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Physical Properties of Pomegranate Fruits

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Abstract. The physical properties of twenty fruits of each of five cultivars of pomegranate were determined. The properties determined were the weight, volume, diameter, surface area, weight density, and sphericity. The statistical analysis indicated that there was no statistically significant difference between the five cultivars in weight, volume surface area, and sphericity. However, the densities were statistically different at the probability level of 0.12%. The difference in mean diameter of the various cultivars was also statistically significant at the 5% level. Prediction equations to compute the surface area and volume using the weight or the mean diameter of the fruit were obtained.

Introduction

Promegranate (*Punica granatum* L.) is a major fruit tree widely grown in Saudi Arabia, and is best adapted to the South-West region [1]. Numerous cultivars are grown in the country, they are either indigenous or introduced from abroad. However, Taifi is the most widespread cultivar in the region [2, p. 329, 334].

It is of great importance to have an accurate estimate of the engineering parameters for any product to be properly handled and processed. These parameters include the dimensions, shape, volume, surface area, and specific gravity. The forementioned properties can be utilized in the design of the cleaning, separating, sorting, packing and conveying mechanisms. Also these properties can be used in the analysis of the temperature distribution within the fruit. Moreover, the physical properties can be used as quality parameters for the cultivars as used by Shaheen [3].

The objectives of this study were:

1. to determine the physical properties of those cultivars; *e.g.* weight, shape, dimensions, surface area, and weight density.
2. to investigate the difference, if any, between the cultivars.
3. to relate the properties, tedious to determine, to the weight of the product.

Materials and Methods

Three local cultivars and two foreign ones of the pomegranate fruit widely grown in Saudi Arabia were studied. The fruits were obtained from Deirab Research and Experimental Farm and were stored at 5°C and 90% relative humidity in the laboratories of the Food Science Dept. The five cultivars investigated were: Taifi, Medina, Ahmer Baladi, Manfaluti, and Banati. The investigation was conducted during the season 1991 in the laboratories of the Dept. of Agricultural Engineering, College of Agriculture, King Saud University.

Twenty fruits of apparent uniform ripeness from each cultivar were randomly selected and were marked with a masterflo pen to specify their type of cultivar. A number was given, from one to twenty, to each fruit. The following experiments were conducted on each of the twenty fruits:

Experiment 1: Determination of weight, volume, and density of the fruits

The procedures used consisted of the standard methods described by Mohsenin [4, p. 51-87]. The fruit was weighed in the air on a balance of accuracy of $\pm$ 0.001 gm. The fruit was then forced into water in a beaker by means of a sinker rod to determine the volume. The displaced water was collected in a measuring cylinder and the volume was determined. The volume of the fruit was equal to the displaced volume of water. The weight density of the fruit was then obtained by the ratio of weight to volume.

Experiment 2: Determination of axial dimensions and sphericity.

Three axial dimensions of the fruit, at right angles to each other, were measured using a vernier caliper. The dimensions were referred to as a, b, and c; the dimension "a" being the longest measurement. The sphericity was determined using the following equation:

$$\text{Sphericity} = \frac{(abc)^{1/3}}{a}$$

Experiment 3: Determination of the surface area

Peeling the skin of the fruit was found to be the most appropriate method to determine the surface area, because the undulating surface of the fruit does not lend itself to the usage of the wrapping method. The surface areas of twenty fruits of each

cultivar of Taifi, Ahmer Baladi, Banati, and Manfaluti were determined. The fruit was peeled in narrow strips and the planimeter sum of the areas of tracings of the strips were taken as the surface area of the fruit.

Results and Discussion

The collected measurements were statistically analyzed using the PC program, Statgraphics (Ver. 5.0), Statistical Graphics Corporation, U.S.A.

The regression analysis was conducted using four types of models, namely, the linear, the multiplicative, the reciprocal and the exponential. The most appropriate model was selected on the basis of the known physical relationships, the coefficient of determination (R^2), and on the basis of the scater diagram.

Weight, volume, and density of the fruits

The weights of twenty fruits of each cultivar were statistically analyzed. The analysis indicated that there was no statistically significant difference between the weights of the five cultivars at the probability level of 1% or 5%. The differences were only significant at the probability level of 15%. However, these differences are appreciable when it comes to the design of handling mechanisms. Table 1 exhibits the means of the weights in grams of the fruits of the five cultivars.

The analysis also showed that the differences between the volumes of the various cultivars were only significant at the probability level of 17%. Table 1 also shows the means for the volumes in cubic centimeters of the fruits of the various cultivars. Figure 1 presents the relationship between weight and volume of the fruits of the five cultivars of pomegranate.

Regressional analysis (Table 2) showed that the weight and volume of the fruits of the five cultivars can be related by the following equation:

$$W_{p,v} = 1.2077 V_m^{0.9608} \quad R^2 = 98.94\% \quad n = 100$$

where

$W_{p,v}$ = the predicted weight, in gm, using volume of the fruit

V_m = measured volume in cm^3

n = the total number of fruits

Table 1. Means[a] of weight, volume, weight density, mean diameter, sphericity, and surface area of five pomegranate cultivars.

Cultivar	Weight (gm)	Volume (cm^3)	Weight density (gm/cm^3)	Mean diameter (cm)	Sphericity	Surface area (cm^2)
Taifi	241.75n.s.	246.25n.s.	0.9847**	7.7096*	0.9529n.s.	171.43n.s.
Ahmar Baladi	229.25n.s.	232.50n.s.	0.9875**	7.5067*	0.9682n.s.	152.07n.s.
Banati	268.73n.s.	275.25n.s.	0.9777**	7.9915*	0.9608n.s.	170.92n.s.
Manfaluti	262.08n.s.	272.50n.s.	0.9648**	7.9033*	0.9588n.s.	162.29n.s.
Madina	227.18n.s.	238.75n.s.	0.9560**	7.4835*	0.9638n.s.	–

[a]means of twenty fruits
*$p< 0.05$, **$p<0.01$, n.s. nonsignificant

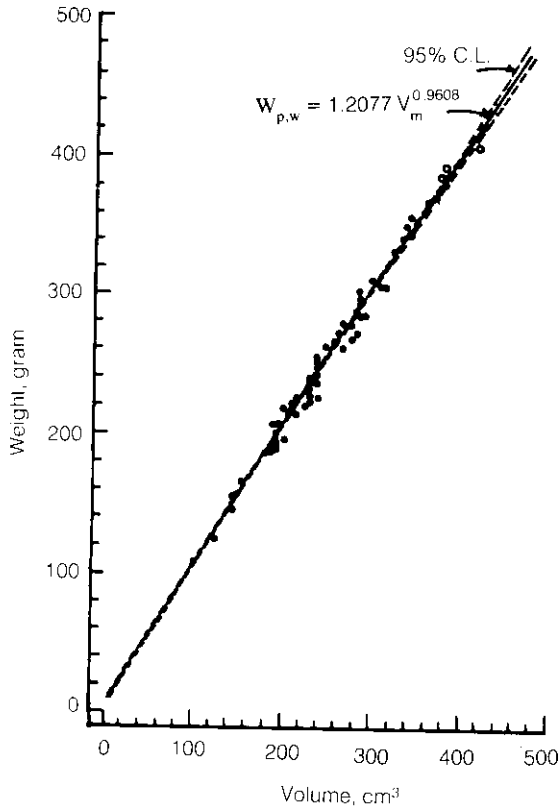

Fig. 1. Weight vs. volume of pomegranate fruits

Table 2. Regression analysis for fruit weight Vs volume.

Dependent variable weight			**Independent variable volume**
Parameter	**Estimate**	**S.E.**	**T value**	**prob. (level)**
Intercept	0.188751	0.0553149	3.4123	0.00094
Slope	0.960807	0.0100522	95.5819	0.00000

Note: The Intercept is equal to log a.

Analysis of variance

Source	Sum of squares	Df	Mean square	F-Ratio	Prob. level
Model	7.1817	1	7.1817	9135.895	0.00000
Residual	0.077038	98	0.000786		
Lack of fit	0.033005	40	0.000825	1.08683	0.38074
Pure error	0.044033	58	0.000759		
Total (corr.)	7.258778	99			

Correlation coefficient = 0.994679 R-squared = 98.94 percent

Stand. Error of Est. = 0.0280375

The densities of the fruits of the five cultivars were statistically analyzed. The differences in densities of the fruits of the various cultivars were significant at the probability level of 0.12%. The values for the density ranged between 0.956 gm/cm^3 and 0.988 gm/cm^3 as presented in Table 1. At the 5% probability level, densities of Medina and Manfaluti fruits were signficantly less than those of the other three cultivars.

Axial dimensions and sphericity

The arithmetical means of the three axial measurements for each fruit were computed. The statistical analysis showed that the mean diameter of the fruits of the various cultivars were statistically different at the probability level of 5%. Table 1 also shows that the Banati cultivar had the largest diameter of 7.99 cm, followed by Manfaluti (7.90 cm), and Taifi (7.71 cm). Ahmar Baladi and Medina cultivars had virtually equal mean diameters of 7.5 cm which were significantly less (5% level) than the diameters of Manfaluti and Banati. The overall mean diameter for the five cultivars was 7.72 cm.

The analysis of variance for the sphericity of the fruits of the various cultivars showed that the sphericities were not statistically different. Table 1 shows the results

for the sphericity of the five cultivars of pomegranate. The sphericity ranged between 0.953 and 0.968. Cultivar Ahmar Baladi had the highest sphericity of 0.968, Taifi and Medina had the lowest sphericity of 0.953 and 0.959 respectively. The mean sphericity for the pomegranate fruit was 0.960

Surface area

The analysis of variance for the surface areas of the four cultivars, namely Taifi, Ahmar Baladi, Banati, and Manfaluti showed that the surface areas were different at a probability level of 20%. Table 1 shows that the mean surface areas for the four cultivars ranged between 152.1 and 171.4 cm^2

Regressional analysis, whose results are presented in Table 3, was conducted to relate the surface areas to the weights of the fruits. The following relationships were obtained:

$$A_{p,w} = 3.3898\ W^{0.703} \qquad R^2 = 86.02\%$$

$$A_{p,w} = 49.61 + 0.4574W \qquad R^2 = 86.94\%$$

where $A_{p,w}$ was the predicted surface area, in cm_2, using fruit weight and W was the fruit weight in grams. Figure 2 shows the multiplicative and the linear relationships for the area versus the weight of the fruit.

Relationships of volume, weight and surface area to the mean diameter

The volume, weight and the surface areas were related to the mean diameter. Comparisons were made between the obtained results and those for a sphere of an equivalent diameter.

The measured volume (Vm) of each fruit was compared to the volume of a sphere (V_s) of an equivalent mean diameter and the following regression equation was obtained:

$$V_{p,s} = 0.856V_s^{1.0326} \qquad R^2 = 93.43\%$$

where $V_{p,s}$ was the predicted volume of the fruit, in cm_3, using the volume of a sphere of an equivalent diameter. Table 4 shows that the error of estimating the volume of the fruit using the volume of a sphere of equivalent diameter ranged between 2.5% and 8.1% of the measured volume for the various cultivars. The predicted volume was always larger than the measured one.

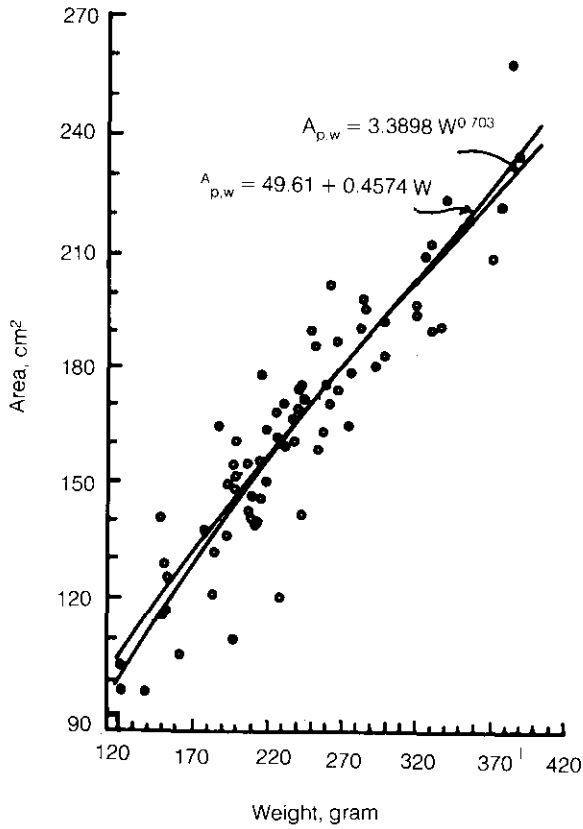

Fig. 2. Surface areas.

Table 3. Regression analysis for surface area Vs weight of the fruit.

Model	Parameter	Estimate	S.E.	Prob. level	R^2
$Y = a + bx$	a	49.6108	5.19809	0.00000	
	b	0.457486	0.0200704	0.00000	86.94%
$Y = ax^b$	ln a	1.22178	0.176338	0.00000	
	b	0.703167	0.0320925	0.00000	86.02%

Table 4. Comparison of measured Vs predicted surface areas, volumes, and weights.

Parameter	Cultivar				
	Taifi	Ahmar Baladi	Banati	Manfaluti	Medina
Mean Diameter, Dm (cm)	7.71	7.51	7.99	7.90	7.48
Measured surface area, Am (cm^2)	171.43	152.07	170.92	162.29	–
Predicted surface area from mean diameter, Ap,Dm (cm^2)	160.00	151.14	172.27	168.68	150.11
% error of predicted Ap, Dm	–6.6 %	–0.61%	+0.79%	+3.93%	–
Surface area of a sphere of equivalent diameter, As (cm^2)	186.75	177.00	200.61	196.22	175.91
% error of surface area of the sphere	–8.94%	–16.39%	–17.37%	–20.9 %	–
Measured volume, Vm (cm^3)	246.25	232.50	275.25	272.50	238.75
Predicted volume from mean diameter, Vp,Dm (cm^3)	245.56	226.08	274.36	265.11	223.85
% error of predicted Vp,Dm	–0.28%	–2.76%	–0.32%	–2.71%	–6.24%
Volume of a sphere of equivalent diameter, Vs (cm^3)	239.97	221.51	267.78	258.45	219.39
Predicted volume from volume of a sphere, Vp,s (cm^3)	245.60	226.12	274.40	265.15	223.88
% error of predicted Vp,s	2.5 %	4.72%	2.7 %	5.2 %	8.1 %
Mean weight of the fruit, W (gm)	241.75	229.25	268.73	262.08	227.18
Predicted weight from mean diameter, Wp,Dm (gm)	238.62	220.19	265.79	257.07	218.07
% error of predicted Wp,Dm	–1.29%	–3.95%	–1.09%	–1.9%	–4.0 %

Regression analysis was conducted to relate the measured volume to the mean diameter of the fruit and the following relationship was obtained:

$$V_{p,Dm} = 0.4386\ D_m^{3.098} \quad R^2 = 93.43\%$$

where $V_{p,Dm}$ was the predicted volume, in cm^3, using the mean diameter in cm. The results in Table 4 also indicated that an error of estimating the volume of the fruit using the mean diameter ranged between 0.28% and 6.24%. It should be noticed the predicted volume was always less than the measured volume.

The weight of the pomegranate fruit was related to the mean diameter of the fruit and could be presented by the following equation:

$$W_{p.Dm} = 0.507\ D_m^{3.013} \qquad R^2 = 94.77\%$$

where $W_{p.Dm}$ was the weight in grams predicted using the mean diameter in centimeters. Table 4 shows that the error for estimating the weight of the fruit using the mean diameter ranged between 1.09% and 4%; the estimated weight being less than the actual one.

The measured surface areas (A_m) of the fruits were regressed on the mean diameter. The following regression equation was obtained:

$$A_{p.Dm} = 2.043\ D_m 2{,}135 \qquad R^2 = 81.12\%$$

where $A_{p.Dm}$ was the predicted surface area in cm^2 using the mean diameter in centimeter. The results in Table 4 indicated that the predicted surface areas of Taifi and Ahmar Bladi were less than the measured surface area by a value ranging between 0.61% to 6.6%. Whereas, the predicted surface areas of the cultivars Banati and Manfaluti were larger than the measured ones by a value ranging between 0.79% and 3.93%.

The measured surface area was also compared to the surface area of a sphere of equivalent mean diameter. The comparison indicated that an estimation error ranging between 8.9% and 20.9% was obtained for the various cultivars as shown in Table 4. The measured surface areas were always less than the predicted ones using the equation of the sphere.

Conclusions

The following conclusions were drawn:

1. Statistical significant differences between the fruits of the various cultivars in the mean diameters and in densities were indicated.
2. The Banati cultivar had the largest diameter, followed by Manfaluti, and Taifi. Ahmar Baladi and Medina had virtually equal and smaller mean diameters.
3. The differences in some of the physical properties of the fruits of the cultivars were not statistically significant at the 1% or 5% probability levels; yet they

deserve to be studied thoroughly for each cultivar. These differences could be very important in the design of the handling or sorting equipment.

4. Prediction equations to compute the surface area and the volume of the fruit from the mean diameter gave closer results to the measured values, than those obtained using the equation of a sphere and the mean diameter.

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References

[1] Al Saad, F.A. "Studies on the Phenomenal Cracking of Pomegranate *(Punica granatum* cr. Taifi) Fruits" *J. Coll. Agric., King Saud Univ.* 7, No. 2 (1985), 399-408.

[2] Nasr, T.A. *Evergreen Deciduous Fruits Production and Important Cultivars in the Arab World.* 1st ed. Cairo: Dar Al Maarif, 1983.

[3] Shaheen, M.A. "Suitability of Some Introduced Pomegranate Cultivars for Riyadh Region." *J. Coll. Agric. King Saud Univ.* 7, No. 1 (1985), 147-182.

[4] Mohsenin, N.N. *Physical Properties of Plant and Animal Materials. Physical Properties.* New York: Gordon and Breach Science Publishers, 1970.

الخواص الفيزيائية لثمار الرمان

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ملخص البحث. تم إيجاد الخواص الفيزيائية لعدد ٢٠ ثمرة من كل صنف لخمسة أصناف مختلفة من الرمان. وقد تضمنت تلك الخواص الوزن، الحجم، القطر ومساحة السطح، الكثافة والكروية للثمار. وقد دل التحليل الإحصائي على أنه لا يوجد هناك فرق معنوي في الوزن والحجم ومساحة السطح والكروية بين ثمار الأصناف المختلفة. كما أظهر التحليل الإحصائي أيضًا أن هناك فرقًا معنويًا في الكثافة، ومتوسط القطر بين ثمار الأصناف المختلفة. ولقد تم استنباط معادلات تنبؤ لتقدير مساحة السطح وحجم ثمرة الرمان باستعمال وزن أو متوسط قطر الثمرة.