

## EFFECT OF WAX COATING ON THE QUALITY OF CUCUMBER FRUITS DURING STORAGE

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### ABSTRACT

*The main objective of this work was to study the effect of waxing and storage temperature on cucumber fruits quality. The parameters study include: diameter change, length change, weight loss, volume change, surface area change, hardness, TSS and shelf life on cucumber fruits. The obtained results can be summarized as follows: The diameter change decreases with increasing wax solution, meanwhile, the diameter change increases with decreasing temperature storage. The length change decreases with increasing wax solution and it increases with decreasing temperature storage. The weight loss decreases with increasing wax solution but it increases with decreasing temperature storage. The volume change decreases with increasing wax solution, meanwhile, it increases with decreasing temperature storage. The surface area change decreases with increasing wax solution but it increases with decreasing temperature storage. The hardness decreases with increasing wax solution but it increases with decreasing temperature storage. The TSS decreases with increasing wax solution but it increases with decreasing temperature storage. The shelf life increases with increasing wax solution but it increases with decreasing temperature storage.*

**Keywords:** wax coating, storage temperature, cucumber, fruit size change, weight loss, TSS, hardness, shelf life

### INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an important vegetable belonging to the family of Cucurbitaceae. Cucumbers contain approximately 95% water, 3.6% carbohydrates, and 0.65% protein, and are low in calories (150 kcal kg<sup>-1</sup>).

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They are a good source of the following nutrients (in mg kg<sup>-1</sup>): pantothenic acid (B5) (0.026); vitamin C (0.28); magnesium (1.3) (**USDA, 2008**). Cucumbers are grown both as a source of pickles, and to be eaten fresh. While consumption of pickles has been waning, the use of cucumbers as a fresh vegetable has been increasing (**Lucier and Jerardo, 2007**).

Cucumber (*Cucumis sativus L.*) is a favorite commodity exports for markets and local consumption and represents one of the most important and economic vegetables in Egypt. It is grown in Egypt in the open field from March to November and under plastic houses from September to May. The total cultivated area of cucumber in Egypt was about 66640 feddans in 2011 according to the statistics of **CAPMS (2011)**.

Waxing was used as a preservation technique for fruits since 1900. Wax has been used since pre-historic times. In 4200 BC, the ancient Egyptians kept bees and used the wax from honeycombs to make models and to preserve their dead and in encaustic painting. The Chinese were using waxing processes on fruits, but it was not until 1922 that a waxing process Waxing of fruits and vegetables is done according to the recommendations. Food grade waxes are used to replace some of the natural; waxes removed in washing and cleaning operations, and this helps to reduce the water loss during handling and marketing. If produce is waxed, the wax coating is allowed to dry thoroughly before further handling. Waxing of the produce is an old age art, which was started in the beginning of the 19<sup>th</sup> century. was introduced for wide spread use on fruits and vegetables (**Thirupathi, 2006**).

Water loss can be controlled by altering the fruit surface or by proper control of storage conditions. Examples of the first method are the application of artificial wax coatings and heat treatments. Artificial, edible coatings are generally applied by spraying or dipping after removal of the natural wax. The effectiveness of the coating depends on the thickness, concentration, and type of coating (**Amarante et al., 2001a and b**).

To avoid deterioration, cucumbers are often stored and transported at cold temperatures. However, cucumbers are among a number of tropical

and subtropical crops that are sensitive to above-freezing cool temperatures. Low-temperature storage of cucumbers may induce damage associated with chilling injury (CI), resulting in compositional as well as in morphological (structural) and microbiological changes (**Fukushima *et al.*, 1977; Marcellin and Ulrich, 1983; Wang, 1989; Musmade and Desai, 1998; Tatsumi *et al.*, 1987, 2006; Fernández-Trujillo and Martínez, 2006; Martínez and Fernández-Trujillo, 2007; Pérez- Díaz and McFeeters, 2008**).

The susceptibility of cucumbers to chilling injury and to yellowing restricts desirable storage temperatures to a narrow range. If held at 10°C or colder, they suffer chilling injury; if held at 15 °C or higher, they rapidly become yellow. Thus, the optimum is 12 to 13 °C. However, for storage of 1 to 2 weeks, 10 °C is preferable because chilling is minimal and yellowing is retarded, although **Apeland (1966)** claims that yellowing is slower at 13 °C than at higher or lower temperatures. The same author found that differences in chilling sensitivity among cultivars are minor.

The susceptibility of cucumbers to chilling injury does not preclude their exposure to temperatures below 5°C as long as they are utilized immediately after removal from cold storage, because symptoms develop rapidly only at higher temperatures. Thus, 2 days at 0 °C, 4 days at 5 °C, or 8 days at 7 °C are harmless under these conditions (**Ryall and Lipton, 1979**). They added that cucumbers can be expected to remain in good condition for 10 to 14 days at 10 °C. For fruits harvested relatively young, where yellowing is not an immediate problem, 13 °C would be preferable and may extend the storage life 2 to 3 days and proper controlled atmosphere (CA) conditions may add a further 4 to 6 days, for a total of about 3 weeks.

Cucumber fruits are losing too much moisture, exposed to damage and bruising, losing the good appearance during handling and storage process, so that using wax as coating is the most common practice to prevent moisture loss, protect the fruits from damage and bruising, increase the shelf life and improve the fruit appearance, which in turn increase the marketability of the cucumber. To achieve that cucumber was waxed with different solution concentrations and stored at different

temperatures, to study the appearance indices and weight loss which in turn affects the final quality of cucumber during storage.

### **MATERIALS AND METHODS**

The experiment was carried out at Agricultural Engineering Department, Faculty of Agriculture, Moshtohor, Benha University, during the period of June to July, 2012.

#### **- Materials:**

The Cucumber (*Cucumis sativus* L.) was brought from the faculty of agriculture farm, Moshtohor, Benha University after harvesting.

Paraffin wax (or simply "paraffin", but see alternative name for kerosene, above) is mostly found as a white, odorless, tasteless, waxy solid, with a typical melting point between about 46 and 68 °C (115 and 154 °F), and having a density of around 0.9 g/cm<sup>3</sup>. It is insoluble in water, but soluble in ether, benzene, and certain esters. Paraffin is unaffected by most common chemical reagents but burns readily.

Refrigeration room used in this study has 3.0 m in length, 3.0 m in width and 3.0 m height. It made prefabricated insulated Panels of thickness from 60mm. the panels insulation are covered with precoated stainless steel sheet on both side.

#### **- Methods:**

The cucumber fruits were dipped into a 25, 50, 75, 100% wax solutions and control. The fruits were then fan-dried at room temperature (approximately 25 °C). The fruits were storage at four temperature 5, 10, 15°C and room temperature. Twenty treatments were applied (five wax solution and four temperature storage) and replicated 3 times. The cucumber fruits are washed and then without being dried are dipped into a wax emulsion paraffin of proper concentration.

#### **- Measurements:**

The dimensions of fruits (length and diameter) were measured by digital vernier caliper (Model TESA 1p65). The mass was measured by electric digital balance (Model HG – 5000). The surface area was measured by wrapping aluminum foil around the cucumber fruit and then cutting the foil away with scissors into thin strips sufficient to lay the foil flat. A planimeter was used to measure the area of the foil which represents the surface area of the cucumber concerned. The volume of fruits was

measured by graduated cylinder. The hardness was measured by Hardness meter (Model GY-1). The TSS was measured by Refractometer (Model HR-010). These measurements were determined before and after of storage.

- **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.

### RESULTS AND DISCUSSION

- **Effect of wax coating and temperature storage on the fruit size change.**

**1. Diameter change:**

Table (1) and figures (1 and 2) show effect of different wax solutions and storage temperatures on change in cucumber fruit size. The results indicate that the change of diameter decreases with increasing wax solution, meanwhile, the diameter change increases with decreasing storage temperature, where, it decreased significantly from 8.388 to 3.814 mm when the wax solution increased from 0 to 100%. On the other hand, loss of diameter decreased significantly from 6.699 to 4.596 mm with the storage temperature from 5°C to room temperature. Statistical analysis of the data showed that there were significant differences for interaction between the wax solution and storage temperature.

Table (1): Effect of wax coating and storage temperature on cucumber fruit diameter change (mm).

Wax Coating (%) \ Storage (°C)	0	25	50	75	100	Mean (B)
5	11.363 <sup>a</sup>	6.813 <sup>b</sup>	5.370 <sup>d</sup>	5.080 <sup>d</sup>	4.870 <sup>d</sup>	6.699 <sup>a</sup>
10	9.133 <sup>b</sup>	5.777 <sup>d</sup>	3.773 <sup>e</sup>	3.050 <sup>f</sup>	3.490 <sup>f</sup>	5.045 <sup>b</sup>
15	7.247 <sup>c</sup>	4.677 <sup>d</sup>	4.210 <sup>de</sup>	3.900 <sup>e</sup>	3.443 <sup>ef</sup>	4.695 <sup>c</sup>
Room temperature	5.810 <sup>d</sup>	5.130 <sup>d</sup>	4.443 <sup>d</sup>	4.143 <sup>e</sup>	3.453 <sup>ef</sup>	4.596 <sup>c</sup>
Mean (A)	8.388 <sup>a</sup>	5.600 <sup>b</sup>	4.449 <sup>c</sup>	4.043 <sup>d</sup>	3.814 <sup>e</sup>	5.259
LSD at 0.05	A		B		AB	
	0.278		0.29		0.648	

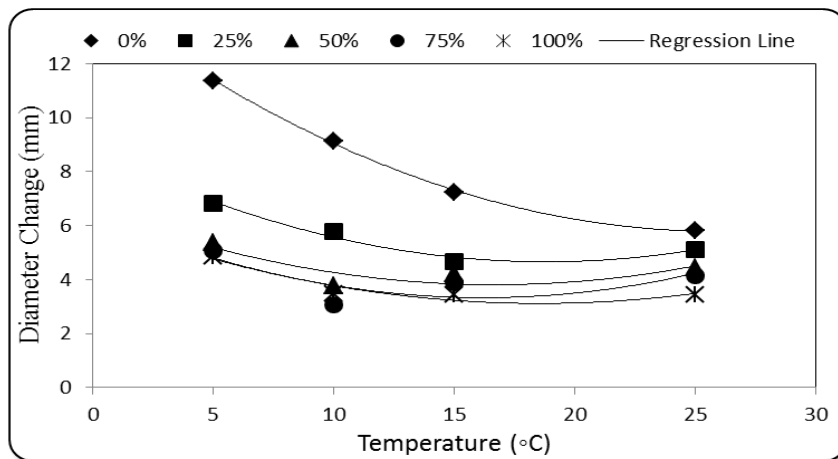


Fig. (1): Effect of wax coating on cucumber fruit diameter change.

Regression analysis was aimed out to find a relation between the diameter change and the wax solution and the most appropriate forms at different storage temperatures are as follows:

At 0 %       $DC = 0.0128WC^2 - 0.6641WC + 14.3998$        $R^2 = 0.99$       (1)

At 25%       $DC = 0.0117WC^2 - 0.4389WC + 8.7937$        $R^2 = 0.97$       (2)

At 50%       $DC = 0.0100WC^2 - 0.335WC + 6.6103$        $R^2 = 0.94$       (3)

At 75%       $DC = 0.0117WC^2 - 0.3796WC + 6.4102$        $R^2 = 0.93$       (4)

At 100%       $DC = 0.009WC^2 - 0.3324WC + 6.202$        $R^2 = 0.95$       (5)

Where:-

DC is the diameter change (mm) - WC is the wax coating (%)

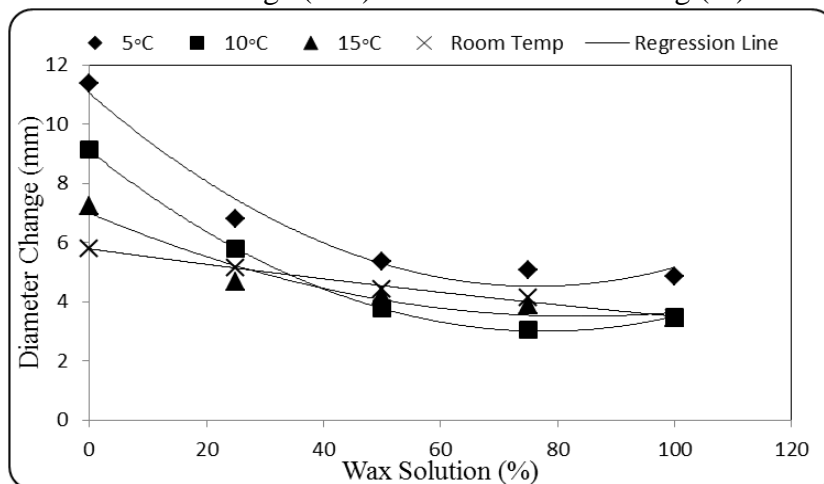


Fig. (2): Effect of temperature storage on cucumber fruit diameter change.

The regression between the diameter change and the storage temperature at different wax solution are shown in the following equations:

$$\text{At } 5^{\circ}\text{C} \quad \text{DC} = 0.0011 T^2 - 0.1713 T + 11.048 \quad R^2 = 0.97 \quad (6)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{DC} = 0.001T^2 - 0.1575T + 9.1148 \quad R^2 = 0.99 \quad (7)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{DC} = 0.0005T^2 - 0.0836T + 6.9985 \quad R^2 = 0.94 \quad (8)$$

$$\text{At room temp.} \quad \text{DC} = 4\text{E-}05T^2 - 0.027T + 5.7884 \quad R^2 = 0.99 \quad (9)$$

Where:-

T is the temperature ( $^{\circ}\text{C}$ )

## 2. Length change:

Table (2) and figures (3 and 4) show effect of different wax coating and storage temperatures on change in cucumber length change. The results indicate that the length decreases with increasing wax solution and it increases with decreasing temperature storage, where, it decreased significantly from 3.052 to 1.198 cm when the wax solution increased from 0 to 100%. On the other hand, the length change decreased significantly from 2.232 to 1.542 cm with the storage temperature change from  $5^{\circ}\text{C}$  to room temperature.

Statistical analysis of the data showed that there were none significant differences for interaction between the wax solution and temperature storage.

Table (2): Effect of waxing and temperature storage on cucumber fruit length change (cm).

Storage ( $^{\circ}\text{C}$ ) \backslash Wax Coating (%)	Wax Coating (%)					
	0	25	50	75	100	Mean (B)
5	3.443	2.33	2.113	1.777	1.497	2.232 <sup>a</sup>
10	3.723	1.943	1.837	1.447	1.223	2.035 <sup>b</sup>
15	2.63	1.79	1.333	1.167	1.072	1.598 <sup>c</sup>
Room temperature	2.41	1.633	1.5	1.17	1	1.542 <sup>d</sup>
Mean (A)	3.052 <sup>a</sup>	1.924 <sup>b</sup>	1.696 <sup>c</sup>	1.390 <sup>d</sup>	1.198 <sup>e</sup>	1.852
LSD at 0.05	A		B		AB	
	0.158		0.145		N.S	

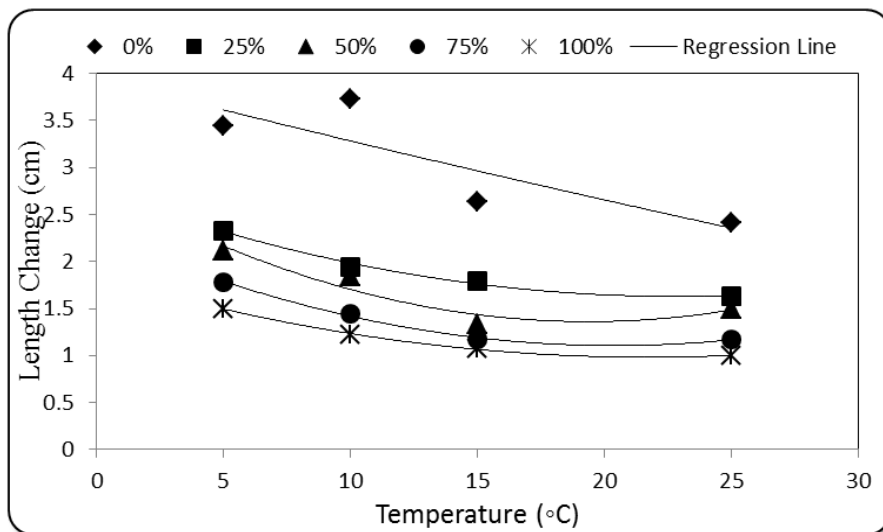


Fig. (3): Effect of wax coating on cucumber fruit length change.

The best fit for the relationship between the length change and the wax coating at different storage temperatures were as follows:

At 0 %                       $LC = 0.0002WC^2 - 0.0687WC + 3.9474$                        $R^2 = 0.91$     (10)

At 25%                       $LC = 0.0022WC^2 - 0.0988WC + 2.7549$                        $R^2 = 0.98$     (11)

At 50%                       $LC = 0.0039WC^2 - 0.1507WC + 2.8201$                        $R^2 = 0.92$     (12)

At 75%                       $LC = 0.0029WC^2 - 0.1174WC + 2.3034$                        $R^2 = 0.99$     (13)

At 100%                       $LC = 0.0018WC^2 - 0.0794WC + 1.8447$                        $R^2 = 0.99$     (14)

Where:-

LC is the Length change (cm)

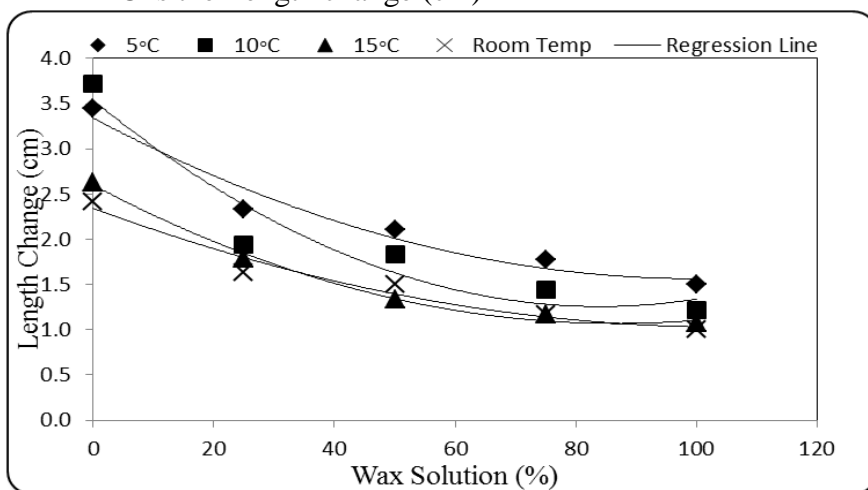


Fig. (4): Effect of temperature storage on cucumber fruit length change.



The best fit for the relationship between the length change and the temperature at different wax solution were as follows:

$$\text{At } 5^{\circ}\text{C} \quad \text{LC} = 0.0002T^2 - 0.0355T + 3.342 \quad R^2 = 0.96 \quad (15)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{LC} = 0.0003T^2 - 0.0543T + 3.5378 \quad R^2 = 0.92 \quad (16)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{LC} = 0.0002T^2 - 0.0353T + 2.6006 \quad R^2 = 0.99 \quad (17)$$

$$\text{At room temp.} \quad \text{LC} = 0.0001T^2 - 0.0248T + 2.3445 \quad R^2 = 0.96 \quad (18)$$

### 3. Weight Loss:

Table (3) and figures (5 and 6) show effect of different wax coating and storage temperatures on change in weight loss of cucumber. The results indicate that the weight loss decreases with increasing wax coating but it increases with decreasing temperature storage, where, it decreased significantly from 54.423 to 27.140 % when the wax solution increased from 0 to 100%. On the other hand, weight loss decreased significantly from 42.383 to 24.935 % with the storage temperatures from 5°C to room temperature. These results were agreed with those obtained by **Yonemoto *et al.* (2002)**.

Statistical analysis of the data showed that there were significant differences for interaction between the wax solution and temperature storage.

Table (3): Effect of wax coating and storage temperature on cucumber fruit weight loss (%).

Storage (°C) \ Wax Coating (%)	0	25	50	75	100	Mean (B)
5	61.923 <sup>a</sup>	48.766 <sup>c</sup>	37.543 <sup>d</sup>	32.588 <sup>d</sup>	31.095 <sup>d</sup>	42.383 <sup>a</sup>
10	57.162 <sup>b</sup>	44.280 <sup>c</sup>	34.505 <sup>d</sup>	32.240 <sup>d</sup>	30.183 <sup>d</sup>	39.674 <sup>b</sup>
15	54.841 <sup>c</sup>	33.684 <sup>d</sup>	28.114 <sup>e</sup>	22.602 <sup>f</sup>	20.140 <sup>f</sup>	31.876 <sup>c</sup>
Room temperature	51.265 <sup>c</sup>	30.687 <sup>d</sup>	19.525 <sup>f</sup>	13.351 <sup>g</sup>	9.847 <sup>g</sup>	24.935 <sup>d</sup>
Mean (A)	54.423 <sup>a</sup>	36.217 <sup>b</sup>	33.388 <sup>b</sup>	29.143 <sup>c</sup>	27.140 <sup>c</sup>	34.717
LSD at 0.05	A		B		AB	
	4.15		2.318		4.383	

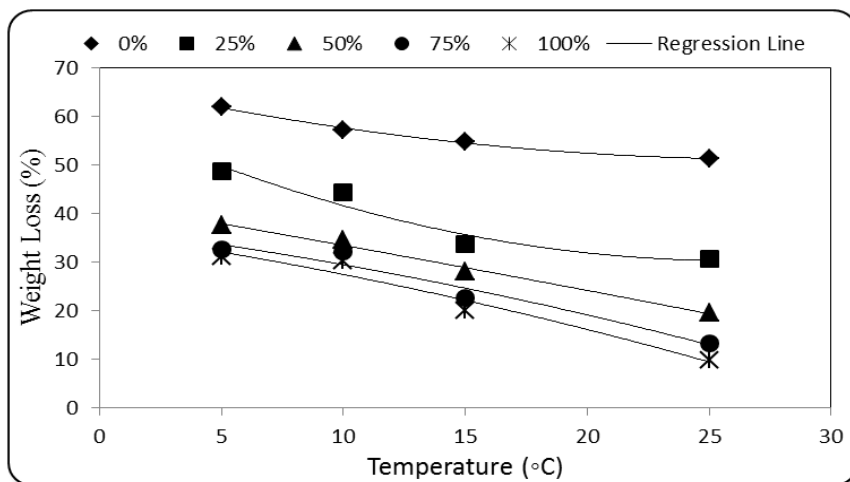


Fig. (5): Effect of wax coating on cucumber fruit weight loss.

The best fit for the relationship between the weight loss and the wax coating at different storage temperatures were as follows:

At 0 %  $WL = 0.0204WC^2 - 1.1326WC + 66.906$   $R^2 = 0.99$  (19)

At 25%  $WL = 0.0438WC^2 - 2.2851WC + 60.092$   $R^2 = 0.94$  (20)

At 50%  $WL = -0.0023WC^2 - 0.8585WC + 42.281$   $R^2 = 0.99$  (21)

At 75%  $WL = -0.0135WC^2 - 0.6244WC + 37.083$   $R^2 = 0.95$  (22)

At 100%  $WL = -0.0136WC^2 - 0.7221WC + 36.06$   $R^2 = 0.96$  (23)

Where:-

WL is the weight loss (%)

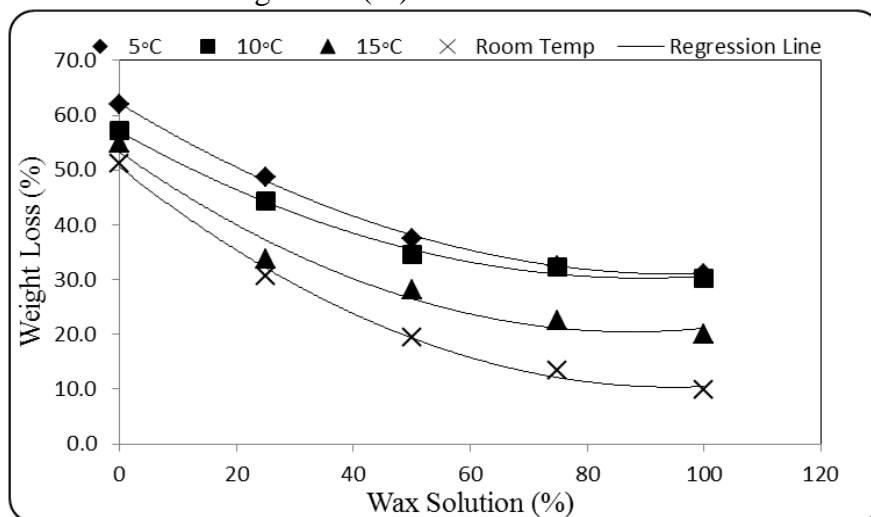


Fig. (6): Effect of storage temperatures on cucumber fruit weight loss.

The best fit for the relationship between the weight loss and the temperature at different wax solution were as follows:

$$\text{At } 5^{\circ}\text{C} \quad \text{WL} = 0.0034T^2 - 0.6495T + 62.177 \quad R^2 = 0.99 \quad (24)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{WL} = 0.0033T^2 - 0.5973T + 57.039 \quad R^2 = 0.99 \quad (25)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{WL} = 0.0043T^2 - 0.7499T + 53.323 \quad R^2 = 0.97 \quad (26)$$

$$\text{At room temp.} \quad \text{WL} = 0.0045T^2 - 0.848T + 50.56 \quad R^2 = 0.99 \quad (27)$$

#### 4. Volume change:

Table (4) and figures (7 and 8) show the effect of different wax coating and different storage temperatures on change in cucumber length change. The results indicate that the volume change decreases with increasing wax coating, meanwhile, it increases with decreasing temperature storage, where, it decreased significantly from 59.833 to 23.083 cm<sup>3</sup> when the wax solution increased from 0 to 100%. On the other hand, loss of volume cucumber fruit decreased significantly from 51.801 to 25.156 cm<sup>3</sup> with the storage temperatures change from 5°C to room temperature.

Statistical analysis of the data showed that there were significant differences for the interaction between the wax coating and temperature storage, also, there were significant differences between the treatments of both storage temperature and wax coating.

Table (4): Effect of wax coating and temperature storage on cucumber fruit volume change (cm<sup>3</sup>).

Wax Coating (%) \ Storage (°C)	0	25	50	75	100	Mean (B)
5	86.000 <sup>a</sup>	53.557 <sup>c</sup>	50.000 <sup>c</sup>	41.113 <sup>d</sup>	28.333 <sup>e</sup>	51.801 <sup>a</sup>
10	64.223 <sup>b</sup>	51.667 <sup>c</sup>	36.000 <sup>d</sup>	33.223 <sup>de</sup>	31.890 <sup>e</sup>	43.401 <sup>c</sup>
15	47.110 <sup>c</sup>	40.443 <sup>d</sup>	26.557 <sup>c</sup>	25.223 <sup>f</sup>	22.443 <sup>f</sup>	32.355 <sup>c</sup>
Room temperature	42.000 <sup>cd</sup>	32.223 <sup>de</sup>	26.113 <sup>ef</sup>	15.777 <sup>g</sup>	9.667 <sup>g</sup>	25.156 <sup>b</sup>
Mean (A)	59.833 <sup>a</sup>	44.472 <sup>b</sup>	34.667 <sup>c</sup>	28.834 <sup>d</sup>	23.083 <sup>e</sup>	38.18
LSD at 0.05	A		B		AB	
	3.366		3.037		6.791	

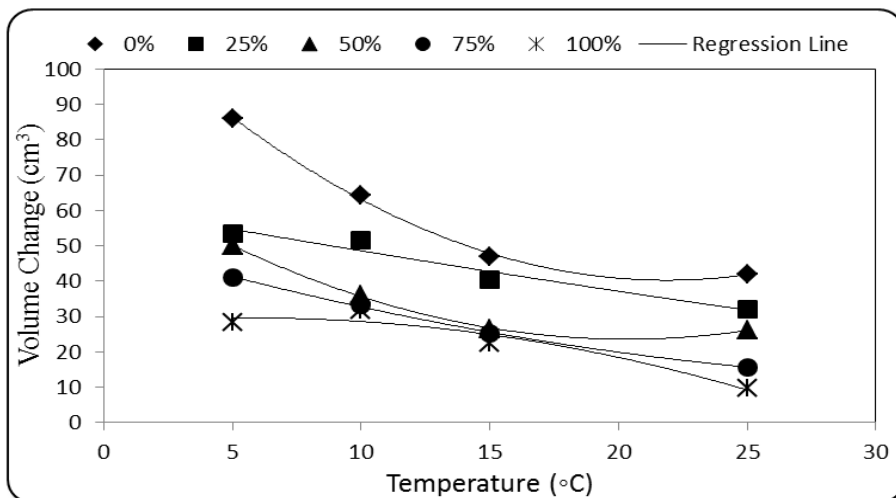


Fig. (7): Effect of wax coating on cucumber fruit volume change.

The best fit for the relationship between the volume change and the wax coating at different storage temperatures were as follows:

At 0 %                       $VC = 0.162WC^2 - 7.0883WC + 117.8$                        $R^2 = 0.99$     (28)

At 25%                       $VC = 0.0053WC^2 - 1.3017WC + 61.085$                        $R^2 = 0.95$     (29)

At 50%                       $VC = 0.1128WC^2 - 4.5878WC + 70.249$                        $R^2 = 0.99$     (30)

At 75%                       $VC = 0.0291WC^2 - 2.152WC + 51.334$                        $R^2 = 0.99$     (31)

At 100%                       $VC = -0.0549WC^2 + 0.633WC + 27.773$                        $R^2 = 0.94$     (32)

Where:-

VC is the volume change (cm<sup>3</sup>)

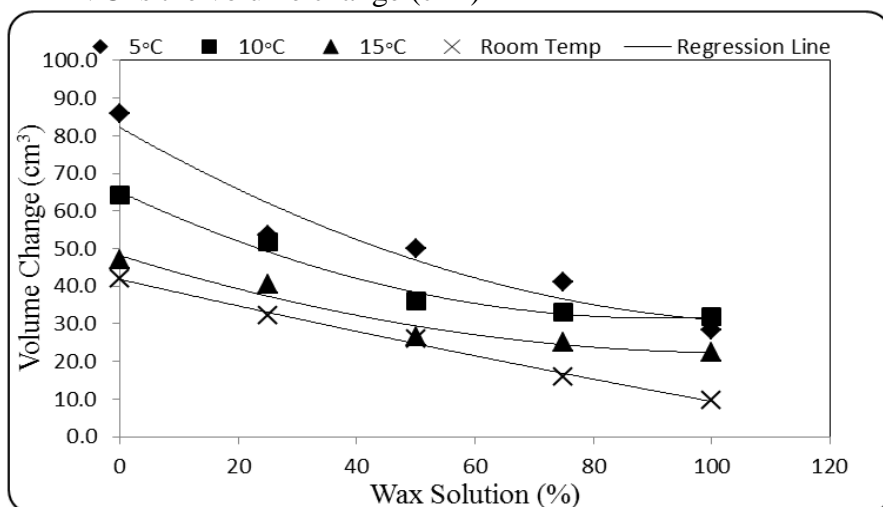


Fig. (8): Effect of temperature storage on cucumber fruit volume change.

The best fit for the relationship between the volume change and the temperature at different wax coating was as follows:

$$\text{At } 5^{\circ}\text{C} \quad \text{VC} = 0.0039T^2 - 0.8996T + 82.213 \quad R^2 = 0.93 \quad (33)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{VC} = 0.004T^2 - 0.7363T + 65.071 \quad R^2 = 0.98 \quad (34)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{VC} = 0.0023T^2 - 0.4905T + 48.17 \quad R^2 = 0.96 \quad (35)$$

$$\text{At room temp.} \quad \text{VC} = 0.0004T^2 - 0.36T + 41.822 \quad R^2 = 0.99 \quad (36)$$

### 5. Surface area change:

Table (5) and figures (9 and 10) show effect of different wax coating and storage temperatures on change in surface area change. The results indicate that the surface area change decreases with increasing wax solution but it increases with decreasing temperature storage, where, it decreased significantly from 65.020 to 20.142 cm<sup>2</sup> when the wax solution increased from 0 to 100%. On the other hand, change of surface area decreased significantly from 42.491 to 30.353 cm<sup>2</sup> with the storage temperatures changed from 5°C to room temperature.

Statistical analysis of the data showed that there were none significant differences for interaction between the wax solution and temperature storage.

Table (5): Effect of wax coating and temperature storage on cucumber fruit surface area change (cm<sup>2</sup>).

Wax Coating (%) \ Storage (°C)	0	25	50	75	100	Mean (B)
5	78.103	44.27	34.69	30.29	25.11	42.491 <sup>a</sup>
10	67.277	42.43	33.24	28.43	24.26	39.129 <sup>b</sup>
15	65.233	41.52	32.98	25.19	22.6	37.504 <sup>b</sup>
Room temperature	49.467	40.82	30.14	22.73	8.6	30.353 <sup>c</sup>
Mean (A)	65.020 <sup>a</sup>	42.262 <sup>b</sup>	32.763 <sup>c</sup>	26.661 <sup>d</sup>	20.142 <sup>e</sup>	37.37
LSD at 0.05	A		B		AB	
	2.94		3.28		N.S	

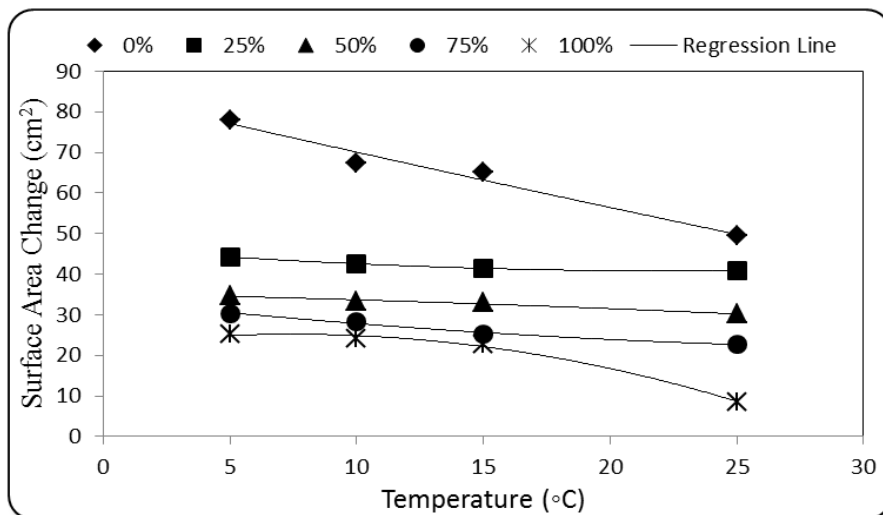


Fig. (9): Effect of wax solution on cucumber fruit surface area change. The best fit for the relationship between the surface area change and the wax coating at different storage temperatures were as follows:

At 0 %      SAC = 0.0028WC<sup>2</sup> - 1.4468WC + 84.23      R<sup>2</sup> = 0.97    (37)

At 25%      SAC = 0.011WC<sup>2</sup> - 0.4997WC + 46.448      R<sup>2</sup> = 0.99    (38)

At 50%      SAC = -0.003WC<sup>2</sup> - 0.1276WC + 35.242      R<sup>2</sup> = 0.97    (39)

At 75%      SAC = 0.0095WC<sup>2</sup> - 0.6776WC + 33.663      R<sup>2</sup> = 0.98    (40)

At 100%      SAC = -0.0537WC<sup>2</sup> + 0.8005WC + 22.225      R<sup>2</sup> = 0.99    (41)

Where:-

SAC is the surface area change (cm<sup>2</sup>)

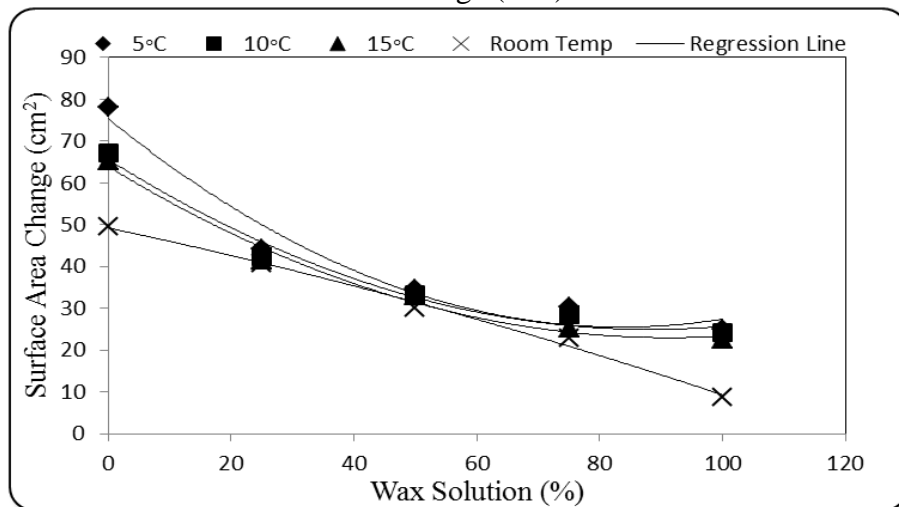


Fig. (10): Effect of temperature storage on cucumber fruit surface area change.

The best fit for the relationship between the surface area change and the temperature at different wax coating were as follows:

$$\text{At } 5^{\circ}\text{C} \quad \text{SAC} = 0.0071T^2 - 1.194T + 75.412 \quad R^2 = 0.96 \quad (42)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{SAC} = 0.0052T^2 - 0.9228T + 65.668 \quad R^2 = 0.98 \quad (43)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{SAC} = 0.0049T^2 - 0.8978T + 63.966 \quad R^2 = 0.99 \quad (44)$$

$$\text{At room temp.} \quad \text{SAC} = -0.0009T^2 - 0.3113T + 49.217 \quad R^2 = 0.99 \quad (45)$$

**- Effect of wax coating and temperature storage on hardness of cucumber fruits.**

Table (6) and figures (11 and 12) show effect of different wax coating and storage temperatures on hardness of cucumber fruits. The results indicate that the hardness decreases with increasing wax coating but it increases with decreasing temperature storage, where, it decreased significantly from 4.108 to 2.933 kg when the wax solution increased from 0 to 100%. On the other hand, the hardness in cucumber fruits decreased significantly from 4.127 to 2.900 kg with the storage temperature changed from 5°C to room temperature.

Statistical analysis of the data showed that there were none significant differences for the interaction between the wax solution and temperature storage.

Table (6): Effect of wax coating and temperature storage on hardness of cucumber fruits (kg).

Wax Coating (%) \ Storage (°C)	0	25	50	75	100	Mean (B)
5	4.567	4.367	4.200	3.967	3.533	4.127 <sup>a</sup>
10	4.400	4.100	3.767	3.300	3.167	3.747 <sup>b</sup>
15	3.933	3.600	3.367	3.033	2.767	3.340 <sup>c</sup>
Room temperature	3.533	3.200	2.833	2.667	2.267	2.900 <sup>d</sup>
Mean (A)	4.108 <sup>a</sup>	3.817 <sup>b</sup>	3.542 <sup>c</sup>	3.242 <sup>d</sup>	2.933 <sup>e</sup>	3.528
LSD at 0.05	A		B		AB	
	0.001		0.001		N.S	

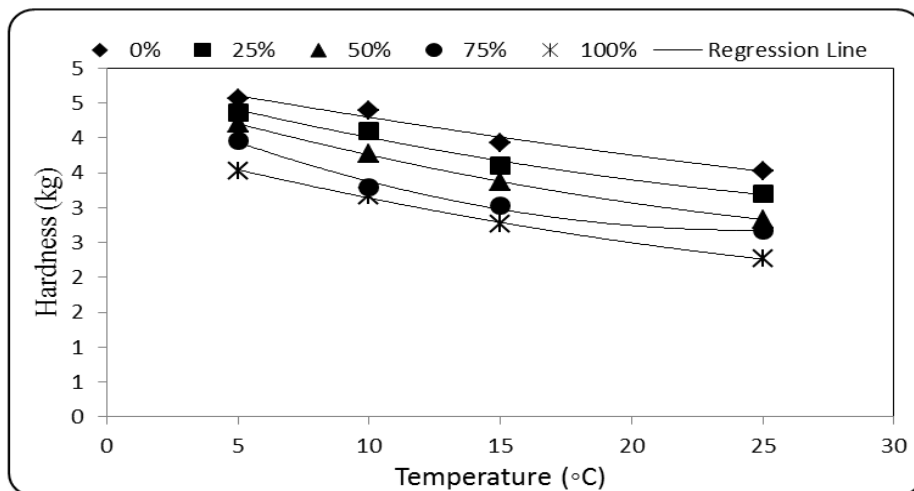


Fig. (11): Effect of wax coating on hardness in cucumber fruits.

The best fit for the relationship between the hardness and the wax coating was as follows:

At 0 %  $H = 0.0005WC^2 - 0.0699WC + 4.9424$   $R^2 = 0.97$  (46)

At 25%  $H = 0.0012WC^2 - 0.098WC + 4.8616$   $R^2 = 0.98$  (47)

At 50%  $H = 0.0014WC^2 - 0.1112WC + 4.7252$   $R^2 = 0.99$  (48)

At 75%  $H = 0.0033WC^2 - 0.1624WC + 4.6681$   $R^2 = 0.99$  (49)

At 100%  $H = 0.0011WC^2 - 0.0984WC + 4.0075$   $R^2 = 0.99$  (50)

Where:-

H is the hardness (kg)

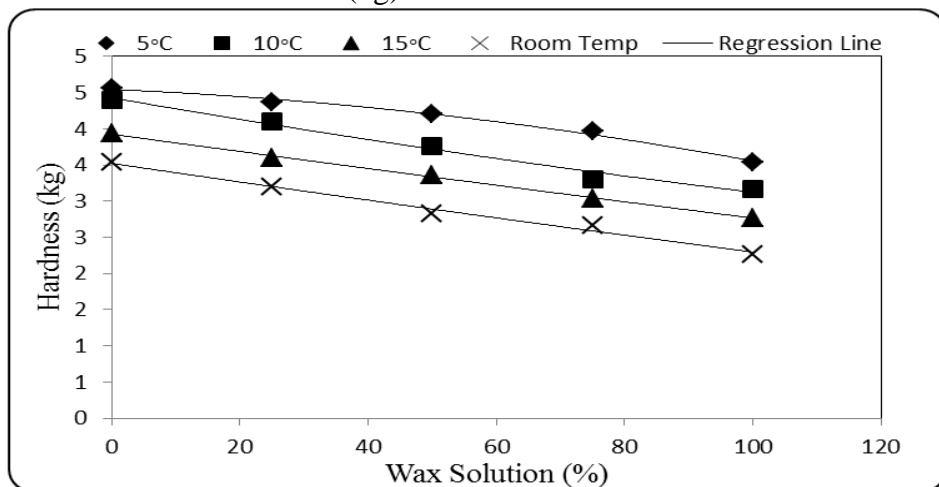


Fig. (12): Effect of temperature storage on hardness in cucumber fruits.



The best fit for the relationship between the hardness and the temperature at different wax coating were as follows:

$$\text{At } 5^{\circ}\text{C} \quad \text{HC} = -6\text{E-}05\text{T}^2 - 0.0038\text{T} + 4.5441 \quad \text{R}^2 = 0.99 \quad (51)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{HC} = 2\text{E-}05\text{T}^2 - 0.0153\text{T} + 4.4286 \quad \text{R}^2 = 0.98 \quad (52)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{HC} = 4\text{E-}06\text{T}^2 - 0.012\text{T} + 3.9245 \quad \text{R}^2 = 0.99 \quad (53)$$

$$\text{At room temp.} \quad \text{HC} = 8\text{E-}06\text{T}^2 - 0.013\text{T} + 3.5226 \quad \text{R}^2 = 0.99 \quad (54)$$

- **Effect of wax coating and temperature storage on total soluble solids (TSS) in cucumber fruits.**

Table (7) and figures (13 and 14) show effect of different wax solution and storage temperatures on TSS change in cucumber fruits. The results indicate that the TSS decreases with increasing wax coating but it increases with decreasing temperature storage, where, it decreased significantly from 1.393 to 0.684 % when the wax solution increased from 0 to 100%. On the other hand, TSS change decreased significantly from 1.489 to 0.553 % with the storage temperatures from 5°C to room temperature. These results were agreed with those obtained by **Yonemoto *et al.* (2002)**.

Statistical analysis of the data showed that there were significant differences for the interaction between the wax solution and temperature storage.

Table (6): Effect of waxing and storage temperature on TSS change in cucumber fruits (%).

Wax Coating (%) \ Storage (°C)	0	25	50	75	100	Mean (B)
5	1.930 <sup>a</sup>	1.740 <sup>b</sup>	1.503 <sup>c</sup>	1.217 <sup>g</sup>	1.027 <sup>j</sup>	1.489 <sup>a</sup>
10	1.493 <sup>d</sup>	1.337 <sup>e</sup>	1.157 <sup>h</sup>	0.967 <sup>k</sup>	0.877 <sup>l</sup>	1.166 <sup>b</sup>
15	1.320 <sup>f</sup>	1.047 <sup>i</sup>	0.850 <sup>m</sup>	0.750 <sup>o</sup>	0.617 <sup>q</sup>	0.917 <sup>c</sup>
Room temperature	0.847 <sup>n</sup>	0.690 <sup>p</sup>	0.613 <sup>r</sup>	0.397 <sup>s</sup>	0.217 <sup>t</sup>	0.553 <sup>d</sup>
Mean (A)	1.393 <sup>a</sup>	1.203 <sup>b</sup>	1.031 <sup>c</sup>	0.839 <sup>d</sup>	0.684 <sup>e</sup>	1.031
LSD at 0.05	A		B		AB	
	0.001		0.002		0.001	

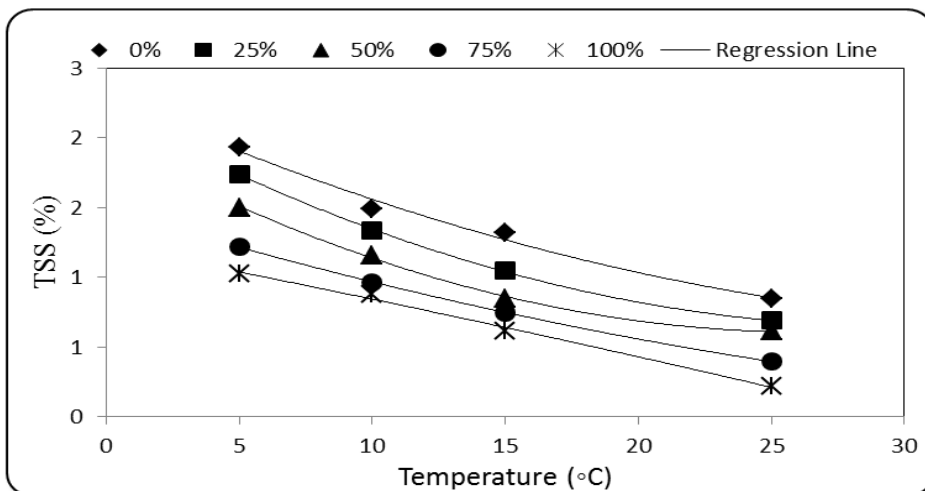


Fig. (13): Effect of wax solution on TSS.

The best fit for the relationship between the TSS and the wax coating at different storage temperatures were as follows:

At 0 %  $TSS = 0.0011WC^2 - 0.0856WC + 2.3052$   $R^2 = 0.99$  (55)

At 25%  $TSS = 0.0017WC^2 - 0.1043WC + 2.2149$   $R^2 = 0.99$  (56)

At 50%  $TSS = 0.002WC^2 - 0.1038WC + 1.9802$   $R^2 = 0.99$  (57)

At 75%  $TSS = 0.0006WC^2 - 0.0583WC + 1.4936$   $R^2 = 0.99$  (58)

At 100%  $TSS = -0.0002WC^2 - 0.0367WC + 1.2265$   $R^2 = 0.99$  (59)

Where:-

TSS is the TSS change (%)

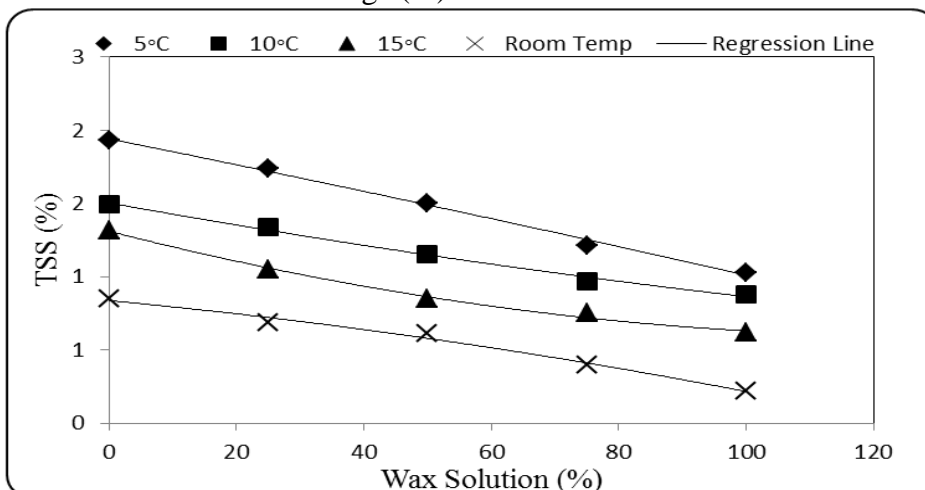


Fig. (14): Effect of temperature storage on TSS.

The best fit for the relationship between the TSS and the temperature at different wax coating were as follows:

$$\text{At } 5^{\circ}\text{C} \quad \text{TSS} = -6\text{E-}06\text{T}^2 - 0.0088\text{T} + 1.9422 \quad \text{R}^2 = 0.99 \quad (60)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{TSS} = 1\text{E-}05\text{T}^2 - 0.0078\text{T} + 1.504 \quad \text{R}^2 = 0.99 \quad (62)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{TSS} = 4\text{E-}05\text{T}^2 - 0.0111\text{T} + 1.3113 \quad \text{R}^2 = 0.99 \quad (63)$$

$$\text{At room temp.} \quad \text{TSS} = -2\text{E-}05\text{T}^2 - 0.0041\text{T} + 0.837 \quad \text{R}^2 = 0.99 \quad (64)$$

**- Effect of storage temperature on the shelf life of the cucumber coated with different wax solution percentage**

Table (8) and figures (15 and 16) show effect of storage temperature on the shelf life of the cucumber coated with different wax solution percentage. The results indicate that the shelf life increases with increasing wax coating but it increases with decreasing temperature storage, where, it increased significantly from 173.4 to 231.6 hour when the wax solution increased from 0 to 100%. On the other hand, the shelf life in cucumber fruits increased significantly from 98.40 to 288.48 hour with the storage temperature changed from 5°C to room temperature.

Statistical analysis of the data showed that there were none significant differences for the interaction between the wax solution and temperature storage.

Table (7): Effect of storage temperature on the shelf life of the cucumber coated with different wax solution percentage (hour).

Wax Coating (%) \ Storage (°C)	0	25	50	75	100	Mean (B)
5	76.8	88.8	98.4	110.4	117.6	98.40 <sup>d</sup>
10	163.2	180	196.8	211.2	213.6	192.96 <sup>c</sup>
15	201.6	223.2	240	259.2	276	240.00 <sup>b</sup>
Room temperature	252	283.2	285.6	302.4	319.2	288.48 <sup>a</sup>
Mean (A)	173.4 <sup>e</sup>	193.8 <sup>d</sup>	205.2 <sup>c</sup>	220.8 <sup>b</sup>	231.6 <sup>a</sup>	204.96
LSD at 0.05	A		B		AB	
	10.361		22.974		N.S	

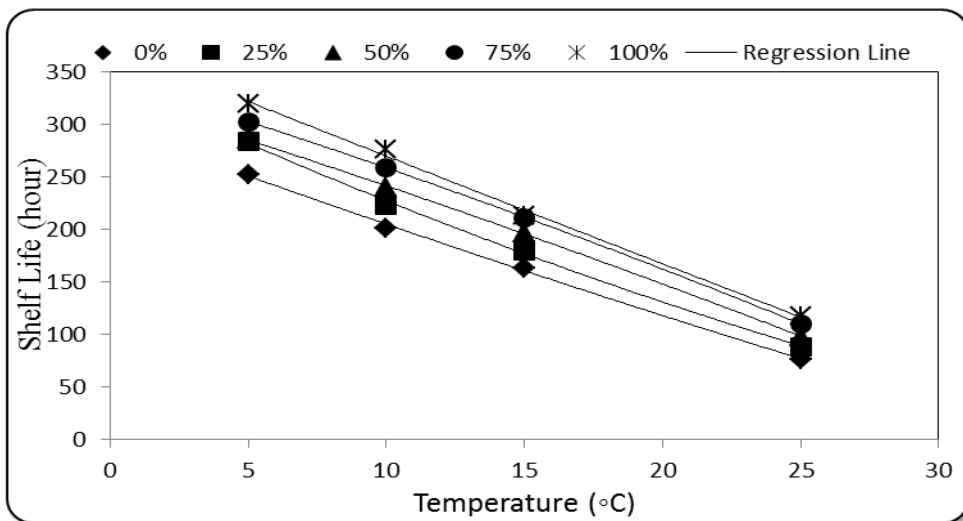


Fig. (15): Effect of wax coating on the shelf life

The best fit for the relationship between the shelf life and the wax coating at different storage temperatures were as follows:

At 0%  $SL = 0.0327WC^2 - 9.6589WC + 298.23$   $R^2 = 0.99$  (65)

At 25%  $SL = 0.0851WC^2 - 12.172WC + 340.43$   $R^2 = 0.99$  (66)

At 50%  $SL = -0.0393WC^2 - 8.1469WC + 326.79$   $R^2 = 0.99$  (67)

At 75%  $SL = -0.0524WC^2 - 8.0465WC + 344.2$   $R^2 = 0.99$  (68)

At 100%  $SL = 0.0087WC^2 - 10.499WC + 373.83$   $R^2 = 0.99$  (69)

Where:-

SL is the shelf life (hour)

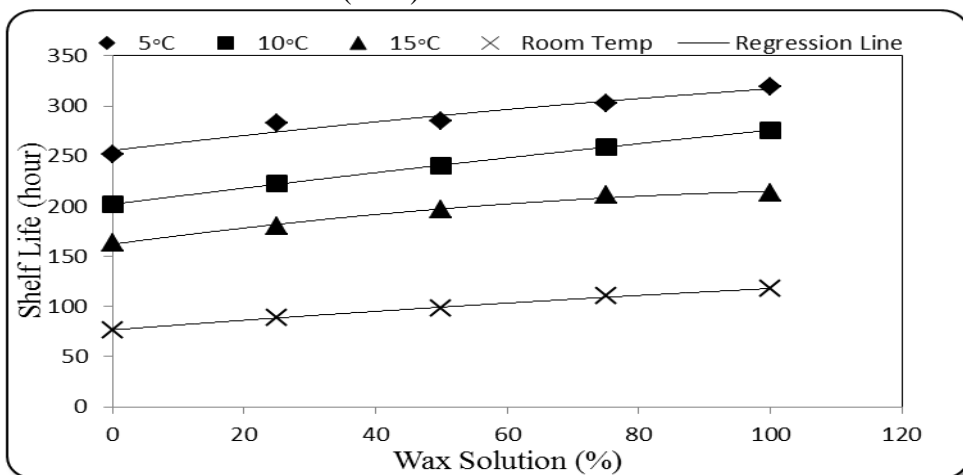


Fig. (16): Effect of storage temperature on the shelf life

The best fit for the relationship between the shelf life and the temperature at different wax coating were as follows:

$$\text{At } 5^{\circ}\text{C} \quad \text{SL} = -0.0016T^2 + 0.779T + 255.7 \quad R^2 = 0.95 \quad (70)$$

$$\text{At } 10^{\circ}\text{C} \quad \text{SL} = -0.0008T^2 + 0.8215T + 202.01 \quad R^2 = 0.99 \quad (71)$$

$$\text{At } 15^{\circ}\text{C} \quad \text{SL} = -0.0036T^2 + 0.8846T + 162.1 \quad R^2 = 0.99 \quad (72)$$

$$\text{At room temp.} \quad \text{SL} = -0.0008T^2 + 0.4951T + 76.731 \quad R^2 = 0.99 \quad (73)$$

### **SUMMARY AND CONCLUSIONS**

The experiment was carried out to study the effect of wax coating and storage temperatures on cucumber fruits quality, the following parameters: diameter change, length change, weight change, volume change, area change, hardness change and TSS change on cucumber fruits. The treatments under study are: wax coating (0, 25, 50, 75 and 100%) and storage temperatures (room temperature, 15, 10 and 5°C). The obtained results can be summarized as follows: The diameter change decreases with increasing wax coating, meanwhile, the diameter change increases with decreasing temperature storage. The length change decreases with increasing wax coating and it increases with decreasing temperature storage. The weight change decreases with increasing wax coating but it increases with decreasing temperature storage. The volume change decreases with increasing wax solution, meanwhile, it increases with decreasing temperature storage. The surface area change decreases with increasing wax coating but it increases with decreasing temperature storage. The hardness change decreases with increasing wax solution but it increases with decreasing temperature storage. The TSS change decreases with increasing wax solution but it increases with decreasing temperature storage.

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## الملخص العربي

### تأثير التشميع على جودة ثمار الخيار أثناء التخزين

عادل حامد بهنساوى\* ، السيد جمعه خاطر\*\*

نظرا لان ثمار الخيار تفقد كمية كبيرة من الرطوبة مما يسبب الفساد وتغيير اللون، وهذا الفاقد يكون واضح أثناء التداول والتخزين. ولذلك يستخدم التشميع بصفة عامة لتقليل الرطوبة المفقودة وحماية ثمار الخيار من الفساد وتعرض الثمار للكدمات والجروح وزيادة العمر التخزيني للثمار ، مما يؤدي الى زيادة المقدرة التسويقية للخيار، ولذا كان الهدف من هذه الدراسة هو دراسة تأثير التشميع ودرجة حرارة التخزين على جودة ثمار الخيار.

وكانت اهم النتائج المتحصل عليها: انخفض التغير في قطر ثمار الخيار بزيادة تركيز محلول التشميع، بينما زاد التغير في قطر الثمار بانخفاض درجة حرارة التخزين. انخفض التغير في طول ثمار الخيار بزيادة تركيز محلول التشميع، بينما زاد التغير في طول الثمار بانخفاض درجة حرارة التخزين. انخفض الفاقد في وزن ثمار الخيار بزيادة تركيز محلول التشميع، بينما زاد الفاقد في وزن الثمار بانخفاض درجة حرارة التخزين. انخفض التغير في حجم ثمار الخيار بزيادة تركيز محلول التشميع، بينما زاد التغير في حجم الثمار بانخفاض درجة حرارة التخزين. انخفض التغير في المساحة السطحية لثمار الخيار بزيادة تركيز محلول التشميع، بينما زاد التغير في المساحة السطحية للثمار بانخفاض درجة حرارة التخزين. انخفضت صلابة ثمار الخيار بزيادة تركيز محلول التشميع، بينما زادت صلابة الثمار بانخفاض درجة حرارة التخزين. انخفضت المواد الصلبة الذائبة الكلية في ثمار الخيار بزيادة تركيز محلول التشميع، بينما زادت المواد الصلبة الذائبة الكلية في الثمار بانخفاض درجة حرارة التخزين. زادت فترة صلاحية ثمار الخيار للاستهلاك بزيادة تركيز محلول التشميع، كما زادت صلاحية الثمار للاستهلاك بانخفاض درجة حرارة التخزين.

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