WATERMELON FRUITS PROPERTIES AS AFFECTED BY STORAGE CONDITIONS

El-Sayed G. Khater* and Adel H. Bahnasawy**

ABSTRACT

The main objective of this article was to study the physical and mechanical properties of watermelon fruits as influenced by storage temperatures. Watermelon fruits with different sizes were stored at two temperatures (15 and 30°C). The results indicated that, the length, major diameter and minor diameter of watermelon fruit value ranged from 22.18 to 28.77 cm, 21.34 to 27.07 cm and 18.92 to 23.01cm, respectively. The spherical coefficient and the geometric mean diameter of the watermelon fruits decreased from 0.933 to 0.907 and 20.70 to 26.08 cm, respectively. The surface area and volume of watermelon fruit values ranged from 1487.10 to 2447.61cm^2 and 5393.90 to 11389.44 cm^3, respectively. The density of the watermelon fruits ranged from 927.84 to 973.57 kg m^{-3}. The thickness of rind of the watermelon fruits ranged from 12.11 to 20.28 mm. The mass of flesh, seeds and rind of watermelon fruit values ranged from 2.929 to 6.277 kg, 0.096 to 0.208 kg and 1.992 to 4.603 kg, respectively. The repose angle and the crushing load of the watermelon fruits increased from 49.67 to 71.00º and 2.333 to 4.600 kN. The change of watermelon fruits dimensions and weight decreased with increasing storage temperature and time. The crushing load of the watermelon fruits decreases with decreasing storage temperature and decreasing watermelon fruit sizes. The marketable watermelon fruits percentage ranged from 75.67 to 90.00% at 15 ºC and from 25.00 to 48.00% at 30ºC.

Keywords: watermelon, properties, dimensions, storage temperature, marketable

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1. INTRODUCTION

Watermelon is one of the most important economic vegetable crops, practiced by the Egyptian farmers. The total cultivated area of watermelon is about 160000 Faddens (67200 ha) **(GAEO, 2013)**. Watermelon has large, round, oval or oblong fruit shape with very rich source of vitamins. It can be used for breakfast as appetizer or snack **(Salk *et al.*, 2008)**. It is also as a good source of phyto-chemical and lycopene, a red carotene pigment which acts as antioxidant during normal metabolism and protects against cancer **(Perkins and Collins, 2004)**. According to **Bawa and Bains (1977)**, **Hour *et al.*, (1980)** and **Ahmed (1996)**, the juice or pulp from watermelon is used for human consumption, while rind and seeds are major solid wastes **(Koocheki *et al.*, 2007)**.

Watermelons were first grown in Egypt nearly 5,000 years ago. They were placed in tombs of kings to provide nourishment for the afterlife. Pictures of watermelons have even been noted in ancient Egyptian hieroglyphics. Watermelons were introduced to China in the 10th century, and eventually made their way west to North America **(Anonymous, 2014)**.

Knowledge of length, width, volume, surface area and weight of the product is necessary to: (a) the design of sorting and grading machines (b) predicting amounts of surface applied chemicals and (c) describing heat and mass transfer during thermal processes and in quantification of bruise, abrasion and damage in handling process. The shape of some fruits is important in determining their suitability for processing as well as their retail value. Many researches have been carried out on the physical and engineering properties of many agricultural products **(Irvine *et al.*, 1992; El-Raie *et al.*, 1996; Bahnasawy *et al.*, 2004)**. The information on size, density, and crushing strength are required for the development of grading system for barriers and for the pulpers **(Gosh, 1969)**. The physical and mechanical properties such as size, friction angle, angle of repose, crushing strength and bulk density are important in the design of the

handling system and grading **(Chandrasekar and Viswanathan, 1999)**.

Watermelons generally are not refrigerated when shipped domestically. However, refrigerated storage and transit may be used to extend the shelf life during export shipment. The recommended range is 10 to 15ºC **(Hardenburg *et al.*, 1986)**. At lower temperatures, fruit are susceptible to chilling injury and decay **(Dow et al., 1979)** and loss of color **(Showalter, 1960)**. At higher temperatures, fruit are subject to decay **(Leupeschen, 1961)** and sugar loss **(Chisholm and Picha, 1986)**. Prestorage conditioning at 26ºC for 4 days reduces development of chilling injury and increases the percentage of marketable fruit following storage **(Picha, 1986)**.

Fresh fruits and vegetables probably receive the greatest temperature abuse at the retail level. Temperature abuse is a function of time and temperature during holding and the relative perishability of a particular commodity. For examples, apples and cabbages are often displayed at improper temperature at retail but they do not lose quality rapidly when compared to strawberries or broccoli. Mean temperatures of display cases used for fruits and vegetable are 7.6 and 8.4°C in winter and summer, respectively **(LeBlanc *et al.*, 1996)**. The majority (90%) of those commodities that should have been stored at less than or equal to 4°C were above the recommended temperature range. The same percentage was found for commodities that should have been held greater than or equal to 12°C. The significance of laboratory studies and to a lesser extent simulated shipping studies may therefore not be relevant to commercial practices in many cases. Broccoli held under simulated retail display and overnight storage treatments showed considerable reduction in shelf life and indicate the possible extent of the commercial retail handling problem **(Perrin and Gaye, 1986)**.

Handling and processing of watermelon fruits is very teddies work due to the big size of fruits, which need accurate information about the physical and mechanical properties, therefore, this article aimed to study some physical and mechanical properties as influenced by storage temperatures.

2. MATERIALS AND METHODS

The experiment was carried out at Agricultural Engineering Department, Faculty of Agriculture, Moshtohor, Benha University, during the period of June to August, 2014.

2.1. Materials:

Watermelon (Citrullus lanatus, Thumb.) was brought from the local market after harvesting with the same maturity stage (the price of one ton equal L.E 2000), then inspected and graded into three categories [5 kg (small), 8 kg (medium) and 11 kg (large)]. These categories were used to measure and determine the physical and mechanical properties.

2.2. Methods:

2.2.1. Physical and mechanical properties:

2.2.1.1. Physical properties:

The dimensions of watermelon fruits (length, major diameter and minor diameter) were measured by tape. Geometric mean diameters and spherical coefficient were determined from equations (1 and 2) **(Sadrnia *et al.*, 2006)**.

$$\text{Geometric mean diameters} = \sqrt[3]{abc} \quad (1)$$

$$\text{Spherical coefficient} = \frac{\sqrt[3]{abc}}{a} \quad (2)$$

Where:-

a is the length of watermelon fruits, cm.

b is the major diameter of watermelon fruits, cm,

c is the minor diameter of watermelon fruits, cm.

The thickness of rind was measured by digital vernier caliper (Model TESA 1p65- Range 0-150 mm ± 0.01 mm, Swiss). The mass was measured by electric digital balance (Model Vibra – Range 0-12000 g ± 0.01 g, Japan). The surface area was measured by wrapping aluminum foil around the watermelon fruit and then cutting the foil away with scissors into thin strips sufficient to lay the foil flat. A planimeter (Model Placom KP -90 N- Range 0-10 m2 ± 0.2 %, Japan) was used to measure the surface area of the watermelon. The volume of fruits was measured by graduated cylinder.

The moisture content of randomly selected watermelon fruits (flesh, seeds and rind) of each category was determined according to **ASAE Standard (1984)**. Three samples of each watermelon fruits were randomly selected and weighed on an electric digital balance. Drying oven (Fisher Scientific Isotemp Oven, Model 655F Cat. No. 13-245-655, Fisher Scientific, Toronto, Ontario, Canada) at 105°C until a constant weight was used to measure the moisture content.

The bulk density was a measurement of a watermelon fruits mass per unit volume. For each case, the determination was replicated three times and the mean was considered.

2.2.1.2. Mechanical Properties:

The angle of repose is the minimum angle at which any piled-up bulky or loose material will stand without falling downhill.

Crushing load implies the partial or complete destruction of watermelon fruits. Crushing load was measured by compressive and tensile device loads ((Model MP2E– Range 0-2000 kN ± 0.1kN, Italy)

2.2.2. Storage conditions:

The watermelon fruits were stored at two temperature 15°C (85 ± 5 % relative humidity) and room temperature 30 ± 3°C (60 ± 5 % relative humidity). The dimensions, mass, surface area, volume and bulk density were measured every five days. The thickness of rind, moisture content and crushing load were measured at the end of the experiment. These measurements were repeated three times and the average was taken.

2.3. Statistical analysis:

The statistical analysis for the data obtained was done according to **Snedecor and Cochran (1980)** and the treatments were compared using at 0.05 level probability.

3. RESULTS AND DISCUSSIONS

3.1. Physical properties

Table (1) shows the dimensions (length, major diameter and minor diameter), spherical coefficient and geometric mean diameter of the watermelon fruits. It could be seen that the length, major diameter and minor diameter of watermelon fruit value ranged from 22.18 ± 0.185 to 28.77 ± 0.185 cm, 21.34 ± 0.102 to 27.07 ± 0.012 cm and 18.92 ± 0.060 to 23.01 ± 0.414 cm, respectively, for different sizes of watermelon fruits. The highest value of length, major diameter and minor diameter of watermelon fruits were 28.77, 27.07 and 23.01 cm, respectively, were found for large size, while, the lowest value of length, major diameter and minor diameter of watermelon fruits were 22.18, 21.34 and 18.92 cm, respectively, were obtained for small size of watermelon fruits. These dimension data are very important in storage capacity determination, for example, the volumes required to storage one ton for the small, medium and large sizes were 2.03, 1.96 and 1.90 m^3, respectively. Figures (1a, b and c) show the frequency distribution of the dimensions of the watermelon fruits.

Table (1): The mean, standard deviation and coefficient of variation for some physical properties of watermelon fruits.

Watermelon size		Dimensions			Spherical coefficient	Geometric mean diameter, cm
		Length, cm	Major diameter, cm	Minor diameter, cm		
Small Size	Mean	22.18	21.34	18.92	0.933	20.70
	SD	0.185	0.102	0.060	0.004	0.074
	CV	0.008	0.005	0.003	0.005	0.004
Medium Size	Mean	25.59	24.20	20.50	0.909	23.26
	SD	0.185	0.099	0.0415	0.014	0.211
	CV	0.007	0.315	0.020	0.015	0.009
Large Size	Mean	28.77	27.07	23.01	0.907	26.08
	SD	0.185	0.320	0.414	0.012	0.210
	CV	0.006	0.012	0.018	0.014	0.008

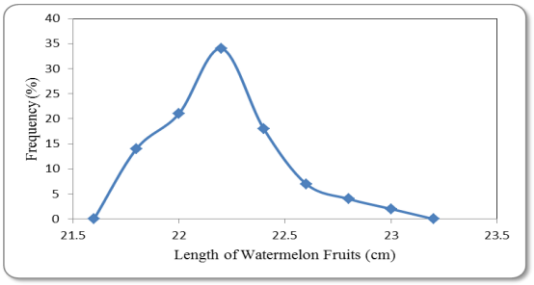

Figure (1a): The frequency distribution of the length of the watermelon fruits

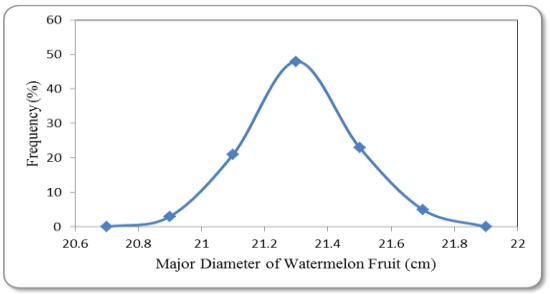

Figure (1b): The frequency distribution of the major diameter of the watermelon fruits

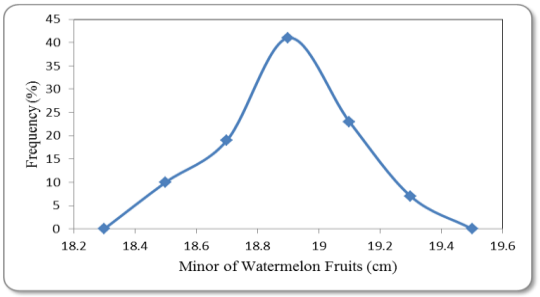

Figure (1c): The frequency distribution of the minor diameter of the watermelon fruits

The results indicated that the spherical coefficient of the watermelon fruits decreases with increasing the watermelon fruits sizes. It indicated that when the watermelon fruits size varies from small size (5.0 kg) to large size (11.0 kg), the spherical coefficient of the watermelon fruits decreased from 0.933 ± 0.004 to 0.907 ± 0.012. The results also indicated that the geometric mean diameter of the watermelon fruits increases with increasing the watermelon fruits sizes. It indicated that when the watermelon fruits size varies from small size (5.0 kg) to large size (11.0 kg), the geometric mean

diameter of the watermelon fruits increased from 20.70 ± 0.074 to 26.08 ± 0.210 cm. These results were in agreement with those obtained by **Sadrnia *et al.* (2006)**.

Table (2) shows the mass, surface area, volume, density and thickness of rind of the watermelon fruits. It could be seen that the mass of watermelon fruit value ranged from 5.00 ± 0.087 to 11.09 ± 0.043 kg for different sizes of watermelon fruits. The surface area and volume of watermelon fruit values ranged from 1487.10 ± 12.55 to 2447.61 ± 16.13 cm^2 and 5393.90 ± 68.19 to 11389.44 ± 112.72 cm^3 for small and large size, respectively. The highest value of surface area and volume of watermelon fruits were 2447.61 ± 16.13 cm^2 and 11389.44 ± 112.72 cm^3 were found for large sizes, while, the lowest value of area and volume of watermelon fruits were 1487.10 ± 12.55 cm^2 and 5393.90 ± 68.19 cm^3 were obtained for small size of watermelon fruits. Surface area of watermelon fruits is important in handling and processing operations.

The results indicated that the density of the watermelon fruits increases with increasing the watermelon fruits sizes. It indicated that when the watermelon fruits size varies from small size (5.0 kg) to large size (11.0 kg), the density of the watermelon fruits increased from 927.84 ± 11.14 to 973.57 ± 11.35 kg m^{-3}.

Table (2): The mean, standard deviation and coefficient of variation for some physical properties of watermelon fruits.

Watermelon size		Mass, kg	Surface area, cm^2	Volume, cm^3	Density, kg m^{-3}	Thickness of rind, mm
Small Size	Mean	5.00	1487.10	5393.90	927.84	12.11
	SD	0.087	12.55	68.19	11.14	0.282
	CV	0.017	0.008	0.013	0.012	0.023
Medium Size	Mean	8.039	1945.89	8073.58	995.81	18.50
	SD	0.067	14.39	89.63	18.35	0.483
	CV	0.008	0.007	0.011	0.018	0.026
Large Size	Mean	11.09	2447.61	11389.44	973.57	20.28
	SD	0.043	16.13	112.72	11.35	0.599
	CV	0.004	0.007	0.010	0.012	0.030

The results also indicated that the thickness of rind of the watermelon fruits increases with increasing the watermelon fruits

sizes. It indicated that when the watermelon fruits size varies from small size (5.0 kg) to large size (11.0 kg), the thickness of rind of the watermelon fruits increased from 12.11 ± 0.282 to 20.28 ± 0.599 mm.

Table (3) and figures (2a, b and c) show the mass and moisture content of flesh, seeds and rind and of the watermelon fruits. It could be seen that the mass of flesh, seeds and rind of watermelon fruit values ranged from 2.929 ± 0.092 to 6.277 ± 0.240 kg, 0.096 ± 0.008 to 0.208 ± 0.042 kg and 1.992 ± 0.069 to 4.603 ± 0.285 kg, respectively, for different sizes of watermelon fruits.

Regarding the moisture content of the different component of watermelon fruit. It was found that the moisture content of the flesh were 1.92, 179 and 1.77 times of the seeds, respectively, for different sizes of watermelon fruits, when it were 93.29 ± 1.025, 91.81 ± 1.353 and 91.57 ± 0.576 % of flesh, respectively, for different sizes of watermelon fruits and 48.69 ± 0.610, 51.29 ± 2.959 and 51.87 ± 2.648 % of seeds, respectively, for different sizes of watermelon fruits. The moisture content of the rind were 1.93, 1.82 and 1.78 times of the seeds, respectively, for different sizes of watermelon fruits, when it were 93.32 ± 0.610, 93.45 ± 0.722 and 91.90 ± 0.180 % of rind, respectively, for different sizes of watermelon fruits.

Table (3): The mean, standard deviation and coefficient of variation for some physical properties of watermelon fruits.

Watermelon size		Mass, kg			Moisture content,%		
		Flesh	Seeds	Rind	Flesh	Seeds	Rind
Small Size	Mean	2.929	0.096	1.992	93.29	48.69	93.32
	SD	0.091	0.008	0.069	1.025	3.379	0.610
	CV	0.031	0.079	0.035	0.011	0.069	0.007
Medium Size	Mean	4.758	0.139	3.141	91.81	51.29	93.45
	SD	0.146	0.028	0.190	1.353	2.959	0.722
	CV	0.031	0.201	0.060	0.015	0.058	0.008
Large Size	Mean	6.277	0.208	4.603	91.57	51.87	91.90
	SD	0.240	0.042	0.285	0.576	2.648	0.180
	CV	0.038	0.202	0.062	0.006	0.051	0.002

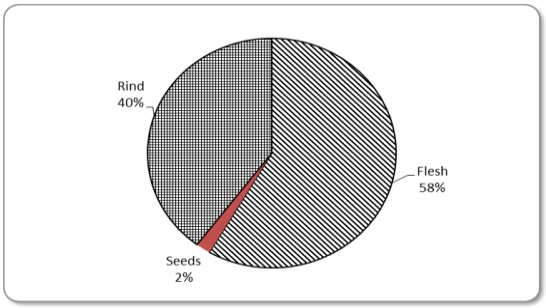

Figure (2a): Mass of flesh of watermelon fruits for small size

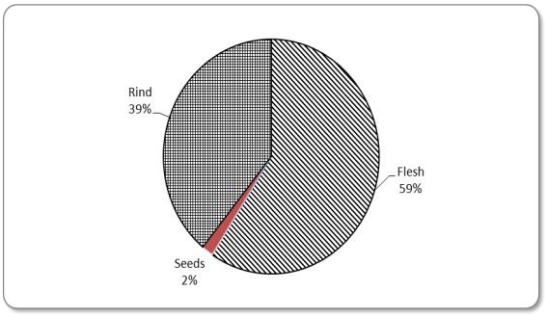

Figure (2b): Mass of flesh of watermelon fruits for medium size

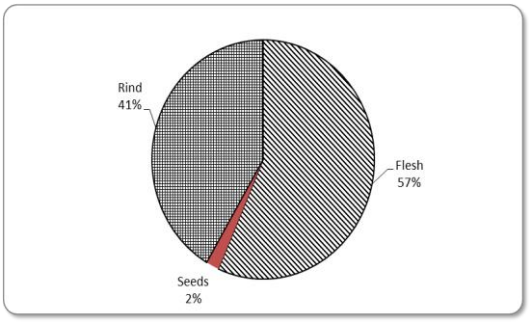

Figure (2c): Mass of flesh of watermelon fruits for large size

3.2. Mechanical properties

Table (4) shows the repose angle and crushing load of the watermelon fruits. The results indicated that the repose angle of the watermelon fruits increases with increasing the watermelon fruits sizes. It indicated that when the watermelon fruits size varies from small size (5.0 kg) to large size (11.0 kg), the repose angle of the watermelon fruits increased from 49.67 ± 2.082 to 71.00 ± 0.028º.

The results indicated that the crushing load of the watermelon fruits increases with increasing the watermelon fruits sizes. It indicated that when the watermelon fruits size varies from small size

(5.0 kg) to large size (11.0 kg), the crushing load of the watermelon fruits increased from 2.333 ± 0.058 to 4.600 ± 0.265 kN.

Table (4): The mean, standard deviation and coefficient of variation for mechanical properties of watermelon fruits.

Watermelon size		Repose angle	Crushing load, kN
Small Size	Mean	49.67	2.333
	SD	2.082	0.058
	CV	0.042	0.025
Medium Size	Mean	64.67	2.867
	SD	0.577	0.058
	CV	0.009	0.020
Large Size	Mean	71.00	4.600
	SD	2.000	0.265
	CV	0.028	0.058

3.3. Effect of storage temperature on physical and mechanical properties:

3.3.1. Dimensions change:

Figure (3) shows the effect of different storage temperatures on change in length of watermelon fruits during storage. The results indicated that the change of watermelon fruits length decreases with increasing storage temperature and increasing storage time, where, it decreased from 22.081 to 21.55 cm (2.40%), 26.539 to 25.903 cm (2.39%) and 28.556 to 27.850 cm (2.47%) for fruits size small size (5.0 kg), medium size (8.0 kg) and large size (11.0 kg), respectively, at storage temperature 30 ºC after 45 days storage. The change of watermelon fruits length decreased from 22.930 to 22.317 cm (2.67%), 27.177 to 26.539 cm (2.35%) and 28.768 to 28.050 cm (2.50%) for fruits small size (5.0 kg), medium size (8.0 kg) and large size (11.0 kg), at storage temperature 15 ºC after 65 days storage.

Multiple regression analysis was carried out to get a relationship between the length changes of watermelon fruits (LC), fruit sizes (FS) and storage temperature (ST). The best form was as follows:

$$LC = 18.178 + 1.0239FS - 0.0336ST \qquad R^2 = 0.94 \qquad (3)$$

Where:

LC is the length change of watermelon fruits, cm

FS is the watermelon fruit sizes

ST is the storage temperature, ºC

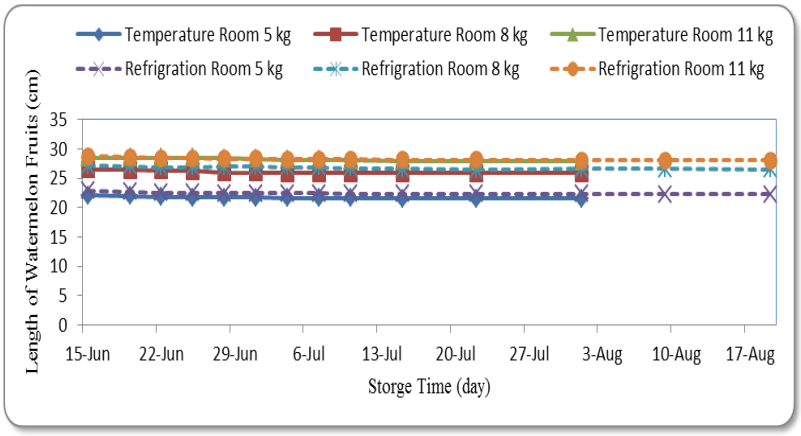

Figure (3): The effect of different storage temperatures on change in length of watermelon fruits during storage.

Figure (4) shows the effect of different storage temperatures on change in major diameter of watermelon fruits during storage. The results indicated that the change of watermelon fruits major diameter were 0.327, 0.379 and 0.425 cm for small size (5.0 kg), medium size (8.0 kg) and large size (11.0 kg) watermelon fruit weight, respectively, at 30 °C storage temperature. The results also indicated that the change of watermelon fruits major diameter were 0.430, 0.640 and 0.670 cm for small size (5.0 kg), medium size (8 kg) and large size (11.0 kg) watermelon fruit weight, respectively, at 15 °C storage temperature.

Multiple regression analysis was carried out to get a relationship between the major diameter changes of watermelon fruits (DC), fruit sizes (FS) and storage temperature (ST). The best form was as follows:

$$DC = 15.948 + 1.0425FS + 0.0105ST \qquad R^2 = 0.98 \qquad (4)$$

Where:

DC is the major diameter change of watermelon fruits, cm

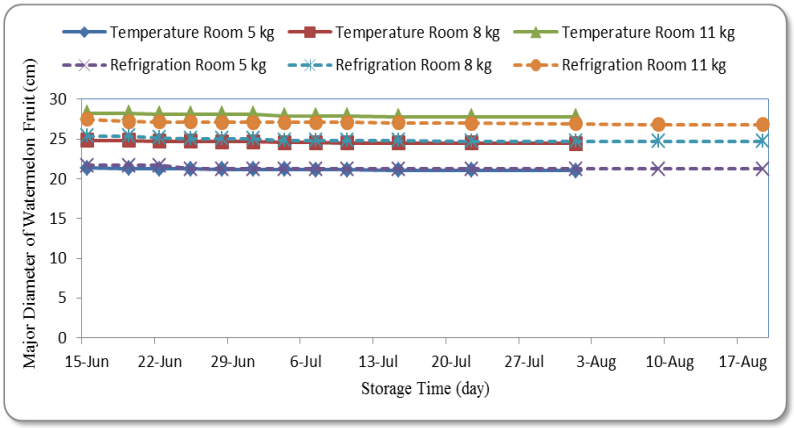

Figure (4): The effect of different storage temperatures on change in major diameter of watermelon fruits during storage.

3.3.2. Weight loss:

Figure (5) shows the effect of different storage temperatures on weight loss of watermelon fruits during storage. The results indicated that the watermelon fruits weight decreased from 4.889 to 4.251 kg (13.05%), 8.126 to 7.162 kg (11.86%) and 10.734 to 9.308 kg (13.28%) for fruits size small size (5.0 kg), medium size (8.0 kg) and large size (11.0 kg), respectively, at storage temperature 30 ºC after 45 days storage. The watermelon fruits weight loss decreased from 4.932 to 4.595 kg (6.83%), 7.952 to 7.501 kg (5.67%) and 10.288 to 9.794 kg (4.80%) for small size (5.0 kg), medium size (8 kg) and large size (11.0 kg) watermelon fruit weight, respectively, at storage temperature 15 ºC after 65 days storage.

The results also indicated that the watermelon fruits weight loss increases with increasing watermelon fruits size. It indicates that when the watermelon fruit weight increased from small size (5 kg) to large size (11 kg), the watermelon fruit weight loss increased from 0.638 to 1.426 kg and 0.337 to 0.494 kg for 27 and 15 °C storage temperature, respectively. This due to the large size fruits has a large surface area which has a great effect on water loss from the fruits.

The weight loss of the fruits stored at 30 ºC was higher than that of the fruits stored 15 ºC, this because of the high vapor pressure

deficit which is the main factor in water evaporation from the fruits at higher temperature storage room.

Multiple regression analysis was carried out to get a relationship between the weight losses of watermelon fruits (WL), fruit sizes (FS) and storage temperature (ST). The best form was as follows:

$$WL = 0.705 + 0.877FS - 0.013ST \qquad R^2 = 0.98 \qquad (5)$$

Where:

WL is the weight loss of watermelon fruits, kg

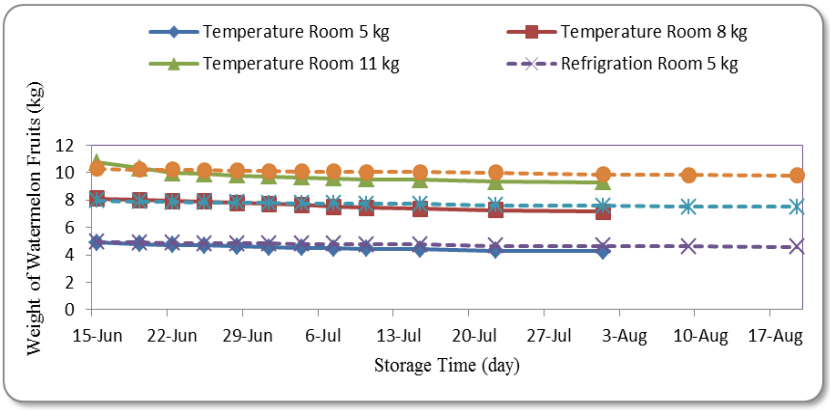

Figure (5): The effect of different storage temperatures on weight loss of watermelon fruits during storage.

3.3.3. Surface area change:

Table (5) shows the effect of different storage temperatures on change in watermelon fruit surface area. The results indicated that the surface area change increases with decreasing storage temperature and increasing watermelon fruit sizes, where, it decreased from 1480.15 ± 50.385 to 1401.80 ± 64.771 cm^2 (5.29%) and 1561.22 ± 80.009 to 1480.60 ± 81.584 cm^2 (6.65%) with the storage temperatures decreased from 30 to 15°C, respectively at small size of watermelon fruits.

Table (5): The effect of different storage temperatures on change in surface area of watermelon fruits during storage.

Watermelon size	Watermelon fruits surface area change, cm^2	
	Storage at 30°C	Storage at 15°C

		Before	after	Before	After
Small Size	Mean	1480.15	1401.80	1561.22	1480.60
	SD	50.385	64.771	80.009	81.584
	CV	0.034	0.046	0.051	0.055
Medium Size	Mean	2073.96	1996.84	2167.70	2063.83
	SD	140.170	101.532	26.277	25.635
	CV	0.068	0.051	0.012	0.012
Large Size	Mean	2532.16	2485.09	2485.06	2401.41
	SD	43.409	42.912	42.908	42.188
	CV	0.017	0.017	0.017	0.018

The results indicated that the surface area change decreased from 2073.96 ± 140.170 to 1999.84 ± 101.582 cm^2 (3.17%) and 2167.70 ± 26.277 to 2063.83 ± 25.635 cm^2 (3.86%) with the storage temperatures decreased from 30 to 15°C, respectively at medium size of watermelon fruits. The results also indicated that the surface area change decreased from 2532.16 ± 43.409 to 2485.09 ± 42.912 cm^2 (1.86%) and 2485.06 ± 42.908 to 2401.41 ± 42.188 cm^2 (3.24%) with the storage temperatures decreased from 30 to 15°C, respectively at large size of watermelon fruits.

The results indicated that the change of watermelon fruits surface area decreases with increasing watermelon fruits size. It indicates that when the watermelon fruit weight increased from small size (5.0 kg) to large size (11.0 kg), the watermelon fruit surface area change decreased from 78.35 ± 23.55 cm^2 (5.29%) to 47.07 ± 16.29 cm^2 (1.86%) and 103.87 ± 25.86 cm^2 (6.65%) to 80.62 ± 12.28 cm^2 (3.24%) for 30 and 15 °C storage temperature, respectively.

3.3.4. Volume change:

Table (6) shows the effect of different storage temperatures on change in watermelon fruit volume. The results indicated that the volume change increases with decreasing storage temperature and increasing watermelon fruit sizes, where, it decreased from 5326.23 ± 274.746 to 4939.08 ± 343.379 cm^3 (7.83%) and 5804.49 ± 443.707 to 5362.55 ± 439.595 cm^3 (8.13%) with the storage temperatures

decreased from 30 to 15°C, respectively at small size of watermelon fruits.

The results indicated that the volume change decreased from 8891.51 ± 891.759 to 8398.09 ± 638.50 cm^3 (4.65%) and 9490.49 ± 172.560 to 8818.82 ± 164.316 cm^3 (4.66%) with the storage temperatures decreased from 30 to 15°C, respectively at medium size of watermelon fruits. The results also indicated that the volume change decreased from 11982.38 ± 308.514 to 11652.75 ± 308.41 cm^3 (2.75%) and 11649.66 ± 301.288 to 11069.19 ± 291.249 cm^3 (3.27%) with the storage temperatures decreased from 30 to 15°C, respectively at large size of watermelon fruits.

The results indicated that the change of watermelon fruits volume decreases with increasing watermelon fruits size. It indicates that when the watermelon fruit weight increased from small size (5.0 kg) to large size (11.0 kg), the watermelon fruit volume change decreased from 417.15 ± 120.12 cm^3 (7.83%) to 329.64 ± 115.23 cm^3 (2.75%) and 471.67 ± 67.42 cm^3 (8.13%) to 380.47 ± 96.12 cm^3 (3.27%) for 30 and 15 °C storage temperature, respectively.

Table (6): The effect of different storage temperatures on change in volume of watermelon fruits during storage.

Watermelon size		Watermelon fruits volume change, cm^3			
		Storage at 30°C		Storage at 15°C	
		Before	After	Before	After
Small Size	Mean	5356.23	4939.08	5804.49	5362.55
	SD	274.746	343.379	443.707	439.595
	CV	0.051	0.069	0.076	0.082
Medium Size	Mean	8891.51	8398.09	9490.49	8818.82
	SD	891.759	638.50	172.560	164.316
	CV	0.100	0.076	0.018	0.019
Large Size	Mean	11982.38	11652.75	11649.66	11069.19
	SD	308.514	301.41	301.288	291.249
	CV	0.026	0.026	0.026	0.026

3.3.5. Density change:

Table (7) shows the effect of different storage temperatures on change in watermelon fruit density. The results indicated that the

density change increases with decreasing storage temperature and increasing watermelon fruit sizes, where, it decreased from 913.63 ± 31.263 to 862.38 ± 36.109 kg m^{-3} (5.61%) and 857.69 ± 20.146 to 850.32 ± 31.342 cm^3 (2.10%) with the storage temperatures decreased from 30 to 15°C, respectively at small size of watermelon fruits.

The results indicated that the change of watermelon fruits density increases with increasing watermelon fruits size. It indicates that when the watermelon fruit weight increased from small size (5.0 kg) to large size (11.0 kg), the watermelon fruit volume change decreased from 51.24 ± 21.17 to 96.82 ± 23.26 kg m^{-3} and 18.01 ± 1.99 to 45.78 ± 1.87 kg m^{-3} for 30 and 15 °C storage temperature, respectively.

Table (7): The effect of different storage temperatures on change in density of watermelon fruits during storage.

Watermelon size		Watermelon fruits density change, kg m^{-3}			
		Storage at 30°C		Storage at 15°C	
		Before	after	Before	After
Small Size	Mean	913.63	862.38	857.69	850.32
	SD	31.263	36.109	20.146	31.342
	CV	0.034	0.042	0.023	0.037
Medium Size	Mean	916.47	853.47	850.74	837.67
	SD	37.865	25.444	38.829	19.432
	CV	0.041	0.030	0.046	0.023
Large Size	Mean	895.88	799.06	885.45	884.35
	SD	9.931	18.181	90.269	93.042
	CV	0.011	0.023	0.102	0.105

3.3.6. Effect of storage temperature on the crushing load of watermelon fruits:

Table (8) shows the effect of storage temperature on the crushing load of the watermelon fruits. The results indicated that the crushing load of the watermelon fruits decreases with decreasing storage temperature and decreasing watermelon fruit sizes, where, it decreased from 2.33 ± 0.058 to 1.20 ± 0.100 kN (48.63%) and 2.33 ± 0.058 to 1.67 ± 0.153 kN (28.63%) with the storage temperatures

decreased from 30 to 15°C, respectively at small size of watermelon fruits.

The results indicated that the change of watermelon fruits crushing load increases with increasing watermelon fruits size. It indicates that when the watermelon fruit weight increased from small size (5.0 kg) to large size (11.0 kg), the watermelon fruit crushing load increased from 1.133 ± 0.053 to 2.333 ± 0.231 kN (51.44%) and 0.667 ± 0.153 to 1.700 ± 0.346 kN (60.76%) for 30 and 15 °C storage temperature, respectively. These results were in agreement with those obtained by **Bahnasawy and Khater (2014)**.

Table (8): The effect of storage temperature on the crushing load of the watermelon fruits.

Watermelon size		Watermelon fruits crushing load change, kN			
		Storage at 30°C		Storage at 15°C	
		Before	after	Before	After
Small Size	Mean	2.33	1.20	2.33	1.67
	SD	0.058	0.100	0.058	0.153
	CV	0.250	0.083	0.250	0.092
Medium Size	Mean	2.87	1.53	2.87	2.00
	SD	0.058	0.208	0.058	0.100
	CV	0.020	0.136	0.020	0.050
Large Size	Mean	4.60	2.27	4.60	2.90
	SD	0.265	0.208	0.265	0.100
	CV	0.058	0.092	0.058	0.034

3.3.7. Effect of storage temperature on the marketable watermelon fruits:

Table (9) shows the effect of storage temperature on the marketable watermelon fruits. The results indicated that the marketable watermelon fruits increases with decreasing storage temperature and decreasing watermelon fruit sizes, where, it increased from 48.00 ± 2.00 to 90.00 ± 1.33 % with the storage temperatures decreased from 30 to 15°C. On the other hand, marketable watermelon fruit decreased from 48.00 ± 2.00 to 25.00 ± 6.70 % for small size (5.0 kg) to large size (11.0 kg) of watermelon fruit weight, respectively at

30 °C storage temperature, but it decreased from 90.00 ± 1.33 to 75.67 ± 5.50 % for small size (5.0 kg) to large size (11.0 kg) of watermelon fruit weight, respectively at 15 °C storage temperature. These results were in agreement with those obtained by **Risse *et al.* (1990)**.

Marketability percentages of the fruit stored at 30 °C were 48.00, 27.00 and 25.00% at different sizes (small, medium and large, respectively), which means one ton of these fruits will loss 52, 73 and 75% of its prices after storage for 45 days. The price of one ton of watermelon fruits is L.E 2000. By the end of storage, the farmer will loss L.E 1040, 1460 and 1500 for small size, medium size and large size of watermelon fruits, respectively. On the other hand, marketability percentages of the fruit stored at 15 °C were 90.00, 80.50 and 75.67% at different sizes, which means the one ton of these fruits will loss 10.00, 19.50 and 24.33 % of its prices after storage for 65 days. By the end of storage, the farmer will loss L.E 200, 390 and 486.6 for small size, medium size and large size of watermelon fruits, respectively.

Table (9): The effect of storage temperature on the marketable watermelon fruits.

Watermelon size		Marketable watermelon fruits, %	
		30 ºC	15 ºC
Small Size	Mean	48.00	90.00
	SD	2.00	1.33
	CV	0.042	0.015
Medium Size	Mean	27.00	80.50
	SD	6.45	5.00
	CV	0.239	0.062
Large Size	Mean	25.00	75.67
	SD	6.70	5.50
	CV	0.268	0.073

4. CONCLUSIONS

The experiment was carried out to study the physical and mechanical properties of watermelon fruits before and after storage under different storage temperatures (15 and 30°C) for three

categories [5 kg (small), 8 kg (medium) and 11 kg (large)]. The obtained results can be summarized as follows:

- The length, major diameter and minor diameter of watermelon fruit value ranged from 22.18 to 28.77 cm, 21.34 to 27.07 cm and 18.92 to 23.01cm, respectively. The spherical coefficient and the geometric mean diameter of the watermelon fruits decreased from 0.933 to 0.907 and 20.70 to 26.08 cm, respectively.
- The surface area and volume of watermelon fruit values ranged from 1487.10 to 2447.61cm^2 and 5393.90 to 11389.44 cm^3, respectively. The density of the watermelon fruits ranged from 927.84 to 973.57 kg m^{-3}.
- The thickness of rind of the watermelon fruits ranged from 12.11 to 20.28 mm. The mass of flesh, seeds and rind of watermelon fruit values ranged from 2.929 to 6.277 kg, 0.096 to 0.208 kg and 1.992 to 4.603 kg, respectively.
- The repose angle and the crushing load of the watermelon fruits increased from 49.67 to 71.00º and 2.333 to 4.600 kN.
- The change of watermelon fruits dimensions decreased ranged from 2.40, 2.39 and 2.47% for fruits size small size (5.0 kg), medium size (8.0 kg) and large size (11.0 kg), respectively, at storage temperature 30 ºC and it decreased from 2.67, 2.35 and 2.50% for fruits small size, medium size and large size of watermelon fruit weight, at storage temperature 15 ºC.
- The watermelon fruits weight decreased from 13.05, 11.86 and 13.28% for fruits size small size, medium size and large size, respectively, at storage temperature 30 ºC. It decreased from 6.83%, 5.67 and 4.80% for small size, medium size and large size of watermelon fruit weight, respectively, at storage temperature 15 ºC after 65 days storage.
- The surface area and volume change increases with decreasing storage temperature and increasing watermelon fruit sizes. It decreased from 5.29 to 6.65% and 7.83 to 8.13%, respectively, with the storage temperatures decreased from 30 to 15°C, respectively at small size of watermelon fruits.

- The crushing load of the watermelon fruits decreases with decreasing storage temperature and decreasing watermelon fruit sizes. It decreased from 48.63 to 28.63 % with the storage temperatures decreased from 30 to 15°C, respectively at small size of watermelon fruits.
- The marketable watermelon fruits increases with decreasing storage temperature and decreasing watermelon fruit sizes. It increased from 48.00 to 90.00 % with the storage temperatures decreased from 30 to 15°C.

5. REFERENCES

Ahmed, J., 1996. Studies on watermelon products. Indian Food Packer, 50: 15-20.

Anonymous, 2014. Watermelon characteristics. http://www.ehow.com/info

ASAE Standard, 1984. ASAE 5352.1.moisture measurement. American Society of Agric. Eng. 2950 Niles Road, St. Joseph, MI 49085-9659.

Bahnasawy, A.H., El-Haddad, Z.A., El-Ansary, M.Y., Sorour H.M., 2004. Physical and mechanical properties of some Egyptian onion cultivars. J. of Food Eng., 62: 255-261.

Bahnasawy, A.H., Khater, E.G., 2014. Effect of wax coating on the quality of cucumber fruits during storage. J. Food Process. Technol. 5 (6): 339. doi:10.4172/2157-7110.1000339

Bawa, A.S., Bains, G.S., 1977. Integrated processing of watermelons for juice and seed. Indian Food Parker, 31: 12.

Chandrasekar, V., Viswanathan, R., 1999. Physical and thermal properties of coffee. J. Agric. Engng. Res., 73, 227-234.

Chisholm, D.N., Picha, D.H., 1986. Effect of storage on sugar and organic acid contents of watermelons. HortScience 21:1031- 1033.

Dow, A.T., Segall, R.H., Hopkins, D.L., Elmstrom, G.W., 1979. Effects of storage temperature and field fungicide treatments on decay of Florida watermelons. Proc. Fla. State Hort. Soc. 91:149- 150.

El-Raie, A.S., Hendawy, N.A., Taib, A.Z., 1996. Study of physical and engineering properties for some agricultural products. Misr J. of Agric.Engng., 13 (1):211-226.

GAEO (General of Agricultural Economics organization) - Ministry of Agriculture and Land Reclamation, 2013. Acreage statistics and vegetable production in the Arab Republic of Egypt (unpublished).

Gosh, B.N., 1969. Physical properties of the different grades of arabica beans. Transactions of the ASAE, 9(3):592-593.

Hardenburg, R.E., Watada, A.E., Wang, C.Y., 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. USDA Agr. Hdbk. 66.

Hour, S.S., Ahmed, E.M., Carter, R.D., 1980. Concentration of watermelon juice. J. Food Sci., 45: 718-719.

Irvine, D.A., Jayas, D.S., White, N.D.G., Britton M.G., 1992. Physical properties of flaxseed, lentils, fababeans. Can.. Agric. Engng, 34(1):75- 82.

Koocheki, A., Razavi, S.M.A., Milani, E., Monghadam, T.M., Alamatiyan, S., Izadkhah, S., 2007. Physical properties of watermelon seed as a function of moisture content and variety. Int. Agrophysics, 21: 349-359.

LeBlanc, D.I., Stark, R., MacNeil, B., Goguen, B., Beraulieu C., 1996. Perishable food temperature in retail stores. In: New Development in Refrigeration for Food Safety and Quality. International Institute Refrigeration Commision C2, 1996-6, 42–57.

Leupschen, N.S., 1961. The development of Mycosphaerella black rot and Pellicularia rolfsii rot of watermelons at various temperatures. Plant Dis. Rptr. 45:557-559.

Perkins-Veazie, P., Collins, J.K., 2004. Flesh quality and lycopene stability of fresh-cut watermelon. Postharvest Biol. Technol., 31: 159-166.

Perrin, P.W., Gaye, M.M., 1986. Effects of simulated retail display and overnight storage treatment on quality maintenance in fresh broccoli. J. Food Sci. 51, 146–149.

Picha, D.H., 1986. Postharvest fruit conditioning reduces chilling injury in watermelons. HortScience 21(6):1407-1409.

Risse, L.A., Breckt, L.K., Sargent, S.A., Locascio, S.J., Crall, J.M., Elmstrom, G.W., Maynard, D.N., 1990. Storage characteristics of small watermelon cultivars. J. Amer. Soc. Hort. Sci., 115 (3): 440 – 443.

Sadrnia, H., Rajabipour, A., Jafary, A., Javadi, A., Mostafi Y., 2006. Comparing physical and mechanical properties of two varieties of watermelon: Charleston Gray and Crimson Sweet. Energy efficiency and agricultural engineering. Proceedings of the union of scientists – Rousse, Third Conference, 7 – 9 June 2006. p. 360 – 367.

Şalk, A., Arin, L., Deveci, M., Polat S., 2008. Özel Sebzecilik (In Turkish). Namık Kemal Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Tekirdağ, Turkey.

Showalter, R.K., 1960. Watermelon color as affected by maturity and storage. Proc. Fla. State Hort. Soc. 73:289-293.

Snedecor, G.W., Cochran, W.G., 1980. Statistical methods, 7th (Ed), Iowa State Univ. Press, Ames, Iowa, USA.

الملخص العربى

تأثير ظروف التخزين على خصائص ثمار البطيخ

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يهدف هذا البحث الى دراسة خصائص ثمار البطيخ قبل وبعد التخزين على درجات حرارة مختلفة. وكانت اهم النتائج المتحصل عليها: تراوح كلا من طول والقطر الخارجى والقطر الداخلى لثمار البطيخ ما بين 22.18 إلى 28.77 و21.34 إلى 27.07 و18.92 إلى 23.01 سم، على التوالى. تراوح كلا من معامل الكروية والقطر الهندسى ما بين 0.933 إلى 0.907 و 20.70 إلى 26.08 سم على التوالى. تراوح كلا من المساحة السطحية والحجم لثمار البطيخ ما بين 1487.10 إلى 2447.61 سم^2 و5393.90 إلى 11389.44 سم^3. تراوحت كثافة ثمار البطيخ ما بين 927.84 إلى 973.57 كجم م$^{-3}$.

تراوح سمك قشرة ثمار البطيخ ما بين 12.11 إلى 20.28 مم. تراوح وزن كلا من اللب والبذور والقشرة لثمار البطيخ ما بين 2.929 إلى 6.277 و 0.096 إلى 0.208 و 1.992 إلى 4.603 كجم، على التوالى. تراوح كلا من زاوية التكويم وقوة السحق ما بين 49.67 إلى 71.00º و2.333 إلى 4.600 كيلو نيوتن. انخفض معدل التغير فى الابعاد بزيادة درجة حرارة التخزين وزيادة وقت التخزين. زاد كلا من المساحة السطحية والحجم لثمار البطيخ بانخفاض درجة حرارة التخزين وزيادة مقاس البطيخ. انخفض الفاقد فى الوزن بانخفاض درجة حرارة التخزين. انخفضت قوة السحق بانخفاض درجة حرارة التخزين. زاد معدل التسويق لثمار البطيخ بانخفاض درجة حرارة التخزين.

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