild steel, glass and plywood surfaces were 0.27, 0.21 and 0.25 for palmyrah fruit and 0.36, 0.28 and 0.27 for nut respectively. The angle of repose of palmyrah fruit and nut were 30.77 and 44.03 respectively.

Keywords: Angle of repose; coefficient of friction; density; palmyrah fruit; porosity; sphericity.

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1. INTRODUCTION

The palmyrah palm (*Borassus flabellifer* L.) has enormous economic potential, and every component can be used in some way or other. Palmyrah palm serves as food as well as building material [1] and also useful in the pharmacopoeia [2]. The palmyrah fruit is nutritionally rich, pulp obtained from the ripe fruit is used in many traditional food items and is a low-priced seasonal drinking juice with commercial and medicinal value [3]. Carbohydrates, pro-vitamin-A, vitamin-C, minerals, and lycopene are abundant in palmyrah fruit and it is a promising raw material for the production of industrially viable product [4,5]. During July/August, the fruits mature, and the ripened fruits fall off the tree between August and October. About 150-200 fruits may be found on each female palm every year. India has the potential to produce more than 20,000 metric tonnes of palmyrah fruit pulp every year [6] and ranks first in the world in terms of its wealth of palmyrah palms with a population of nearly 122 million palms [7]. The palm is found growing in Andhra Pradesh, Bihar, Orissa and Tamilnadu, and more number of palms was found in southern states of India. In Andhra Pradesh 15 to 20 million palm trees are available from which 3,000 metric tonnes of pulp can be extracted every year.

Investigation into engineering properties of biological materials play a major role in assessing the quality of the products, reducing the post harvest losses due to transportation and other mechanical handling during processing of the products, storage and packaging system. Many researchers have conducted studies on the physical and mechanical properties of diverse crops like hazel nuts [8], areca nut kernels [9], turmeric rhizomes [10], orange [11, 12], doum palm fruit [13], wild mango fruit [14]. Some database have been established on physical and mechanical properties of fruits such as pear [15], jujube fruit [16] palm fruit [17]. Size and shape of agricultural fruits are important because they are used in grading of fruits and vegetable. Size and shape are also necessary in heat and mass transfer calculations of biomaterials. Aspect ratio is needed to determine how easily an object will move. Roundness and angle of repose are important for the design of equipment. Bulk density, true density and porosity are useful in designing hoppers and storage structure.

Currently palmyrah fruits and nuts are handled and processed using traditional techniques. This method involves drudgery and huge post-harvest losses. These approaches are labour intensive and results in substantial post-harvest losses. Engineering properties database is needed to develop innovative methods for handling and processing of palmyrah fruits. Design of the equipment for cleaning, grading, and separation require accurate information of the size distribution of palmyrah fruits. Investigation of bulk and true densities, porosity of any agricultural materials is imperative for the design of equipment i.e grader, pulper, separation equipment, drying, storage, and transport systems. Investigation into flow ability of fruit is determined through the angle of repose and coefficient of friction. Hence a study was done to determine detailed information on physical properties of palmyrah fruits so as to aid in designing of processing and handling machines.

2. MATERIALS AND METHODS

2.1 Procurement of Palmyrah Palm Fruits

The palmyrah palm fruits (Fig. 1) used for this research were procured from germplasm block (1991 planted) of Horticultural Research Station, Dr. YSR Horticultural University, Pandirimamidi, Andhra Pradesh, India. The mature and healthy fresh palmyrah palm fruits were selected for conduct the experiments.

2.2 Physical Properties

2.2.1 Moisture content determination

The pulp, fibrous nut, sheath cum skin (fibre and calyx) were manually separated from the fresh palmyrah fruits (10 numbers). The mass of pulp, nut, and sheath cum calyx were determined separately using electronic balance (Shemadzu AP 124 X) reading to 0.01g. The moisture content of the samples was determined by using the AOAC official method 925.40 [18] procedure and using the following formula.

$$M.C\ (\%\ w.b) = \frac{(m_{pi}-m_{pf})+(m_{ni}-m_{nf})+(m_{si}-m_{sf})}{(m_{pi}+m_{ni}+m_{si})} \quad (1)$$

Where

M.C. = moisture content of palmyrah fruit, % (w.b)
m_{pi} = initial mass of fruit pulp, g
m_{pf} = final mass of fruit pulp, g
m_{ni} = initial mass of nut, g
m_{nf} = final mass of nut, g
m_{si} = initial mass of sheath cum calyx, g
m_{sf} = final mass of sheath cum calyx , g

Fig. 1. Palmyrah fruit and pulp availability in nature. (a) Bunch of Palmyrah fruits to tree; (b) Palmyrah fruits; (c) Palmyrah pulp; (d) Palmyrah fibre

2.2.2 Mass, size and shape

The average mass of fifty palmyrah fruits and nuts, which picked randomly, were determined by using the electronic balance (Shemadzu AP 124 X) reading to 0.01 g. The three axial diameters i.e. major (L), medium (W) and minor (T) were determined using a digital vernier caliper of least count 0.01 mm. The arithmetic mean diameter (D_a), geometric mean diameter (D_g), sphericity (ϕ), of pamyrah fruit and nut were calculated by using the following formulae [19].

Arithmetic mean diameter, $$D_a = \frac{L+W+T}{3} \quad (2)$$

Geometric mean diameter $$D_g = (LWT)^{1/3} \quad (3)$$

Sphericity, $$\phi = \frac{(LWT)^{1/3}}{L} \quad (4)$$

2.2.3 Surface area and aspect ratio

The surface area of bulk sample (fruit and nut) was found by analogy with a sphere of the same geometric mean diameter, using the following relationship [20] corresponding to geometrical shape of fruit and nut which are spherical and ellipsoidal.

Surface area, $$S = \pi(D_g)^2 \quad (5)$$

The aspect ratio, R_a was calculated by the following relationship [21].

Aspect ratio, $$R_a = \frac{W}{L} \quad (6)$$

2.2.4 Bulk density, solid density and porosity

The bulk density was determined using the mass/volume relationship [22] by filling an empty container of predetermined volume. Bulk material of fruits/nuts kept in container of known mass and volume were weighed. Bulk density (ρ_b) is equal to the mass of the bulk material divided by volume containing the mass. Bulk density was calculated for three replications.

The true density or solid density (ρ_s) is defined as the ratio between the mass and its true volume. The true volume was determined by weighing the material in toluene using the toluene displacement method [19].

$$V = \frac{m_t}{\rho_t} \tag{7}$$

Where

m_t= mass of sample in toluene, g
ρ_t= density of toluene (0.86 g/cm^3)

The porosity of fruits/nuts was determined from the bulk and true density, using the following formula [10].

$$\text{Porosity}, \varepsilon = (1 - \frac{\rho_b}{\rho_s}) X 100 \tag{8}$$

2.2.5 Coefficient of friction on various surfaces

The static coefficients of friction of palmyrah fruits and nuts on three different structural surfaces namely; galvanized iron (GI), glass and plywood were determined immediately after collection of the fruits using an inclined plane apparatus as described by Dutta [23]. The inclined plane was gently raised and the angle of inclination (θ) at which the sample started sliding was read off the protractor with sensitivity of one degree. The coefficient of friction is the tangent of the angle and was calculated by the following formula [24], [23].

$$\mu = \tan\theta \tag{9}$$

2.2.6 Angle of repose

Angle of repose is the static angle with the horizontal at which the material will stand when piled and is the characteristics of the bulk material which indicates the cohesion among the individuals. This was determined using topless and bottomless cylinder of 0.4 m diameter and 1.0 m height. The cylinder filled with palm fruits/nuts, and it was raised until fruits formed a cone shape. The height of the cone (h) and the diameter of the cone (d) were measured. The angle of repose (θ) was calculated by the following relationship [9]. The experiment was replicated ten times.

$$\theta = \tan^{-1}(2h/d) \tag{10}$$

3. RESULTS AND DISCUSSION

3.1 Fruit Characteristics

One hundred randomly selected ripened palmyrah fruits showed that 76 number of large three seeded fruits with an average weight of 1002 g, and 18 fruits with two seeded with mean weight of 575 g, remaining single seed with average weight of 350 g. In this study the average mass of a palmyrah seed was found to be 248 g and the average pulp mass per fruit was about 350 g.

Out of one hundred fruits, 14 number of fruits having weight between 400 - 600 g, 22 fruits in the range of 600 - 800 g and maximum number of fruits (28) in the range of 800g to 1000g, another 36 fruits more than 1000 g, in this only 4 fruits having weight of 1800 g (Fig. 2).

3.1.1 Composition of the fruit

The experimental values show that the palmyrah fruit pulp percentage ranged from 21.67 to 56.67%(w.b) with the average value 37.82%, nut percentage ranged from 27.78 to 58.33% (w.b) with the average value 46.06%, and sheeth/fibre percentage ranged from 9.82 to 20% (w.b) with the average value 16.12% as given in Fig.3. The palmyrah fruit pulp average value is in agreement with the average value (37.54 %) quoted by Aman [25].

3.2 Physical Properties

3.2.1 Moisture content

The average moisture content for palmyrah fruit was 47.3% (w.b), whereas pulp, nut, sheet and clayx had 81.8, 8.4, 33.0 and 26.5 % (w.b.) respectively. The results for palmyrah pulp are in agreement with the results quoted by Ali *et al.* (2010), Wijewardan et al. (2016) for palmyrah pulp whereas Artnarong [26] quoted was high 91.0% (w.b).

3.2.2 Geometric properties

The summary of measured and calculated geometrical characteristics of palmyrah fruit are tabulated in Table 1. The average values of major, median and minor diameters of palmyrah fruit were 11.54, 10.45 and 9.85 cm respectively. The average geometric mean diameter and sphericity were 10.58 cm and 91.94 %

respectively. The shape of the palmyrah fruit was compared with the standard chart [19] and can be considered as round as its shape is approaching spheroid. The surface area varies between 140.28 to 600.24 cm^2 with the mean value of 359.17 cm^2 and aspect ratio 0.714 to 0.991 with an average value of 0.906.

The measured and calculated geometrical characteristics of palmyrah nut are tabulated in Table 1. The average values of major, medium and minor diameters of palmyrah nut were 8.59, 7.35, and 4.99 cm respectively. The average geometric mean diameter and sphericity were 6.79 cm and 79.19% respectively. The surface area varies between 130.12 to 163.34 cm^2 with mean value of 145.16 cm^2 and aspect ratio between 0.72 and 0.97 with mean value of 0.86.

3.2.3 Gravimetric properties

The gravimetric properties were given Table 1. The average mass of the palmyrah fruit and nut is 927.78 g and 248.1 g respectively. The mean volume of fruit and nut is 787 cm^3 and 195 cm^3 respectively. The bulk density and true density of fruit and nut are 525.91 kg/m^3 and 1245.27 kg/m^3, 693.0 kg/m^3 and 1305.31 kg/m^3 respectively. The bulk density of fruit is less compared to the nut as the fruit includes pulp and fiber also which are light in weight compared to the same volume of nut. The porosity is 0.57 and 0.45 for fruit and nut respectively.

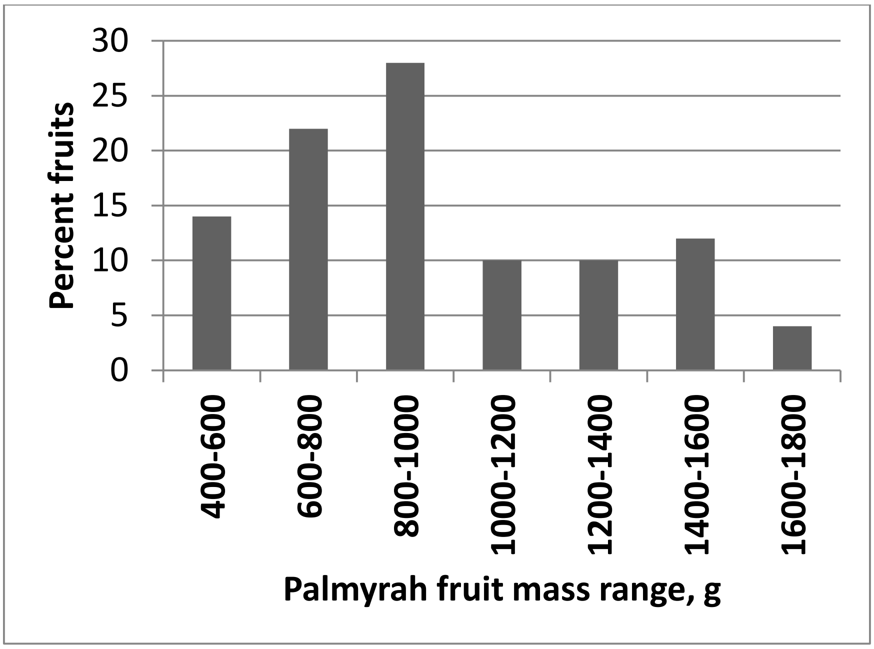

Fig. 2. Frequency distribution curve for weight of fresh palmyrah fruit

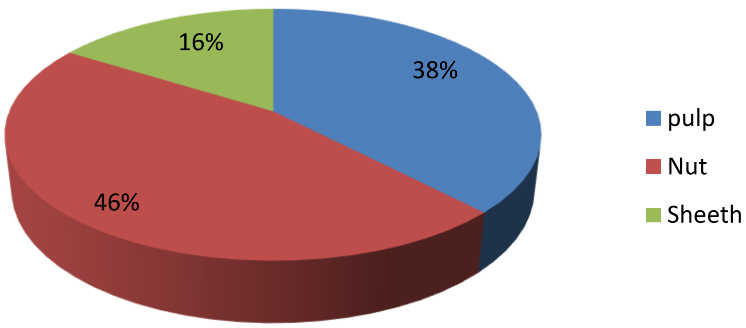

Fig. 3. Average values of fruit composition

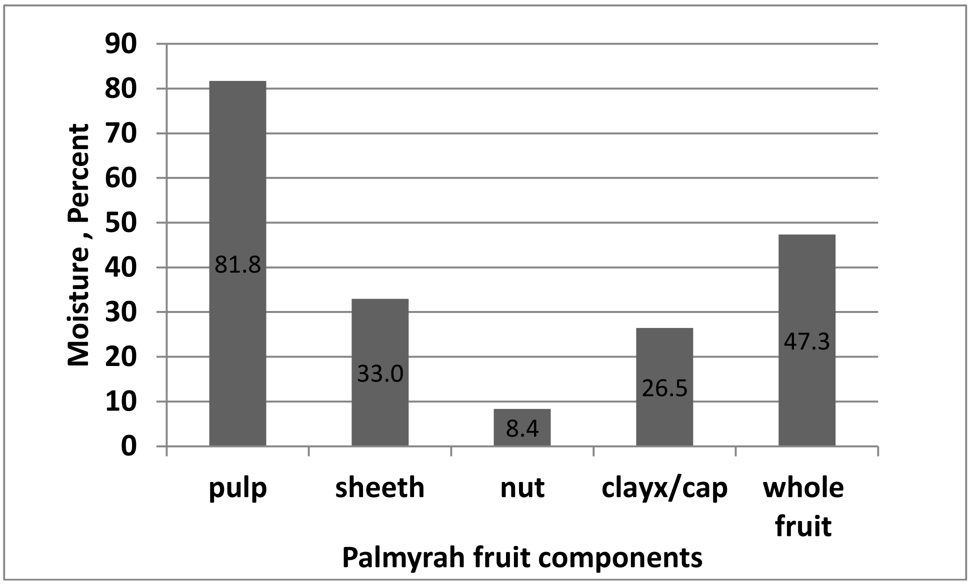

Fig. 4. Palmyrah fruit components and its moisture content (% w.b)

Table. 1. Geometric, Gravimetric and frictional properties of palmyrah fruit and nut

Parameter	Palmyrah fruit	Palmyrah Nut
Geometric properties		
Major diameter, cm	11.54±1.74	8.59±0.47
Medium diameter, cm	10.45±1.52	7.35±0.48
Minor diameter, cm	9.85±1.63	4.99±0.52
Arithmetic mean diameter, cm	10.62±1.55	6.98±0.49
Geometric mean diameter, cm	10.58±1.54	6.79±1.14
Sphericity, %	91.94±5.17	79.19±2.94
Surface area, cm^2	359.17±101.61	145.16±4.05
Aspect ratio	0.906±0.08	0.86±0.07
Gravimetric properties		
Mass, g	927.78±333.09	248.10±24.43
Volume, cm^3	787.00±221.91	195.00±32.58
Bulk density, kg/m^3	525.92±25.13	693.00±58.08
True density, kg/m^3	1245.27±127.44	1305.31±164.68
Porosity	0.57±0.04	0.45±0.10
Frictional properties		
Coefficient of friction on		
Galvanised iron	0.27±0.05	0.36±0.03
Glass	0.25±0.01	0.28±0.06
Plywood	0.21±0.04	0.27±0.03
Angle of repose, degree	30.77±1.56	44.03±3.27

3.2.4 Frictional properties

The coefficient of friction of fruit and nut on various surfaces was investigated and the data is presented in the Table 1. The coefficient of friction of palmyrah fruit and nut are high on galvanised iron sheet followed by glass and plywood surface. Similar type of results were quoted by Kaleemullah [27] in the case of groundnut kernels. The coefficient of friction of palmyrah nut is more than the palmyrah fruit on all the three surfaces namely galvanised iron, glass and plywood sheet as the palmyrah nut had more rough surface compared to palmyrah fruit.

3.2.5 Angle of repose

The angle of repose for fresh palmyrah fruit is less compared to palmyrah nut (Table 1). The reason may be that the palmyrah fruit has smooth surface, round shape when compared to palmyrah nut having rough surface and not having round shape, which made the fruit rolled over cone. Gunasekar and Kaleemullah [10] also reported that the angle of repose of turmeric rhizomes was less at higher moisture content when compared to the one at lower moisture content as it had more wrinkles on turmeric rhizomes surface.

4. CONCLUSIONS

1. The average values of major, medium and minor diameters of palmyrah fruit were 11.54, 10.45 and 9.85 cm respectively, while the geometric mean diameter was 10.58 cm at 47.34% (w.b.) moisture content. The average values of major, medium and minor diameters of palmyrah nut were 8.59, 7.35, and 4.99 cm respectively with average geometric mean diameter 6.79 at 8.0% (w.b.).
2. The average sphericity, surface area and aspect ratio were found to be 91.94%, 359.17 cm^2 and 0.9 for palmyrah fruit and whereas that of palmyrah nut were 79.19%, 145.16 cm^2 and 0.86 respectively.
3. The shape of the palmyrah fruit was round.
4. The mean mass of palmyrah fruit and nut was 927.78 g and 248.10 g respectively whereas the bulk density of palmyrah fruit and nut was 525.92 kg/m^3 and 693.0 kg/m^3 respectively.
5. The angle of repose of palmyrah fruit and nut was 30.77° and 44.03° respectively.

ACKNOWLEDGEMENTS

I am very much thankful to Dr. Y.S.R. Horticultural University, Venkatarammangudem for deputing me to pursue Ph.D at Acharya N.G. Ranga Agricultural University.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/73834