SOME PHYSICAL AND MECHANICAL CHARACTERISTICS OF PALM DATE FRUITS

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ABSTRACT

The present study aimed to determine and recognize some physical and mechanical properties as an important role in designing and developing of specific machines and their operations. Some physical and mechanical characteristics of date fruits (Phoenix dactylifera L), Joezee variety, were determined. These characteristics included the date dimensions, surface area, mass, bulk density, real density, void ratio, moisture content, repose angle, static friction coefficient and rigidity force. For each dimension, the date fruits gave the highest value in width of 42.9 mm, the lowest value in length of 25.9 mm. the highest value of repose angle was 26.1º for galvanized sheet while the lowest value was 16.4º for glass. The date fruits gave the lowest value of static coefficient of friction of 0.12 for ply wood while the highest value was 0.17 for galvanized sheet.

INTRODUCTION

Date palm is one of the most important horticulture crops rich in vitamins. Date production in the world is only confined to a small number of countries, most of them being the Arab countries. Date palm is the economic crop in Egypt, where production was approximately 1470 thousand tons of dates, ***FAO (2012***). However, the date industry in the Arab world is not yet fully developed. Great efforts were carried out to evaluate the basic physical and mechanical properties of some agricultural materials to point out their practical utility in machine structural design and food processes, ***Waziri and Mittal (1993)***. Dates provide a wide range of essential nutrients, and are a very good source of dietary potassium. The sugar content of ripe dates is about 80%; the remainder consists of protein, fiber, and trace elements including boron, cobalt, copper, fluorine, magnesium, manganese, selenium, and zinc, ***Al-Shahib*** **and** ***Marshall*** **(2003).**

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Knowledge of the physical properties of date fruit is necessary for the design of post harvesting equipment such as cleaning, sorting, grading, kernel removing, and packing. The importance of dimensions is in determining the aperture size of machines, particularly in separation of materials as discussed by ***Mohsenin (1986)***.

Nesvadba, et. al. (2004) mentioned that the physical characteristics of the material such as shape, size, volume, density, surface area and coefficient of friction are important and essential engineering data in design of machine structures, and controls, in analyzing and determining the efficiency of a machine or an operation. Many authors**: *{Akubuo and Odigboh (1999), Abou-Elmagd, et al. (2002), Awady et al. (2004), El Sayed et al. (2009) and Yehia et al. (2009)}*** mentioned that the knowledge of the physical and mechanical characteristics of agricultural products is important in the design, of agricultural machines and equipment. They studied the physical properties and characteristics of some agricultural crops and fruits, which can be used in the design and development of equipment.

Several investigations have shown some of the chemical compositional changes that take place during maturation, including free sugars and tannins ***Myhara et al., (1999); Sawaya et al., (1983); Sawaya et al., (1982***). Green dates stage (kimri) are firm in texture with highest moisture and tannin contents. At the Khalaal stage, dates begin to lose moisture and form considerable quantities of sucrose. In the Rutab stage, the loss of moisture is accelerated, and the fruits become softer in texture, and sucrose is converted into sugars. Dates at Rutab stage are the most desirable since they are at their softest and sweetest states. In the final maturity stage the fruits contain the least amount of moisture and maintain a soft texture with a sweet taste. ***Ismail et al., (2001)*** studied the consumer preference for quality attributes of date (maturity of Tamr stage). Consumer gave weight on the acceptance as: high (color, appearance, and sweetness), medium (fruit size, flesh thickness, chewiness, and solubility).

The objective of the present research is to study some physical and mechanical properties of date fruits that can be used in fruits handling and classifications.

MATERIAL AND METHODS

Raw Material:

Dates fruits, variety of Joezee, **Fig. (1)** used in this investigation were obtained from the local small market, Mansoura, Daqahlia Governorate**.**

Fig. (1): Palm dates fruits.

This study was carried out at the Faculty of Agricultural Engineering, Al-Azhar University, and Cairo, Egypt during season 2014. Physical and some mechanical characteristics of date fruits, Joezee variety which planted in Kuwait, were determined at maturity stage (Khaleal stage).

Tests procedures:

Date fruits dimensions:

Physical characteristics can be utilized effectively in machines design, one of those physical characteristics is dimension characteristic as length, width, and thickness (mm). Length and diameter (mm) were measured by using digital dial caliber (accuracy of 0.01). One hundred and fifty 150 date fruits were randomly selected from the variety of Joezee. The two major dimensions, length (parallel with the longitudinal axle "a"), Diameter (perpendicular on the longitudinal axle "b") Fig. (2), of each fruit were recorded.

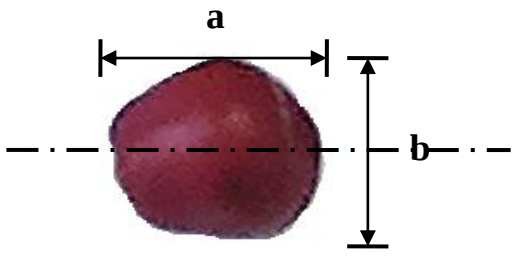

Fig (2): Length "a" and diameter "b" positions of individual date fruit.

Date fruits surface area:

The surface area of date fruits is very important characteristic in determining both volumetric and gravimetric heat transfer coefficients and in analyzing heat and moisture transfer during drying processes, and it is also useful for describing the re-hydration process. The following relation was used for calculating the flat surface area (A_f) in (mm^2), according to **Matthews (1991)** as:

$$A_f = \frac{\pi}{4}(a.b) \ \text{mm}^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Date fruits mass:

A random sample of two hundred date fruits were taken manually and weighed by an electric digital balance, Sartorius: 1413-MP8-1, manufactured in Germany with capacities 500g and 5000g at accuracies 0.01g and 0.1g respectively. The mass of each treatment was replicated three times.

Bulk density, real density and void ratio:

Bulk density:

The bulk density was determined by using a graduated cylinder of 1000 ml, the volume was determined by pouring ten date fruits in the pervious graduated cylinder **Boumans, (1985) Kaleemullah (1992)**, each test was done in three replicates. The bulk density was calculated for the palm date fruits by dividing the mass of quantity of Palm date fruits on its volume, which was measured by using a graduated cylinder **Matthews (1991)** as:

$$\rho_b = \frac{M_b}{V_b} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

ρ_b : Bulk density of palm date fruits, (kg/m^3);

M_b : Mass of the quantity of palm date fruits, (kg); and

V_b : Volume of the quantity of palm date fruits, (m^3).

Real density:

The real density was determined by measuring the actual volume (by using a graduated cylinder of 1000 ml) of a known mass of a random date fruits sample. The actual volume of the palm date fruits was determined by water displacement method, in a graduated measuring cylinder, the immersion time was about 10 second which was too small to absorb water. The density is calculated by finding the ratio of mass to volume of displaced water (g/mm^3). The real density for each variety was replicated three times.

$$\rho_r = \frac{M_r}{V_r} \qquad \text{……..…… (3)}$$

Where:

ρ_r : Real density of palm date fruits, (kg/m^3);

M_r : Mass of the quantity of palm date fruits, (kg); and

V_r : Volume of displaced water, (m^3).

Void ratio:

The void ratio (ε) was achieved by the following equation:

$$\varepsilon = 1 - \frac{\rho_b}{\rho_r} \qquad \text{……..…… (4)}$$

ρ_b : Bulk density of palm date fruits, (kg/m^3);

ρ_r : Real density of Palm date fruits, (kg/m^3);

Date fruits moisture content:

The moisture content was determined for the flesh of dates using AOAC procedures **AOAC (1995**) where the samples of date fruits were dried at 70^oC for 48 hours. The moisture content was calculated on wet and dry basis as follows:

Moisture content "*M.C*" wet basis, (%):

$$M.C = \frac{W_m}{W_m + W_d} \times 100 \quad \text{…..…..……..... (5)}$$

Moisture content "*M*" dry basis, (%):

$$M = \frac{W_m}{W_d} \times 100 \quad \text{…….……..... (6)}$$

Where:

W_m: Mass of moisture in sample, (g); and

W_d: Mass of bone-dry material, (g).

Repose angle:

The angle of repose of date fruits was measured. The dynamic angle of repose was measured between the horizontal and the natural slope of the fruits heap, the different material surfaces namely: plywood, glass and galvanized sheet were used for measuring. The height of the heap was measured and the dynamic angle of repose was calculated by the following equation **Kaleemullah (1992)** and **Soliman (1994)**

$$\alpha = \tan^{-1}\left(\frac{2H}{Dp}\right) \quad \text{…….. (7)}$$

Where: α = dynamic angle of repose, degree.

H = heap height, mm and

D_p = platform diameter, mm.

The dynamic angle of repose for date fruits was including three replicates.

Static friction coefficient:

The test procedure started by leveling the apparatus that was fabricated in the workshop of Agricultural Engineering Faculty, Al-azhar University, Nasr city, Cairo, Egypt. The apparatus was used to measure the angle of static friction for the different material surfaces, namely: plywood, glass and galvanized sheet. The static coefficient of friction was determined using the following equation **Mohsenin (1986).**

Static coefficient of friction = tan θ …….. (8)

Where:

θ = the tilt angle between the surface and the horizontal.

The angle of friction (θ) was measured three times for each selected materials for Date fruits.

Rigidity force:

A digital force gauge (SHIMPO, DF-5.0 series) with accuracy of ± 0.2 % was used for measuring the rigidity force with maximum capacity of 2200g. The rigidity force was recording of each date fruit in two surface positions (vertical and horizontal) after installing the Cone sensing head in the digital force gage. The rigidity force was recording three replicates for each date fruit.

RESULTS AND DISCUSSIONS

Some physical and mechanical characteristics of date fruits under study were conducted in the laboratory of Physical Properties at Faculty of Agricultural Engineering, Al-azhar University.

The two- Major dimensions:

Averages of three replicates for the two-major dimensions are shown in table (1). The measurements of length (a) and diameter (b) in (mm) of hundred and fifty date fruits, randomly selected, were conducted. The highest value of date fruit length and diameter was 36.8 and 42.9 mm respectively, while the lowest values of date fruit length and width were 25.9 and 28.1 mm respectively.

Table (1): The two - Major dimensions of date fruits.

Two-major dimensions	Max.	Min.	Ave.	S.D	C.V %
Length (mm)	36.8	25.9	32.8	2.23	0.06
Diameter (mm)	42.9	28.1	33.8	2.44	0.07

Fig. (3 and 4) indicated that the highest frequencies of date fruit length and diameter were 33.3 and 40 % at (33.5 – 35.3 mm) and (30.8 – 33.3 mm) respectively. Dimensions are important to design the cleaning, sizing and grading machines.

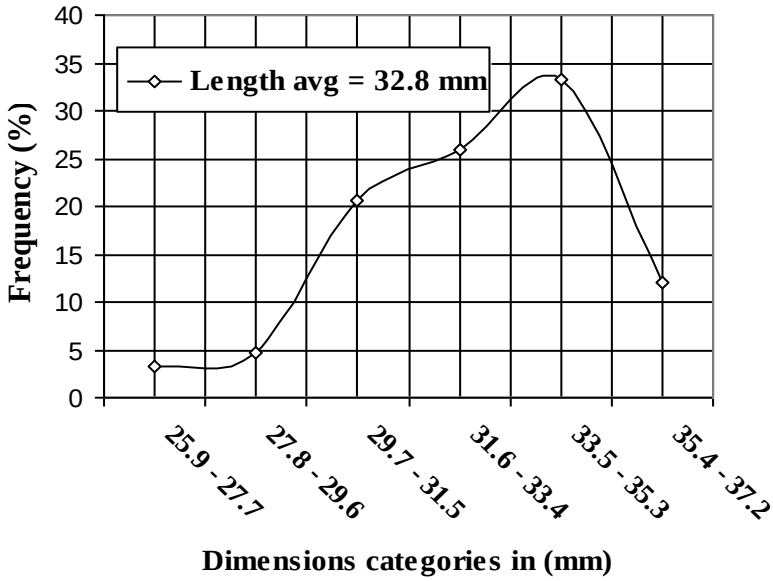

Fig. (3): Length of date fruits.

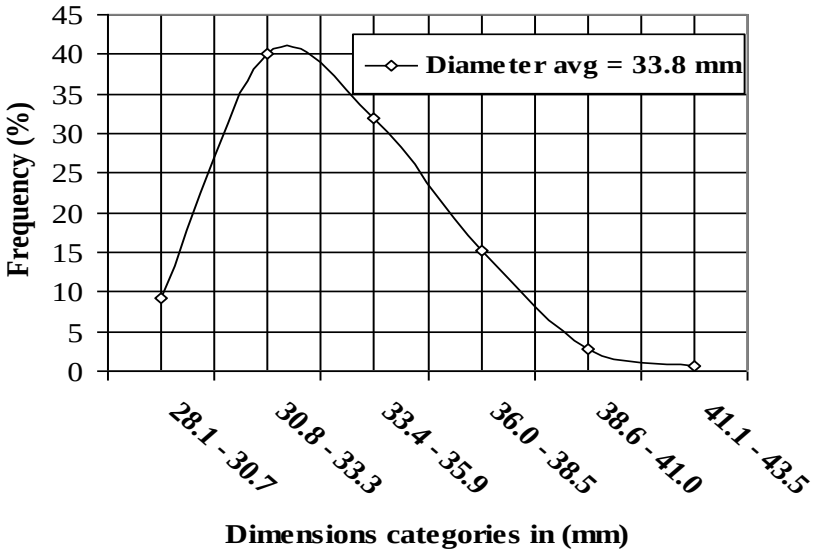

Fig. (4): Diameter of Date fruits.

Date fruits surface area:

Table (2) shows the flat surface area of date fruits. The maximum value of flat surface area is 1239.9 mm^2, while the minimum value is 571.6 mm^2.

Fig. (5) shows that the highest frequency of date fruit flat surface area was 32 % at (89.9 – 98.6 mm^2).

Table (2) Flat surface area of date fruits.

Date fruit surface area	Max.	Min.	Ave.	S.D	C.V %
Flat surface area (mm^2)	1239.9	571.6	874.2	120.23	0.14

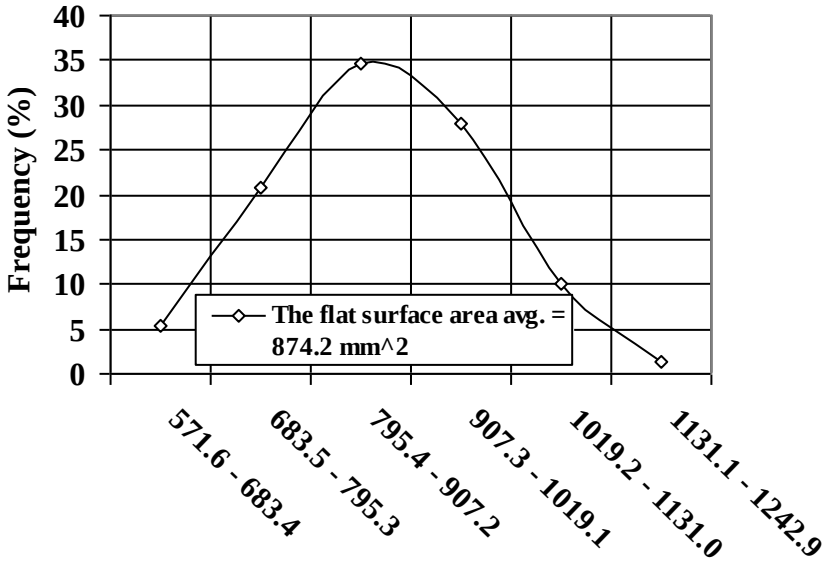

Fig. (5):The flat surface area (mm^2) of individual date fruit.

Mass of 200 date fruits, real density, bulk density, void ratio and moisture content:

Measurements of mass of two hundred date fruits under study, real and bulk density; also, void ratio and moisture content were conducted in three replicates.

Table (3) shows the other physical characteristics for the mass, real density, bulk density, void ratio and moisture content. It shows that the fruits gave values of 3680.2 (g), 0.95 (g/cm^3), 0.36 (g/cm^3), 62.00 % and 67.20 % w.b & 206.00 % d.b for the previous characteristics respectively. Mass of two hundred date fruits is major considerations in designing containers. Bulk and real density are major considerations in designing the converting, drying, aeration and storage systems, bulk density is also considered for determination of paging capacity, designing, cleaning and grading equipment.

Table (3): The mass of two hundred date fruits, real density, bulk density, void ratio and moisture content.

Date fruits	Mass (g)	Real density (g/cm^3)	Bulk density (g/cm^3)	Void ratio (%)	Moisture content (%)	
	3680.2	0.95	0.36	62.00	67.20 w.b	206.00 d.b

Angle of repose and static friction coefficient:

The angle of repose for date fruits of the investigated variety was 16.4°, 21.6° and 26.1°for glass, plywood and galvanized sheet respectively. The previous data can be utilized to storage containers to allow an easily sliding. Coefficient of friction is the tangent of dynamic angle of repose. The repose angle for date fruits of the investigated variety on the selected material surfaces including galvanized sheet, plywood and glass are shown in **Fig (6).**

The lowest values of static coefficient of friction for the date fruits were on plywood followed by glass, and the highest galvanized sheet, (0.12, 0.14 and 0.17) for the date fruits variety respectively.

It is recommended to use this material in the structure of storage containers. The static coefficient of friction for date fruits of the investigated variety on the selected material surfaces including galvanized sheet, glass and plywood are shown in **Fig (7).**

Rigidity force:

The rigidity force of each date fruit in two surface positions (vertical and horizontal) was 15.99 N and 7.69 N respectively.

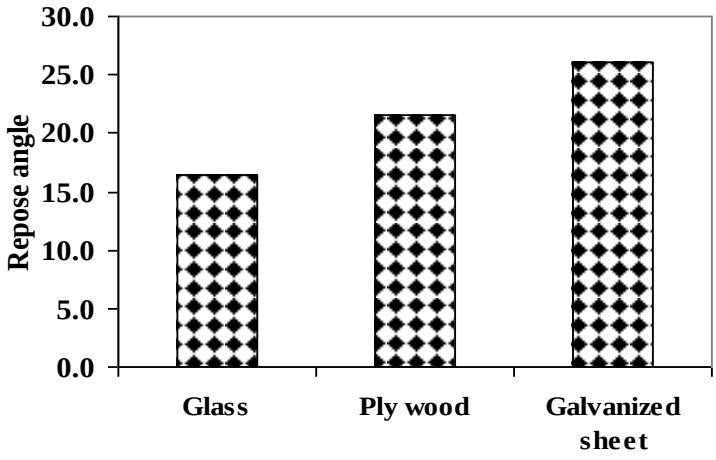

Fig.(6): Angle of repose for date fruits on different material surface.

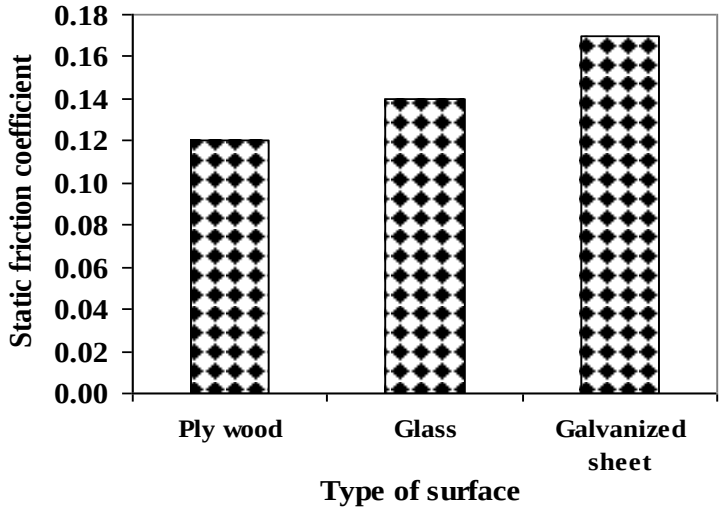

Fig. (7):Static friction coefficient for date fruits on different material surface.

CONCLUSION

The obtained results can be summarized as follows:

1- The highest values of the two- major dimensions were 42.9 mm for the diameter while the lowest value was 25.9 mm for the length.
2- The date fruits gave the highest of flat surface area of 1239.9 mm^2, while the lowest value of 571.6 mm^2.

3- The values of 3680.2 g, 0.95 g/cm^3, o.36 g/cm^3 and 62.00 % were for mass of two hundred date fruits, real density, bulk density and void ratio respectively.
4- The moisture content of 67.20 % w.b and 206.00 % d.b.
5- The highest value in repose angle of 26.10º for galvanized sheet while the lowest value was 16.40 º for glass surface.
6- The lowest value of static coefficient of friction was 0.12 with glass surface while the highest value was 0.17 with galvanized sheet.
7- The rigidity force of 15.99 N and 7.69 N in two surface positions (vertical and horizontal) respectively.

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الملخص العربى

بعض الخصائص الطبيعيه والميكانيكيه لثمار البلح

***رزق ربيع كامل البسومي**

تهدف هذه الدراسة إلى توفير قاعدة معلومات للخصائص الطبيعية لثمار البلح "نوع جوزى" فى مرحلة قبل الرطب لما تمثله هذه الخواص من أهمية فى عمليات حصاد و تداول وتنظيف ثمار البلح فى المراحل المختلفة للنضج، وبغرض المساهمة فى تقليل الأضرار الميكانيكية التى تتعرض لها ثمار البلح خلال عمليات النقل والتخزين. وكانت الخصائص الطبيعية المدروسة هى الخصائص البعدية، وتشمل طول وقطر الثمرة (مم) والكثافة الظاهرية والحقيقية (جرام/سم^3) ونسبة الفراغات البينية ووزن ٢٠٠ ثمرة و والمحتوى الرطوبى وزاوية المكوث ومعامل الإحتكاك الإستاتيكى للثمار على ثلاثة أسطح مختلفة وهى الخشب والزجاج والصاج وقوة الإختراق السطحية للثمار.

ويمكن تلخيص النتائج التي توصل إليها البحث فيما يلي:

- الخصائص البعديه:

كانت أعلى قيمة للطول (البعد الموازى للمحور الطولى للثمرة) ٣٦,٨٠ مم و أقل قيمة ٢٥,٩٠ مم، وأعلى قيمة للقطر (البعد العمودى على المحور الطولى للثمرة) ٤٢,٩٠ مم وأقل قيمة ٢٨,١٠مم.

- وزن مائتان ثمره:

أظهرت النتائج أن وزن ٢٠٠ ثمرة من ثمار البلح كانت ٣٦٨٠,٢٠ جرام.

- الكثافه الظاهريه :

سجلت ثمار البلح كثافة ظاهرية مقدارها ٠,٣٦ جرام/سم٣.

- الكثافه الحقيقيه :

سجلت ثمار البلح كثافة حقيقية مقدارها ٠,٩٥ جرام/سم٣.

- المحتوى الرطوبى:

سجلت ثمار البلح محتوى رطوبى ٦٧,٢٠٪ على أساس رطب و ٢٠٦,٠٠ ٪ على أساس جاف.

- زاوية المكوث الطبيعى للأسطح المختلفه:

سجلت ثمار البلح فى زاوية المكوث الطبيعى الإستاتيكى ١٦,٤° ، ٢١,٦٠° ، ٢٦,١٠° على أسطح الزجاج والخشب والصاج على التوالى.

- معامل الإحتكاك الإستاتيكى للأسطح المختلفه:

سجلت ثمار البلح فى معامل الإحتكاك الإستاتيكى ٠,١٢ ، ٠,١٤ ، ٠,١٧ على أسطح الخشب والزجاج والصاج على التوالى.

- قوة الصلابة السطحيه:

سجلت ثمار البلح قوة اختراق سطحية قدرها ١٥,٩٩ نيوتن و ٧,٦٩ نيوتن فى الوضع العمودى الأفقى على الترتيب.

***مدرس بقسم هندسة المنشآت الزراعية والتحكم البيئى - كلية الهندسة الزراعية- جامعة الأزهر- القاهرة - مصر.**