

# Mathematical model for some physical characteristics of smany and zaghoul date fruit varieties

Abd El-Rahman Abd El-Raouf Ahmed<sup>1\*</sup>, Helmy EL-Sayed Hassan<sup>2</sup>,  
Heba Abdel Mohsen Lotfy<sup>3</sup>

(1. Prof. of Agric. Eng. Res. Institute, Agric. Res. Center, Egypt;

2. Prof. of National Institute of Laser Enhanced Sciences (NILES), Cairo University, Egypt;

3. Researcher, Agric. Eng. Res. Institute, Agric. Res. Center, Egypt)

**Abstract:** The date palm (*Phoenix dactylifera* L) is one of the oldest fruit trees of the world and is closely associated with the life of the people in the Middle East. The objectives of this study were to determine and model the physical properties of Smany and Zaghoul date fruits and their relationship between them. For resulting mathematical model equations according to experimental modeling between (length and mass) and between (diameter and mass) and between (volume and length) are determined. The date fruit samples Smany and Zaghoul date fruit varieties were randomly selected from a local market in Mansoura city, Dakhliya Governorate, Egypt. The date fruit physical properties of size, mass, volume and bulk density were measured, for modelling the relation between these parameters. The obtained results were shown as the following: a) Fruit length was varied (35.54-46.14 mm) and (42.17-62.95 mm); fruit upper diameter ( $D_1$ ), was (13.64-25.59 mm) and (15.67-24.35 mm); fruit middle diameter ( $D_2$ ) was recorded (35.54-46.14 mm) and (42.17-62.95 mm); fruit lower diameter ( $D_3$ ) was recorded (8.68-14.64 mm) and (9.63-16.22 mm); and fruit mean diameter ( $D_m$ ) was recorded (15.56-20.64 mm) and (15.75-22.48 mm) for Smany and Zaghoul date fruit varieties, respectively., b) Volume of individual fruits, the date fruits was recorded the ranged values (10.0-23.1 mm<sup>3</sup>) and (14.0-34.2 mm<sup>3</sup>) in Smany and Zaghoul of date. While, fruit mass of the Smany and Zaghoul date were ranged values (12.00-16.23 g) and (11.90-16.88 g). So, bulk density was recorded the ranged values (858.5-1660 g/cm<sup>3</sup>) and (791.7-963.6 g/cm<sup>3</sup>) in Smany and Zaghoul of date fruits for minimum and maximum of density date fruits, respectively., c) Experimental models to calculate volume and mass of date fruit according to length of fruit were resulting., and d) The correlation between mass and length of Zaghoul date fruit which is 82% higher than that of Smany date fruit 68% must be noticed. While, the relation between volume and length was higher in Zaghoul date fruit, 84% than in Smany date fruit 66%. So, it is preferred Zaghoul to use the mean diameter of the Smany date fruit to calculate the mass of date fruit.

**Keywords:** date fruit, dimensions, physical properties, post-harvest, model

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## 1 Introduction

Size and shape are most often used to describe agricultural materials. Shape and physical dimensions are important in sorting and sizing of fruits, and determining

how many fruits can be placed in shipping containers or plastic bags of a given size. Quality differences in fruits, vegetables, grains and seeds can often be detected from the variations of their densities. Volumes and surface areas of solids must be known for accurate modeling of heat and mass transfer during cooling and drying. (Stroshine, 1998). Vishwakarma et al. (2012) mentioned that the knowledge of some important physical properties such as spatial dimensions, bulk density, true density, and porosity of different fruits/vegetables/grains is essential

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\* Corresponding author: Abd El-Rahman Abd El-Raouf Ahmed, Ph.D., Professor of Agricultural Engineering Department, Agricultural Engineering Research Institute, Agricultural Research Center, 256 Dokki, Egypt. Email: abdo\_aaaa2000@yahoo.com.

for the design of storage structures, processing equipments, and processes.

Linear dimensions and colour values are Zaghoul, especially for the design of equipment related to sorting and grading. Estimation of bulk density is Zaghoul to determine the capacity of storage and transport, while the true density is useful to design proper separation equipment. Porosity of the fruit mass determines the resistance to airflow during aeration and drying operations.

In the Middle-East date palm has been cultivated at least since 6000 BC (Al-Qarawi et al., 2003). The world production of dates has increased extensively during the last 30 years. In fact, the production has tripled from 1 915 615 tones in 1975 to 6 002 040 tones in 2005 (FAOSTAT, 2006). Date palm plays an important role in the economic and social life of the people in the date producing countries (Basuni and AL-Marzooq, 2010). The Arab countries of the Middle-East and North Africa account for 60 percent of the world's production where 800 different kinds of date cultivars are reported to be grown (Al-Afifi and Al-Badawi, 1998).

Al-Abdoulhadi et al. (2011) studied standardize quality norms of major date cultivars in the Kingdom of Saudi Arabia. It was taken up to ascertain fruit characteristics of dates (Tamar stage) in the cultivars Khalas, Sheshi and Reziz with respect to fruit weight (g), size of fruit (length and breath), number of fruits /500 g, fruit moisture, colour and texture. Kashaninejad et al. (2006) recorded the maximum fruit length in all the three categories of large, medium and small sized fruits. With regard to the breath of fruits, the cultivar Sheshi register Zaghoul the highest values. Further, Sheshi recorded the highest fruit weight values, which in turn influenced the number of fruits per unit weight, with Sheshi recording the least number of fruits per 500 g.

Jaradat and Zaid (2004) studying quality traits of date palm fruits revealed that fruit colour, shape, size, ripening and their interactions Zaghoul ominantly reflect differences in consumer preferences, with fruit colour, softness and consumption.

Eisa Hazbavi et al. (2015) studying of some physical properties of the Iranian Stamaran date variety was Zaghoul during 6 months storage (25 C of temperature and 75% of humidity). The results showed that the length

of the samples decreased by 8.31% from 39.21 to 35.95 mm, and no significant change for width and thickness. Mean mass and volume of the fruit did not change significantly. The fruit density, bulk density, porosity and sphericity did not change significantly. The geometric mean diameter and surface area decreased by 5.01%, from 25.53 to 24.25 mm, and 9.57%, from 2049.3 to 1853.1 mm<sup>2</sup>, respectively.

Amrane et al. (2016) showed that the physical properties of date whole fruit and seeds such as linear dimensions, equivalent diameter, volume, mass, sphericity, surface area, bulk density, porosity, angle of repose and hardness Zaghoul due to the date variety.

Mahawarm et al. (2017) found the date fruit physical properties such as fruit dimensions (Major and minor intercept), arithmetic mean diameter, geometric mean diameter, sphericity, colour values, bulk density, true density, porosity and coefficient of static friction recorded a significant difference due to the distinctive features of the date variety (Jahromi et al. 2008). Varietal difference of fruits is also one of the prominent reasons for having deviations in physical properties. There are plentiful studies which include the determination of physical properties of different fruits with varietal differences. (Jahromi et al. 2008).

Sakr et al. (2010) reported fruit length to significantly differ among the fruits of eight date palm cultivars studied with the cultivar Kuboshy and Zaghoul registering the maximum fruit length of 6.65 and 6.10 cm, respectively, while the cultivar Samany registeZaghoul the maximum breath of 3.31 cm. Asif et al. (1986) categorized date fruits of both Khalas and Sheshi as medium to big and that of Reziz to being small. In the Western region of Saudi Arabia, large fruit size characteristic of the cultivar Anbarah from Al Medina is reported to be a unique variant found with relatively low frequency and high polymorphic index (Jaradat and Zaid, 2004).

Almost constant dimensions and volume should be considered Zaghoul in designing separation machine components and parameters. The mean projected areas along the length, width, and thickness were obtained at 341.52-333.92, 647.41-619.8 and 666.89-611.43 mm<sup>2</sup>, respectively.

The objectives of this study were to determine the physical properties of Smany and Zaghoul date fruits and their relation between them. For resulting equations according to experimental modeling between length and mass; between diameter and mass and between volume and length are determined. Also, to find the basic physical properties of date fruit that may affect the design of machines to handle their processing.

## 2 Materials and methods

To fulfill the study objective, during the 2017 product season, the date fruit samples of Smany and Zaghoul varieties at the Tamar stage were randomly selected from the local market of Mansoura City, Dakahlia Governorate, Egypt. The experiments were carried out at the laboratory of Handling and Processing Engineering of Agricultural Products Dep., Agric. Eng. Inst., Agric. Rees. Center, Egypt.

### 2.1 Samples

In this study, the date fruit samples Smany (yellow) and Zaghoul (red) date fruit varieties were selected randomly from a local market in Mansoura city., Egypt (Fig. 1). Date samples of major Egyptian date cultivars viz. Smany and Zaghoul date fruits were collected at Tamar stage. The fruits were transported to the Laboratory of Handling and Processing of Agricultural Product Department, Agricultural Engineering Research Institute of Egypt. All experiments were carried out at a temperature range of 25-30°C and 75%-80% of humidity. Fifty fruits of each variety were randomly selected and sorted to eliminate defects. At air ambient room temperature of 25°C ( $\pm 5$ ) and air relative humidity of 75% ( $\pm 5$ ), some date fruit physical properties were determined as follows.

### 2.2 Physical properties

#### 2.2.1 Size fruit

Size, As shown in Fig. 1, the fruit size was determined by measuring the dimensions of the principle axes, namely: length ( $L$ ), upper diameter ( $D_1$ ), middle diameter ( $D_2$ ) and lower diameter ( $D_3$ ) using a Vernier caliper with an accuracy of 0.1 mm.

#### 2.2.2 Mass fruit

Mass: It was measured by using an electronic balance with an accuracy of 0.01 g.

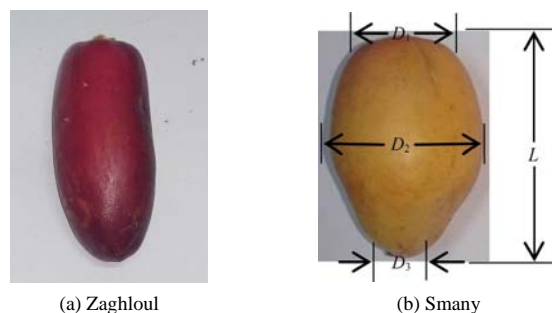


Figure 1 Three major dimensions ( $D_1$ ,  $D_2$  and  $D_3$ ) of date fruit sample

#### 2.2.3 Volume fruit

Volume and bulk density: The date fruit was immersed in a graduated cylinder, which was filled with water. Then, the displaced water volume was determined. Then, the bulk density was calculated by finding the date mass in unit volume, which will be used in Eq. (1) to calculate volume.

$$\text{Fruit volume, cm}^3 = \frac{\text{Weight of displaced water (g)}}{\text{Density of water (g cm}^{-3}\text{)}} \quad (1)$$

#### 2.2.4 Fruit densities

Bulk density was determined using the mass/volume relationship Eq. (2) (AOAC, 1984; Owolarafe et al., 2007) by filling an empty plastic container in fruit to determine volume and mass with fruits that were from a constant height, and weight:

$$Pb = \frac{M}{V} \quad (2)$$

where,  $Pb$  – the bulk density ( $\text{g cm}^{-3}$ );  $M$  – bulk mass of fruit (g);  $V$  – the plastic container volume ( $\text{cm}^3$ ).

This method was based on the work of Al-Farsi et al. (2007), Owolarafe et al. (2007), and Suthar et al., (1996).

In case of a number of fruits /500 g observations were recorded on a three replicate basis and data was subjected.

## 3 Results and discussion

These properties were found in specific moisture contents about 11% wet basis for date fruit. This could be due to the different arrangements in the fruit varieties. According to the results, the mean values of properties which were studied in this research (length, Upper diameter ( $D_1$ ), Middle diameter ( $D_2$ ), Lower diameter ( $D_3$ ), Mean diameter ( $D_m$ ), weight, volume and density) were 41.05, 17.0, 41.05, 11.39 mm, 18.15 and 16.23 g, 16.31  $\text{mm}^3$  and 1011.4  $\text{g cm}^{-3}$  for Smany date fruits, respectively. While, they were 50.77, 19.62, 50.77,

12.65 mm, 18.45 and 19.37 g, 19.37 mm<sup>3</sup>, 16.88 g and 963.6 g cm<sup>-3</sup> for Zaghoul date fruits, respectively.

**3.1 Date Fruit Size**

Results presented in Table 1 and Figures 2, 3, 4, 5, and 6 reveal that the cultivar Smany date fruit recorded the minimum and maximum fruit length (35.54-46.14 mm) with an average of 41.05 mm and (42.71-62.95 mm) with an average 50.77 mm of Zaghoul date fruit in length of ruits. Also, Table 1 reveals different diameters of individual date fruit that the Smany date fruit recorded the minimum and maximum fruit upper diameter ( $D_1$ ), (13.64-25.59 mm) with average of 17.0 mm and (15.67-24.35 mm) with average 19.62 mm of Smany and Zaghoul date fruits in diameter of fruits, respectively and the values of the minimum and maximum of fruit middle diameter ( $D_2$ ) were recorded (21.55-29.52 mm) with average of 26.07 mm and (19.33-28.14 mm) with average 23.08 mm of Smany and Zaghoul date fruits,

respectively., and the values of the minimum and maximum of fruit lower diameter ( $D_3$ ) were recorded (8.68-14.64 mm) with average of 11.39 mm and (9.63-16.22 mm) with average 12.65 mm of Smany and Zaghoul date fruits, respectively., and the values of the minimum and maximum of fruit mean diameter ( $D_m$ ) were recorded (15.56-20.64 mm) with average of 18.15 mm and (15.75-22.48 mm) with average 18.45 mm of Smany and Zaghoul date fruits, respectively.

**Table 1 Principle dimensions of Smany and Zaghoul date fruit varieties.**

Dimensions of date fruit	Zaghoul date fruits			Smany date fruits		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Length "L", mm	35.54	46.14	41.05	42.71	62.95	50.77
Upper diameter " $D_1$ "	13.64	25.59	17	15.67	24.35	19.62
Middle diameter " $D_2$ "	21.55	29.52	26.07	19.33	28.14	23.08
Lowerdiameter " $D_3$ "	8.68	14.64	11.39	9.63	16.22	12.65
Mean diameter " $D_m$ "	15.56	20.64	18.15	15.75	22.48	18.45

Note: Min.: Minimum, mm; Max.: Maximum, mm; Ave.: Average, mm.

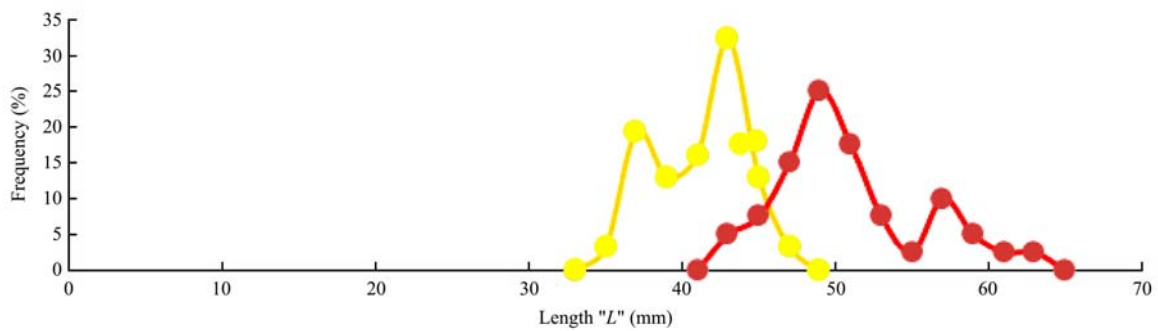


Figure 2 Frequency of Smany and Zaghoul date lengths "L"

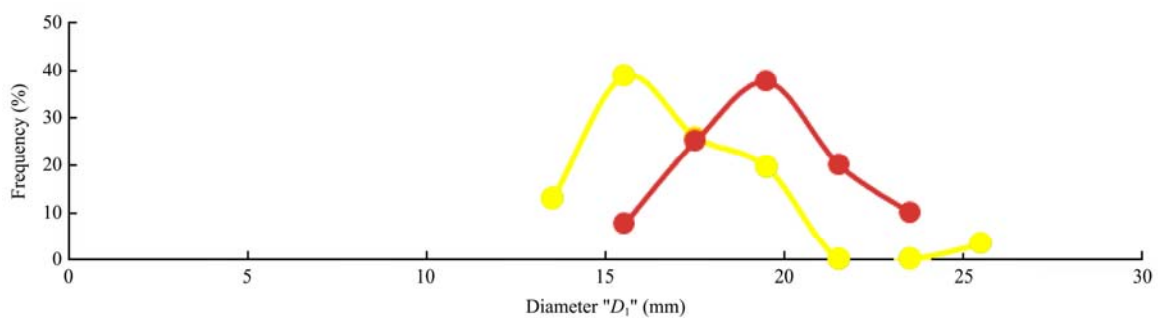


Figure 3 Frequency of Smany and Zaghoul dates maximum diameters " $D_1$ "

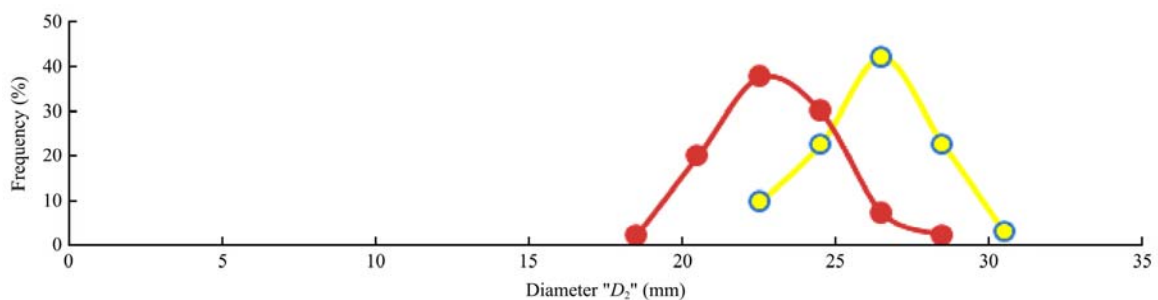


Figure 4 Frequency of Smany and Zaghoul dates middle diameter " $D_2$ "

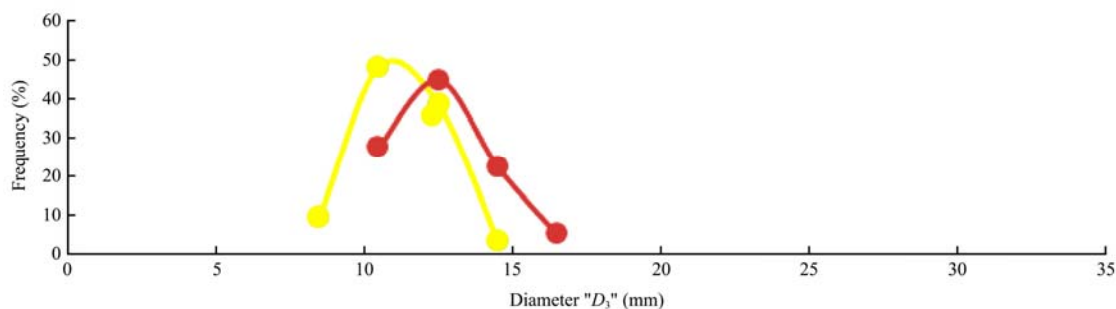


Figure 5 Frequency of Smany and Zaghoul dates, minimum diameter "D<sub>3</sub>"

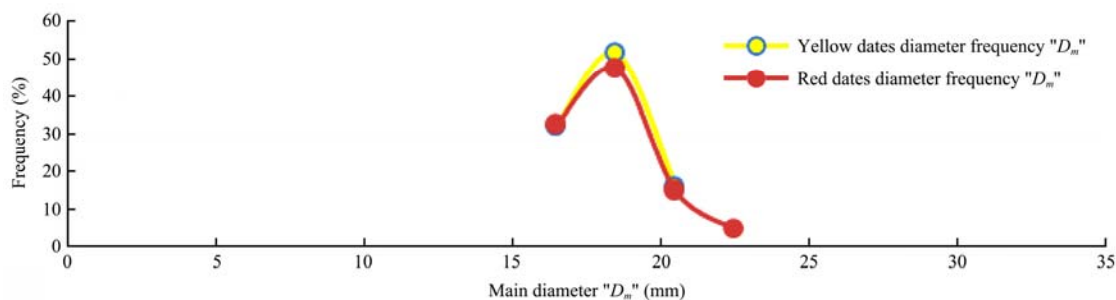


Figure 6 Frequency of the main diameter of Smany and Zaghoul dates "D<sub>m</sub>"

### 3.2 Date Fruit Mass

With regard to mass of individual fruits, the Smany and Zaghoul date varieties recorded the ranged values (12.00-21.50 g) with average 16.23 g and (11.90-30.20 g) with average 16.88 g in Smany and Zaghoul of date fruits for minimum and maximum of mass date fruits, respectively. Fruit mass influenced the number of fruits per unit mass, was significantly different from Smany and Zaghoul in the three categories of maximum, average and minimum fruits (Table 2 and Figure 7).

Table 2 Mass of Smany and Zaghoul date fruit varieties

Fruit date type	Actual Mass "m", g		
	Min.	Max.	Ave.
	12	21.5	16.23
Smany date fruits	Experimental modeling "M <sub>th</sub> "		
	$m_{th} = 1.076D_{2yel} - 11.823$		
	11.9	30.2	16.88
Zaghoul date fruits	Experimental modeling "M <sub>th</sub> "		
	$m_{th} = 0.723L_{Zaghoul} - 19.808$		

Note: Min.: Minimum, g; Max.: Maximum, g; Ave.: Average, g.

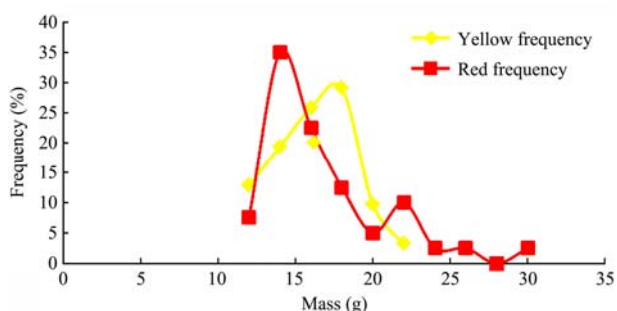


Figure 7 Mass frequency of Smany (yellow) and Zaghoul (red) dates

### 3.4 Date Fruit Volume and Bulk Density

With regard to volume of individual fruits, the date fruits were recorded the ranged values (10.0-23.1 mm<sup>3</sup>) with average 16.31 mm<sup>3</sup> and (14.0-34.2 mm<sup>3</sup>) with average 19.37 mm<sup>3</sup> in Smany and Zaghoul of date fruits for minimum and maximum of volume date fruits, respectively. Consequently, fruit weight influenced the number of fruits per unit weight of date fruit samples (Table 3 and Fig. 8). While, With regard to density of individual fruits, the date fruits were recorded the ranged between (858.5-1660 g/cm<sup>3</sup>) with average 1011.4 g/cm<sup>3</sup> and (791.7-963.6 g/cm<sup>3</sup>) with average 963.6 g/cm<sup>3</sup> in Smany and Zaghoul of date fruits for minimum and maximum of density date fruits, respectively.

The bulk density of fruit is a useful tool in the design of silos and storage bins which resulting from two parameters mass and volume date fruit. Because of the bulk density of the Zaghoul date fruit variety is less than that of the Smany date fruit variety. So, will require a larger silo Smany compare to the Zaghoul date variety with the same weight.

Volume is known to be a parameter affecting consumer acceptance. The real volume of Zaghoul date fruits is higher than Smany date fruits. So, consumers will accept Zaghoul date fruits more than Smany according to volume; moreover, will need different packing boxes with the same weight and the price maybe different too.

**Table 3 Volume and bulk density of Smany and Zaghloul date fruit varieties**

Date fruit types	Actual Volume, mm <sup>3</sup> “V”		
	Min.	Max.	Ave.
Smany date fruits	10	23.1	16.31
	Experimental modeling “M <sub>th</sub> ” $V_{th} = 0.899L_{yel} - 20.596$		
Zaghloul date fruits	14	34.2	19.37
	$V_{th} = 0.795L_{Zaghloul} - 20.972$		
	Density “ρ”, g/cm <sup>3</sup>		
Smany date fruits	858.5	1660	1011.4
Zaghloul date fruits	791.7	963.6	870.1

Note: Min.: Minimum, mm<sup>3</sup>; Max. : Maximum, mm<sup>3</sup>; Ave.: Average, mm<sup>3</sup>.

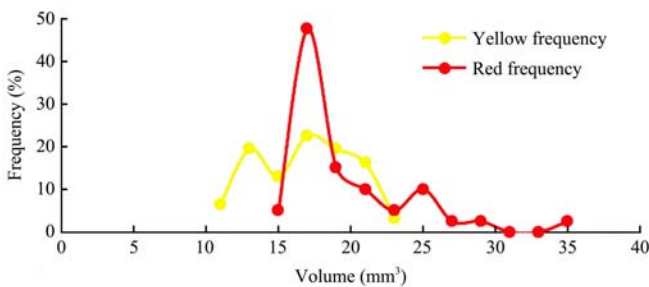


Figure 8 Volume frequency of Smany (yellow) and Zaghloul (red) dates

**3.5 Relationship between physical parameters**

**3.5.1 Experimental model to calculate volume of date fruit**

From Table (3) and Figures 9 and 10 illustrated that the relationship between sample volume and length of Smany and Zaghloul date fruits. It was noticed that the high relation was found in length of Smany date fruit as shown in the following equation (3) with a correlation factor of 67% as shown in Figure 9:

$$V_{th} = 0.899L_{Samany} - 20.596 \quad (3)$$

Meanwhile, the relation which between volume and length of Zaghloul dates fruit as shown in the following equation (4) with a correlation factor of 85% as shown in Figure 10:

$$V_{th} = 0.795L_{Zaghloul} - 20.972 \quad (4)$$

**3.5.2 Experimental model to calculate mass of date fruit**

Table 3 and Figures 11, 12 and 13 showed that the relationship between sample mass and length and mean diameter of Smany and Zaghloul date fruits. It was noticed that the high relation was found in the mean diameter of the Smany date fruit as shown in the following equation (5) with a correlation factor of 72% as shown in Figure 11:

$$m_{th} = 1.076D_{2\text{ Samany}} - 11.823 \quad (5)$$

Meanwhile, the relation which between mass and length of Smany date fruit as shown in following equation (6) with a correlation factor of 68% as shown in Figure 12:

$$m_{th} = 0.695L_{Samany} - 12.309 \quad (6)$$

So, it is preferred Zaghloul to use the mean diameter of the Smany date fruit to calculate mass of date fruit

But, the relation which between mass and length of Zaghloul dates fruit as shown in the following equation (7) with a correlation factor of 83% as shown in Figure 13:

$$m_{th} = 0.723L_{Zaghloul} - 19.808 \quad (7)$$

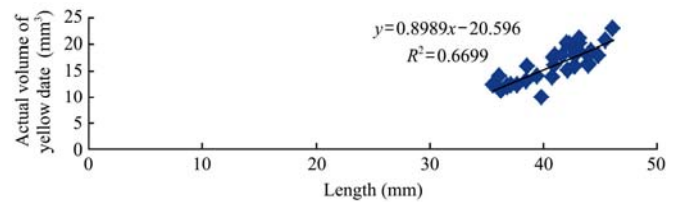


Figure 9 Relationship between length and volume of Smany fruit

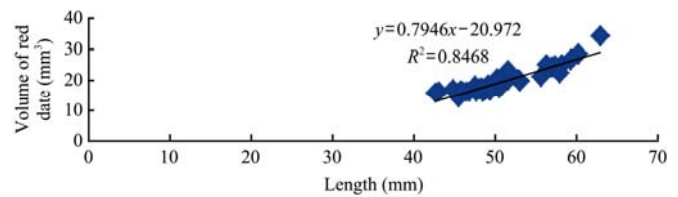


Figure 10 Relationship between length and volume of Smany fruit

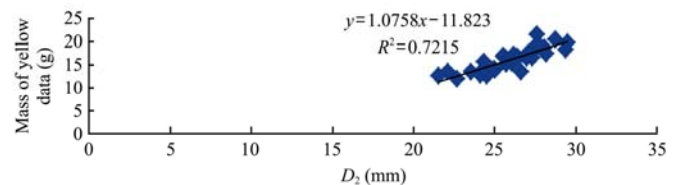


Figure 11 Relationship between middle diameter “D<sub>2</sub>” and mass of Smany fruit

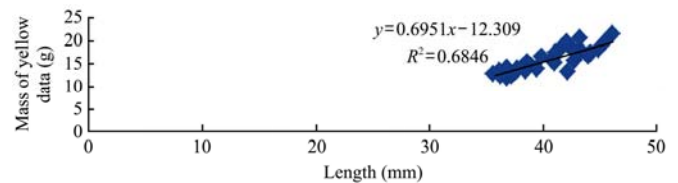


Figure 12 Relationship between length and Mass of Smany date

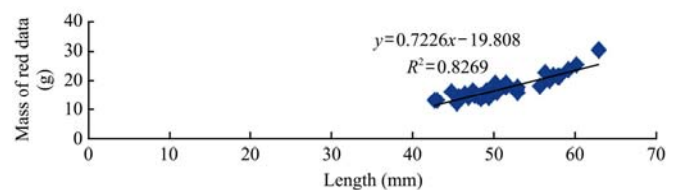


Figure 13 Relationship between length and mass of Zaghloul fruit

Regarding the physical parameters were studied, next table shows the correlation values of Smany and Zaghloul date fruits varieties, the comparison of relationships of

physical properties for Smany and Zaghoul date fruits (Table 4). Moreover, the relation between mass and length of Zaghoul date fruit which is 83% higher than that of Smany date fruit 68% must be noticed. While, the relation between volume and length was higher in Zaghoul date fruit of 85% than in Smany date fruit 66%.

**Table 4 Correlation factor from analysis results of Smany and Zaghoul date fruits**

Relationship	Smany date fruit	Zaghoul date fruit
Volume with length	67	85
Mass and length	68	83
Mass and mean diameter	72	80

## 4 Conclusions

This study dealt with measurement of physical properties of two date varieties (Smany and Zaghoul date fruits). Therefore, the measuring of Zaghoul physical properties of Smany and Zaghoul date fruits changed linear with different varieties under Egyptian conditions, as shown the following:

- Fruit length was varied (35.54-46.14 mm) and (42.71-62.95 mm) of Smany and Zaghoul date fruit varieties. Also, fruit upper diameter ( $D_1$ ), was of (13.64-25.59 mm) and (15.67-24.35 mm) of Smany and Zaghoul date fruits. As well as, fruit middle diameter ( $D_2$ ) was recorded (21.55-29.52 mm) and (19.33-28.14 mm) of Smany and Zaghoul date fruits. Fruit lower diameter ( $D_3$ ) was recorded (8.68-14.64 mm) and (9.63-16.22 mm) of Smany and Zaghoul date fruits. Fruit mean diameter ( $D_m$ ) was recorded (14.62-23.25 mm) and (14.88-22.90 mm) of Smany and Zaghoul date fruit varieties.

- Volume of individual fruits, the date fruits was recorded the ranged values (10.0-23.1 mm<sup>3</sup>) and (14.0-34.2 mm<sup>3</sup>) in Smany and Zaghoul of date. While, fruit mass of the Smany and Zaghoul date were ranged values (12.00-21.50 g) and (11.90-30.20 g). So, bulk density was recorded the ranged values (858.5-1660 g cm<sup>-3</sup>) and (791.7-963.6 g cm<sup>-3</sup>) in Smany and Zaghoul of date fruits for minimum and maximum of density date fruits, respectively.

- Experimental models to calculate volume and mass of date fruit according to length of fruit were resulting.

- The correlation between mass and length of Zaghoul date fruit which is 83% higher than that of Smany date fruit 68% must be noticed. While, the

relation between volume and length was higher in Zaghoul date fruit, 85% than in Smany date fruit 66%. So, it is preferred Zaghoul to use the mean diameter of the Smany date fruit to calculate the mass of date fruit

- The physical properties were affected by the differences varieties, may contribute in design and development of equipment belong to post harvest technology and processing of these fruits.

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