PHYSICAL AND MECHANICAL PROPERTIES OF CANTALOUPE "CHARENTAIS" FRUITS APPLIED TO DESIGN SEED-EXTRACTOR

A. M. El Lithy (*)

ABSTRACT

The aim of this research is to study some physical and mechanical properties of cantaloupe "charentais" variety that provide the basic data for the proper design of handling-machines. The tested physical and mechanical properties were incorporated in the design of the seed-extraction machine as a case study.

The main results in this study can be summarized as follows:

Physical properties of cantaloupe fruits: diameter = 81.99 – 112.16 mm, height = 66.69 – 127.55 mm, geometric diameter = 83.5 – 117.31 mm, mass = 332 – 902 g, volume = 345 - 1000 cm^3, projected area = 85.21 – 173.79 cm^2, real density = 0.87 – 1.00 g/cm^3, bulk density = 0.695 g/cm^3, sphericity = 0.84 – 1.18.

Mechanical properties: maximum rolling-angle was 20 – 25 degree, minimum rolling-angle was 12 – 20 degree and the average firmness of cantaloupe-fruit was 85.71 N/cm^2.

The physical and mechanical properties are incorporated in the design of the cantaloupe-fruit hopper size and wall angle, convey belt with pressing fingers, pressing mechanism and separation mechanism (vibrated chain-belt) of the proposed design idea of seed-extraction machine is given also in the paper as a case study.

INTRODUCTION

Cantaloupe (*Cucumis melo*) is a subtropical fruits and belongs to family Cucurbitaceae. Cantaloupe is considered as one of the best fruits due to its high nutritive value. Besides a rich source of vitamin A and C, it contains a fair amount of nutrients (calcium,

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magnesium, phosphorus, potassium and iron) and vitamins B1, B3 and B5. **Arabsalmani (1996).** Cantaloupe is the major horticultural crop in Egypt. The cultivated area of cantaloupe is 74.147 thousand feddans (31.14 thousand hectare) in 2009 and the annual production is about 755.6 thousand ton in 2009. **Ministry of Agriculture (2009)**.

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. **Abou-Elmagd**, **et al. (2006)** designed and tested a crushing machine for watermelon seeds-extraction. The machine consists of hopper, crushing drum with knives, screw conveyer and water source.

Ghanbarian et al. (2008) found that the average masses of cantaloupe fruits were 697 to 1272 g, the fruit volumes were 1084 and 1409 cm^3 and geometric mean diameters were 11.7 and 13.12 cm for Samsouri and shahabadi varieties respectively.

Rashidi and Seyfi (2007) found that the mass of cantaloupe fruit (Samsouri variety) ranges from about 510 to 3380 g, the fruit volume from 538 to 3654 cm^3 and the length from 95 to 185 cm, Major diameter from 106 to 205 cm, Minor diameter from 101 to 190 cm and density from 0.78 to 1.07 g/cm^3.

Hassan (1994) reported that the methods of extracting vegetable seeds from soft fruits include the following steps: 1) Cutting and smashing the fruits mechanically as in tomatoes and watermelons or cutting them into two-halves manually using a knife as in sweet melon. 2) Extracting seeds from surrounding gelatin and smashed fruit parts by leaving the mixture from 2 to 4 days to ferment as in tomatoes or proceeding extraction mechanically as in pepper, eggplant and tomato. 3) Washing seed using running water. 4) Drying seeds naturally in drying climate or by exposing them to current of warm air in humid climate.

Vergano et al. (1992) studied the design aspects and performance of an axial-flow vegetable seed extracting machine. They compared the manual

with the mechanical seed extraction for different vegetable fruits. They found that the manual seed extraction output was 0.47, 1.20, 1.26, 1.56, 1.83, 2.20 and 3.14 kg/man-h for cucumber, watermelon, tomato, summer squash, brinjal, squash melon and chillies, respectively. Meanwhile, the productivity of the seed extracting machine varied from 310 to 1930 kg/h for all investigated vegetable fruits. They added that germination count for mechanically extracted seeds was higher than for the manually extracted seeds.

Yehia et al. (2010) studied some physical and mechanical properties of cantaloupe "Galia" variety. The main results in this study were: Physical properties of cantaloupe fruits: diameter = 82.12 – 113.51 mm, height = 82.07 – 119.95 mm, mass = 329.2 – 940.6 g, volume = 380 - 860 cm^3, projected area = 85.85 – 160.95 cm^2, real density = 0.69 – 1.08 g/cm^3, bulk density = 0.51 g/cm^3, sphericity = 0.88 – 1.07. Mechanical properties: the average of cantaloupe-fruit firmness was 62.5 N/cm^2, the maximum = 80.4 N/cm^2 and the minimum = 28.6 N/cm^2.

The objective of the present research is to study some physical and mechanical properties of cantaloupe fruits, as a data base, to help the design of handling machines. The physical and mechanical properties are incorporated in the design of the seed-extraction machine as a case study.

MATERIALS AND METHODS

a. Fruits.: Cantaloupe crop "Charentais" variety was considered in this study. All measurements were done using a random sample of 100 fruits. The samples were taken randomly from cantaloupe trees (private farm in El Sharkia Governorate (محافظة الشرقية) at acceptable harvesting date) and from "El Oboor" (سوق العبور) Market; and the measurements were taken in the same day.

b. Instrumentation:

b1. Digital caliper with vernier: with accuracy of 0.01 mm, to measure different dimensions of cantaloupe fruits.

b2. Digital balance: with accuracy of 0.2 g, to measure mass of cantaloupe fruits.

b3. Graduated cylinder: of 2000 mL with accuracy of 25 mL to determine the real density and volume of fruit by immersion in water.

b4. Friction and repose angle measurement: The friction angle was measured by placing a bounded group of fruits together (sample of (4) fruits) on a horizontal surface and gradually increasing the angle of inclination until the fruits begin sliding without rolling. The repose angle (internal friction) was measured by placing two bounded groups of fruits above each other and gradually increasing the angle of inclination until the upper group begin sliding without rolling.

b5. Rolling angle measurement: The fruits are placed on a horizontal surface one by one then the angle of inclination is gradually increased until the fruits begin to roll. For each fruit of an average sample (50), two angles of rolling are determined: for the maximum stable (with their base down) and minimum stable positions.

b.6 Penetrometer: Penetrometer, made in Italy, with accuracy of 0.1 N was used to measure penetration force of cantaloupe fruits. The firmness of fruit was obtained by dividing the penetration force by the area (0.28 cm^2) of cylindrical probe with circular edge, which had 0.6 cm diameter.

c. Equations and calculations:

The following equations were used to calculate sphericity, projected area and real density according to **Mohsenin, 1986** and **Wilhelm et al., 2005**

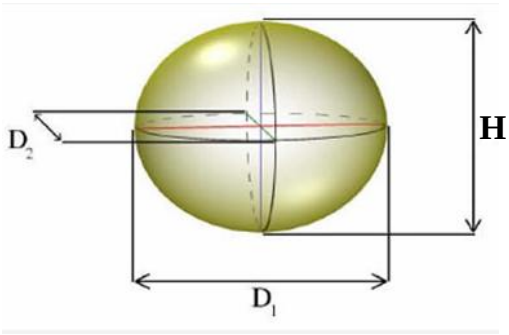
Sphericity ratio = D / H ---------- (1)

Where: H = Fruit height, mm and D = Diameter of fruit, mm (fig. 1).

Projected area = $4/\pi$ (D * H) ---------- (2)

Real density = Mass / Volume ---------- (3)

Geometric diameter = $(D_1 \times D_2 \times H)^{1/3}$ ---------- (4)



$D = D_1 = D_2$ for studied varieties

Fig. 1: View and photograph of cantaloupe fruit.

d. The designed seed-extraction machine:

Fig. 2 shows a schematic diagram of a design-idea of cantaloupe seed-extraction machine. Parameters shown on the figure are essentially those to be determined for cantaloupe through this work, for design the seed-extraction machine.

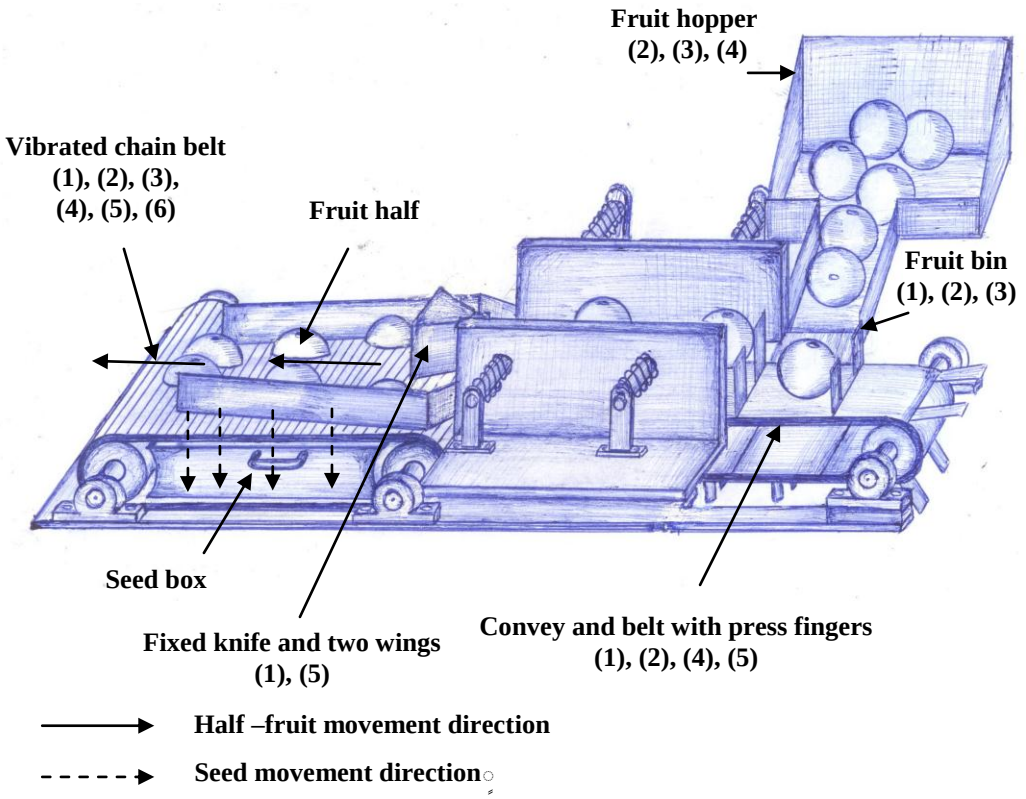


Fig. 2: Diagram demonstrating idea of extracting machine, with the numbers in brackets indicating parameters necessary for design of different parts.

Associated parameters:

(1) Fruit dimensions, (2) Bulk density, (3) Friction and rolling angles, (4) Fruit mass, (5) Fruit firmness, and (6) Seed size.

RESULTS AND DISCUSSION

a. Physical properties of cantaloupe fruits.

Table 1 shows dimensions, sphericity, mass, volume, real density, projected area, mass, juice volume, seed number per fruit and bulb thickness of cantaloupe (Charentais variety). These data were measured on 100 fruit sample, according to the standards set in **(Mohsenin, 1986 and Wilhelm et al., 2005)**.

Table 1: Physical properties of cantaloupe fruits (Charentais variety).

Physical properties	Min.	Max.	Average	S. D.(1)	C. V.(2)
Diameter, mm	81.99	112.16	95.24	6.54	6.87
Height, mm	66.69	127.55	94.41	11.22	11.88
Geometric diameter, mm	83.5	117.31	94.83	7.87	8.30
Sphericity	0.84	1.18	1.00	0.07	6.61
Mass, g	332	902	515.71	138.56	26.87
Volume, cm^3	345	1000	541.20	155.66	28.76
Bulk density, g/cm^3	0.695				
Real density, g/cm^3	0.87	1.00	0.96	0.04	4.06
Projected area, cm^2	85.21	173.79	115.04	20.04	17.42
No. of seeds/fruits	419	561	468	16.28	15.16
Bulb thickness, cm	3	3.5	3.22	4.22	5.12

(1) S. D. is standard deviation.

(2) C. V. is coefficient of variation.

a1. Dimensions of fruit:

Fig. 3 indicates that the fruit diameter, height and geometric diameter ranges of sample were 81.99 – 112.16 mm (average 95.24 mm), 66.69 - 127.55 mm (average 94.41 mm) and 83.5 – 117.31 mm (average 94.83 mm) respectively. The most frequent percent (96 %) of cantaloupe fruits in the sample have 90 – 110 mm diameter, (86 %) of cantaloupe fruits in the sample have 90 – 110 mm height and (92 %) of cantaloupe fruits in the sample have 90 – 110 mm geometric diameter.

a2. Shape and size of fruit:

If sphericity is less than 0.9, the fruit belongs to oblate group; if sphericity is greater than 1.1, it belongs to oblong group. The remaining fruits with

intermediate index values are considered to be round **(Buyanov and Voronyuk, 1985).**

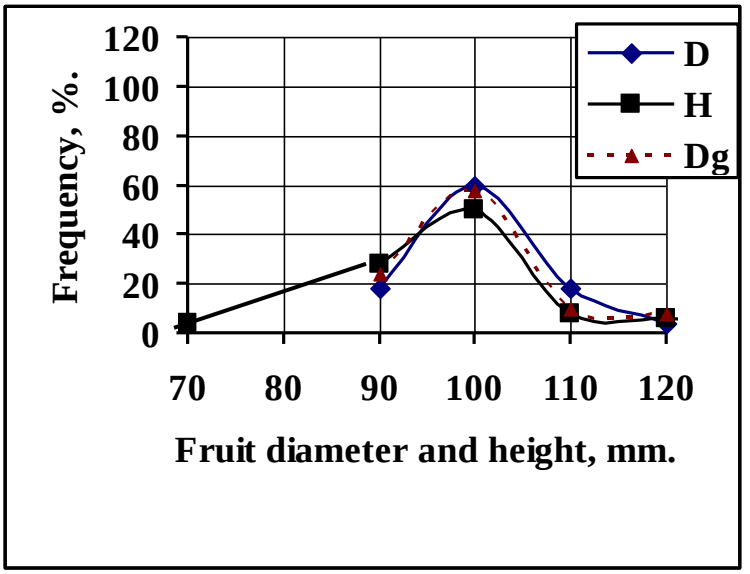


Fig. 3: Frequency curves distribution of fruit dimensions (diameter "D" , geometric diameter "D_g"and height "H") of cantaloupe fruits (Charentais variety).

Fig. 4 indicates that the fruit spericity ranged in sample between 0.84 and 1.18. The most frequent percent (96 %) of cantaloupe fruits in the sample was round (sphericity 0.9 - 1.1) and (4 %) of cantaloupe fruits in the sample were oblong (sphericity > 1.1).

a3. Mass and volume of fruit:

Fig. 5 indicates that the fruit mass and volume ranges of sample were 332 - 902 g (average 514.83 g) and 345 - 1000 cm^3 (average 540.25 cm^3) respectively. The most frequent percent (80 %) of cantaloupe fruits in the sample had 400 - 600 g mass and (80 %) had 400 - 600 cm^3 volume.

a4. Real density of fruit:

The fruit real density of sample ranged between 0.87 and 1.0 g/cm^3 (average 0.90 g/cm^3). The most frequent percent (100 %) of cantaloupe fruits in the sample had 0.87 – 1.00 g/cm^3 real density.

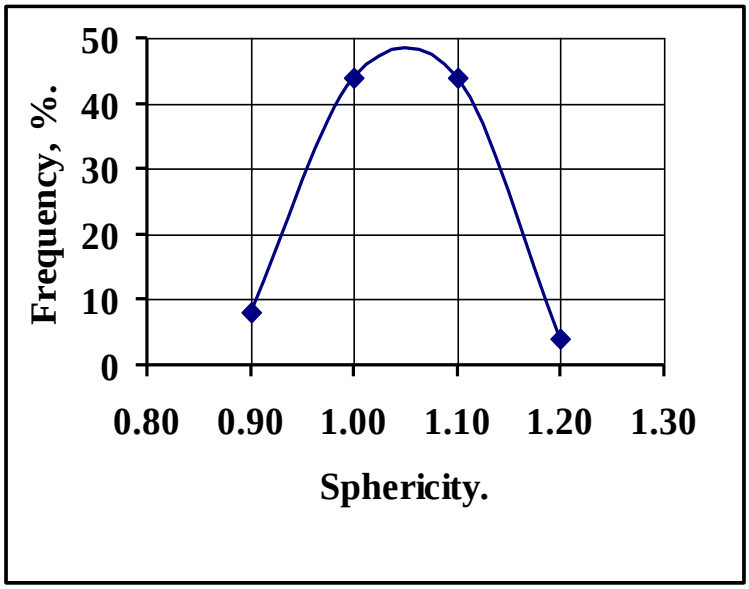


Fig. 4: Frequency distribution of fruit sphericity of cantaloupe fruits (Charentais variety).

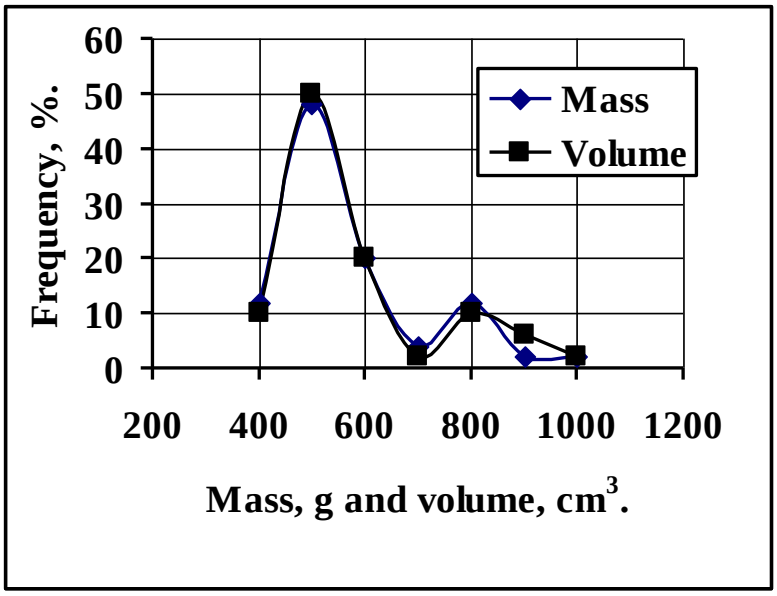


Fig. 5: Frequency curves distribution of fruit mass and volume of cantaloupe fruits (Charentais variety).

a5. Projected area of fruit:

Fig. 6 indicates that the fruit projected area of sample ranged between 85.21 and 173.79 cm^2 (average 115.04 cm^2). The most frequent percent 90 %) of cantaloupe fruits in the sample have 100 - 140 cm^2 projected area.

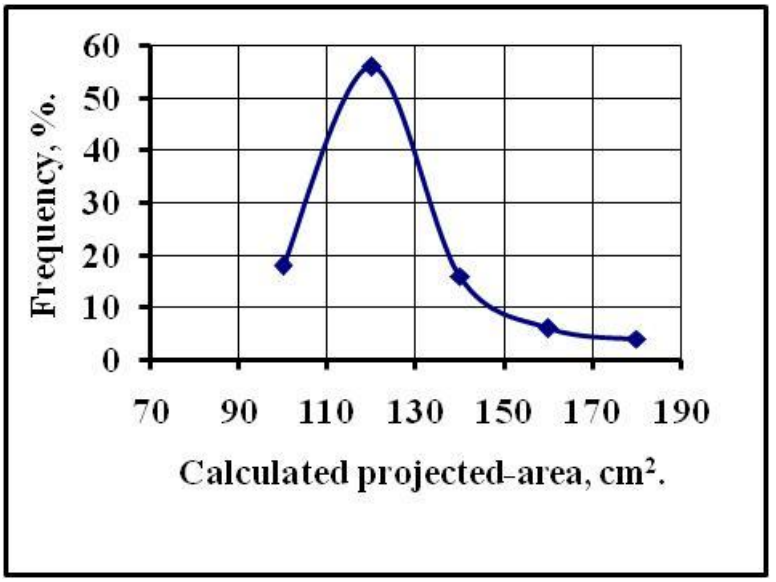


Fig. 6: Frequency curve distribution of fruit projected-area of cantaloupe fruits (Charentais variety).

b. Mechanical properties of cantaloupe fruits.

b1. Friction, rolling and repose angles of cantaloupe fruits:

Table 2 shows friction and rolling angles of cantaloupe fruits. The maximum friction angle (28 - 34 degree) and the maximum rolling-angle ranges (23 - 25 degree) were obtained with wood surface. Whereas, the minimum ranges of friction and rolling angles (9 - 12 and 11 - 18 respectively) were obtained with aluminum surface. The average repose-angle was about 32.5 degree.

Table 2: Friction and rolling angles for cantaloupe fruits (Charentais variety) with different surface types.

Surface type	Friction angle, degree			Rolling angle, degree					
				Maximum			Minimum		
	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.
Wood	34	28	30	25	23	24	21	18	20
Metal	12	10	10.3	25	20	22.7	20	12	15.7
Galv. I.	12	10	10.7	25	20	22.8	20	12	15.2
Alum.	12	9	10.4	23	15	20.1	18	11	12.8
SS	12	10	10.5	25	15	20.2	19	12	12.9

Wood: wood sheet No. 2; Galv. I.: Galvanized iron; Alum.: Aluminium; and SS.: Stainless steal.

b2. Firmness of cantaloupe fruits:

The cantaloupe-fruit firmness was 85.71 N/cm^2.

c. Application of the theory to the design of the cantaloupe seed-extraction machine:

Parameters required for design of seed-extraction machine have been explained in the part 2d in the section on "Materials and Methods". Fig. 2 shows the parameters. The physical and mechanical properties are incorporated in the design of the cantaloupe-fruit hopper, convey belt with pressing fingers and separated mechanism (vibrated chain-belt) of the designed seed-extraction machine as follows:

Design of fruit hopper and bin (Fig. 2):

Fruit-hopper dimensions=60 x 60 x 40 cm.(about 10-12 kg. fruit capacity)

Fruit-hopper tilt angle = more than maximum friction angle between cantaloupe fruits and stainless steal surface = more than 25^0.

Fruit bin width =more than maximum fruit diameter and height =130 mm.

Fruit-bin tilt angle = more than maximum friction angle between cantaloupe fruits and stainless steal surface = more than 25^0.

Design of convey belt and pressing fingers:

Convey-belt width = more than maximum diameter of cantaloupe fruits = 200 mm.

Pressing-fingers height = more than the maximum height = about 15 cm.

No. of pressing fingers = 2 fingers .

Design of separated mechanism:

Vibrated-chain belt width = more than maximum diameter of cantaloupe fruits = 200 mm.

Distance between rods of chain belt = more than seed size= about 10 mm.

CONCLUSION

The main results in this study can be summarized as follows:

Physical properties of cantaloupe fruits: diameter = 81.99 – 112.16 mm, height = 66.69 – 127.55 mm, geometric diameter = 83.5 – 117.31 mm, mass = 332 – 902 g, volume = 345 - 1000 cm^3, projected area = 85.21 – 173.79 cm^2, real density = 0.87 – 1.00 g/cm^3, bulk density = 0.695 g/cm^3, sphericity = 0.84 – 1.18. Mechanical properties: maximum rolling-angle was 20 – 25 degree, minimum rolling-angle was 12 – 20 degree and the average of cantaloupe-fruit firmness was 85.71 N/cm^2.

The physical and mechanical properties are incorporated in the design of the cantaloupe-fruit hopper, convey belt with pressing fingers and separated mechanism (vibrated chain-belt) of the designed seed-extraction machine as follows:

Design of fruit hopper: Fruit-hopper dimensions = 60 x 60 x 40 cm.

Fruit-hopper tilt angle = more than maximum friction angle between cantaloupe fruits and stainless steal surface = more than 25^0.

Design of convey belt and pressing fingers: Convey-belt width = more than maximum diameter of cantaloupe fruits = 200 mm. Pressing-fingers height = more than the maximum height = about 15 cm. No. of pressing fingers = 2 fingers.

Design of separated mechanism: Vibrated-chain belt width = more than maximum diameter of cantaloupe fruits = 200 mm. Distance between rods of chain belt = more than seed size = about 10 mm.

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الملخص العربى

الخواص الطبيعية والميكانيكية لثمار الكنتالوب " شارنتيز" وإستخدامها فى تصميم آلة استخلاص بذور

د / أحمد ماهر الليثى (*)

تهدف هذه الدراسة إلى تعيين الخواص الطبيعية والميكانيكية لثمار الكنتالوب صنف "شارنتيز"، للاستفادة منها فى تصميم وتشغيل آلات ومعدات تداول ثمار الكنتالوب، وتم تصميم بعض أجزاء آلة استخلاص بذور الكنتالوب كمثال. وتم الحصول على النتائج التالية:

(١) الخواص الطبيعية:

(أ) أبعاد الثمرة: وجد أن قطر ثمار "الكنتالوب" يتراوح بين ٨١.٩٩ و ١١٢.١٦مم والارتفاع بين ٦٦.٦٩ و١٢٧.٥٥ مم،

(ب) الشكل والحجم: وجد أن ٩٦ % من الثمار الموجودة فى العينة تأخذ الشكل الكروى، ٤ % تأخذ الشكل المفلطح. وتراوح الحجم بين ٣٤٥ و١٠٠٠ سم^{٣}.

(ج) كتلة وكثافة الثمار: وجد أن كتلة ثمار " الكنتالوب" تتراوح بين ٣٣٢ و٩٠٢ ج، وكثافتها الحقيقية تتراوح بين ٠.٨٧ و١.٠٠ ج/سم^{٣}.

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(د) المساحة المعرضة: وجد أن المساحة المعرضة تتراوح بين ٨٥.٢١ و١٧٣.٧٩ سم^{٢}.

(هـ) عدد البذور لكل ثمرة: وجد أن عدد البذور/الثمرة تراوح بين ٤١٩ و٥٦١.

(٢) الخواص الميكانيكية:

(أ) زاوية الاحتكاك والتدحرج والتكويم: وجد أن أقصى زاويتى إحتكاك وتدحرج لثمار "الكنتالوب" هى ٢٨ - ٣٤ ، ٢٣ - ٢٥ درجة تم الحصول عليها مع السطح الخشب، بينما كانت أقل زاويتى إحتكاك وتدحرج هما ٩ – ١٢، ١١ – ١٨ درجة تم الحصول عليها مع السطح الألمونيوم. ووجد أن متوسط زاوية التكويم حوالى ٣٢.٥ درجة.

(ب) صلابة الثمار: وجد أن صلابة ثمار "الكنتالوب " هى ٨٥.٧١ نيوتن/سم^{٢}.

وفى داخل البحث فكرة لتصميم آلة لأستخلاص بذور الكنتالوب باستخدام الخواص الطبيعية والميكانيكية للثمار.