PHYSICAL PROPERTIES FOR SOME EGYPTIAN VARIETIES OF OLIVE FRUITS AND THEIR RELATION TO OLIVE CONVEYING AUGER DESIGN

MATOUK, A. M.[1], A. E. ABOU ELMAGD[1], A. S. HAMAM[2] AND T. R. OWIES[2]

[1] *Agric. Eng., Dept., Faculty of Agric., Mansoura Univ.*

[2] *Agric. Eng., Res. Inst. A. R. C, Giza.*

(Manuscript received 14 July 2004)

Abstract

The aim of the present investigation is to determine most of the physical properties for five different varieties of olive fruits that represent the two main classes of olive oil production, namely: (*Shimlaly* and *Cronaki*, as oil production varieties), and (*Watiken*, *Picual*, and *Manzanillo*, as double purpose varieties) and their relation to olive conveying auger design.

Physical properties for the investigated varieties of olive fruits were measured or calculated in terms of dimensional characteristics (length, diameter, and flesh thickness), mass, volume, bulk density and real densities, porosity, sphericity, number of fruits per kilogram, percentage of flesh/fruit, and flesh/pit ratio.

Statistical analyses were carried out to express the significant variation among varieties and the deviation of the measured values around its average. The results showed that there are highly significant differences among the investigated varieties. Therefore, the mean values of physical properties for the investigated fruits and their pits ranged from (11.85 to 31.53 mm), (7.49 to 24.01 mm), (1.18 to 7.20 mm) for length, diameter, flesh thickness, respectively. As well, the properties for fruit mass, bulk density, real densities, porosity, sphericity, number of fruits per kilogram ranged from (0.46 to 9.00 g), (627.91 to 713.58 kg/m^3), (1118.92 to 1201.44 kg/m^3), (40.6 to 43.88 %), (0.999 to 1.93), (165.32 to 833.33 fruit/kg).

In addition, the values of mass percentage of flesh/fruit, flesh/pit ratio, pit length, pit diameter, and pit weight ranged from (19.36 to 93.00 %), (0.24 to 13.29), (11.36 to 21.68 mm), (5.52 to 16.24 mm) and (0.20 to 2.14 g), respectively.

A set of empirical equations have been proposed with reasonable accuracy to predict the actual volume from the measurements of the three main dimensions of the investigated varieties of olive fruits. A conveyor auger was designed and tested based on the obtained results.

INTRODUCTION

During the last two decades, a great care has been given in Egypt to increase the planted area of olive trees. Therefore, the cultivated area increased from 82.685 in

1996 to 134.608 thousand feddans in 1999 with an increase approximately 62.8 %, this led to an increase in the total production of olive fruits from 208.133 to 288.027 thousand tons in the years 1996 and 1999 respectively with approximately 38.4 % increase. (Agricultural statistics, 1999). Meanwhile future increase is expected since many newly reclaimed areas were planted with new olive varieties and not yet arrived to a full productivity.

Therefore, number of olive varieties have been imported as foreign varieties and grown side by side the local varieties in different locations in Egypt. Olive's fruit is the main source of the unique edible oil among vegetable oils.

It is essential to have a rational understanding of the physical properties of olive fruits, which govern the response of agricultural biological materials. This understanding will permit the designers to achieve the proper design or the development of any specific machine dealing with the crop such as the conveying augers.

Therefore, the aim of the present study is to investigate some of the most important physical properties for five different varieties of olive fruits representing local and introduced olive cultivars in the areas surrounding Cairo-Alexandria desert road and Borg El Arab area. It is hoped that the results may be considered as a rational step towards a complete data base helping in determining the most promising characteristics of olive fruits during harvesting, handling, and grading, and could be considered as important engineering parameters for designing or developing some specific machines or working units during processing, especially the olive conveying augers.

REVIEW OF LITERATURE

Mohsenin (1984) stated the importance of economical increase in food materials and supplies together with the complexity of modern technology for their production, handling, storage, processing, preservation, quality evaluation, distribution and marketing and utilization,which demand a better knowledge of significant physical and mechanical properties of these materials from their production on the farm till they reach the consumers. Knowledge of physical and mechanical properties should constitute important and essential engineering data base in the design of machines, structures, processes, and controls and in the analysis and determination of the efficiency of their performance.

Klenin *et al.* (1985) also stated that the agricultural products are cleaned and graded according to various criteria governing each material. These criteria are: geometric size of each particle, its aerodynamic properties, the shape and state of the surface, density and specific weight, electric conductivity and color.

Meanwhile Buyanov and Voronyuk (1985) concluded that, for example, the size-weight characteristics of pumpkins are compiled by the methods used for similar crops. They found that the shape index of fruits (I) can be estimated according to the ratio of the main dimensions such as length (L) and diameter (D). If (I) is less than 0.9, the fruit belongs to the oblate group, if (I) is greater than 1.1, it belongs to the oblong group. The remaining fruits with intermediate index values are considered round.

According to Chakraverty (1987), the knowledge of important physical properties such as shape, size, volume, surface area, density, porosity, color, etc., of different agricultural materials are necessary for the design of various separating, processing and handling, storing and drying systems. The density and specific gravity values are also used for the calculation of thermal diffusivity and Reynolds number. He added that the angle of repose and frictional properties of agricultural materials play an important role in selection or in design features of hoppers, chutes, dryers, storage bins and others equipment for agricultural materials flow.

Wherever Ibrahim (1992), mentioned that the processed materials vary considerably in their physical properties such as size, shape, density, volume, specific gravity, porosity, and surface texture. These characteristics are very important in many problems associated with design or development of a specific machine, analysis of the behavior of the product in handling of the material, and stress distribution in the material under load.

On the other hand, Fouad *et al.*(1992) illustrated that in Egypt, a great care has been given in the last few years to increase the area cultivated with olives, therefore a number of foreign cultivars of olive trees have been imported and grown, beside local cultivars in different locations in Egypt. Data are lacking about fruit characteristics of most cultivars under the local conditions. They evaluated 35 local and newly introduced olive cultivars in the experimental orchard concerning fruit physio-chemical properties. They found that fruit length ranged from 1.51-3.59 cm, fruit width from 0.93 – 2.73 cm, fruit shape index from 1.09-1.74, fruit weight from

0.98-12.90 g, pit weight from 0.26-1.68 g, percentage of oil of the entire fruit from (5.15-26.24) and (23.26-60.04) at fresh weight and dry weight, respectively.

The physical properties for different agricultural products have been recognized by many researchers [Cyrus (1992), Pearson *et al.*(1994), and Mosa (1998)], as important factors in designing various handling equipment.

Sitkei (1986) stated that knowledge of the properties of agricultural materials permits the design of more modern machines and technological processes with improved work quality characteristics, involving lower losses and more efficient operations.

MATERIALS AND METHODS

The overall objective of the present study is to investigate physical properties for some prevailing olive fruit varieties used in Egypt, especially in the areas surrounding the Cairo-Alexandria desert road and in Borg El Arab area. These properties may be utilized effectively in designing or developing new olive oil production, pickling processing, grading machines, and in the analysis of the behavior of olive fruit in handling, packing, and storage. Therefore the machines, processes and handling operations can be designed for maximum performance and highest possible quality of the final products.

3.1. Material: the investigated olive fruits in the present study were classified as:

a - Oil production varieties : (*Shimlaly* and *Cronaki*),

b - Double purpose varieties : (*Watiken*, *Picual*, and *Manzanillo*).

The selected varieties of the present study were collected from different farms along Cairo-Alexandria desert road and Borg El Arab area through seasons from 1998 to 2001 with random samples of 100 ripened fruits for each variety per season. The average moisture contents ranged from 58.24 to 62.86,% (w.b.) The collected data were statistically analyzed to clear the variation between varieties, and also to deduce empirical equations for predicting some of the required results.

3.2. Physical properties of fruits and their pits:

3.2.1. Size and Shape index: size of olive fruit was determined by measuring the main two axes of fruit and its pit to obtain the major axis as [fruit length (L), pit length $(L_{pit})_f$], the intermediate diameter as [fruit diameter (D), pit diameter $(D_{pit})_f$], and the thickness of flesh $(T)_{f1.}$ in millimeters using a digital vernier caliper with an accuracy of 0.01 mm, for each olive fruit of the investigated varieties. Shape index or sphericity of the measured samples was calculated according to (Buyanov and Voronyuk 1985) as follows:

where: $I = L / D_f$

I = Shape index,

L = Length of fruit, mm,

D_f = Diameter of fruit at the middle of its length, mm.

The obtained data were compared and classified according to the recommended limits.

3.2.2. Mass and Volume: the mass of each fruit and its pit were determined using an electronic digital balance having a sensitivity of 0.001 g.. Volume of olive fruits was measured by immersing each fruit in 10 or 20 ml graduated cylindrical beaker filled with tap water to a fixed limit, the displaced water was sucked by 2 ml pipette with 0.01 cm^3 accuracy to determine the accurate volumes of individual fruit according to the following equation:

$$V = \frac{W_{d.w.}}{SP.\,W_w}$$

where:

V = The volume of individual fruit, mm^3 ,

$W_{d.w.}$ = Mass of displaced water of the individual fruit, g,

$SP.\,W_w$ = Specific mass of water of the individual fruit , g / mm^3.

The obtained (actual) volume of the individual fruits for the investigated varieties was compared with the theoretical volume, which was determined according to (Mohsenin, 1984) as follows:

$$V = (\pi / 6) * L * D_f^2$$

where:

V = Is the volume of individual fruit, mm^3,

L = Length of the olive fruit, mm,

D_f = Diameter of the olive fruit, mm.

Regression analysis for the actual and calculated volumes for olive fruits were carried out to find the correction factor which should be applied with the theoretical calculations (Mohsenin 1984) to be applicable for the investigated olive varieties with minimum errors.

3.2.3. Densities: the density of the agricultural material can be described in two ways. The real density or solid density of a material which refers to the density of a single kernel, whereas bulk density refers to the density of the material in bulk with the inter space between fruits, each of them was calculated by dividing either the mass of individual fruit or mass of a bulk of fruit per its volume, respectively.

a- Real density: real density of the olive fruits was measured and calculated as follows:

$$P_R = We / V_{meas.}$$

where:

P_R = Real density of the individual fruit,g/cm^3,

We = Mass of the olive fruit, g,

$V_{meas.}$ = Measured volume for the individual olive fruit, cm^3.

b- Bulk density: the bulk density of the olive fruits was calculated by dividing the mass of olive fruits in a specified volume, given by:

$$P_B = We_{Bulk} / V_{Bulk}$$

where:

P_B = Bulk density of the olive fruits, kg/m^3,

We_{Bulk} = Mass of bulk olive fruit, kg,

V_{Bulk} = Calculated volume of bulk olive fruit, m^3.

The obtained values of each variety were the average of five replicates.

3.2.4. Porosity: porosity of the investigated varieties was determined as the percentage of volume of inter-fruit space within the volume of a bulk of fruits by using porosity measuring device as shown in figure (1). It was designed and fabricated according to both (*Mohsenin 1984*, and *Matouk 2001*) at the workshop of Agric. Eng. Dept., Mansoura University, and it was checked for air leakage thoroughly.

Olive fruits were filled in tank No.2 before closing both of valves 2 and 3. The air was supplied in tank No.1, when a suitable manometer displacement was used, valve 1 was closed and the steady state pressure P_1 was recorded. After that, valve 2 was opened keeping valves 1 and 3 closed. A steady state manometer reading P_2 was recorded. Then, the porosity of olive fruits was found by the following formula:

$$p = ((P_1 - P_2) / P_2) * 100$$

where:

- p = the porosity of agricultural materials, %,
- P_1 = steady state pressure inside tank 1, bar,
- P_2 = steady state pressure in both tank 1 and 2 together, bar.

The obtained values are the average of five recorded replicates for all samples.

Figure 1. Porosity measuring device.

3.2.5. Flesh/ fruit mass %, and flesh/pit mass ratio: these percentages or ratios were calculated for the individual fruit by using the weight of fruits and its pit as follows:

$$\text{Flesh/fruit mass \%} = (W_{fr} - W_{Pit})*100 / W_{fr}$$

$$\text{Flesh/pit mass ratio} = (W_{fr} - W_{Pit}) / W_{Pit}$$

where:

- W_{fr} = the mass of a single olive fruit, g,
- W_{Pit} = mass of a pit for the same olive fruit, g.

3.3. Technical parameters calculation of olive conveying auger: the capacity of a feed auger was calculated according to (El-Sahrigi, 1997) as follows:

$$Q = 60\frac{\pi}{4}(D_o^2 - D_s^2)\,(P - p_1)\rho\eta n = 15(D_o^2 - D_s^2)\,2)(P - p_1)\rho\eta n$$

where:

- Q = The auger (screw) capacity, kg/h,
- D_O = Outer diameter of the screw, m,
- D_S = Diameter of auger shaft, m,
- P = Pitch of the auger, m,
- T_h = Thickness of screw wall, m,
- ρ = Bulk density of olive fruits, kg/m^3
- η = Auger conveying efficiency,%,
- n = Auger rotating speed, rpm.

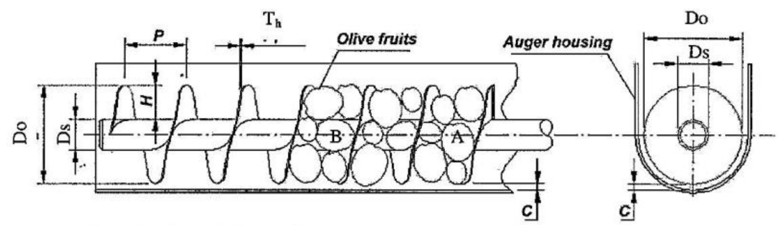

Figure 2. Schematic diagram of conveying auger for the investigated varieties of olive fruits.

Determination of the auger dimensions may be assumed as follows:

1- The auger pitch (P) should be more than the maximum length of one or more fruits, then: $P > L_{max.}$

where: $L_{max.}$ is the maximum length of the investigated fruits, mm.

2- The depth of auger groove (H) should be more than the maximum length of olive fruits if the fruits move in the vertical position A, or it should be more than 1-2 of the maximum diameter of fruits if it moves in the horizontal position B, then: $H = [(D-d)/2] > L_{max.}$ or $D_{f\ max.}$

where:

$D_{f\ max.}$ = Maximum diameter of fruits, mm.

3- The clearance between auger lips and housing (C) should be less than the minimum diameter of the investigated fruits, then:

$$C < D_{f\ min.}$$

where:

$D_{f\ min.}$ = Minimum diameter of fruits, mm.

4- The auger conveying efficiencies (η) were laboratory estimated for all of the investigated varieties using the designed feeding box.

Therefore, both of the capacity or auger and the rotating speed could be estimated by knowing one of them:

RESULTS AND DISCUSSION

4.1. Physical properties of the investigated fruits and their pits: determinations of the main dimensions of olive fruits are very important for describing their technological characteristics in many respects. The measured dimensions of olive fruits such as, length, diameter, and flesh thickness affect the processes involved in many applications such as grading, sorting and conveying with belts or augers. The results of physical properties for the five different investigated varieties of olive fruits, which were measured or calculated, were statistically analyzed, represented graphically either in a variation frequency distribution curves or plotted in a histogram of the mean values, and discussed as follows:

Typical mean values obtained from large number of observations for the investigated olive varieties are given in Table (1), with the arithmetic means of all samples, range of values, and other statistical indices for the main dimensions of the studied varieties such as, [standard deviation (σ_{n-1}), standard error (S.E), and coefficient of variance (C.V.,%)] to show the dispersion of the measured values around their mean.

4.1.1. Size of the fruit, its pit, and shape index (Sphericity): it can be seen from Table 1 and (Fig. 3) that olive fruits under study vary greatly in fruit size and shape index as follows:

a- Fruit length: the results showed that the dispersions are higher in both Picual and Manzanillo than Shimlaly than other varieties. The obtained values of C.V. for fruit length were sorted gradually from the maximum to the minimum such as, (12.96, 10.11, 10.10, 9.52, and 7.86, %) for Shimlaly, Picual, Cronaki, Manzanillo, and Watiken variety, respectively. The general average values of fruit length for the investigated varieties were (16.46, 17.34, 20.89, 25.85, and 24.03, mm) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo, respectively. The maximum length of the investigated variety was 31.53 mm for Picual variety, the design of the auger pitch should be more than that value.

b- Fruit diameter: the frequency distribution curves for fruit diameter illustrated that the curves for Picual and Cronaki have much bigger base than other varieties, indicating that the two varieties are much more variable, and that curves showed a general specific peculiarity. Consequently, the obtained values of C.V. for fruit diameter were sorted gradually from the largest to the smallest for instance, (12.70, 11.29, 8.67, 8.00, and 7.89, %) for Shimlaly, Manzanillo, Cronaki, Picual, and Watiken variety, respectively. The general average values of fruit diameter for the investigated varieties were (10.82, 13.48, 16.40, 19.85, and 19.58, mm) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo, respectively. The maximum value of fruit diameter was 23.91 mm, consequently the depth of the designed auger should be more than that value.

c- Flesh thickness: the frequency distribution curves for flesh thickness of fruits indicated that Picual and Shimlaly have much bigger base than other varieties. The calculated values of C.V of fruit flesh thickness were sorted from the highest to the lowest such as, (23.20, 14.81, 14.21, 11.65, and 10.20,%) for Shimlaly, Watiken, Picual, Manzanillo, and Cronaki variety, respectively. It can be noticed that Shimlaly variety has the heightest values of coefficient of variance compared with other values, which may be considered as indicator to the biggest diffusion of the flesh thickness inside Shimlaly variety. The general average values of fruit flesh thickness for the investigated varieties were (2.22, 2.61, 3.39, 5.18, and 5.45, mm) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo, respectively.

d- Pit length: the frequency distribution curves for pit length as shown in Fig. (4) showed that the dispersions are higher in both Picual and Manzanillo than other varieties. The obtained values of C.V. for pit length were sorted from the highest to the lowest such as; (9.86, 8.69, 8.23, 6.58, and 5.60, %) for Picual, Manzanillo, Shimlaly, Watiken, and Cronaki variety, respectively.

The general average values of pit length for the investigated varieties were (14.535, 13.509, 15.584, 18.510, and 14.938, mm) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo, respectively.

e- Pit diameter: the obtained values of C.V. for pit diameter (Fig. 4) were sorted from the largest to the smallest such as,(14.60, 14.13, 7.87, 6.68, and 4.50, %) for Manzanillo, Picual, Watiken, Shimlaly, and Cronaki variety, respectively. The average values of pit diameter for the investigated varieties were (6.36, 6.09, 8.44, 11.35, and 8.82, mm) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

f- Sphericity or shape index: the results in (Fig. 4) showed that all varieties except Shimlaly variety plotted through the same limit ranged From 1.1 to 1.7, but Shimlaly variety ranged from 1.3- 2.0, considered more pronounced in length than diameter. Meanwhile, most of the fruits of all varieties may be considered as belong to oblong group according to the classification of (Buyanov and Voronyuk, 1985). The average sphericity of the investigated varieties were (1.53, 1.29, 1.28, 1.30, and 1.23) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

Table 1. Statistical index of physical properties for the investigated varieties of olive fruits and their pit.

Properties	Varieties	Average $\bar{X}$	Range, Min - max	S.D. (δn-1)	S.E. ($S_{\bar{x}}$)	C.V. %
Fruit Length, mm	*Shimlaly*	16.46	11.85 - 25.48	2.1327	0.2133	12.96
	Cronaki	17.34	13.26 - 22.15	1.7519	0.1752	10.10
	Watiken	20.89	14.85 - 24.92	1.6422	0.1642	7.86
	Picual	25.85	17.90 - 31.53	2.6121	0.2612	10.11
	Manzanillo	24.03	17.96 - 29.34	2.2885	0.2289	9.52
Fruit Diameter, mm	*Shimlaly*	10.82	07.49 - 15.02	1.3743	0.1374	12.70
	Cronaki	13.48	10.49 - 16.71	1.1681	0.1168	8.67
	Watiken	16.40	11.98 - 18.11	1.2944	0.1294	7.89
	Picual	19.85	14.97 - 24.01	1.5886	0.1589	8.00
	Manzanillo	19.58	13.50 - 23.91	2.2115	0.2211	11.29
Pit Length, mm	*Shimlaly*	14.54	12.42 - 17.44	1.196	0.120	8.23
	Cronaki	13.51	11.73 - 14.78	0.757	0.076	5.60
	Watiken	15.58	12.82 - 17.81	1.025	0.103	6.58
	Picual	18.51	11.39 - 21.68	1.791	0.179	9.68
	Manzanillo	14.94	11.36 - 17.64	1.297	0.130	8.69
Pit Diameter, mm	*Shimlaly*	6.36	5.520 - 7.15	0.425	0.042	6.68
	Cronaki	6.09	5.550 - 6.64	0.274	0.027	4.50
	Watiken	8.44	7.020 - 10.20	0.664	0.066	7.87
	Picual	11.35	8.100 - 16.24	1.604	0.160	14.13
	Manzanillo	8.82	6.010 - 11.23	1.288	0.129	14.60
Flesh thickness, mm.	*Shimlaly*	2.22	1.180 - 3.900	0.5148	0.0515	23.20
	Cronaki	2.61	1.960 - 3.550	0.2667	0.0267	10.20
	Watiken	3.39	1.900 - 4.210	0.5021	0.0502	14.81
	Picual	5.18	3.150 - 6.610	0.7353	0.0735	14.21
	Manzanillo	5.45	4.010 - 7.200	0.6349	0.0635	11.65
Sphericity, or shape Index	*Shimlaly*	1.53	1.300 - 1.930	0.1239	0.0124	8.12
	Cronaki	1.29	1.002 - 1.606	0.1112	0.0111	8.62
	Watiken	1.28	1.001 - 1.470	0.0925	0.0092	7.24
	Picual	1.30	1.141 - 1.501	0.0842	0.0084	6.47
	Manzanillo	1.23	1.068 - 1.514	0.0871	0.0087	7.49

where:

S.D. = Standard deviation,

S.E. = Standard error,

C.V. = Coefficient of variance.

Table (2) shows that the percentages of shape classes for each variety were (0, 3, 5, 0, and 1, %) belonging to the round shape, and (100,97,95,100,and 99 %) were belonging to the oblong shape for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

Table 2. Distribution of the obtained data within the three main classes of shape index or sphericity.

Varieties	Classes of shape		
	Oblate < 0.9	0.9< Round <1.1	1.1<Oblong
Shimlaly	---	0 %	100 %
Cronaki	---	3 %	97 %
Watiken	---	5 %	95 %
Picual	---	0	100 %
Manzanillo	---	1 %	99 %

Generally, the results and the overlapping among the frequency distribution curves for most of the studied parameters indicated that the investigated varieties should be classified according to their physical properties into three classes or groups as follows:

1- 1st group including Shimlaly and Cronaki varieties which were approximately similar in most of their properties.

2- 2nd group including Picual and Manzanillo varieties which were approximately similar in most of their properties but having big differences from the first group.

3- 3rd group including (Watiken variety) which has specifications lie between the previous two groups.

4.1.2. Weight of fruits and their pits: the results of the frequency distribution curves of fruit weight as shown in Fig. (5) showed that, the curves of both Picual and Manzanillo varieties have much larger bases than other varieties. The statistical analysis in Table (3) showed that the maximum C.V. was (35.10, %) for Shimlaly variety, but the minimum C.V was (14.89, %) for Cronaki variety, while the mean values were (1.20, 1.80, 3.14, 6.05, and 5.43, g) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

On the other hand, the investigated olive varieties varied greatly in pit weight as illustrated in Table (3) ranged from [(0.24-0.50), (0.20-0.40), (0.50-0.90), (0.75-2.14), and (0.28-1.09), g] for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively. The statistical analysis showed that the maximum C.V. was (26.27, %) for Manzanillo variety, but the minimum C.V was (16.88, %) for Watiken variety, while the mean values were (0.34, 0.28, 0.62, 1.09, and 0.70, g) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

4.1.3. Number of fruits per kilogram:

It can be seen in Fig. (5) that the number of olive fruits per kilogram for the investigated varieties were 666.67, 556.17, 318.47, 165.32, and 184.26 for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

These results were expected since the number of fruits per kilogram inversely proportional with the weight of one fruit.

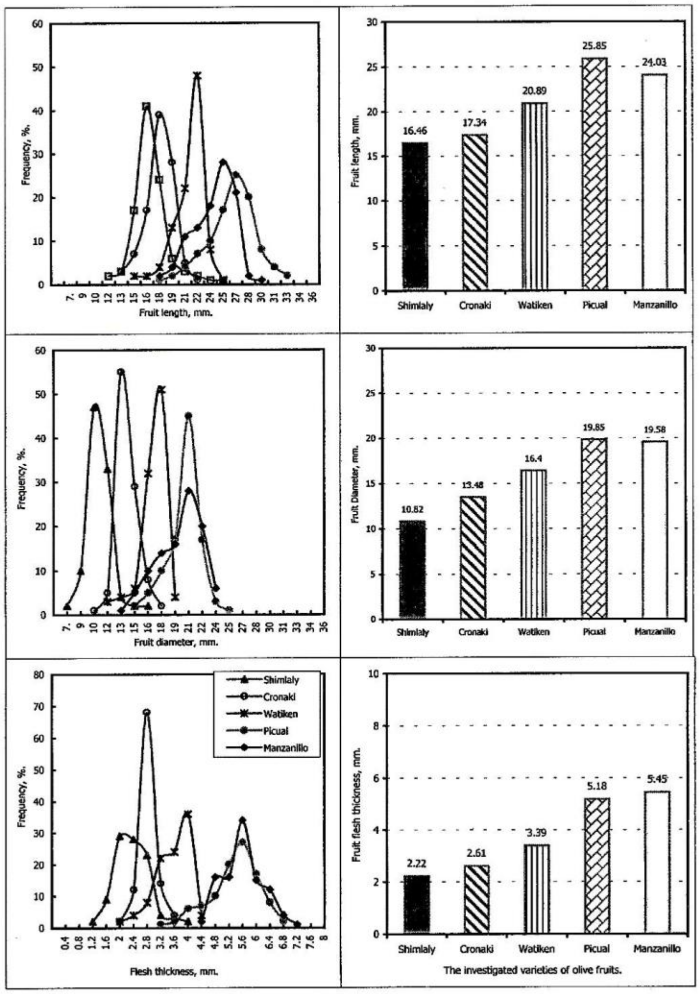

Fig.(3): Frequency distribution curves and mean values of fruit le diameter, and flesh thichness for the investigated varie

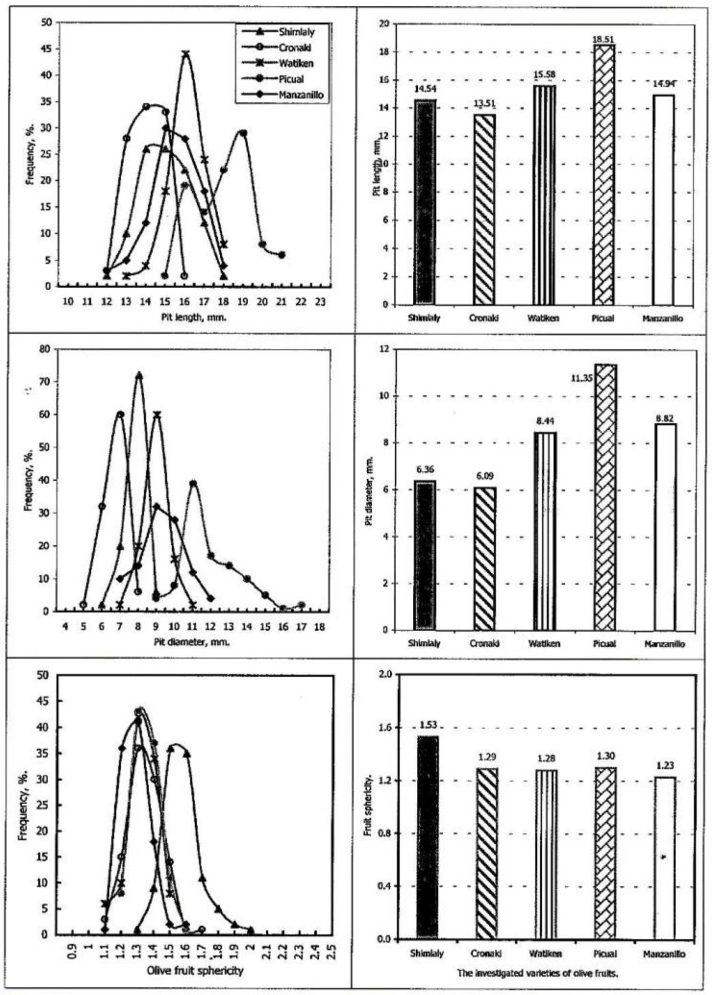

Fig.(4): Frequency distribution curves and mean values of fruit sphericity, pit length, and pit diameter for the investigated varieties.

Table 3 . Statistical index of physical properties for the investigated varieties of olive fruits and their pits .

Properties	Varieties	Average $\overline{X}$	Range, Min - max	S.D. (δn-1)	S.E. ($S_{\bar{x}}$)	C.V. %
Fruit Weight, g.	SHIMLALY	1.203	0.46 - 2.68	0.4220	0.0422	35.10
	CRONAKI	1.798	0.88 - 2.93	0.3753	0.0375	20.87
	WATIKEN	3.142	1.86 - 4.25	0.4677	0.0468	14.89
	PICUAL	6.0490	2.52 - 9.00	1.3270	0.1327	21.94
	MANZANILLO	5.427	2.01 - 8.87	1.5346	0.1535	28.28
Pit Weight, g	SHIMLALY	0.343	0.240 - 0.50	0.059	0.006	17.22
	CRONAKI	0.278	0.200 - 0.40	0.058	0.006	20.82
	WATIKEN	0.622	0.500 - 0.90	0.105	0.011	16.88
	PICUAL	1.088	0.750 - 2.14	0.259	0.026	23.83
	MANZANILLO	0.700	0.280 - 1.09	0.184	0.018	26.27
Measured volume, cm^3	SHIMLALY	1.003	0.38 - 2.18	0.3495	0.0349	34.86
	CRONAKI	1.500	0.74 - 2.51	0.3230	0.0323	21.54
	WATIKEN	2.685	1.58 - 3.64	0.4121	0.0412	15.35
	PICUAL	5.2404	2.15 - 8.38	1.2082	0.1208	23.06
	MANZANILLO	4.859	1.79 - 7.72	1.3856	0.1386	28.52
Calculated volume, cm^3	SHIMLALY	1.051	0.391 - 2.834	0.4100	0.0410	39.00
	CRONAKI	1.677	0.777 - 2.831	0.4146	0.0415	24.72
	WATIKEN	2.976	1.129 - 3.908	0.5476	0.0548	18.40
	PICUAL	5.4303	2.287 - 8.601	1.2425	0.1242	22.88
	MANZANILLO	4.965	1.857 - 7.919	1.4186	0.1419	28.58
Real Density, g/cm^3	SHIMLALY	1.1987	1.118 - 1.233	0.0234	0.0023	1.953
	CRONAKI	1.2014	1.102 - 1.259	0.0383	0.0038	3.19
	WATIKEN	1.1726	1.064 - 1.258	0.0345	0.0034	2.94
	PICUAL	1.1574	1.048 - 1.229	0.0383	0.0038	3.31
	MANZANILLO	1.1189	0.988 - 1.177	0.0362	0.0036	3.23
Flesh/fruit Percentage	SHIMLALY	68.106	19.36 - 89.18	12.4201	1.2420	18.24
	CRONAKI	84.277	76.92 - 89.76	3.0978	0.3098	3.68
	WATIKEN	79.897	69.85 - 85.58	3.7451	0.3745	4.69
	PICUAL	80.999	52.38 - 87.17	7.0994	0.7099	8.77
	MANZANILLO	86.719	72.82 - 93.00	3.1300	0.3130	3.61
Flesh/Pit Ratio.	SHIMLALY	2.615	0.24 - 8.24	1.4702	0.1470	56.23
	CRONAKI	5.599	3.33 - 8.77	1.2532	0.1253	22.38
	WATIKEN	4.137	2.32 - 5.93	0.9027	0.0903	21.82
	PICUAL	4.7503	1.10 - 6.79	1.3886	0.1389	29.23
	MANZANILLO	6.857	2.68 - 13.29	1.5180	0.1518	22.14

where:

S.D. = Standard deviation,

C.V. = Coefficient of variance.

S.E. = Standard error,

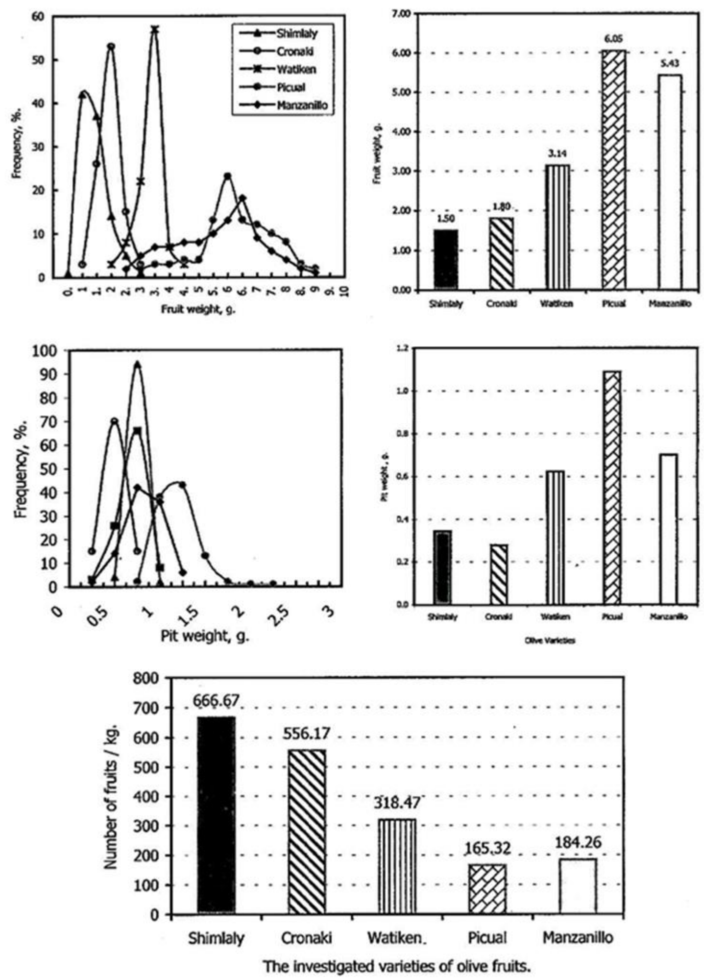

Fig.(5): Frequency distribution curves and mean values of fruit weight, pit weight, and number of fruits per kilogram for the investigated varieties.

4. 1.4. Fruit volume (measured and calculated): the obtained data of measured volume: ($V_{mea.}$) showed that the maximum value of C.V was 34.86 % for Shimlaly variety, while the minimum value of C.V. was 15.35 % for Watiken variety. Data in Table 3 also showed that there is a wide variation within the general averages of the varieties, which were (1.00, 1.50, 2.69, 5.24, and 4.86, cm^3) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

On the other hand, the maximum value of C.V of calculated volume: ($V_{Cal.}$) was 39.00 % for Shimlaly variety, while the minimum value was 18.40 % for Watiken variety, meanwhile the averages were (1.05, 1.68, 2.98, 5.43, and 4.97, cm^3) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

Generally, the results showed that there are significant differences between the calculated and measured volumes of each fruit varieties. The following linear model was fitted to the data by using liner regressions analysis as shown in Fig. (6):

$$Y = b\,X$$

where:

X = the calculated volume $[(\pi / 6) * L * D^2]$, ($V_{Ca.l}$), cm^3,

Y = the measured volume, ($V_{Mea.}$) cm^3.

b = constant, (varied according to the investigated varieties).

The regression equations for the studied varieties were as follows:

Shimlaly variety	: $V_{Mea} = 0.5014\ L.\ D^2$	$R^2 = 0.9311$
Cronaki variety	: $V_{Mea} = 0.4754\ L.\ D^2$	$R^2 = 0.9572$
Watiken variety	: $V_{Mea} = 0.4738\ L.\ D^2$	$R^2 = 0.9640$
Picual variety	: $V_{Mea} = 0.5056\ L.\ D^2$	$R^2 = 0.9901$
Manzanillo variety	: $V_{Mea} = 0.5124\ L.\ D^2$	$R^2 = 0.9834$
All investigated varieties	: $V_{emp} = 0.4946\ L.\ D^2$	$R^2 = 0.9940$

where:

V_{Mea} = the measured values of volume, mm^3,

L = the fruit length, mm,

D = the fruit diameter, mm.

4.1.5. Real density, bulk density and porosity of olive fruits: the results of real density, bulk density, and porosity of olive fruits showed that the values of the three observed characteristics were widely varied as shown in Fig. (7).These variation depend greatly on the difference in fruit sizes, volumes, and the inter-spaces between the fruits each other, consequently, each characteristic was measured and represented as follow:

a- Real density: the maximum values of real density were 1201.44 kg/m^3 and 1198.70 kg/m^3 for both Cronaki and Shimlaly varieties, while the minimum values were 1118.92 kg/m^3 and 1157.37 kg/m^3 for both Manzanillo and Picual varieties, respectively. Consequently, this observed of the evident variations of real density led to the mass effect of the percentage of oil and other components inside the fruits which affect on the mass of that fruits.

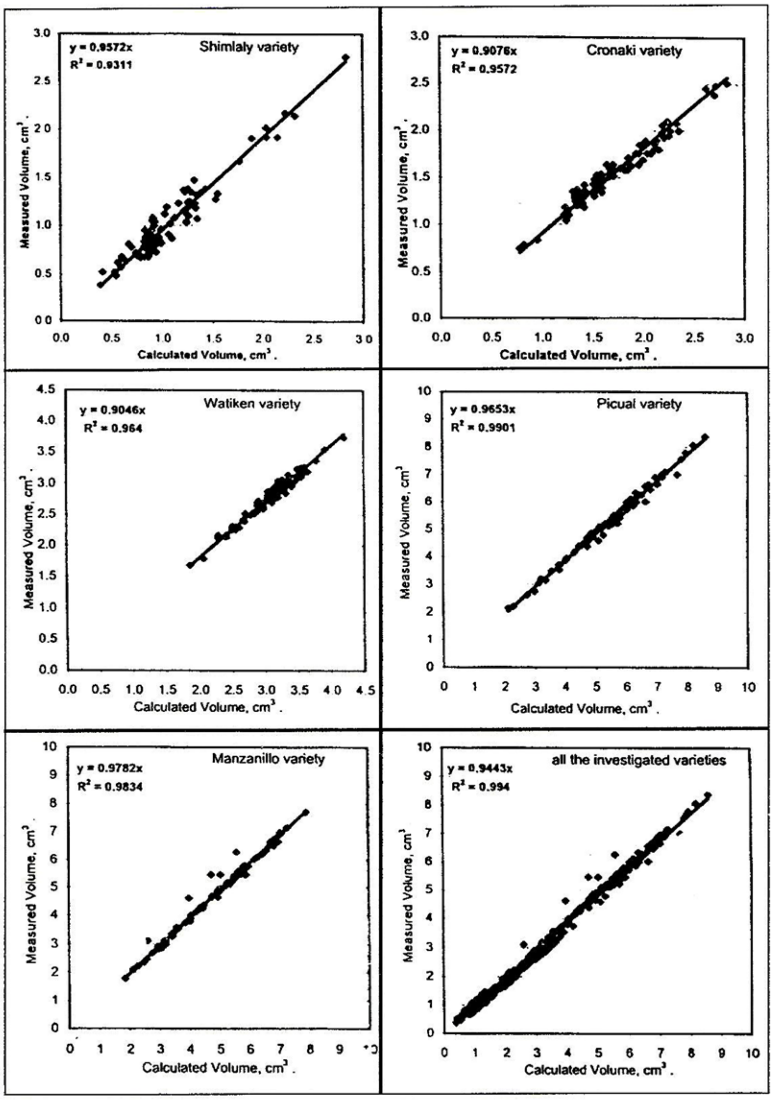

Fig.(6): Regression analysis and emperical equations for estimating the actual volume of individual olive fruits for the investigated varieties

b- Bulk density: the results indicated that bulk densities of olive fruits were inversely proportional with its volume and size. The maximum values of bulk density were 713.58 kg/m^3 and 710.23 kg/m^3 for both Cronaki and Shimlaly varieties, while the minimum values were 662.43 and 627.91 kg/m^3 for Picual and Manzanillo variety, respectively. In this research, the bulk density used practically as important parameter for designing the conveyor auger, which could be used for feeding the crushing unit by olive fruits.

c- Porosity: the obtained mean values were represented graphically in Fig (7). Fruit porosity of Manzanillo variety was the highest compared with those for all other varieties, while porosity of Cronaki variety was the lowest compared with those for all other varieties. The mean values of the obtained porosity were 40.75, 40.6, 41.16, 43.25, and 43.91 % for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

4.1.6. Flesh / fruit mass percentage and flesh / pit massRatio:

a- flesh / fruit mass percentage: it is clear that the value of C.V., for Shimlaly variety was very high, which was (18.24, %), while for the remaining varieties were (3.68, 4.69, 8.77, and 3.61, %) for Cronaki, Watiken, Picual, and Manzanillo variety, respectively. So, the frequency distribution curves as shown in Fig. (8) cleared that the curve for Shimlaly variety has much larger base than other varieties, indicating that the variation within Shimlaly variety is much greater than other varieties.

The mean values of (flesh / fruit mass percentage) were (68.11, 84.28, 79.90, 81.00, and 86.72, %) for the investigated varieties Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

b- flesh / pit mass Ratio:

Similarly, the results indicate that there are significant differences in flesh/pit mass ratio between the studied varieties. Meanwhile, Shimlaly, Picual, and Manzanillo varieties have much wider bases than Cronaki, and Watiken varieties, which indicate that they have a big dispersion around the mean values.

The maximum values of C.V. were (56.23, %) and (29.23, %) for Shimlaly and Picual variety, respectively while the minimum value was (21.82, %) for Watiken variety.

Fig. (8) Indicated that the general averages of flesh/pit mass ratio for all the investigated varieties were (2.62, 5.60, 4.14, 4.75, and 6.86) for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo variety, respectively.

Those results agree with *Fouad, et al. (1992),* who mentioned that olive cultivars varied in their flash/pit mass ratio, which is an important index in determining fruit quality.

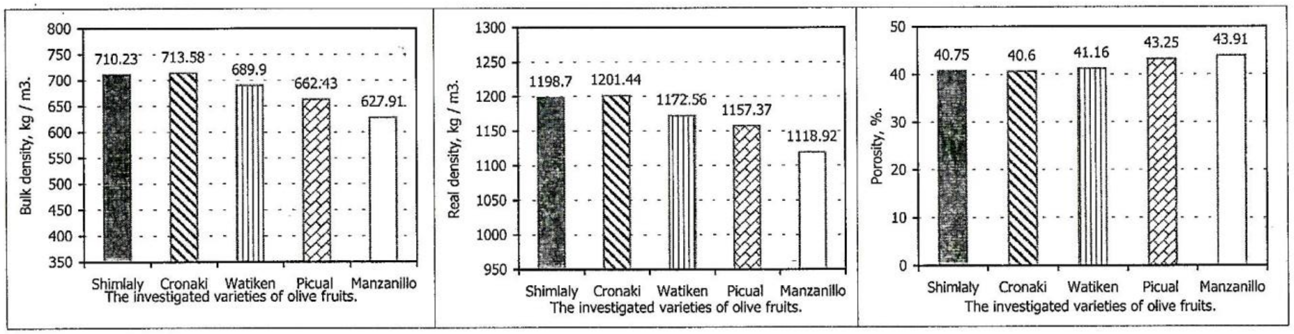

Fig.(7): Mean values of fruit bulk density, real density, and porosity for the investigated varieties.

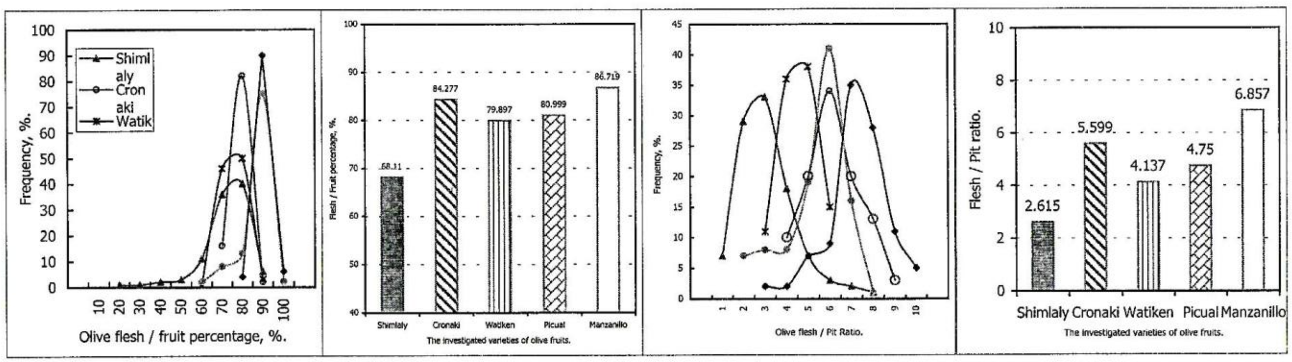

Fig.(8): Frequency distribution curves and mean values of flesh/fruit percentage and flesh/pit ratio for the investigated varieties.

4.2. Technical parameters of olive fruit conveying auger: the most widely used conveying of olive fruits is the augers, while the main parameters affecting the conveying capacity are pitch (P), outer diameter (D_o), shaft diameter (D_s), bulk density of fruits (ρ), rotating speed (n), and conveying efficiency (η).

The auger conveying efficiency (η) is affected by different factors such as: the coefficient of friction between olive fruits and auger surfaces, centrifugal force, repose angle of fruits, fruit densities, tilt angle, and rotating speed, therefore in the present investigation the efficiency (η) could be estimated as a function of the previously parameters from empirical tests relating to the cultivars and auger speed. Therefore all of those parameters were designed or calculated as follows:

a- Auger pitch (P):

From Table (1) and Fig. (3) the maximum value of olive length was 31.53 mm, then, the value P in equation (10) should be more than 31.53 mm. So the value of auger pitch assumed to be 60 mm.

b- Depth of auger groove (H):

Fig. (3) and Table (1) indicated that the maximum value of fruit diameter was 24.01 mm, then, the value H in equation (11) should be more than 24.01 mm. So the value of auger groove assumed to be 30 mm. then, the outer diameter of auger (D) should be 80 mm because the inner diameter of auger [shaft diameter (d)] was designed to be 20 mm.

c- Auger Clearance (C):

The minimum value of olive diameter was 7.49 mm as shown in Fig. (3), then, the value C should be less than that value as shown in equation (12). So the value of auger clearance assumed to be 5 mm.

d- Conveying efficiency (η):

The obtained results of the laboratory test to calculate the conveying efficiency (η), as shown in Fig. (9) indicated that the value of conveying efficiency varied according to the olive cultivars and the bulk density. The obtained values of conveying efficiency were 83.77, 84.24, 81.86, 79.54, and 78.81 % for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo, respectively.

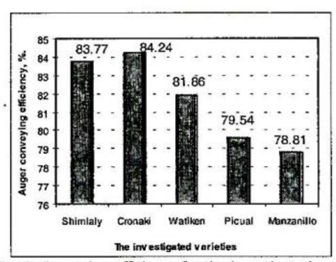

Fig. 9. Conveying efficiency for the investigated varieties

SUMMARY AND CONCLUSION

1- Five cultivars of olive fruits that represent the two main classes of olive oil production, namely: (*Shimlaly* and *Cronaki*, as oil production varieties), and (*Watiken*, *Picual*, and *Manzanillo*, as double purpose varieties) were investigated.

2- The obtained results of physical properties for the investigated five varieties of olive fruits as database can summarized as follows:

   a- The fruit length, diameter, flesh thickness ranged from (11.85 to 31.53 mm), (7.49 to 24.01 mm), (1.18 to 7.20 mm), respectively.

   b- Fruit weight, bulk density, real densities, porosity, sphericity, number of fruits per kilogram were ranged from (0.46 to 9.00 g), (627.91 to 713.58 kg/m^3), (1118.92 to 1201.44 kg/m^3), (40.6 to 43.88 %), (0.999 to 1.93), (165.32 to 833.33 fruit / kg), respectively.

   c- The percentage of flesh/fruit, flesh/pit ratio, pit length, pit diameter, and pit weight were ranged from (19.36 to 93.00 %), (0.24 to 13.29), (11.36 to 21.68 mm), (5.52 to 16.24 mm) and (0.20 to 2.14 g), respectively.

3- A set of equations were suggested to predict with reasonable accuracy the values of actual volume of each variety of the investigated olive fruits, consequently the following general equation was suggested to predict the actual volume of all the investigated varieties:

   $V = 0.4946\ L\ D^2$, where L and D are the length and the diameter of the fruits.

4- The optimum dimensions of the auger were assumed to be 60, 20, 80, and 5 mm for auger pitch (P), shaft diameter (D_S), outer diameter (D_O), and auger clearance, respectively, with 0.2 cm wall thick of the auger according to the results of physical properties of the investigated varieties.

5- A laboratory tests were carried out on the designed auger to calculate the auger conveying efficiency. They were 83.77, 84.24, 81.86, 79.54, and 78.81% for Shimlaly, Cronaki, Watiken, Picual, and Manzanillo, respectively.

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– معتوق، أ.م. ، رضوان، ش.م. ، حمام، ع.س. ، الخولى، م.م. ، عويس، ط. ر.، ٢٠٠٢ . مشروع دراسة الخصائص والخواص الطبيعية لبعض المحاصيل الزراعية للاستفادة منها فى تصميم وتطوير نظم ومعدات الحصاد الميكانيكى والتداول (لمحاصيل الحبوب) – كلية الزراعة – جامعة المنصورة – بالتعاون مع أكاديمية البحث العلمى – شارع القصر العينى – القاهرة .

الخصائص الطبيعية لبعض الأصناف المصرية من ثمار الزيتون وعلاقاتها بتصميم البريمة الناقلة للزيتون.

أحمد محمود معتوق[١] ، على السيد ابو المجد[١] ، عاطف سليمان حمام[٢] ، طاهر رشاد عويس[٢]

١ *قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة.*

٢ *قسم التصميم – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية.*

تهدف هذه الدراسة إلى دراسة معظم الخصائص الطبيعية لخمسة أصناف مختلفة من ثمار الزيتون والممثلة للقسمين الأساسيين المستخدمين فى إنتاج الزيوت مثل أصناف أنتاج الزيوت (الشملالى والكروناكى)، والأصناف ثنائية الغرض مثل (وطيقن، بيكوال ، مانزانللو) ومنها يمكن استنتاج الأبعاد الرئيسية لبريمة نقل ثمار الزيتون فى وحدة طحن الثمار، ولقد تم قياس الخصائص الطبيعية للأصناف موضع الدراسة والمتمثلة فى الأبعاد (الطول، القطر، سُمك طبقة اللحم)، الوزن، الحجم، الكثافة الظاهرية والحقيقية والمسامية، التكور، عدد الثمار لكل كيلوجرام، نسبة اللحم للثمرة، ونسبة وزن اللحم إلى وزن البذرة.

وأجريت التحليلات ألإحصائية للنتائج المتحصل عليها بغرض التعبير عن الفروق المعنوية والاختلاف فى الخصائص وكذلك انحراف القيم عن المتوسطات لكل صنف، وأظهرت نتائج التحليل الإحصائى وجود اختلافات عالية المعنوية بين الأصناف موضع الدراسة حيث تراوحت قيم الخصائص الطبيعية لتلك الأصناف بين(١١,٨٥ – ٣١,٥٣ مم) لطول الثمرة، (٧,٤٩ – ٢٤,٠١ مم) لقطر الثمرة، (١,١٨–٧,٢٠ مم) لسُمك طبقة اللحم . كما تراوحت القيم الخاصة بوزن الثمرة، الكثافة الظاهرية، الكثافة الحقيقية، المسامية، الكروية، وعدد الثمار/ كجم بين(٠,٤٦–٩ جم)، (٦٢٧,١١–٧١٣,٥٨ كجم/م٣)،(١١١٨,٩٢–١٢٠١,٤٤كجم/م٣) (٤٠,٦–٤٣,٨٨ %)، (٠,٩٩٩ – ١,٩٣)،(١٦٥,٣٢ – ٨٣٣,٣٣ ثمرة/كجم) على التوالي. بالإضافة إلى ذلك تراوحت القيم الخاصة بنسبة اللحم/الثمرة، اللحم/النواة وكذلك طول النواة، قطر النواة، وزن النواة بين (١٩,٣٦–٩٣,٠٠%)، (٠,٢٤ – ١٣,٢٩)، (١١,٣٦ – ٢١,٦٨ مم)، (٥,٥٢–١٦,٢٤ مم)، (٠,٢٠–٢,١٤ جم)، على التوالي.

وتم استنتاج مجموعة من المعادلات التنبؤية لكل صنف من الأصناف موضع الدراسة التى يمكن استخدامها بدقة عالية فى التنبؤ بالحجم الفعلى للثمار بمعلومية الأبعاد الرئيسية للثمار، بالإضافة إلى استنتاج معادلة عامة لجميع الأصناف.

تم استخدام الخصائص الطبيعية فى تحديد وتصميم الأبعاد الرئيسية للبريمة الناقلة لثمار الزيتون فكانت أبعادها كالتالى [٦٠ مم لخطوة البريمة ، ٨٠ مم للقطر الخارجى، ٢٠ مم لقطر عامود البريمة، ٥ مم لخلوص البريمة].

وبإجراء التجارب المعملية للبريمة المصممة مع الأصناف المختلفة موضع الدراسة مع الأخذ فى الاعتبار الكثافة الظاهرية لكل صنف أمكن تحديد كفاءة نقل البريمة لكل صنف، حيث كانت ٨٣,٧٧ ، ٨٤,٢٤ ، ٨١,٨٦ ، ٧٩,٥٤ ، ٧٨,٨١ % للاصناف شملالى ، كروناكى، وطيقن، بيكوال، مانزانللو على التوالى.