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PHYSICAL PROPERTIES FOR SOME VEGETABLE CROPS

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ABSTRACT

Physical and mechanical properties were carried out on random samples of different cultivars that belong to different vegetable crops to build up database for these crops. These vegetables were collected and investigated on the 1st day of harvesting, it was picked up from the Faculty of Agriculture-Farm, (sandy soil of 89.9% sand) Suez-Canal University within the period from 26-6-2001 to 17-3-2003. Investigations were carried out on those vegetables, which were prepared for the local Egyptian market. Three cultivars of Tomato (*Lycopersicon esculentum*) i.e. Peto86, Castlerock and Oriet; Three cultivars of Cucumber (*Cucumis sativus*): Rawa, Catya and Zorba, three cultivars i.e. Orobelle, Markoni and Godeon of Pepper (*Capsicum annuum*) and one cultivar (Nicola) of Potato (*Solanum tuberosum*) were included in this study. The investigated properties were conducted at average moisture contents of 77.3% for potato, 92.5% (wet basis) for tomato, 93% for cucumber and 89.2% for pepper. Wide variation in the shape differences between the cultivars of the same crop for all vegetables, which were involved in the study. Differences were found between the two methods of the vegetable volume determination; the calculated and the actual which was determined from the displacement water volume. Relationships between the two methods were driven for all of the investigated vegetables.

INTRODUCTION

Great efforts had carried out to evaluate the basic physical properties of some agricultural materials to point out their practical utility in machine structural design, food processes (**Waziri and Mittal, 1983**). As, the physical properties determination are useful to build up data base for standardize each crop this will be required for the international marketing (**El-Raie et al., 1996**). The agricultural materials pose special problems in determining their physical properties because of their diversity in shape, size, moisture content and maturity levels (**El-Amir, 1989**). Studies were carried out on the physical properties of some Onion-bulbs (**Essa and Gamea, 2003**) but still more research are required for fast decay vegetables.

Tomato properties must be considered and classified according to its maturity at the harvesting time. It is classified due to the maturity to the mature green, Breaker, Turning, Pink, Light Red and Red. It is picked up at

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the light red if it will be consumed by the local market and in the red mature if it will be used by the food factories to produce tomato juice or tomato paste (**Hassan and Badawy, 1992**). Also, it was classified visually using a scoring system (**Sabbah et al., 1994**) according to the following table.

Table (1): Scoring system maturity and ripeness of tomato (**Pictaw and Studer, 1977**)

Score	Class	Description
1	Green mature (GM)	Green; jelly like substance well formed in the locuus' seeds is not easily cut by a knife.
2	Breaker (BR)	First appearance of external pink color.
3	Dark Pink (PI)	Overall pink to light red.
4	Table Red (TR)	Full red color.

Potato tubers are approximately ellipsoidal in shape, i.e. they are approximately ellipsoidal in both longitudinal and transverse cross section. The amount of elliptically varies considerably within a given cultivar (**Marvin and Gary, 1987**).

Ismail (1988) investigated different physical parameters of four potato cultivars; Alpha, Esponta, Nicola and Escort. Parameters which was investigated were tubers volume and mass, oblong and transverse surfaces, geometric and arithmetic diameters, the coefficient of contact, and the coefficient of the spherical shape. Differences between the four cultivars also between the same cultivar were found.

The shape and size are inseparable in a physical object. Both are generally necessary if the object is to be satisfactorily described. Shape can be described either by charted standard or using the relationship, (**Mohsenin, 1965**). Two ways for determination of the physical dimensions can be followed; by tracing the outline of the vegetable shape boundary using a transparent graph paper and overhead projector. Also, using the vernier calipers method, which can be used to find the dimensions and size of the different material-shapes. The vernier caliper has a least count of 0.1cm. Readings can be taken in three axes to obtain major, minor and intermediate diameters of the materials.

In general, still there is a lack of research on determination of physical properties for vegetables such as Cucumber, Pepper, Tomato and some Potato cultivars such Nicola. So, more research are required to be carried out on the physical properties of these vegetable crops especially that grows in the sandy soils where, the remote farms with the difficulty in means of the transport which leads to the fast decay, damage and spoilage.

The objective of this study is to investigate the physical and mechanical properties of some vegetables which are growing in Ismailia sandy soils to establish data base for these crops which can be used to conduct a resolution for the storage, transportation and handling problems of such these vegetable crops.

MATERIAL AND METHODS

Materials:

A random sample contains 100 for the each of different vegetable cultivars, which are growing in Ismailia sandy-farms (the new and recently reclaimed farms) were picked up on the exact day of harvesting. Vegetable crops, which are given in table (2), were harvested and prepared for the consumption by the Egyptian consumers, it was ready to be sold to the local markets. The following table gives the investigated selected species for vegetable crops that were involved in the study. A mechanical analysis was carried out on the farm-soil, which was reclaimed 14 years ago. The results of the farm-soil mechanical analysis where these crops were cultivated are represented in table (3).

Table (2): The investigated cultivars of vegetable crops, which involved in the present study

Vegetable crop	Spices	Harvesting and investigation date
Tomato *Lycopersicon esculentum*	Peto86, Castlerock and Oriet	09-7-2001 17-5-2002 26-4-2002
Cucumber *Cucumis sativus*	Rawa Catya Zorba	28-3-2002 28-3-2002 13-4-2002
Pepper *Capsicum annuum*	Orobelle Markoni Godeon	03-7-2001 08-7-2001 26-6-2001
Potato *Solanum tuberosum*	Nicola	17-3-2003

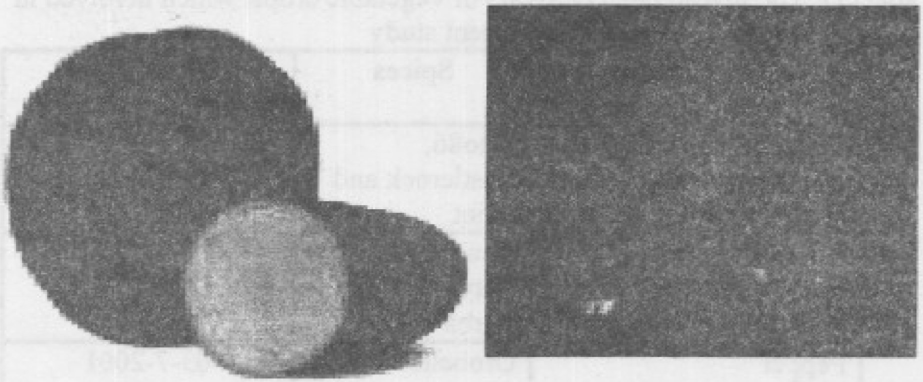
Table (3): The mechanical analysis for the farm-soil where the vegetable crops were cultivated

Sand, %	Silt, %	Clay, %
89.9	6.9	3.2

These vegetable crops were picked up and harvested for the local Egyptian consumer taste. Cucumber crop were picked up after 45 to 60 days from the planting date, Potato was harvested after 120days, Tomato was picked up at the light red stage and pepper was picked up after 90 days of planting date. Physical and mechanical properties investigations were lasted from 26-6-2001 to 17-3-2003.

Methods and Measurements:

The following parameters were considered within the study of physical and mechanical properties: vegetable moisture content, determination of the vegetable dimensions i.e. length, width diameter and determination of the geometric and the arithmetic diameters and the relations between these parameters. Determination of the vegetables density, mass and its volume which was determined with two methods (the calculated volume and the actual volume using the displacement water volume). The relationship between the two methods was driven. Transverse and oblong surface areas for tomato and potato and its relations were investigated (figure 1 shows potato tuber and one of the investigated tomato cultivar as an example). The friction angles between all vegetables and different surfaces i.e. steel, galvanized steel and wood were carried out, also the specific heat for all the investigated vegetables were considered.



Potato tuber (Nicola cultivar) Tomato (Castlerock cultivar)

Figure (1): Potato tuber and one of the investigated tomato cultivar

To determine the vegetables moisture content; It was cut into a small rings from 1cm to 1.5 cm thick, to ease the moisture removal. The fresh sample was weighted using a digital balance and was put in an electric oven at 65°C for 24hours. The moisture content (wet basis) was determined from the following formula:

$$\text{Moisture content } (W.B,\%) = \frac{\text{Fresh sample mass } (M_i) - \text{Dried sample mass } (M_f)}{\text{Fresh sample mass } (M_i)} \times 10$$

(1)

A slide caliper of 0.1cm accuracy was used to measure the dimensions of each vegetable, these dimensions was substituted in the following formulae to obtain the geometric diameter,(G_d), arithmetic diameter, (A_d), oblong surface area, (F_s), transverse surface area, (T_s), the coefficient of contact, (C_c) and the coefficient of the spherical shape, ($C.S.S$) **(Ismail, 1988)**.

$$G_d = \sqrt[3]{L \times W \times H} \tag{2}$$

$$A_d = \frac{1}{3}(L + W + H) \tag{3}$$

$$F_s = \frac{\pi}{4}(L \times W) \tag{4}$$

$$T_s = \frac{\pi}{4}(W \times H) \tag{5}$$

$$C_c = \frac{F_s - T_s}{F_s} \times 100 \tag{6}$$

$$C.S.S = L/\sqrt{W \times L} \tag{7}$$

The coefficient of spherical shape ($C.S.S$), which is given in formula (7), is the ratio between the tuber length to the square root of the multiplication of the tuber width by its height. If this ratio was found less than 1.5 the tuber will take the spherical shape but if it is more than 1.5, it will have oblong shape **(Ismail, 1991)**

The actual volume of each vegetable (V_d) was determined using the amount of water displacement technique. While a driven mathematical formula to relate the investigating vegetable crop shape to the nearest engineering object shape. These driven equations were differed due to the difference in the vegetable shape, as it is discussed within this study. A comparison between the actual volume (V_d), that was obtained from the determination of the displaced water amount and the calculated volume (V_{cal}) for each vegetable crop and each cultivar was given.

The density in g/cm^3 was determined for each vegetable by considering the ratio of its mass to its actual volume (V_d).

The friction coefficient (f) which is the angle between a tilted plane and the horizontal plane which the vegetable crop over-comes the static friction and begins to slide down the surface of the tilted plane as it is tilted slowly and gradually **(Awady, 1979)**. The angle of friction was determined for the investigated vegetable crop and different materials i.e. steel, galvanized steel and wood, which are considered the most materials can make a friction with the investigated vegetable crops either in the harvesting machines or within the post harvesting and handling processes. The following equation was used to determine the friction coefficient factor (f) where θ is the angle, where the investigated crop begin to move (slide) on the examined surface:

$$f = \tan(\theta) \tag{8}$$

The specific heat (c_p) of the vegetable crop is needed to know the "field heat" which is a part of the cooling load determinations. The specific heat was determined with dimensions of Cal/g^oC using a locally made calorimeter according to **Mohsenin, (1984)**. A known volume of water has specific heat (c_{pw}) with dimensions of Cal/g°C, was added to the calorimeter in order to immerse the calorimeter capsule into water, that capsule has a specific heat (c_{pc}). To decrease the heat loss from the container walls, an insulation material was used to wrap the calorimeter. A thermocouple was placed in the water to monitor the water temperature. Another thermocouple was placed in the capsule to monitor the sample temperature. The capsule which is contained the vegetable crop (which previously was cut into small pieces), was heated up to 60°C and placed immediately in the water. Temperatures of vegetable (T_1) and water (T_3) were recorded until they became equal (T_2). The specific heat of the vegetable crop (c_p) in Cal/g°C was determined as it is given in equation (9) where the vegetable sample mass (M_s), mass of the used capsule (M_c), mass of the used water (M_w), and mass of the medium cup (M_m) all are in grams.

$$c_p = \frac{(M_w \times c_{pw})(T_2 - T_3) - (M_c \times c_{pc})(T_1 - T_2)}{M_s(T_1 - T_2)} \tag{9}$$

RESULTS AND DISCUSSIONS

Due to the shape variations between the investigated vegetable crops and between the cultivars for the same crop, the physical and engineering characteristics for each crop that was investigated are discussed separately:

Potato (*Solanum tuberosum*):

Investigations on the potato (Nicola cultivar) were carried out at average moisture content of 77.3% with a standard deviation of 0.35. The analysis, which was, carried out on potato tubers (Nicola cultivar) showed that, the relationship between the tubers mass (M) and the geometric diameter (G_d), and the arithmetic diameter (A_d), which are given as the following equations and in figure 2:

$$M = C_{Gd} \times (Gd)^3 \tag{10}$$

$$M = C_{Ad} \times (A_d)^3 \tag{11}$$

Where, C_{Gd} and C_{Ad} are constants and it was found that, C_{Gd}=0.76 and C_{Ad}= 0.83 Also, the linear relationship between the geometric diameter (G_d) and the arithmetic diameter (A_d) for Nicola cultivar potato tubers which is given in figure (2) was found to be:

$$G_d = 0.92A_d + 0.29 \tag{12}$$

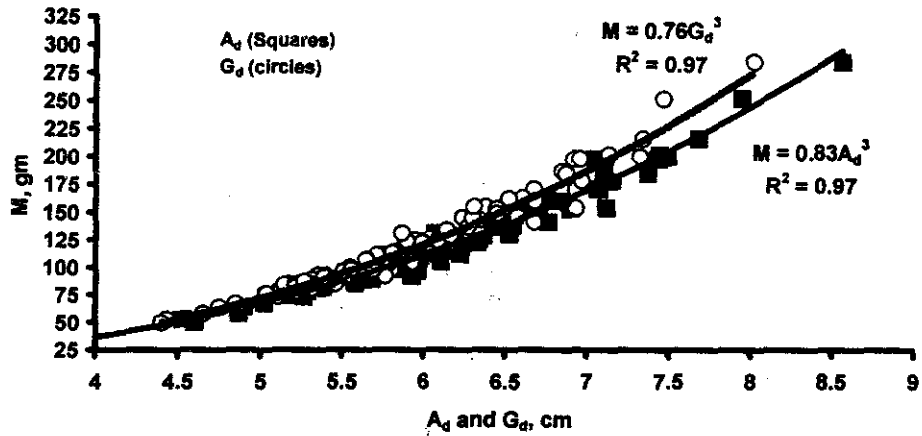


Figure (2): The relationship between mass of potato tubers (Nicola cultivar) and its geometric and arithmetic diameters.

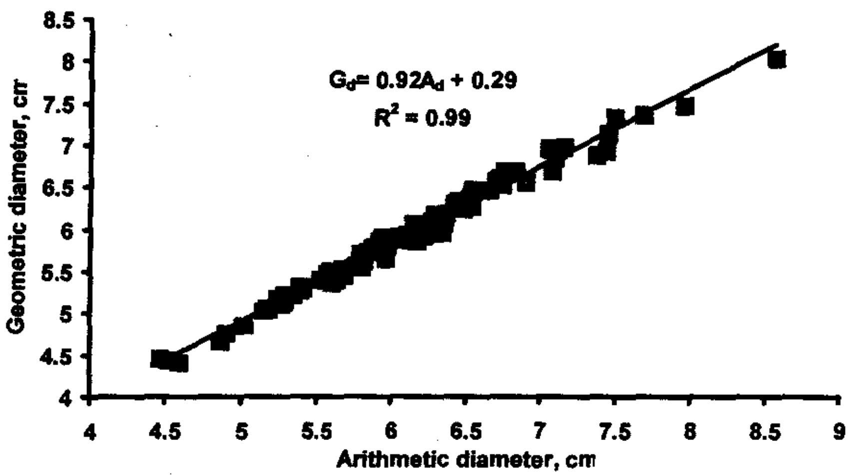


Figure (3): The linear relationship between the geometric and the arithmetic diameter of potato tubers

Oblong surface area (F_s), which was determined as equation (4) of **Ismail, (1988)**, was averaged for the potato tubers (Nicola cultivar) and it was found to be 35.7 with standard deviation of 9.4 and the average transverse surface area (T_s) which was determined as equation 5, was found 20.3cm^2 with standard deviation of 4.55. Figure (4) represents a linear relationship between the transverse surface area (T_s) and the oblong surface area (F_s) for potato tubers (Nicola cultivar).

Coefficient of contact (C_C) was determined according to formula (6); the average C_C was found 42.3% with standard deviation of 7.63:

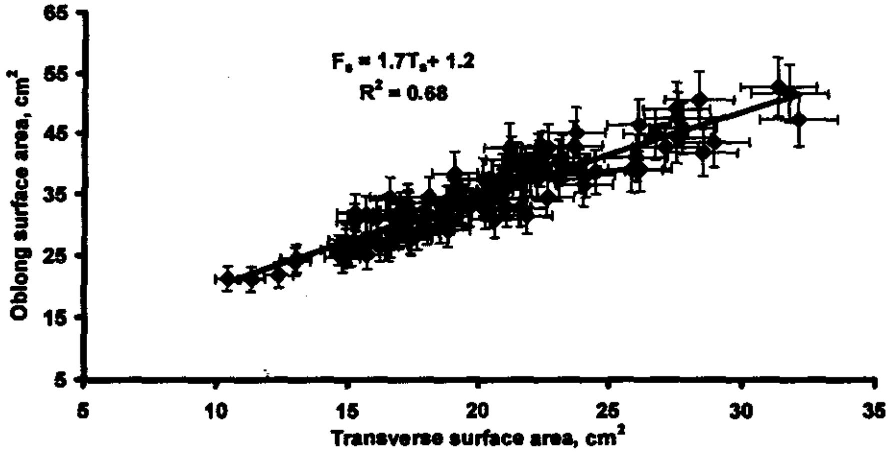


Figure (4): Linear relationship between the transverse surface area (T_s) and the oblong surface area, (F_s) for potato tubers.

It was found that the relationship between the two ways which were followed to calculate and determine the volume of the Potato tubers of Nicola cultivar, (V_{cal}, and V_d), were found follow the given relationship in equation (13) with dimensions of cubic centimeters.

$$V_d = V_{cal} - 14.7cm^3 \tag{13}$$

The determined friction angle for Nicola cultivar with steel surface was found 31° for 99% from the total number of the investigated tubers (100 tubers), with an average friction coefficient of 0.601 and with a standard deviation of 1.07. Meanwhile the friction angle for the 1% remain, was 30° with a friction coefficient of 0.577. Also, the average friction angle was found to be 31.5° between the potato tubers and the galvanized steel surfaces with average friction factor of 0.613 and standard deviation of 1.85. When the angles of friction and the friction coefficients were investigated between the potato tubers and wood surface, the friction angle was vary between 28° and 32° with an average of 30° as presented in the following table:

Table (4): Friction angle, friction factor and frequency for potato (Nicola) with wood

Friction angle, (°)	Friction factor	Frequency, %
28	0.532	6
29	0.554	5
30	0.577	51
31	0.601	32
32	0.625	6

Tuber density was determined by dividing the tuber mass by the volume of the displacement water (V_d) when the tuber was immersed in a certain volume of water. The average density for the potato tubers (Nicola) was found to be 1.118g/cm^3 with a standard deviation of 0.078.

It was found that, 29% from the investigated potato tubers has spherical shape. The average coefficient of spherical shape (*C.S.S*), which, was determined as formula (7) was found to be 1.4 with standard deviation of 0.103. While, 71% from the tubers has a flatly (oblong) shape with an average coefficient of spherical shape of 1.68 and with standard deviation of 0.153.

The Potato-tubers specific heat, which was determined (at average moisture content of 77.3%, W.B) according to the calorimeter method, was found 0.54Cal/g^{o}C with a standard deviation of 0.072.

Tomato (*Lycopersicon esculentum*):

Investigations were carried out on tomato while it has average moisture content (for the three investigated tomato cultivars) 92.5% with a standard deviation of 1.11. The investigated cultivars have different shapes so the formulae, which were driven for the volume calculation (V_{cal}) were differed as it is presented in table (5).

Table (5): Descriptions and the mathematical formulae that were driven to calculate volume of different tomato cultivars.

Cultivar	Shape description	The driven formula for the volume calculation
Peto86	Has elliptical longitudinal section and circular cross section with maximum diameter of (D_{max}) and minimum diameter of (D_{min}) and length of (L).	$V_{cal} = \frac{\pi}{4}(D_{max} . D_{min} .) L$
Castlerock	Nearly approaching to the spherical shape with diameter of (D).	$V_{cal} = \frac{4\pi}{3}\left(\frac{D}{2}\right)^3$
Oriet	Nearly approaching to the spherical shape with diameter of (D).	$V_{cal} = \frac{4\pi}{3}\left(\frac{D}{2}\right)^3$

It was found that, the relationships between the calculated volume ($V_{cal,}$ in cm^3) using the mentioned formulae and the determined volume (V_d, in cm^3) by the displacement water volume method are given in the following table for the three different tomato-cultivars.

Table (6): Relationship between V_{cal} and the V_d for the three different tomato-cultivars

Cultivar	Relationship between V_{cal} and V_d, (cm^3)
Peto86	$V_d = V_{cal} - 15.2$
Castlerock	$V_d = V_{cal} + 3.1$
Oriet	$V_d = V_{cal} + 5.5$

Average vertical longitudinal axis for the three different tomato cultivars: Castlerock (= *D*), Oriet (= *D*) and Peto86 (= *L*) were found as 4.8cm, 4.29cm and 5.28cm meanwhile, the average diameter at each cm of that axis is given in the following table:

Table (7): Average cross-section diameter for the different tomato cultivars for each 1cm of its length

Cultivar	1st cm	2nd cm	3r cm	4th cm	5th cm	6th cm
Castle Rock	3.78	5.4	6	4.9	0.91	-
Oriet	3.56	4.12	3.92	3.11	-	-
Peto86	3.37	4.01	4.25	3.97	2.68	0.95

It was found that, the average G_d for Castlerock, Oriet and Peto86 cultivars determined as mentioned before in equation (2) were 4.83, 4.25 and 9.18cm respectively, with standard deviation of 0.973, 0.327 and 1.36 respectively. While the average (A_d) determined using equation (3), were 4.88, 4.27 and 4.4cm respectively, with standard deviation of 0.988, 0.328 and0.433 respectively.

The relationships between the geometric diameter (G_d) and the arithmetic diameter (A_d) for the three cultivars are given in figure (5) with a correlation coefficient (R^2) near to the unity.

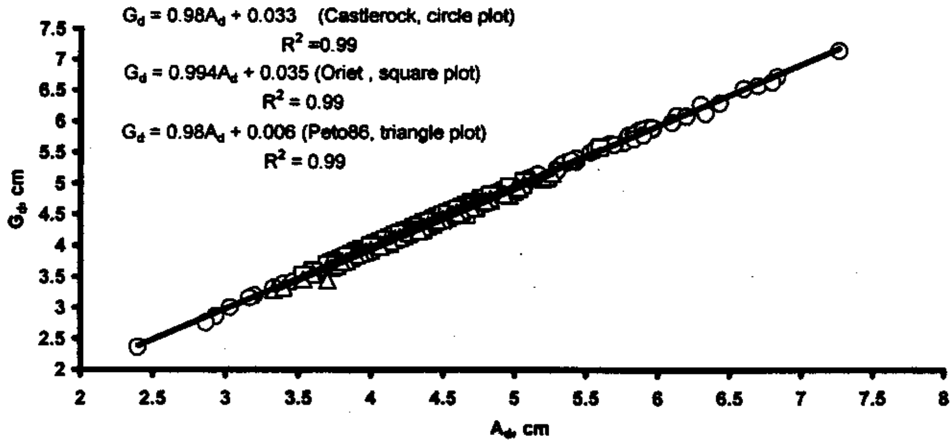


Figure (5): Relationship between the geometric diameter (G_d) and the arithmetic diameter (A_d) for the three tomato cultivars.

The relationship between mass of the three investigated tomato cultivars and the geometric diameters (G_d), arithmetic diameters (A_d) which were determined using equations (2 and 3), respectively are given in table (8). While an instance presentation for the mass of Castlerock cultivar relates its geometric and arithmetic diameters are given in figure (6) with correlation coefficient (R^2) of 0.91.

Table (8): Relationships between mass and geometric and arithmetic diameters for different Tomato cultivars

Cultivars	Relations	R^2
Castlerock	$M = 1.14 \times (G_d)^3$	0.91
	$M = 1.10 \times (A_d)^3$	0.91
Oriet	$M = 0.82 \times (G_d)^3$	0.75
	$M = 0.88 \times (A_d)^3$	0.78
Peto 86	$M = 0.97 \times (G_d)^3$	0.87
	$M = 0.88 \times (A_d)^3$	0.88

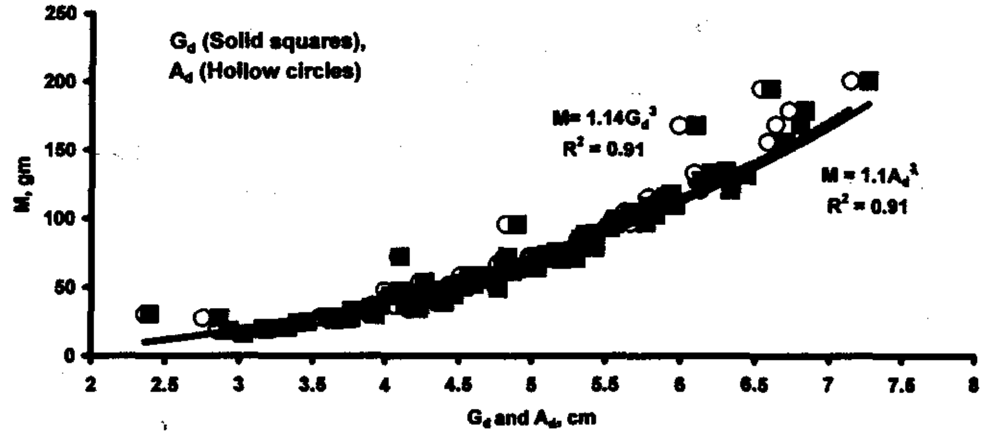


Figure (6): Relationship between mass and the geometric and the arithmetic diameters for the Castlerock tomato cultivar

The oblong surface area (F_s), transverse surface area (T_s) and Coefficient of contact (C_C) was determined for the tomato-cultivars as it was given before in equations (4, 5 and 6) of **Ismail, (1988)**. It was found that, the average F_s for the Castlerock, Oriet and Peto86 cultivars was 18, 14.46 and 16.43cm^2 respectively. Average T_s was found to be 16.91, 14.03 and 13.49cm^2, respectively, and average coefficient of contact (C_C) of 0.0694, 2.29 and 17.73%, with standard deviation of 0.072, 10 and 7.8 for the three cultivars respectively.

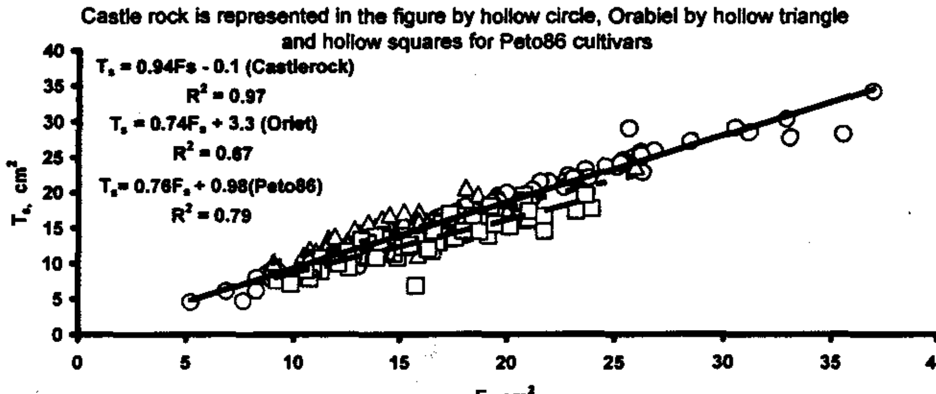


Figure (7): Relationship between F_s and T_s for the three tomato cultivars

Figure (7): Relationship between F_s and T_s for the three tomato cultivars

Average density for the three cultivars (Castlerock, Oriet and Peto86) were determined to be 1.07, 0.95 and 0.95g/cm^3 respectively, with standard deviation of 0.33, 0.11 and 0.09 respectively.

The friction factor for tomato with different surfaces such as a galvanized steel, Steel and wood was investigated with the three different cultivars and the average friction angle was found to be 27^o, 28.9^o and 27.6^o for the average friction angle between the three tomato cultivars with the galvanized steel, steel and wood surfaces with a standard deviation of 1.66, 1.10 and 1.34, respectively, and with a friction factors of 0.51, 0.55 and 0.52 respectively.

The average specific heat of the three different tomato cultivars, which were determined according to the calorimeter method, was found to be 0.65Cal/g^{o}C with a standard deviation of 0.042, determined at average moisture contents of 92.5%.

<u>Cucumber (*Cucumis sativus*)</u>:

Investigations of physical and mechanical properties were carried out at average moisture content for the three investigated cucumber cultivars of 93% with a standard deviation of 0.56.

To drive a mathematical formula to calculate the cucumber volume, the shape of the three investigated cucumber cultivars was considered as a cylinder with two semi-spheres attached to the both sides of the cylinder. Formula (14) was driven to determine the cucumber volume with the illustrated dimensions that is given in the following figure (8):

$$V_{cal} = \left[\left(\frac{\pi}{4}(D_{max})^2 \times L\right) + \left(\frac{4\pi}{3}\left(\frac{D_{min}}{2}\right)^3\right)\right] \quad (14)$$

Figure (8): Measured dimensions that were used to calculate Cucumber volume (V_{cal})

Where, L is the cylindrical part length, D_{max} and D_{min} are the maximum and minimum diameter respectively.

The average dimensions for the Katya, Rawa and Zorba cultivars at an average mass of 98.3, 99.9 and 69.1grams was found to have 12.6, 12.6 and 13.3cm length, and 3.6, 3.4 and 3.1cm average maximum diameter (D_{max}) and 3.5, 3.3 and 2.8cm the average minimum diameter (D_{min}). The average volume was determined using the displaced water, it was of 98.7, 85.1 and 70.2cm^3 for Katya, Rawa and Zorba cultivars respectively.

Table (9): Average cross-section diameter (cm) for the different cucumber cultivars each 2cm of the length.

Cultivar	2cm	4 cm	6cm	8 cm	10cm	12cm
Rawa	2.76	2.76	3.25	3.34	2.9	2.29
Katya	2.57	3.38	3.50	3.43	2.89	1.54
Zorba	2.50	3.13	3.12	3.00	2.80	2.70

The relationship between the two ways of cucumber volume determination V_{cal} and V_d are given in the following table for Katya, Rawa and Zorba cultivars.

Table (10): Relationship between V_{cal} and the V_d (in cm^3) for the three different cucumber-cultivars.

Cultivar	Relationship between V_{cal} and V_d (cm^3)
Katya	$V_d = V_{cal} - 55.1$
Rawa	$V_d = V_{cal} - 52.8$
Zorba	$V_d = V_{cal} - 39.3$

The average density for Katya, Rawa and Zorba was found to be 1.001, 1.000 and1.2g/cm^3, respectively, with a standard deviation of 0.0144, 0.0302 and 0.226 for each of the investigated cultivar samples, respectively.

The average friction factor for cucumber (the three different cultivars) with different surfaces was determined. The average was found to be 34.4° with the galvanized steel, 39.1° with steel surfaces and 38.4° with wood; with standard deviation of 1.62, 1.16 and 2.19 respectively and with average friction factors of 0.685, 0.813 and 0.793 respectively.

The average specific heat for the three different cucumber cultivars was found 0.71Cal/g°C with a standard deviation of 0.091 determined at an average moisture content of 93% (W.B).

Pepper (*Capsicum annuum*):

The average moisture content for the three investigated pepper cultivars when the investigations were carried out was found 89.20% with a standard deviation of 1.96.

The formulae which are given in the following table were used to calculate the volume (V_{cal}) of the three pepper cultivars: Orobelle, Markoni and Godeon, respectively. While table (12) represents the relationships between the V_{cal} which are given in table (11) and V_d for the same cultivars.

Table (11): Description and the driven mathematical formulae to calculate volume (V_{cal}) of different Pepper cultivars.

Cultivar	Shape description	The driven formula for the volume calculation
Orobelle	The shape is near a rectangular prism has length of (L) and upper base length (l_1), width (w_1) and lower base length (l_2) and width (w_2)	$V_{cal} = \left(\frac{l_1 w_1 + l_2 w_2}{2}\right) \times L$
Markoni	The shape is near the cone with length of (L), maximum diameter (D_{max}) and minimum diameter (D_{min}).	$V_{cal} = \left(\frac{1}{3}\right)\frac{\pi}{4}(D_{max} \times D_{min}) \times L$
Godeon	The shape is near a rectangular prism has length of (L) and upper base length (l_1), width (w_1) and lower base length (l_2) and width (w_2)	$V_{cal} = \left(\frac{l_1 w_1 + l_2 w_2}{2}\right) \times L$

Table(12): Relationship between V_{cal} and the V_d for the three different pepper-cultivars.

Cultivar	Relationship between V_{cal} and V_d (cm³)
Orobelle	$V_d = V_{cal} - 56.5$
Markoni	$V_d = V_{cal} + 9.1$
Godeon	$V_d = V_{cal} - 38.1$

The top part of Orobelle cultivar has a rectangular cross sectional area with an average length (l_1) and width (w_1)of 4.4 and 4.9 cm, respectively, meanwhile the bottom part has an average dimensions of (l_2) 4.4cm and (w_2) 3.9cm, respectively. For Markoni cultivar, the general shape was approaching to the conical shape with the top diameter (D_{max}) of 2.4cm, 2.2cm (D_{min}) for the bottom diameter and 9.8cm length. Average dimensions of Godeon cultivar was found has an average height of 6.62cm the top part has a rectangular cross sectional area length and width of 4.07cm (l_1) and 3.51 (w_1), respectively meanwhile the bottom part has an average dimensions of 4.3cm (l_2) and 3.9cm (w_2), respectively. Table (13) gives the averages of cross section dimensions for the different investigated Pepper cultivars, which are presented schematically in figure (9).

Table (13): Average cross section (cm) for the different pepper cultivars each 1cm of its length.

Cultivar	1st cm	2nd cm	3rd cm	4th cm	5th cm	6th cm	7th cm	8th cm	9th cm	10th cm
Orobelle	2.5	3.64	4.2	4.5	4.4	3.84	3.1	1.98	0.7	-
Markoni	2.3	2.23	2.09	1.92	1.78	1.68	1.43	1.2	0.86	0.51
Godeon	3.77	4.27	4.4	4.46	4.26	2.9	1.36	0.36	-	-

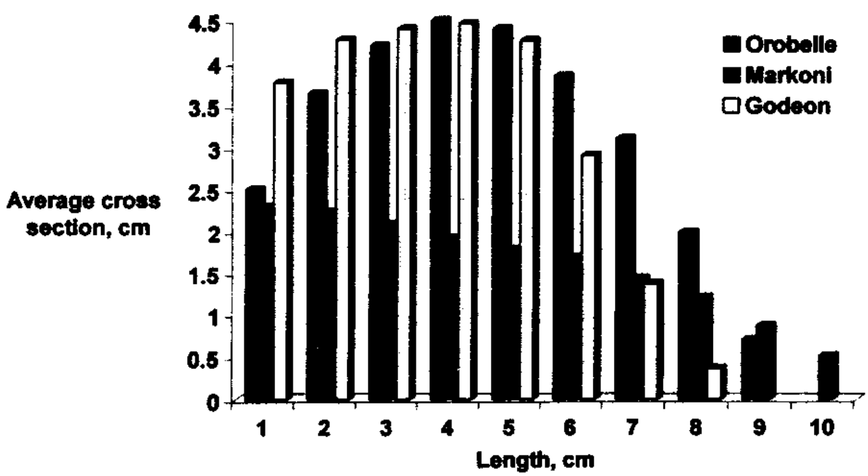


Figure (9): Average cross section (in cm) for each cm length of the three-pepper cultivars.

Average Densities of the Orobelle, Markoni cultivars were found to be 0.477g/cm^3 with a standard deviation of 0.0635 and 0.658 gm/cm^3 with a standard deviation of 0.657. While, it was found as 0.527gm/cm^3 with average standard deviation of 0.1445 for the Godeon cultivar.

The average friction angle (θ) (for the three different cultivars) with the galvanized steel, steel and wood was found 28.1°, 31.3 ° and 31.1° with a standard deviation of 1.98, 2.09 and 2.61 respectively, as the friction factors were 0.53, 0.61 and 0.60 respectively.

The average specific heat (c_p) for the three different pepper cultivars, which was determined according to the calorimeter method at an average moisture content of 89.2% (W.B.), was found 0.79Cal/g°C with a standard deviation of 0.035.

NOMENCLATURES

A_d	Arithmetic diameter, cm
C_C	Coefficient of contact
$C.S.S$	Coefficient of spherical shape
C_{Ad}	Constant relates the mass to the arithmetic diameter
C_{Gd}	Constant relates the mass to the geometric diameter
c_p	Specific heat of the vegetable sample , Cal/g°C
c_{pc}	Specific heat of the capsule, Cal/g°C
c_{pw}	Specific heat of water, Cal/g°C
D	Diameter, cm
D_{max}	Maximum diameter, cm
D_{min}	Minimum diameter, cm
f	Friction factor
F_s	Oblong surface , cm^2
G_d	Geometric diameter, cm
H	Height, cm
L	Length, cm
M	Mass, g
M_c	Mass of the used capsule, g
M_f	Mass of the dried sample, g
M_i	Mass of the fresh sample, g
M_m	Mass of the medium cup, g
M_s	Mass of the vegetable sample, g
M_w	Water mass, g
T_1	Vegetable crop sample temperature when it was dropped in water, °C
T_2	Final temperature when reaching the equilibrium of temperature, °C
T_3	Water temperature before dropping in the capsule, °C
T_s	Transverse surface, cm^2
V_{cal}	Calculated volume, cm^3
V_d	Determined volume, cm^3
W	Width, cm
θ	Friction angle, °

CONCLUSIONS

The study conducted to the following:

- Due to the differences in the vegetable shape for the different cultivars of the same crop, physical properties measurements must be considered for each cultivar separately in the future research.
- Differences were found between the calculated volume method and the determined volume using immerse the vegetable in water and determine the displacement water for all the vegetable crops and all cultivars, which were involved in the study. In spite of that the, mathematical relationships are given in the study.
- Mass of the different investigated cultivars can be determined with knowing the crop engineering dimensions from the relationships, which were conducted in the study to relate these relationships.
- Average specific heats of the different vegetable crops that were determined with the calorimeter method were found: 0.54, 0.65, 0.71 and 0.79Cal/g°C with standard deviation of 0.072, 0.042, 0.091 and 0.035 for potato, tomato, cucumber and pepper respectively. That was determined at average moisture contents of 77.3%, 92.5%, 93% and 89.2% with standard deviation of 0.53, 1.11, 0.56 and 1.96 respectively for Potato, tomato, cucumber and pepper respectively.
- Average friction angles for the vegetables on the different materials such as steel, galvanized steel and wood were: 31°, 31°, 30° for potato, 39.1°, 34.4° and 38.4° for cucumber and 31.3°, 28.1° and 31.1° for pepper respectively.
- The oblong and transverse area for potato and the three tomato cultivars with the related mathematical relationships are given in the study.
- The density differences between the cultivars of each vegetable crop were small so it was averaged to be 1.12g/cm^3 for potato, 0.99g/cm^3 for tomato, 1.07g/cm^3 for cucumbers and 0.55g/cm^3 for pepper.

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الملخص العربي

الخواص الطبيعية لبعض محاصيل الخضر

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أجريت دراسة الخواص الفيزيائية و الميكانيكية لبعض أصناف محاصيل الخضر التي تزرع في الأراضي الرملية بالإسماعيلية و ذلك لعمل قاعدة بيانات لخواص هذه المحاصيل و التي يحتاج إليها عند تصميم و تطوير الآلات و المعدات الزراعية للقيام بعمليات الحصاد و ما بعد الحصاد من عمليات النقل و التخزين و عمليات التصنيع الغذائي حيث تعاني محاصيل الخضر من سرعة تلفها و خاصة في مناطق الاستصلاح النائية في منطقة القناة و سيناء.

وقد أجريت الدراسة في الفترة من 26-6-2001م حتى 17-3-2003م حيث تم دراسة خواص أصناف بيتا86، كاسيل روك و اوريت من أصناف الطماطم، و أصناف راوا ، كاتيه، زوربا من أصناف الخيار، و اوروبيل ، ماركوني و جوديون من أصناف الفلفل بالإضافة لصنف نيقولا من أصناف البطاطس. و جمعت هذه الأصناف من مزرعة كلية الزراعة بالإسماعيلية جامعة قناة السويس (ارض رملية نسبة الرمل فيها 89.9%).

مدرسين بشعبة الميكنة الزراعية- كلية الزراعة بالإسماعيلية – جامعة قناة السويس

و تضمنت الدراسة تقدير العوامل التالية لكافة محاصيل الخضر و أصنافها المدروسة هي:
دراسة المحتوى الرطوبي، و الذي كان علية محصول الخضر وقت تقدير باقي المعاملات. تقدير الأبعاد الهندسية من حيث الطول، العرض، القطر، القطر الهندسي، القطر الرياضي و العلاقات التي تربطهم ببعض و ذلك لكافة المحاصيل. تقدير كثافة المحصول و متوسط كتلة المحصول و علاقته بالأبعاد الهندسية له. دراسة حجم المحصول بطريقتين الأولى بالغمر في الماء و تقدير حجم الماء المزاح كمدلول حقيقي ثم حساب الحجم حسابيا عن طريق تقريب شكل المحصول لأحد الأشكال الهندسية ثم دراسة العلاقة بين الطريقتين لكل محصول خضر و كل صنف على حدة. دراسة المساحة الطولية و كذا المساحة المستعرضة للأشكال الثمار الكروية الشكل كالبطاطس و الطماطم. دراسة زاوية الاحتكاك لمحاصيل الخضر تحت الدراسة مع ثلاثة من الأسطح شائعة الاحتكاك معها سواء في الحصاد أم في عمليات ما بعد الحصاد و هي الخشب و الحديد و الحديد المجلفن. دراسة الحرارة النوعية لكل محصول على حدة حيث تفيد عند تبريد و تخزين محصول الخضر.

وتوصلت الدراسة للآتي:

- نتيجة للاختلافات في شكل أصناف محصول الخضر الواحد فأن قياسات الخواص الفيزيائية و الميكانيكية يجب أن تجرى لكل صنف على حدة في الدراسات المستقبلية.
- اختلاف الحجم المقدر بالطريقة الحسابية عن طريقة الغمر في الماء و تقدير حجم الماء المزاح لكل المحاصيل التي تم دراستها و يرجع ذلك لعدم انتظامية الشكل الهندسي في كل المحاصيل التي تم دراستها و كذا أصنافها و على الرغم من ذلك فقد تم إيجاد علاقات رياضية تربط هذه العلاقة لكل صنف من الأصناف و التي يمكن الرجوع إليها عند الحاجة.
- يمكن توقع كتلة الأصناف و التي تم دراستها و ذلك بمعرفة أبعاد الثمار الهندسية و التي يمكن حساب أقطارها الهندسية و الرياضية و قد توصلت الدراسة لإيجاد العلاقات الرياضية التي تربطها جميعا ببعضها.
- وجدت الدراسة أن متوسط الحرارة النوعية لمحاصيل الخضر المختلفة البطاطس و الطماطم و الخيار و الفلفل و المقدرة بطريقة الكالورى ميتر هي على التوالى0.54 ، 0.65 ، 0.71 ، 0.79 بوحدات كالورى /جم.درجة منوية عند انحراف معياري قدره 0.072 ، 0.042 ، 0.091 و 0.035 على التوالي للبطاطس و الطماطم و الخيار و الفلفل. حيث تم تقدير الحرارة النوعية عندما كان محتوى الرطوبة المتوسط عند 3و77% ، 5و92% ، 93% و 2و89% بانحراف معياري قدره 0.35 و 1.11 و 0.56 و 1.96 على التوالي للبطاطس و الطماطم و الخيار و الفلفل.
- قدرت زوايا الاحتكاك لمحاصيل الخضر و التي تضمنتها الدراسة مع الحديد و الحديد المجلفن و الخشب حيث كانت متوسطاتها هي على التوالي 31°، 5و31° ، 30° للبطاطس و كانت 1و39° ، 4و34° ، 4و38° للخيار و كانت للفلفل 1و28° ، 3و31° ، 1و31°.
- المساحة الدورانية و المستعرضة أو الجانبية لكلا من محصولي البطاطس و الطماطم تم إيجاد العلاقة الرياضية الخطية التي تربطهما ببعضهما.
- قدرت كثافة أصناف محاصيل الخضر تحت الدراسة عند المحتوى الرطوبي للمحصول و التي تم الاختبار عندها حيث كان متوسط الكثافة 1.12 جم/سم3 للبطاطس و 0.99 جم/سم3 للطماطم و 1.07 جم/سم3 للخيار و 0.55جم/سم3 للفلفل.