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QUALITY CHARACTERISTICS AND SHELF LIFE OF PEPPER FRUITS AS INFLUENCED BY STORAGE CONDITIONS AND PEPPER VARIETIES

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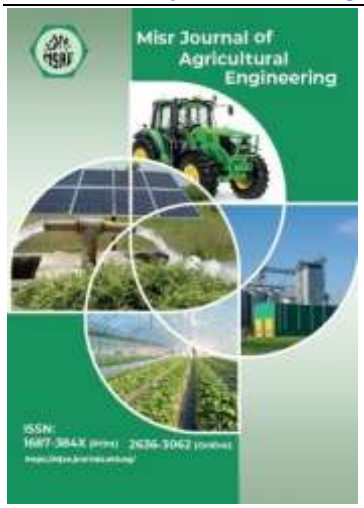

Keywords:
Pepper, physical properties, mechanical properties, storage temperature, weight loss, shelf life, TSS

ABSTRACT

The main aim of this research was to study the effect of storage conditions (room temperature and refrigeration temperature) on the quality (weight loss and chemical composition change on pepper fruits) and shelf life of different varieties of pepper (Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical Century White, Rush Red and Rush Green). The results indicated that, the accumulated weight loss of pepper fruits increases with increasing storage period. The highest value of the accumulated weight loss of pepper fruits (43.22 %) was found for green Rush variety at room temperature (25 ºC) after 20 days storage, while, the lowest value of the accumulated weight loss (25.44 %) was found for yellow Lumos variety at cold storage (10 ºC) after 46 days storage. The shelf- life of pepper fruits increased from 20 to 46 days for all varieties under study, when the storage temperatures decreased from 25 to 10°C. Average total soluble solids (TSS) increased from 3.50 to 5.63 % when the storage temperature changed from 10 to 25 ºC for all varieties used in this experiment.

1. INTRODUCTION

Pepper (*Capsicum annuum L.*) is one of the most important among vegetable crops throughout the world. Pepper fruits have a wide variety of shapes, sizes, colors, and include many different varieties of hot and sweet peppers. Peppers are generally considered as a balanced source of most of essential nutrients, high content of vitamins, important antioxidants, rich in flavonoids and phytochemicals (Costa *et al.*, 2009 and Maria *et al.*, 2010). Dimensions, geometric mean diameter, mass, surface area, volume, apparent volumetric, real volumetric, packaging coefficient, porosity, sphericity and static friction angle were measured through experiment. These properties determine the quality and identification of correlation among these properties makes quality control easier (Jannatizadeh, 2008). The design of processing machines, storage structures and environmental parameter controls depend on the properties of bio-materials. These properties are useful in the analysis and determination of the efficiency of a machine or an operation,

development of new products and new equipment and final quality of new products (Mohsenin, 1986 and Khater and Bahnasawy, 2016).

Watada *et al.* (1996) and Roura *et al.* (2000) reported that storage temperature is an essential parameter in maintaining quality and shelf life of fresh produce. Low temperature prolongs storage life by reducing respiration rate and senescence, as well as reducing growth of spoilage microorganisms. Optimum storage temperatures vary among commodity types. For fruits and vegetables susceptible to chilling injury, excessively low temperature can also cause chilling injury and resulted in loss of quality and shelf-life. Improper storage temperatures may adversely affect quality factors such as appearance, flavor, and color. In addition, product deterioration may proceed rapidly. Therefore, it is important to select the optimum storage temperature to maintain quality and extend storage-life of fresh fruits and vegetables (Kim *et al.*, 2004 and Khater and Bhnasawy, 2016).

The most effective method of maintaining quality and controlling decay of peppers is by a rapid cooling after harvest followed by storage at low temperature with a high relative humidity. However, peppers are very sensitive to chilling injury which limits storage temperature to above 10°C. On the other hand, without refrigeration, peppers turn color and deteriorate in a few days as a result of rapid aging and parasitic infections (Hardenburg *et al.*, 1986). Proper storage temperature selection is the most important parameter for storage of chilies and peppers. Optimum storage temperature range for chilies is reported between 7 to 13 °C for 2 - 3 weeks (Rico *et al.*, 2002).

Temperature of 10°C and 90 - 95% relative humidity maintain sweet pepper quality satisfactorily for a period of up to 12 - 18 days (Sealand, 1991). Low temperature storage remains the most effective tool for maintaining quality and extending shelf life, but it results in chilling injury. However, seal packaging ameliorates chilling injury in many fresh products by prevention of water loss (Ben-Yoshua, 1987).

Proper storage system reduces wastes, adds value and makes the product qualitatively and quantitatively acceptable. Respiration rate and gas exchange through the package material are the processes involved in creating a modified atmosphere inside a package that will extend shelf life of fresh bell peppers (Susana *et al.*, 2002). Bell peppers are not suitable for long term cold storage; the recommended range of storage temperatures for bell peppers is from 7 to 13 °C, depending on the variety and the maturity stage (Paull, 1995).

Postharvest losses of fresh horticultural crops ranged from 5 to 25% in developed countries and of 20 to 50% in developing countries (Kader, 2007). Optimum storage conditions are required to reduce these losses. Storage temperature is considered as main factors affecting the quality during storage. Also, one of the export problems is the lack of characteristics of fruits pepper which affect the value of pepper prices and their quality during storage. Therefore, the main aim of this work is to study the properties of different varieties of pepper fruits and investigate the quality and shelf-life of the fruit under different storage conditions.

2. MATERIALS AND METHODS

The experiment was carried out at Agricultural and Bio-Systems Engineering Department, Faculty of Agriculture, Moshtohor, Benha University, Qaluiobia Governorate, Egypt, during the period of March to May, 2020.

2.1. Materials

Pepper (*Capsicum annuum L.*) was brought from the Experimental Research Station at the Faculty of Agriculture, Moshtohor, Benha University after harvesting at the same maturity stage. Nine pepper varieties namely, Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical Century White, Rush Red and Rush Green Peppers were used in this study to measure and determine the physical and mechanical properties, also to study the effect of storage temperature on the quality and shelf life of pepper varieties.

2.2. Methods

2.2.1. Physical and mechanical properties

2.2.1.1.Physical properties

For each pepper fruit, three linear dimensions were measured by using a digital vernier caliper (Model TESA 1p65- Range 0-150 mm ± 0.01 mm, Swiss) with an accuracy of ±0.01mm, including length (L), width (W) and thickness (T) as shown in fig. 1. The rind thickness of pepper fruit rind was also measured by digital vernier caliper. The mass of fruit pepper was measured by electric digital balance (Model Vibra – Range 0-12000 g ± 0.01 g, Japan). Fruits geometric mean diameter (D_g) and surface are (S) were calculated as suggested by Mohsenin (1986):

$$D_g = \sqrt[3]{LWT} \quad (1)$$

$$S = \pi(D_g)^2 \quad (2)$$

Where:-

D_g is the geometric mean diameter, mm
L is the length of pepper fruits, mm
W is the width of pepper fruits, mm
T is the thickness of pepper fruits, mm
S is the fruit surface area, mm^2

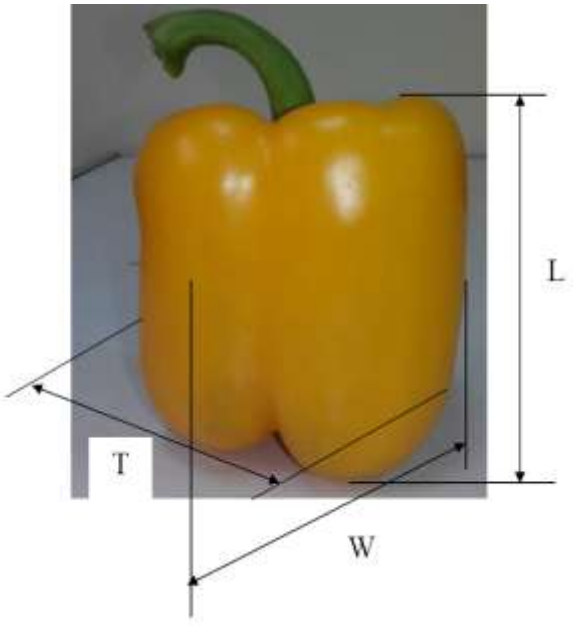

Fig. 1. Dimensions of pepper fruit: length (L), width (W) and thickness (T)

Water displacement method was used for determining the fruits measured volume (V_m). The criteria projected area (CPA) was calculated as suggested by Mohsenin (1986):

$$\mathrm{CPA} = \frac{AP_1 + AP_2 + AP_3}{3} \tag{3}$$

Where:

PA_1 is the projected area perpendicular to L direction of fruit, mm^2

PA_2 is the projected area perpendicular to T direction of fruit, mm^2

PA_3 is the projected area perpendicular to W direction of fruit, mm^2

Oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes were calculated as:

$$V_{osp} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)^2 \tag{4}$$

$$V_{ellip} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)\left(\frac{T}{2}\right) \tag{5}$$

Where:

V_{osp} is the oblate spheroid volume, mm^3

V_{ellip} is the ellipsoid shape volume, mm^3

The moisture content of randomly selected pepper fruits of each variety was determined according to ASAE Standard (1984). Three samples of each pepper fruits were randomly selected and weighed on an electrical digital balance. Drying oven (Model 655F Cat. No. 13-245-655, range 50 to 300 ºC, Canada) at 105°C until a constant weight was reached. The true density was calculated for pepper 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 hardness was measured by Hardness meter (Model GY-1-Range 20-150 N cm^{-2} ± 1 N cm^{-2}, China). Crushing load implies the partial or complete destruction of pepper fruits. Crushing load was measured by compressive and tensile device loads ((Model MP2E– Range 0-2000 kN ± 0.1kN, Italy).

Crushing load implies the partial or complete destruction of pepper fruits, pepper fruit was sat upon a flat plate until the cross-head of a handmade apparatus was brought in contact with the fruit and compression force was applied by adding weights or loads until permanent (destruction) was caused and then the loads were recorded (Khater *et al.*, 2014).

2.2.2. Storage conditions:

The pepper fruits were stored at cold storage of 10°C (85 ± 5 % relative humidity) and room temperature of 25 ± 3°C (60 ± 5 % relative humidity). The weight loss was measured every two days. The TSS was measured at the start and end of the experiment by Refractometer (Model HR-010-Range 0- 10% Brix ± 0.1% Brix, Japan).

3. RESULTS AND DISCUSSIONS

3.1. Physical properties

Table 1 shows the dimensions (length, width and thickness), rind thickness of pepper fruit, geometric mean diameter, mass, moisture content and density of the pepper fruits for different varieties (Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green,

Relampago Orange, Conical Century White, Rush Red and Rush Green). It could be seen that the length, width and thickness of pepper fruit value ranged from 71.858 to 200.246, 29.038 to 89.692 and 21.964 to 82.974 mm, respectively, for different varieties of pepper fruits. The lowest value of length, width and thickness of pepper fruits were 71.858, 29.038 and 21.964 mm were found for orange (Relampago), red (Rush) and red (Rush), respectively. While, the highest value of length, width and thickness of pepper fruits were 200.246, 89.692 and 82.974 mm were found for red (Rush), yellow (Dicaprio) and green (Dicaprio), respectively. These dimensions data are very important in handling, packing and storage capacity determination. These results agreed with those obtained by Shahbazi and Rahmati (2015) whose found that the length, width and thickness of pepper fruit were 84.254, 84.415 and 74.071 mm, respectively.

Table 1: The dimensions, rind thickness of pepper fruit, geometric mean diameter, mass, moisture content and density for different varieties of pepper fruits.

Pepper Variety		Dimensions, mm			Rind thickness of fruit, mm	Geometric mean diameter, mm	Mass, g	Moisture Content, % w.b	True Density, kg m^{-3}
		Length	Width	Thickness					
Sweet	Red (Alonso)	84.277	77.24	73.54	6.572	78.202	201.364	89.567	774.832
	Yellow (Lumos)	91.518	79.431	76.506	6.369	82.183	226.029	90.687	759.537
	Red (Relampago)	78.232	84.952	81.55	6.119	81.509	210.036	93.019	712.478
	Yellow (Dicaprio)	79.942	89.692	82.054	5.810	83.689	232.692	90.046	693.294
	Green (Dicaprio)	78.39	87.356	82.974	5.606	82.801	200.846	89.785	651.327
	Orang (Relampago)	71.858	86.79	79.524	5.896	79.103	190.734	90.345	699.781
	White (Conical century)	130.538	48.034	43.092	3.465	64.567	90.588	92.712	607.710
Hot	Red (Rush)	200.246	29.038	21.964	2.837	50.185	52.135	92.305	652.383
	Green (Rush)	194.036	31.708	26.598	3.144	54.623	65.989	88.790	690.487

The results indicated that the rind thickness of pepper fruit ranged from 2.837 to 6.572 mm. The lowest value of rind thickness of pepper fruits (2.837 mm) was found for red (Rush), on the other hand, the highest value of rind thickness of pepper fruits (6.572 mm) was found for red (Alonso).

The results also indicated that the geometric mean diameters of the pepper fruits were 78.202, 82.183, 83.679, 82.801, 79.103, 64.571, 50.185 and 54.623 mm for Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical century White, Rush Red and Rush Green varieties of pepper fruits, respectively.

Regarding the mass of pepper fruit value ranged from 52.135 to 232.692 g for different varieties of pepper fruits. The highest value of the mass of pepper fruit was 232.692 g was found for yellow (Dicaprio) variety, while, the lowest value of the mass of pepper fruit was 52.135 g was obtained for red (Rush) variety.

The results revealed that the moisture content of fruit were 89.567, 90.687, 93.019, 90.046, 89.785, 90.345, 92.305 and 88.790 % w.b, for Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical century White, Rush Red and Rush Green varieties of pepper fruits, respectively. The highest value of moisture content of pepper fruit (93.019 % w.b) was found for red (Relampago) variety, while, the lowest value of moisture content of pepper fruit (88.790 % w.b) was obtained for green (Rush) variety.

The true density of fruit were 774.832, 759.537, 712.478, 693.294, 651.327, 699.781, 607.710, 652.383 and 690.487 kg m^{-3}, for Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical Century White, Rush Red and Rush Green varieties of pepper fruits, respectively The highest value of true density of pepper fruit (774.832 kg m^{-3}) was found for red (Alonso) variety, while, the lowest value of true density of pepper fruit (607.710 kg m^{-3}) was obtained for white (Conical Century) variety. The trend of the results agreed with those obtained by Ilori *et al.,* (2010).

Table 2 shows the surface area, projected area, criteria projected area, measured volume, oblate spheroid volume and ellipsoid shape volume for different varieties of the pepper fruits. It could be seen that the surface area of the pepper fruits were 192.293, 212.536, 208.672, 220.530, 215.542, 197.038, 131.024, 79.147 and 93.878 cm^2 for Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical Century White, Rush Red and Rush Green varieties of pepper fruits, respectively. These results agreed with those obtained by Ikrang and Okoko (2014) whose found that the surface area of pepper fruit was 83.67 cm^2. Additionally, the highest value of surface area of pepper fruit (220.530 cm^2) was found for yellow (Dicaprio) variety, on the other hand, the lowest value of surface area of pepper fruit (79.147 cm^2) was obtained for red (Rush) variety.

Table 2: Surface area, projected area (AP), criteria projected area (CPA), measured volume, oblate spheroid volume (V_{osp}) and ellipsoid shape volume (V_{ellip}) for different varieties of pepper fruits.

Pepper variety		Surface Area, cm^2	AP1, cm^2	AP2, cm^2	AP3, cm^2	CPA, cm^2	Volume , cm^3	V_{osp}, cm^3	V_{ellip}, cm^3
Sweet	Red (Alonso)	192.293	65.187	62.043	56.842	257.381	264.098	251.308	61.357
	Yellow (Lumos)	212.536	72.717	70.130	60.926	293.053	303.187	292.377	67.925
	Red (Relampago)	208.672	66.470	63.786	69.281	291.610	295.641	283.637	66.512
	Yellow (Dicaprio)	220.530	71.701	65.660	73.884	319.899	337.273	309.410	70.415
	Green (Dicaprio)	215.542	68.614	65.054	72.528	304.443	314.874	298.172	68.732
	Orang (Relampago)	197.038	62.537	57.319	69.070	267.061	285.992	261.297	62.975
	White (Conical century)	131.024	62.700	56.266	20.668	143.863	157.688	141.229	46.545
Hot	Red (Rush)	79.147	58.258	43.645	6.362	72.006	88.934	66.308	36.089
	Green (Rush)	93.878	61.419	51.573	8.471	90.694	102.610	85.805	40.487

The projected area perpendicular to L, T and W directions of fruit were 58.130 to 72.717, 43.645 to 70.130 and 6.362 to 72.528 cm^2, respectively, for different varieties of pepper fruits. The criteria projected area of the pepper fruits were 61.357, 67.925, 66.512, 70.415,

68.732, 62.975, 46.545, 36.089 and 40.487 cm^2 for Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical century White, Rush Red and Rush Green varieties of pepper fruits, respectively. The highest value of criteria projected area of pepper fruit (70.415 cm^2) was found for yellow (Dicaprio) variety, while, the lowest value of criteria projected area of pepper fruit (36.089 cm^2) was obtained for red (Rush) variety.

The measured, oblate spheroid and ellipsoid shape volume of pepper fruit values ranged from 72.006 to 319.899, 88.934 to 337.273 and 66.308 to 309.410 cm^3 for different pepper varieties, respectively. The highest value of measured, oblate spheroid and ellipsoid shape volume of pepper fruit (319.899, 337.273 and 309.410 cm^3) were found for yellow (Dicaprio) variety, while, the lowest value of measured, oblate spheroid and ellipsoid shape volume of pepper fruit (72.006, 88.934 and 66.308 cm^3) were obtained for red (Rush) variety. The measured, oblate spheroid and ellipsoid shape volume of pepper fruit are important in handling and processing operations.

3.2. Mechanical properties

Table 3 shows the hardness and crushing load of the pepper fruits. The results indicated that the hardness of the pepper fruits ranged from 14.18 to 18.213 N cm^{-2}. The highest value of hardness of pepper fruit (18.213 N cm^{-2}) was found for red (Alonso) variety, while, the lowest value of hardness of pepper fruit (14.18 N cm^{-2}) was obtained for red (Rush) variety.

The crushing load of the pepper fruits ranged from 43.687 to 203.348 and 25.742 to 163.262 N for vertical and horizontal positions, respectively. The highest value of crushing load of pepper fruit (203.348 and 163.262 N) were found for red (Alonso) and red (Relampago) varieties, respectively. While, the lowest value of crushing load of pepper fruit (43.687 and 25.742 N) were found for green (Rush) and red (Rush) varieties, respectively.

Table 3: Some of the mechanical properties for different varieties of pepper fruits.

Pepper variety		Hardness, N cm^{-2}	Crushing Load, N	
			Vertical	Horizontal
Sweet	Red (Alonso)	18.213	203.348	161.415
	Yellow (Lumos)	17.038	183.883	149.927
	Red (Relampago)	16.954	198.611	163.262
	Yellow (Dicaprio)	16.503	182.714	150.708
	Green (Dicaprio)	15.991	172.669	149.940
	Orang (Relampago)	16.663	178.971	150.727
	White (Conical century)	15.8	93.265	46.936
Hot	Red (Rush)	14.18	43.780	25.742
	Green (Rush)	14.4	43.687	29.013

3.3. Effect of storage conditions on weight loss of different varieties pepper fruits

Fig. 2 shows the accumulated weight loss of pepper fruits that stored under different storage conditions. The results indicate that the accumulated weight loss of pepper fruits increases with increasing storage period. It could be seen that the accumulated weight loss of pepper fruits increased from 2.92 to 32.93, 2.64 to 27.97, 1.83 to 33.05, 1.59 to 29.50, 2.93 to 30.87

and 2.14 to 28.35 %, when the storage period proceeds from 2 to 26 days at room temperature of 25 ± 3°C and relative humidity of 60 ± 5 % (room temperature) for Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green and Relampago Orange, respectively.

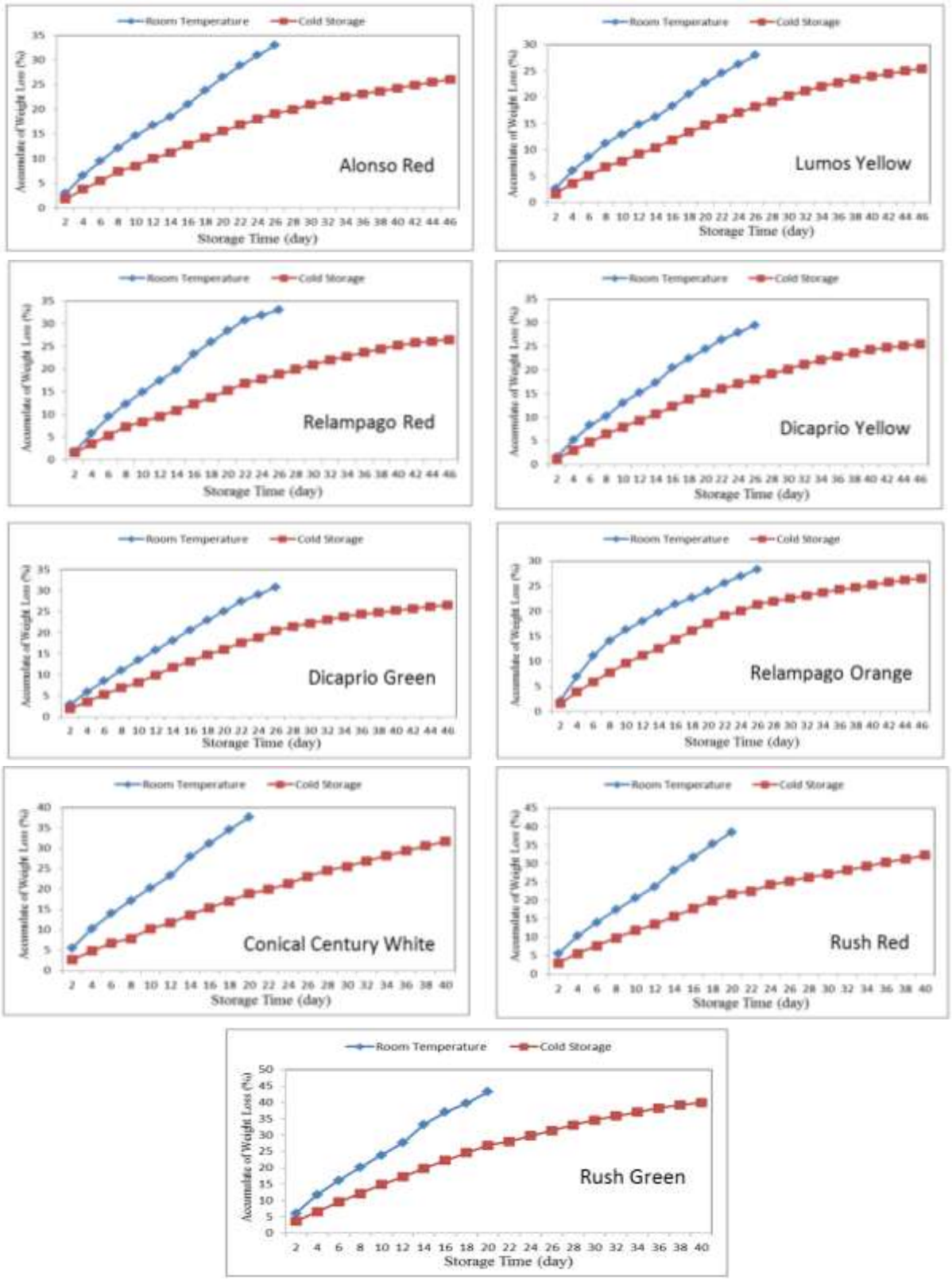

Fig. 2. The accumulated weight loss of different varieties pepper fruits at different storage conditions.

While, the accumulated weight loss of pepper fruits increased from 1.75 to 26.05, 1.62 to 25.44, 1.59 to 26.49, 1.13 to 25.51, 1.89 to 26.59 and 1.54 to 26.56 %, when the storage period increased from 2 to 46 days at cold storage of 10°C and relative humidity of 85 ± 5 % for the same previous mentioned species. Also, the accumulated weight loss of pepper fruits increased from 5.43 to 37.63, 5.48 to 38.54 and 6.07 to 43.22 %, when the storage period increased from 2 to 20 days at room temperature of 25 ± 3°C and relative humidity of 60 ± 5 % for Conical Century White, Rush Red and Rush Green, respectively. While, the accumulated weight loss of pepper fruits increased from 2.59 to 31.68, 3.03 to 32.23 and 3.63 to 39.91 %, when the storage period increased from 2 to 40 days at cold storage of 10°C and relative humidity of 85 ± 5 % for Conical Century White, Rush Red and Rush Green, respectively.

The results show the accumulated weight loss of pepper fruits stored at room temperature (25 ± 3°C) higher than of the fruits stored at cold storage (10°C). Storing the pepper under room temperature (25 ± 3°C and 60 ± 5 % relative humidity) lost 33.56 ± 3.99 % of its weight during the storage period (20 to 26 days). Meanwhile, it lost 28.94 ± 3.65 % of its weight when it was stored at cold storage (20°C and 85 ± 5 % relative humidity) for all varieties under study. Generally, the higher storage temperature, the higher vapor pressure deficit, the higher weight losses of fruits. These results were in agreement with those obtained by Khater and Bahnasawy (2016). The highest value of accumulated weight loss of pepper fruits was 43.22 % was found for green Rush variety at room temperature of 25 ºC after 20 days storage, while, the lowest value of accumulated weight loss of pepper fruits was 25.44 % was found for yellow Lumos variety at cold storage of 10 ºC after 46 days storage.

Regression analysis was carried out to find a relation between the accumulated weight loss of pepper fruits and storage times for different storage conditions and varieties. Equation 6 shows the most appropriate form for the relationship between the fruit accumulated weight loss and storage times for different storage condition and varieties. The constants of these equations and coefficient of determination are listed in Table 4.

$$WL = a\,t^2 + b\,t + c \quad (6)$$

Where:-

WL is the accumulated weight loss of pepper fruits (%)

t is the storage time (day)

3.4. Effect of storage conditions on the shelf life of different varieties pepper fruits

Table 5 shows the effect of storage conditions on the shelf life of pepper fruits for different varieties. The results indicated that the shelf life of pepper fruits increases with decreasing storage temperature, where, it increased from 26 to 46 days for Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green and Relampago Orange varieties under the storage temperatures decreased from 25 to 10°C. While, it increased from 20 to 40 days for Conical Century White, Rush Red and Rush Green varieties with the storage temperatures decreased from 25 to 10°C. Cold storage gave the fruit a long shelf life as twice as the room temperature gave, which may be due to that the cold storage decrease the respiration and transpiration rate which in turn the affects the shelf life of the fruits.

Table 4: The constants a, b, c and coefficient of determination for accumulated weight loss of pepper fruits at the storage times for different storage conditions and pepper varieties.

Pepper Variety	Constants and coefficient of determination							
	Room Temperature				Cold Storage			
	a	B	c	R^2	A	b	c	R^2
Red (Alonso)	-0.024	2.785	0.858	0.998	-0.033	1.881	0.004	0.999
Yellow (Lumos)	-0.034	2.519	0.905	0.997	0.028	1.768	-0.154	0.999
Red (Relampago)	-0.079	3.737	-1.571	0.998	-0.029	1.831	-0.113	0.999
Yellow (Dicaprio)	-0.058	3.123	-1.118	0.999	-0.031	1.861	-0.628	0.999
Green (Dicaprio)	-0.037	2.856	0.213	0.999	-0.039	2.112	-0.278	0.998
Orang (Relampago)	-0.126	3.744	-0.039	0.989	-0.049	2.279	0.574	0.999
White (Conical century)	0.025	3.798	2.243	0.998	-0.024	2.027	0.613	0.999
Red (Rush)	-0.017	3.801	2.289	0.998	-0.048	2.526	0.563	0.999
Green (Rush)	-0.076	4.945	1.568	0.998	-0.061	3.196	0.417	0.999

Table 5: The effect of storage conditions on the self life of different varieties pepper fruits.

Pepper Variety		Self Life of pepper fruits, day	
		Room Temperature	Cold Storage
Sweet	Red (Alonso)	26	46
	Yellow (Lumos)	26	46
	Red (Relampago)	26	46
	Yellow (Dicaprio)	26	46
	Green (Dicaprio)	26	46
	Orang (Relampago)	26	46
	White (Conical century)	20	40
Hot	Red (Rush)	20	40
	Green (Rush)	20	40

3.5. Effect of storage conditions on TSS

Table 6 shows the effect of storage conditions on the TSS change in pepper fruits for different varieties. The results indicated that the TSS in pepper fruits increases with increasing storage temperature. It could be seen that the TSS increased from 6.624 to 9.817 % (32.53%) and 6.624 to 11.362 % (41.70%) with the storage temperatures increased from 10 to 25°C, respectively, for Alonso Red variety. It increased from 6.072 to 9.093 % (33.22%) and 6.072 to 11.117 % (45.38%), 5.116 to 8.055 % (36.49%) and 5.116 to 10.568 % (51.59%), 4.738 to 8.016% (40.89%) and 4.738 to 10.109 % (53.13%), 3.165 to 7.264 % (56.43%) and 3.165 to 9.891 % (68.00%), 3.949 to 7.880 % (49.89%) and 3.949 to 10.194 % (61.26%), 4.001 to 7.875% (49.19%) and 4.001 to 10.194% (60.75%), 6.716 to 9.912 % (32.24%) and 6.716 to

11.580% (42.00%) and 3.534 to 7.473% (52.71%) and 3.534 to 9.726% (63.66%) for Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical Century White, Rush Red and Rush Green, respectively, with the storage temperatures increased from 10 to 25°C. These results were in agreement with those obtained by Yonemoto *et al.* (2002) and Bahnasawy and Khater (2014).

Additionally, the highest value of TSS change in pepper fruits was 68.00 % was found for Dicaprio Green variety at storage temperature 25 ºC, while, the lowest value of TSS change in pepper fruits was 32.24 % was found for Rush Red variety at storage temperature 10 ºC.

Table 6: The effect of storage conditions on TSS change in pepper fruits.

Pepper Variety		Total Soluble Solids, %			
		Room Temperature		Cold Storage	
		Before	After	Before	After
Sweet	Red (Alonso)	6.624	11.362	6.624	9.817
	Yellow (Lumos)	6.072	11.117	6.072	9.093
	Red (Relampago)	5.116	10.568	5.116	8.055
	Yellow (Dicaprio)	4.738	10.109	4.738	8.016
	Green (Dicaprio)	3.168	9.891	3.168	7.264
	Orang (Relampago)	3.949	10.005	3.949	7.880
	White (Conical century)	4.001	10.194	4.001	7.875
Hot	Red (Rush)	6.716	11.580	6.716	9.912
	Green (Rush)	3.534	9.726	3.534	7.473

4. CONCLUSIONS

The experiment was carried out successively to determine some physical and mechnical properties of some varieties of pepper (Alonso Red, Lumos Yellow, Relampago Red, Dicaprio Yellow, Dicaprio Green, Relampago Orange, Conical Century White, Rush Red and Rush Green) and study the effect of storage conditions on pepper fruits quality for different varieties. The obtained results can be summarized as follows:

- The length, width and thickness of pepper fruit value ranged from 71.858 to 200.246, 29.038 to 89.692 and 21.964 to 82.974 mm, respectively. The thickness of pepper fruit and the geometric mean diameter of the pepper fruits ranged from 2.837 to 6.572 and 50.185 to 83.679 mm, respectively.
- The surface area of pepper fruit values ranged from 79.147 to 220.530 cm^2. The moisture content of the pepper fruits ranged from 88.790 to 93.019 %. The density of the pepper fruits ranged from 607.710 to 774.832 kg m^{-3}.
- The mass of pepper fruit value ranged from 52.135 to 232.692 g. The measured, oblate spheroid and ellipsoid shape volume of pepper fruit values ranged from 72.006 to 319.899, 88.934 to 337.273 and 66.308 to 309.410 cm^3 for different pepper varieties, respectively.
- The hardness of the pepper fruits ranged from 14.18 to 18.213 N cm^{-2}. The crushing load (vertical and horizontal) of the pepper fruits ranged from 43.687 to 203.348 and 25.742 to 163.262 N for vertical and horizontal, respectively.

- The highest value of the accumulated weight loss of pepper fruits (43.22 %) was found for green Rush variety at room temperature of 25 ºC after 20 days storage, while, the lowest value of the accumulated weight loss of pepper fruits (25.44 %) was found for yellow Lumos variety at cold storage of 10 ºC after 46 days storage.
- The shelf life of pepper fruits increased from 20 to 46 days for all varieties under study, when the storage temperatures decreased from 25 to 10°C.
- Average total soluble solids (TSS) increased from 3.50 to 5.63 % when the storage temperature changed from 10 to 25 ºC for all varieties.

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خواص الجودة والعمر التخزينى لثمار اصناف مختلفة من الفلفل نتيجة ظروف التخزين

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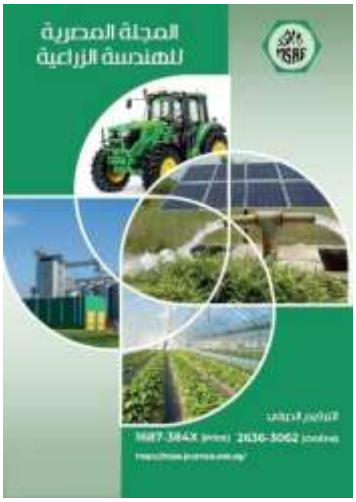

الكلمات المفتاحية:
الفلفل، الخصائص الطبيعية، الخصائص الميكانيكية، درجة حرارة التخزين، الفاقد فى الوزن، العمر التخزينى

الملخص العربى

يهدف هذا البحث الى دراسة تأثير ظروف التخزين (درجة حرارة الغرفة ودرجة حرارة غرفة التبريد) على خواص الجودة والعمر التخزينى لبعض اصناف الفلفل. وكانت اهم النتائج المتحصل عليها: كانت اعلى قيمة للفاقد فى الوزن التراكمى لثمار الفلفل هى ٤٣.٢٢ % وكانت لصنف Rush الأخضر المخزن على درجة حرارة الغرفة (٢٥°م) بعد ٢٠ يوم من التخزين، بينما كانت أقل قيمة للفاقد فى الوزن التراكمى لثمار الفلفل هى ٢٥.٤٤ % وكانت لصنف Lumos الأصفر المخزن على درجة حرارة ١٠°م بعد ٤٦ يوم من التخزين. زاد العمر التخزينى لثمار الفلفل من ٢٦ إلى ٤٦ يوم للأصناف Alonso الأحمر وLumos الأصفر وRelampogo الأحمر وDicaprio الأصفر وDicaprio الأخضر وRelampago البرتقالى، بينما زادت من ٢٠ إلى ٤٠ يوم للأصناف Conical Century الأبيض وRush الأحمر وRush الأخضر عند انخفاض درجة حرارة التخزين من ٢٥ إلى ١٠ °م. كانت أعلى قيمة للتغير فى المواد الصلبة الذائبة هى ٦٨.٠٠ % وكانت لصنف Dicaprio الأخضر المخزن على درجة حرارة ٢٥°م، بينما كانت أقل قيمة للتغير فى المواد الصلبة الذائبة هى ٣٢.٢٤% وكانت لصنف Rush الأحمر المخزن على درجة حرارة ١٠°م.