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PHYSICAL AND MECHANICAL PROPERTIES OF CUCUMBER APPLIED TO SEED EXTRACTOR

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ABSTRACT

The aim of this research is to study some physical and mechanical properties of cucumber fruits for seed production, to help the design of handling machines. The physical and mechanical properties are incorporated in the development of the seed-extraction machine as a case study.

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

Physical properties of cucumber fruits: diameter = 52.15 – 229.5 mm, length = 52.15 – 68.87 mm, mass = 273.8 – 470.4 g, volume = 380 - 860 cm^3, projected area = 250 - 500 cm^2, real density = 0.94 -1.10 g/cm^3, bulk density = 0.41 g/cm^3, sphericity = 3.13 – 3.77.

Mechanical properties: cucumber-fruit firmness = 64 – 100.9 N/cm^2, the axial cutting- force = 30 - 70 N.

The physical and mechanical properties are incorporated in the design of seed-extraction machine is given also in the paper as a case study.

INTRODUCTION

Plant breeding and biotechnology research on cucumber (*Cucumis sativus* L.) often requires that mature fruits be harvested for seed recovery from controlled pollinations. Cucumber seed extraction has become more mechanized in the last few years following the design of machines such the seed sluice for small plots (Steiner and Letizia, 1986) and the bulk seed extractor (Wehner *et al*., 1983).

The single-fruit seed extractor is similar in purpose to the bulk seed extractor, but operates on different principle. The bulk seed extractor (suitable for large quantities) crushes the fruit, creating a of pulp. After using the bulk extractor in a field isolation block, the mound of pulp and fragments of discarded fruit can be disked into the field. In contrast, the single-fruit seed extractor bores into the end of the fruit, leaving the fruit mostly intact for easy disposal from greenhouse or laboratory where extractor often is used.

Wehner and Humphries (1995) designed and construct a single-fruit extractor for cucumber which consists of extractor cone or auger for excavating the seed cavity and means to drive it, a pail or containment both hands of the operator for other tasks. The designed machine increases the speed and ease of removing seeds from individual, mature cucumbers for later drying and planting. The machine saves about 47 second/fruit compared to hand methods and is suited to handling single fruit (or batches of up to 50) by researchers needing seeds from controlled pollinations. In 5 years of use, no reduction in seed recovery or germination has been observed using the seed extractor relative to hand harvest.

The cucumber crop for seeds is ready for harvest when the fruits have turned pale yellow or golden. The seeds are obtained by cutting individual fruits in half, longitudinally, and scraping them out with knife. At the time of extraction, the seed will not separate completely from the pulp surrounding it. Its adherence to this material is broken by one of three methods: (a) Fermentation, (b) Mechanical means and (c) Chemical extraction. Fermentation: In this method, the pulp is poured into wooden barrels where it is allowed to ferment for several days. The fermenting material is occasionally stirred to prevent any discoloration or blackening of seed from mold, which may form on the material floating at the surface. As the seed separates from the disintegrating pulp, it tends to sink to the bottom of the container. the seeds are then washed and dried in the sun to moisture contents below seven per cent, before storage.

Mechanical means: Seed can be extracted by the use of special machines also. In these machines, the fruits are not only cut and macerated, but also the pulp is squeezed so that the seed is forcibly separated from it. In this operation, considerable water is used for washing towards the end of the operation. The seeds are later washed and dried to moisture content below seven per cent. Chemical extraction: Either an acid or an alkali may be used to speed up the extraction of cucumber seed. 100 cm^3 of hydrochloric acid per 11 to 12 kg of pulp, or 12 parts of 25 percent technical grade ammonia per 1000 parts of material, is thoroughly stirred into the pulp. After about thirty minutes, water is added while stirring. The pulp, other impurities, and empty seeds will float and mature seeds will sink to the bottom. Later, the seeds are washed anddried to moisture content below seven per cent. The average seed yield is about 110 to130 kg per hectare (Desai et. al., 1997).

Abd-Alla (1993) found that the cucumber fruits variety Beta-alpha properties were: fruit length = 20 – 26 cm, fruit diameter = 5 – 6.5 cm, fruit mass = 500 – 650 g and seed number per fruit = 200 – 600.

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

MATERIALS AND METHODS

Fruits.

Cucumber Beta-alpha variety crop was used in this study. All measurements were done using a random sample of 100 fruits. The samples were taken randomly from cucumber plants (special farm at Belbis, El Sharkia Governorate during acceptable seeds-harvesting date); and the measurements were taken in the same day.

Instrumentation:

Digital caliper with vernier: with accuracy of 0.01 mm was used to measure different dimensions of cucumber fruits.

Digital balance: with accuracy of 0.2 g was used to measure mass of cucumber fruits and constituents (fruits and seeds).

Graduated cylinder: of 1000 mL with accuracy of 25 mL was used to determine the volume of fruit by immersion in water.
Friction and rolling-angle measuring device: An inclined plane was used to measure friction and rolling angles.
Friction and repose angle measurement: the fruits are placed as a group bounded together on a horizontal surface then the angle of inclination is gradually increased until the fruits begin sliding without rolling. For each fruits group of an average sample of (10), the friction and repose angles were determined.
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 roll. For each fruit of an average sample (50), rolling are determined for the maximum stable position.
Bulk density: Sample of cucumber of not less than 20 kg, was put into a box. Bulk density is calculated in the usual manner.
Bulk density = fruit mass / box volume
Penetrometer: Penetrometer, made in Italy, with accuracy of 0.1 N was used to measure penetration force of cucumber fruits. The firmness of fruit was obtained by dividing the penetration force by the area (0.28 cm^2) of cylindrical probe, which had 0.6 cm diameter.
Equations and calculations.

The following equations were used to calculate sphericity, projected area and real density according to Mohsenin, 1986 (Fig. 1).

Sphericity ratio = fruit length (L) / fruit diameter (D) -------- (1)
Projected area = D * L ---------- (2)
Real density = mass / real volume ---------- (3)

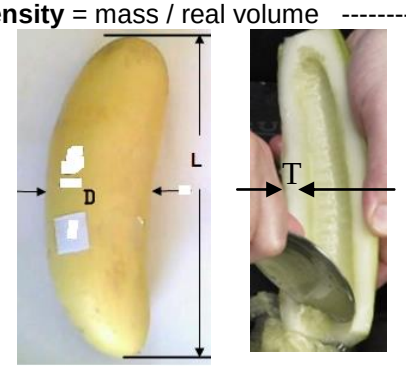

Fig. 1: View of cucumber fruit for seeds (L: length, D: diameter and T: pulp thickness).

The developed seed extractor.

Fig. 2 shows a model photograph demonstrating the design-idea of the seed extractor of cucumber fruits. Parameters shown on the figure are essentially those to be determined for cucumber through this work, for design the extractor to operate efficiently on this fruit.

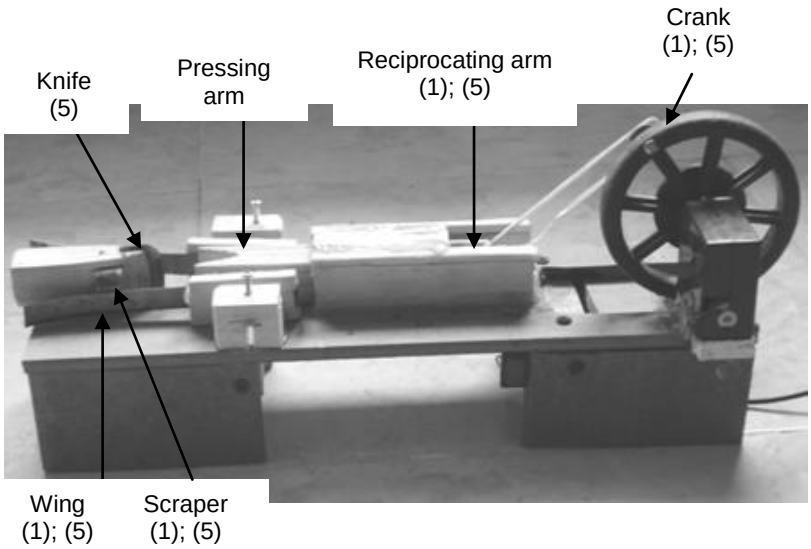

Fig. 2: Model photograph demonstrating the design idea of a seed extractor, with the numbers in brackets indicating parameters necessary for design of different parts.

Associated parameters:

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

Other physical and mechanical properties in this paper were conducted as a data base to help the design of some handling machines.

RESULTS AND DISCUSSION

Physical properties of cucumber fruits.

Table 1 shows dimensions, sphericity, mass, volume, real density, projected area, pulp thickness and mass and seed number and mass per fruit of cucumber fruits. These data were measured on 100 fruit sample, according to the standards set in (Mohsenin, 1986).

Dimensions of fruit.

Fig. 3 indicates that the fruit diameter and length ranges of sample were 52.15 – 68.87 mm (average 61.87 mm) and 196.4 – 229.5 mm (average 210.53 mm) respectively. The most frequent percent (87.5 %) of cucumber fruits in the sample have 60 - 70 mm diameter and (100 %) of cucumber fruits in the sample have 200 - 230 mm length.

Mass and volume of fruit.

Fig. 4 indicates that the fruit mass and volume ranges of sample were 273.8 – 470.4 g (average 351.3 g) and 250 - 500 cm^3 (average 343.75 cm^3) respectively. The most frequent percent (87.5 %) of cucumber fruits in the sample had 320 - 420 g mass and (75 %) had 300 - 400 cm^3 volume.

Table 1: Physical properties of cucumber fruits.

Physical properties	Max.	Min.	Average	S. D.(1)	C. V.(2)
Length, mm	229.5	196.4	210.53	10.76	5.11
Diameter, mm	68.87	52.15	61.87	5.25	8.49
Sphericity	3.13	3.77	3.42	0.21	6.03
Mass, g	470.4	273.8	351.3	68.74	19.57
Volume, cm^3	500	250	343.75	81.23	23.63
Bulk density, g/cm^3			0.41		
Real density, g/cm^3	1.10	0.94	1.03	0.04	4.23
Projected area, cm^2	149.73	102.42	130.61	16.42	12.57
Pulp thickness, mm	10	7	8.38	1.06	12.66
Pulp mass, g	438.20	257.60	324.29	61.99	19.12
No. of seeds	580	390	471	61,80	13.11
Seed mass, g	42.4	12.2	27.01	9.38	34.74

(1) S. D. is standard deviation. (2) C. V. is coefficient of variation.

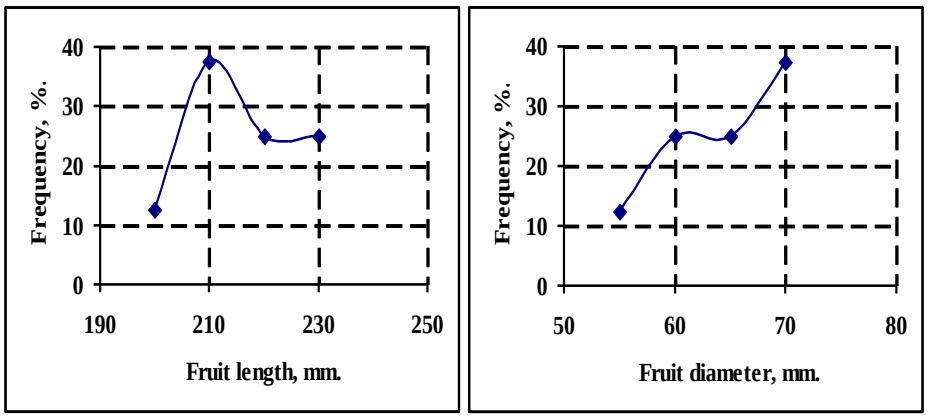

Fig. 3: Frequency curves distribution of fruit diameter and length of cucumber fruits.

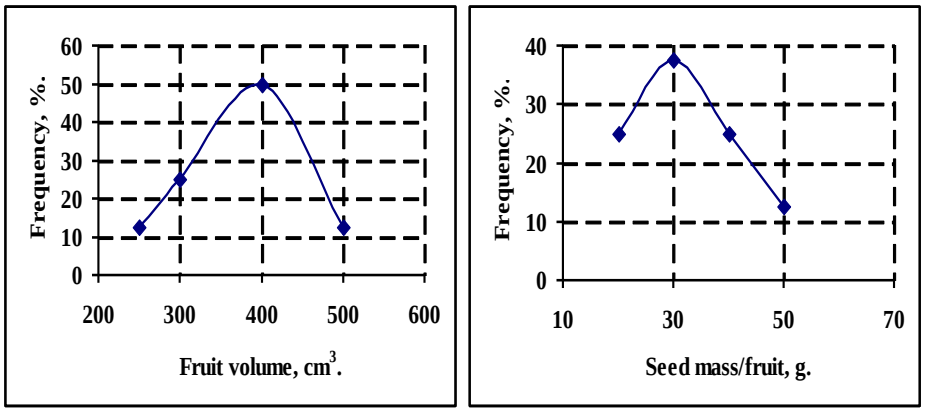

Fig. 4: Frequency curves distribution of fruit mass and volume of cucumber fruits.

Fig. 5 shows the best fitted curve and the relation between fruit mass (M) and volume (V) of cucumber as follows: M = 0.97 V, R^2 = 0.99.

Real density of fruit:

Fig. 6 indicates that the fruit real density of sample ranged between 0.94 and 1.10 g/cm^3 (average 1.03 g/cm^3). The most frequent percent (75 %) of cucumber fruits in the sample had 0.95 – 1.05 g/cm^3 real density.

Projected area of fruit.

Fig. 6 indicates that the fruit projected area of sample ranges between 149.73 and 102.42 cm^2 (average 103.61 cm^2). The most frequent percent (75 %) of cucumber fruits in the sample have 130 - 150 cm^2 projected area.

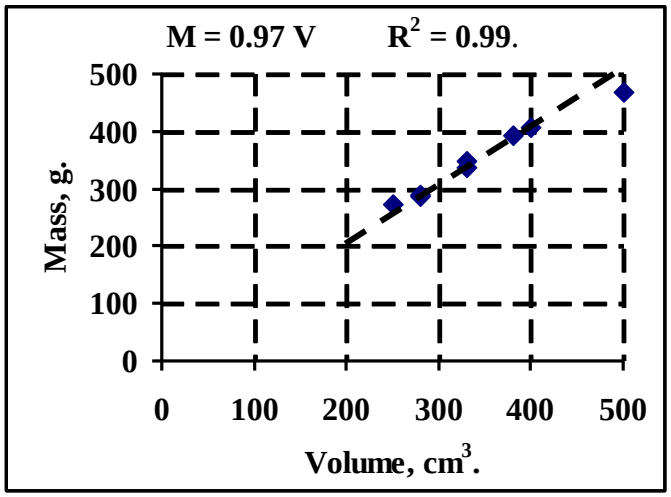

Fig. 5: The best fitted curve shows the relation between fruit volume and mass of cucumber fruits.

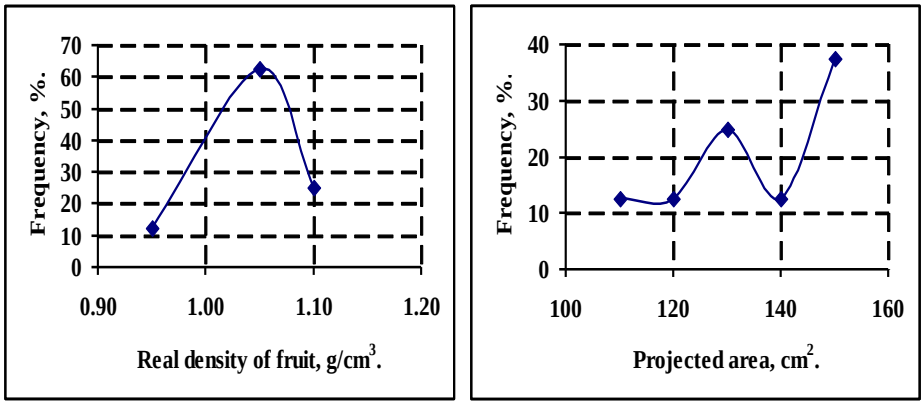

Fig. 6: Frequency curves distribution of fruit real-density and projected area of cucumber fruits.

Pulp thickness and mass.

Fig. 7 indicates that the pulp thickness and mass ranges of sample were 7 - 10 mm (average 8.4 mm) and 257.6 – 438.2 g (average 324.3 g)

respectively. The most frequent percent (87.5 %) of cucumber fruits in the sample have 7 - 9 mm thickness and (87.5 %) have 300 - 400 g mass.

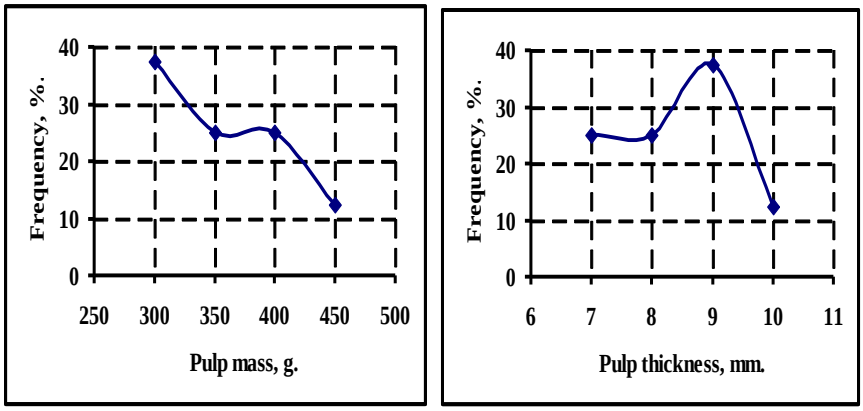

Fig. 7: Frequency curves distribution of pulp thickness and mass of cucumber fruits.

Mechanical properties of cucumber fruits:

Friction, rolling and repose angles of cucumber fruits.

Table 2 shows friction and rolling angles of cucumber fruits. The maximum friction angle (26 - 27 degree) and rolling angle ranges (22 - 26 degree) were obtained with wood surface. Whereas, the minimum ranges of friction and rolling angles (18 - 20 and 12 – 20 degree respectively) were obtained with aluminum surface.

Table 2: Friction and rolling angles for cucumber fruits with different surface types.

Surface type	Friction angle, degree			Rolling angle, degree		
	Min.	Max.	Av.	Min.	Max.	Av.
Wood	26	27	26	22	26	19.6
Metal	23	25	24	13	22	15.4
Galvan. Iron	22	24	23	9	20	13.3
Aluminum	17	20	18.5	11	20	15.8
Stainless Steal	18	20	19	12	20	16.3

Wood: wood sheet No. 2. Galvan.: galvanized.
The average repose-angle was about 22 degree.

Penetration force and firmness of cucumber fruits.

Table 3 shows the averages of penetration force and firmness distribution along cucumber surface were: the maximum = 42.7 N and 100.9 N/cm^2 at 10 mm from top of fruit, the minimum = 40 N and 94.7 N/cm^2 at 5 mm from top of fruit.

Cutting force of cucumber fruits.

Table 3 shows the axial cutting-forces of cucumber fruits were: the maximum = 65 N, the minimum = 30 N and the average = 42.8 N.

Table 3: Penetration force, Firmness and cutting force of cucumber fruits.

Mechanical properties	L, cm(1)	Min.	Max.	Av.	S. D.(2)	C. V.(3)
Penetration force, N	5	27	53	40	9.07	22.7
	10	27	70	42.7	28.57	12.18
	15	27	58	42.5	9.67	22.74
Firmness, N/cm^2	5	64	125	94.7	21.47	22.68
	10	64	166	100.9	28.82	28.57
	15	64	137	100.6	22.88	22.74
Cutting force, N	Axial	30	65	42.8	11.58	27.09

(1) L is the distance from top of fruit.
(1) S. D. is standard deviation.
(2) C. V. is coefficient of variation.

Application of the theory to the design of the cucumber seed-extractor.

Parameters required for development of the design of cucumber seed-extractor have been explained in the part 2d in the section on "Materials and Methods". Fig. 4 shows the parameters. Some results of this investigation point out to the following:

The physical and mechanical properties are incorporated in the design of the fruit hopper, reciprocating arm for fruit feeding (length and diameter), fixed cutting-knife to cut the cucumber fruit in axial direction (dimensions and sharpness) and two wings with scraper to extract the seeds from each fruit half and exit of the designed extractor as follows:

Fruit hopper (Fig. 4).

Hopper dimensions: to suit feeding rate, fruit length and bulk density of fruits = 100 x 25 x 60 cm for length, width and height respectively.

Fruit hopper bottom-slope = more than maximum friction angle of cucumber fruits with stainless steal surface (> 20^o) = 30^o.

Reciprocating arm.

Reciprocating arm with flexible finger is used to press the fruit to fixed knife.

Reciprocating arm stroke = Maximum fruit-length + 30 mm ≈ 233 mm.

Pressing-arm groove:

Groove length = Maximum fruit-length – Minimum fruit-length
= 230 – 200 = 30 mm.

Groove diameter = > maximum fruit-diameter = > 7 cm ≈ 7.4 cm.

No. of stroke per min to suit machine productivity = 30 to give 630 kg fruits/h and about 50 kg seeds/h.

Cutting knife.

Cutting knife used to cut the cucumber fruit in axial direction,

Knife height = more than maximum fruit diameter = > 7 cm = 7.2 cm.

Knife thickness = 1 mm.

Two wings with scrapers.

Two wings with scrapers used to extract the seeds from each fruit half.

Scraper diameter = minimum fruit diameter – 2 x maximum pulp thickness
= 52 – 2 x 10 = 32 mm.

Scraper height = 0.5 minimum fruit-diameter – maximum pulp-thickness
= 0.5 x 52 – 10 = 16 mm.

CONCLUSION

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

Physical properties of cantaloupe fruits: diameter = 52.15 – 229.5 mm, length = 52.15 – 68.87 mm, mass = 273.8 – 470.4 g, volume = 380 - 860 cm^3, projected area = 250 - 500 cm^2, real density = 0.94 -1.10 g/cm^3, bulk density = 0.41 g/cm^3, sphericity = 3.13 – 3.77.

Mechanical properties: cucumber-fruit firmness = 64 – 100.9 N/cm^2, the axial cutting- force = 30 - 70 N.

The physical and mechanical properties are incorporated in the design of the fruit hopper, reciprocating arm for fruit feeding (length and diameter), fixed cutting-knife to cut the cucumber fruit in axial direction (dimensions and sharpness) and two wings with scraper to extract the seeds from each fruit half and exit of the designed extractor.

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الخواص الطبيعية والميكانيكية لثمار الخيار واستخدامها لالة استخلاص بذور

إبراهيم يحيى السيد[1]، مرفت محمد عطاالله[1]، خليل السيد خليل[1] و أحمد ماهر الليثى[2]
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تهدف هذه الدراسة إلى تعيين الخواص الطبيعية والميكانيكية لثمار خيار البذرة، للاستفادة منها فى تصميم وتشغيل آلات ومعدات تداول ثمار الخيار، وتم أقتراح فكرة تصميم آلة استخلاص بذور من ثمار الخيار كمثال. وتم الحصول على النتائج التالية:

(1) الخواص الطبيعية:

(أ) أبعاد الثمرة: وجد أن قطر ثمار الخيار يتراوح بين 52.15 و 68.87 مم والطول بين 196.4 و229.5 مم،

(ب) كتلة وحجم وكثافة الثمار: وجد أن كتلة ثمار الخيار تتروا ح بين 273.8 و 470.4 ج، والحجم بين 250 و 500 سم^3 وكثافتها الحقيقية تتراوح بين 0.94 و1.01ج/سم^3.

(ج) المساحة المعرضة: وجد أن المساحة المعرضة تتروا ح بين 102.42 و149.73 سم^2.

(د) سمك وكتلة القشرة: وجد أن سمك القشرة يتراوح بين 7 و10 مم، وكتلة القشرة بين 257.6 و438.2 ج.

(هـ) كتلة وعدد البذور في الثمرة: وجد أن عدد كتلة الثمرة تراوح بين 12.2 و42.4، وعدد البذور/الثمرة بين 390 و580 بذرة.

(2) الخواص الميكانيكية:

(أ) زاوية الاحتكاك والتدحرج والتكويم: وجد أن متوسط زاوية الاحتكاك لثمار الخيار هى 26، 24، 23، 18.5، 19 درجة على أسطح خشب، صاج عادى، صاج مجلفن، ألومنيوم، ستانلس ستيل على الترتيب. بينما كان متوسط أقصى زاوية تدحرج هى 19.6، 15.4، 13,3، 15.8، 16.3 درجة للأسطح السابقة الذكر على الترتيب. ووجد أن متوسط زاوية التكويم حوالى 22 درجة.

(ب) صلابة الثمار: وجد أن متوسط أقصى صلابة لثمار الخيار هو 166 نيوتن/سم^2 عند بعد 10سم من طرف الثمرة، ومتوسط أقل صلابة هو 64 نيوتن/سم^2 عند بعد 5 سم من طرف الثمرة.

(ج) قوة القطع المحورية: وجد أن متوسط القوة اللازمة لقطع الثمرة محورياً باستخدام سكينة يسمك 1 مم تراوحت بين 30– 65 نيوتن

وبالدراسة تطبيق لبعض النتائج على تصميم آلة لإستخلاص بذور الخيار.

قام بتحكيم البحث

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