Research Article

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 (control, 25, 50, 75 and 100%) and storage temperature (room temperature, 15, 10 and 5°C) on cucumber fruits quality. The diameter change, length change, volume change, surface area change, weight loss, hardness change rate, Total Soluble Solids (TSS) were studied as the most important factors affecting the fruit quality. Shelf life of cucumber fruits was also determined. The obtained results indicated that the diameter change decreases with increasing wax solution, meanwhile, the diameter change increases with increasing storage temperature. The length change decreases with increasing wax solution and it increases with increasing storage temperature. The volume change decreases with increasing wax solution, meanwhile, it increases with increasing storage temperature. The surface area change decreases with increasing wax solution but it increases with increasing temperature storage. The weight loss decreases with increasing wax solution but it increases with increasing storage temperature. The hardness change rate decreases with increasing wax solution but it increases with increasing storage temperature. The TSS decreases with increasing wax solution but it increases with increasing storage temperature. The shelf life increases with increasing wax solution but it increases with increasing storage temperature.

Keywords: Wax coating; Storage temperature; Cucumber; Fruit size change; Weight loss; TSS; Hardness; Shelf life

Nomenclature

- DC   diameter change (mm)
- WC   wax coating (%)
- T   temperature (°C)
- LC   length change (cm)
- WL   weight loss (%)
- VC   volume change (cm^3)
- SAC   surface area change (cm^2)
- H   hardness (kg)
- TSS   TSS change (%)
- SL   shelf life (hour)

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^{-1}). They are a good source of the following nutrients (in mg kg^{-1}): pantothenic acid (B5) (0.026); vitamin C (0.28); magnesium (1.3). 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 [1]. 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 27989 ha in 2011 according to the statistics of CAPMS [2]. 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. Waxes are used to replace some of the natural waxes that 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 19th century [3].

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 [4,5].

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 [6-14].

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 from chilling injury; if held at 15°C or higher, they rapidly become yellow. Thus, the optimum temperature is 12 to 13. However, for storage of 1 to 2 weeks, 10°C is preferable because chilling is minimal and yellowing is retarded, although [15] 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.
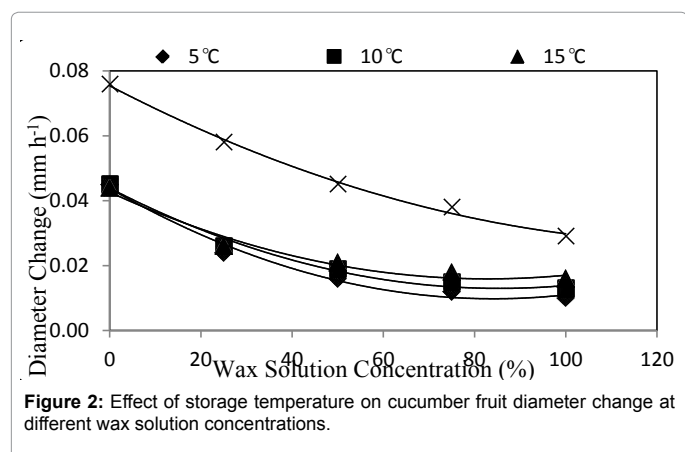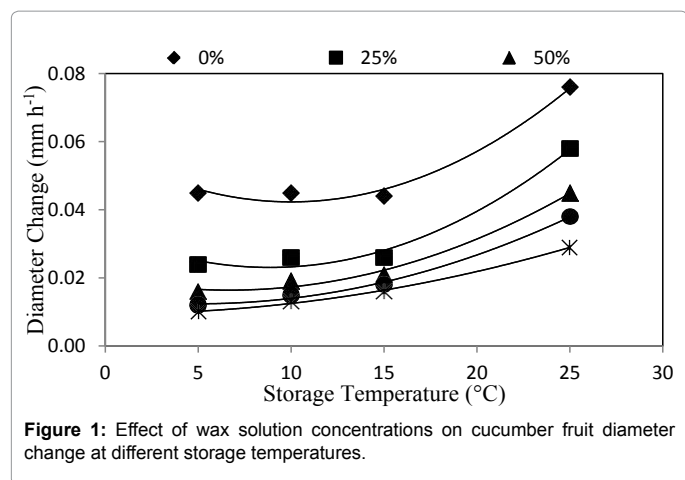
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Figure 1: Effect of wax solution concentrations on cucumber fruit diameter change at different storage temperatures.

Figure 2: Effect of storage temperature on cucumber fruit diameter change at different wax solution concentrations.

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 [16]. 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 prolong storage quality and postharvest shelf life, the cucumber was waxed with different solution concentrations and stored at different temperatures. The appearance indices weight loss and cucumber shelf life were determined as the most important factors affecting 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 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/cm³. 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 a dimension of 3.0 m length, 3.0 m in width and 3.0 m height. It made prefabricated insulated panels of thickness of 60 mm. the panels insulation are covered with precoated stainless steel sheet on both sides.

Methods

The cucumber fruits were dipped into a 0, 25, 50, 75, 100% wax solutions. The fruits were then fan-dried at room temperature (approximately 25°C). The waxed fruits were stored at four temperature 5, 10, 15°C and room temperature (25°C). Twenty treatments were applied (five wax solution concentrations and four storage temperatures) and replicated 3 times.

Measurements

The dimensions of fruits (length and diameter) were 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 HG – 5000– Range 0-5000 g ± 0.01 g, Japan). 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 (Model Placom KP -90 N- Range 0-10 m² ± 0.2 %, Japan) was used to measure the surface area of the cucumber. The volume of fruits was measured by graduated cylinder. The hardness was measured by Hardness meter (Model GY-1-Range 2-15 kg cm⁻² ± 0.1 kg cm⁻², China). The TSS was measured by Refractometer (Model HR-010-Range 0- 10% Brix ± 0.1% Brix, Japan). These measurements were repeated three times and the average was taken before and after storage.

Results and Discussion

Cucumber quality was determined by measuring the change of fruit diameter, length, volume, volume, surface area, mass, hardness and total soluble solids (TSS). Weight loss and shelf life of the fruit during storage were also studied.

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

Diameter change: Figures 1 and 2 show the effect of different wax solution concentrations and storage temperatures on change in cucumber fruit diameter. The results indicated that the change of diameter decreases with increasing wax solution concentrations, meanwhile, the diameter change increases with increasing storage temperature, where, it decreased from 0.053 to 0.017 mm h⁻¹ when the wax solution increased from 0 (control) to 100%. On the other hand, loss of diameter increased from 0.021 to 0.049 mm h⁻¹ with the storage temperature increased from 5°C to 25°C (room temperature). These results agreed with those obtained by [16]. The overall average of diameter change decreased from 0.053 ± 0.014 to 0.017 ± 0.007 mm h⁻¹ when the wax concentration changed from 0 to 100%. The overall

Cucumber Diameter Change				
Wax Solution Concentrations (%)	**Constants**			**R²**
	A	**b**	**c**	
0 (control)	0.0001	- 0.0028	0.0567	0.983
25	0.0001	- 0.0024	0.0335	0.985
50	6×10^{-5}	- 0.001	0.0129	0.994
75	6×10^{-5}	- 0.0005	0.0129	0.999
100	4×10^{-5}	- 0.0001	0.01	0.999
Temperature (˚C)	**Constants**			**R²**
	A	**b**	**c**	
5	5×10^{-6}	- 0.0008	0.044	0.986
10	4×10^{-6}	- 0.0007	0.0442	0.983
15	4×10^{-6}	- 0.0006	0.0429	0.962
25 (Room Temperature)	3×10^{-6}	- 0.0007	0.0751	0.997

Table 1: The constants a, b, c and coefficient of determination for diameter change at the different wax solution concentrations and the different storage temperatures.
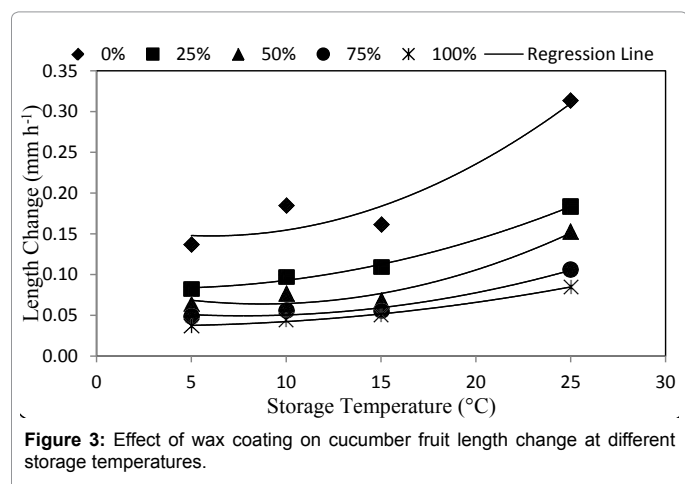
Figure 3: Effect of wax coating on cucumber fruit length change at different storage temperatures.
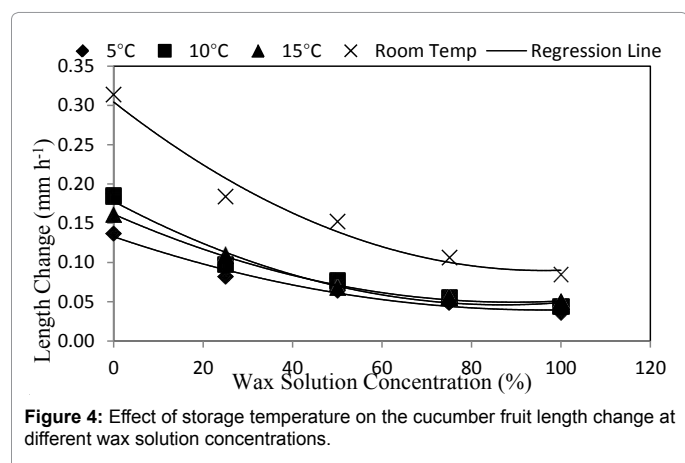
Figure 4: Effect of storage temperature on the cucumber fruit length change at different wax solution concentrations.

average of diameter change ranged from 0.021 ± 0.013 to 0.049 ± 0.016 mm h⁻¹ depending on the storage temperature (5 to 25°C).

Regression analysis was carried out to find a relation between the fruit diameter change and both wax solution concentrations and storage temperatures. Equation (1) shows the most appropriate form for the relationship between the fruit diameter change and wax solution concentrations at different storage temperatures. Equation (2) shows the relationship between the fruit diameter change and storage

temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 1.

$$DC = a\,WX^2 + b\,WX + c \tag{1}$$

$$DC = a\,T^2 + b\,T + c \tag{2}$$

Where:-

DC is the cucumber diameter change (mm h⁻¹)

WX is the wax coating (%)

T is the storage temperature (°C)

Length change: Figures 3 and 4 show the effect of different wax solution concentrations and storage temperatures on change in cucumber fruit length. The results indicate that the length decreases with increasing wax solution and it increases with increasing storage temperature, where, it decreased from 0.199 to 0.0054 mm h⁻¹ when the wax solution concentrations increased from 0 (control) to 100%. On the other hand, the length change increased from 0.074 to 0.168 mm h⁻¹ with the storage temperature changed from 5 to 25°C (room temperature). The overall average of length change decreased from 0.199 ± 0.068 to 0.0547 ± 0.018 mm h⁻¹ when the wax concentration changed from 0 to 100%. The overall average of length change ranged from 0.074 ± 0.035 to 0.168 ± 0.081 mm h⁻¹ depending on the storage temperature (5 to 25°C).

Regression analysis was carried out to find a relation between the fruit length change and both wax solution concentrations and storage temperatures. Equation (3) shows the most appropriate form for the relationship between the fruit length change and wax solution concentrations at different storage temperatures. Equation (4) shows the relationship between the fruit length change and storage temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 2.

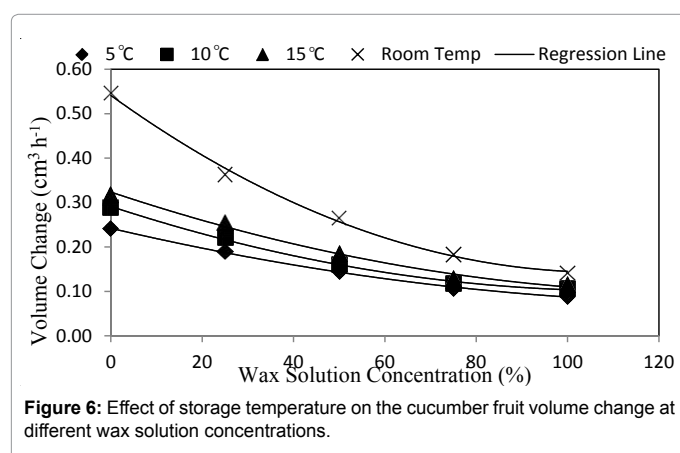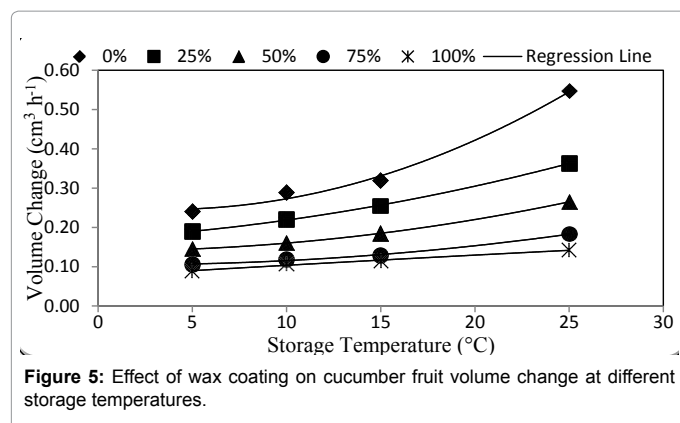$$LC = a\,WX^2 + b\,WX + c \tag{3}$$

$$LC = a\,T^2 + b\,T + c \tag{4}$$

Where:-

LC is the cucumber length change (mm h⁻¹)

Volume change: Figures 5 and 6 show the effect of different wax solution concentrations and different storage temperatures on change in cucumber fruit volume. The results indicated that the volume change decreases with increasing wax solution concentrations, meanwhile, it increases with increasing storage temperature, where, it decreased from

Cucumber Length Change				
Wax Solution Concentrations (%)	**Constants**			**R²**
	a	**b**	**c**	
0 (Control)	0.0005	- 0.0055	0. 1639	0.917
25	0.0002	- 0.0013	0.0853	0.996
50	0.0003	- 0.0058	0.0891	0.996
75	0.0002	- 0.0029	0.0606	0.976
100	1×10^{-4}	- 0.0005	0.0378	0.995
Temperature (˚C)	**Constants**			**R²**
	a	**b**	**c**	
5	1×10^{-5}	- 0.0192	0.1329	0.980
10	2×10^{-5}	- 0.003	0.1778	0.971
15	1×10^{-5}	- 0.0025	0.1615	0.989
25 (Room Temperature)	2×10^{-5}	- 0.0045	0. 3043	0.973

Table 2: The constants a, b, c and coefficient of determination for length change at the different wax solution concentrations and the different storage temperatures.

Figure 5: Effect of wax coating on cucumber fruit volume change at different storage temperatures.

Figure 6: Effect of storage temperature on the cucumber fruit volume change at different wax solution concentrations.

0.349 to 0.113 cm³ h⁻¹ when the wax solution increased from 0 (control) to 100%. On the other hand, loss of volume cucumber fruit increased from 0.154 to 0.300 cm³ h⁻¹ with the storage temperatures increased from 5 to 25°C (room temperature). The overall average of volume change decreased from 0.349 ± 0.118 to 0.113 ± 0.019 cm³ h⁻¹ when the wax concentration changed from 0 to 100%. The overall average of volume change ranged from 0.154 ± 0.056 to 0.300 ± 0.145 cm³ h⁻¹ depending on the storage temperature (5 to 25°C).

Regression analysis was carried out to find a relation between the fruit volume change and both wax solution concentrations and storage temperatures. Equation (5) shows the most appropriate form for the relationship between the fruit volume change and wax solution concentrations at different storage temperatures. Equation (6) shows the most appropriate form for the relationship between the fruit volume change and storage temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 3.

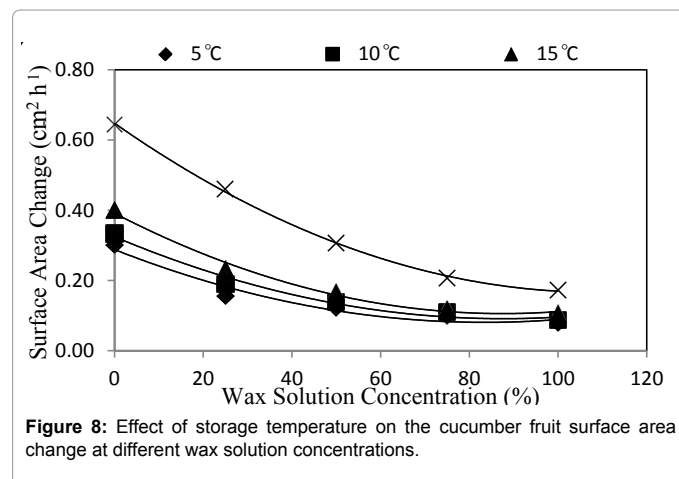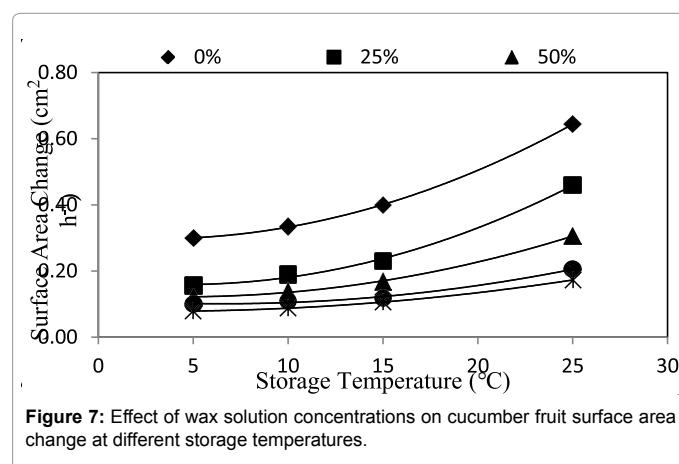$$VC = a\,WX^2 + b\,WX + c \qquad (5)$$

$$VC = a\,T^2 + b\,T + c \qquad (6)$$

Where:-

VC is the cucumber volume change (cm³ h⁻¹)

Surface area change: Figures 7 and 8 show the effect of different wax solution concentrations and storage temperatures on change in cucumber fruit surface area. The results indicated that the surface area change decreases with increasing wax solution concentrations but it

increases with increasing storage temperature, where, it decreased from 0.419 to 0.111 cm² h⁻¹ when the wax solution concentrations increased from 0 (control) to 100%. On the other hand, change of surface area increased from 0.151 to 0.358 cm² hr⁻¹ with the storage temperatures increased from 5 to 25°C (room temperature). The overall average of surface area change decreased from 0.419 ± 0.135 to 0.111 ± 0.037 cm² h⁻¹ when the wax concentration changed from 0 to 100%. The overall average of surface area change ranged from 0.151 ± 0.079 to 0.358 ± 0.174 cm² h⁻¹ depending on the storage temperature (5 to 25°C).

Cucumber Volume Change				
Wax Solution Concentrations (%)	**Constants**			**R²**
	a	b	c	
0 (Control)	0.0007	- 0.0047	0.2546	0.992
25	0.0002	0.0028	0.1715	0.999
50	0.0002	- 6 × 10⁻⁵	0.1403	1
75	0.0001	- 0.0003	0.1048	0.997
100	- 9 × 10⁻⁶	0.0029	0.0753	0.995
Temperature (°C)	**Constants**			**R²**
	a	b	c	
5	9 × 10⁻⁶	- 0.0024	0.2424	0.998
10	1 × 10⁻⁵	- 0.0033	0.291	0.998
15	1 × 10⁻⁵	- 0.0034	0.3233	0.993
25 (Room Temperature)	3 × 10⁻⁵	- 0.0074	0.541	0.997

Table 3: The constants a, b, c and coefficient of determination for volume change at the different wax solution concentrations and the different storage temperatures.

Figure 7: Effect of wax solution concentrations on cucumber fruit surface area change at different storage temperatures.

Figure 8: Effect of storage temperature on the cucumber fruit surface area change at different wax solution concentrations.

Cucumber Surface Area Change				
Wax Solution Concentrations (%)	**Constants**			**R²**
	a	**b**	**c**	
0 (Control)	0.0007	- 0.0043	0.3039	1
25	0.0007	- 0.0065	0.1745	0.997
50	0.0004	- 0.0041	0.1322	0.999
75	0.0003	- 0.004	0.1146	0.994
100	0.0002	- 0.0012	0.0801	0.999
Temperature (˚C)	**Constants**			**R²**
	a	**b**	**c**	
5	3×10^{-5}	- 0.0049	0.2879	0.959
10	3×10^{-5}	- 0.0053	0.3245	0.980
15	4×10^{-5}	- 0.0065	0.391	0.988
25 (Room Temperature)	4×10^{-5}	- 0.0089	0.6479	0.999

Table 4: The constants a, b, c and coefficient of determination for surface area change at the different wax solution concentrations and the different storage temperatures.
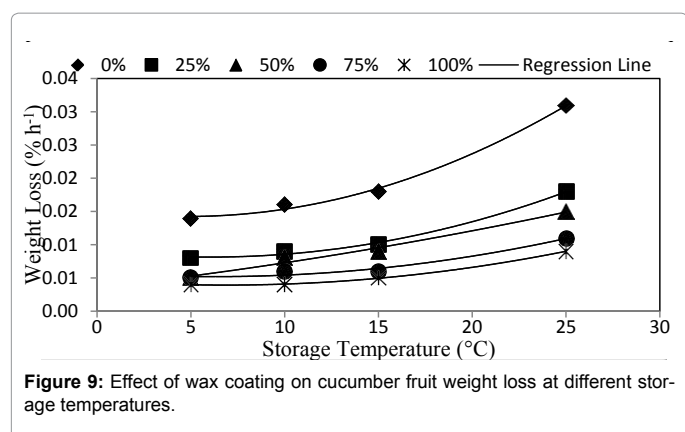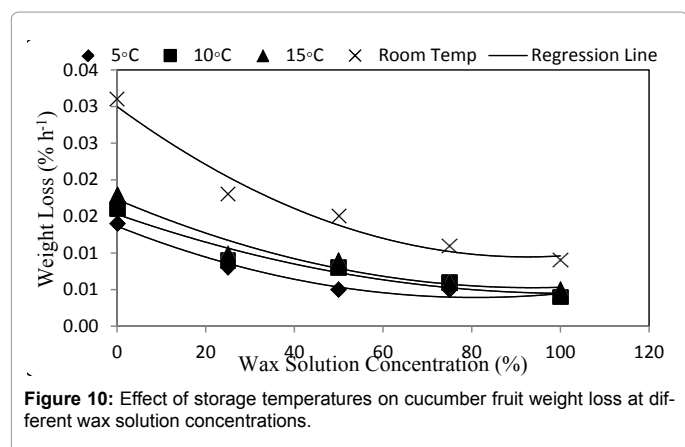

Figure 9: Effect of wax coating on cucumber fruit weight loss at different storage temperatures.

Figure 10: Effect of storage temperatures on cucumber fruit weight loss at different wax solution concentrations.

Regression analysis was carried out to find a relation between the fruit surface area change and both wax solution concentrations and storage temperatures. Equation (7) shows the most appropriate form for the relationship between the fruit surface area change and wax solution concentrations at different storage temperatures. Equation (8) shows the most appropriate form for the relationship between the fruit surface area change and storage temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 4.

$$SAC = a\,WX^2 + b\,WX + c \qquad (7)$$

$$SAC = a\,T^2 + b\,T + c \qquad (8)$$

Where:-

SAC is the cucumber surface area change ($cm^2\,h^{-1}$)

Weight Loss: Figures 9 and 10 show the effect of different wax solution concentrations and storage temperatures on change in weight loss of fruit cucumber. The results indicated that the weight loss decreases with increasing wax solution concentrations but it increases with increasing temperature storage, where, it decreased from 0.020 to 0.005% h^{-1} when the wax solution increased from 0 (control) to 100%. On the other hand, weight loss increased from 00073 to 0.017% h^{-1} with the storage temperatures increased from 5 to 25°C (room temperature). These results agreed with those obtained by [17]. The overall average of weight loss decreased from 0.020 ± 0.007 to 0.005 ± 0.002% h^{-1} when the wax concentration changed from 0 to 100%. The overall average of weight loss ranged from 0.007 ± 0.004 to 0.017 ± 0.008% h^{-1} depending on the storage temperature (5 to 25°C).

Regression analysis was carried out to find a relation between the fruit weight loss and both wax solution concentrations and storage temperatures. Equation (9) shows the most appropriate form for the relationship between the fruit weight loss and wax solution concentrations at different storage temperatures. Equation (10) shows the most appropriate form for the relationship between the fruit weight loss and storage temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 5.

$$WL = a\,WX^2 + b\,WX + c \qquad (9)$$

$$WL = a\,T^2 + b\,T + c \qquad (10)$$
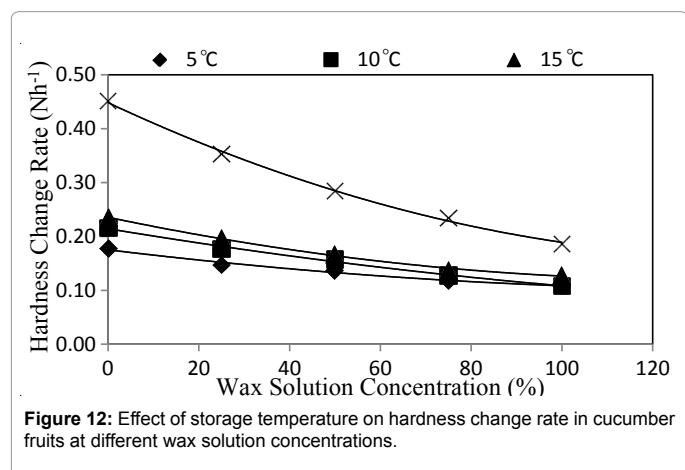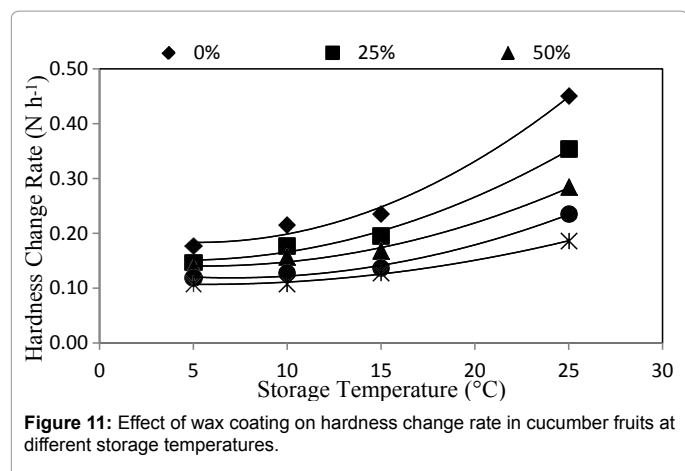
Where:-

WL is the cucumber weight loss (% h^{-1})

Effect of wax coating and temperature storage on hardness change rate of cucumber fruits: Figures 11 and 12 show the effect of different wax solution concentrations and storage temperatures on hardness change rate of cucumber fruits. The results indicated that the hardness change rate decreases with increasing wax solution concentrations but it increases with increasing storage temperature, where, it decreased from 1.079 to 0.530 N h^{-1} when the wax solution concentrations increased from 0 (control) to 100%. On the other hand, the hardness in cucumber fruits increased from 0.687 to 1.511 N h^{-1} with the storage temperature increased from 5 to 25°C [18]. The overall

Cucumber Weight Change				
Wax Solution Concentrations (%)	**Constants**			**R²**
	a	**b**	**c**	
0 (Control)	4×10^{-5}	- 0.0003	0.0145	0.991
25	2×10^{-5}	- 0.0005	0.0098	0.998
50	2×10^{-5}	0.0001	0.0047	0.990
75	2×10^{-5}	- 0.0002	0.0055	0.972
100	1×10^{-5}	$- 5 \times 10^{-5}$	0.0038	0.995
Temperature (˚C)	**Constants**			**R²**
	a	**b**	**c**	
5	1×10^{-6}	- 0.0002	0.0134	0.988
10	1×10^{-6}	- 0.0002	0.0158	0.948
15	2×10^{-6}	- 0.0003	0.0175	0.959
25 (Room Temperature)	2×10^{-6}	- 0.0004	0.0304	0.973

Table 5: The constants a, b, c and coefficient of determination for weight loss at the different wax solution concentrations and the different storage temperatures.

Figure 11: Effect of wax coating on hardness change rate in cucumber fruits at different storage temperatures.

Figure 12: Effect of storage temperature on hardness change rate in cucumber fruits at different wax solution concentrations.

Cucumber Hardness Change Rate				
Wax Solution Concentrations (%)	**Constants**			R^2
	a	**b**	**c**	
Control	0.0007	- 0.0072	0.2024	0.989
25	0.0005	- 0.0041	0.1599	0.992
50	0.0004	- 0.0042	0.1523	0.989
75	0.0004	- 0.0051	0.1364	0.993
100	0.0002	- 0.0023	0.1131	0.996
Temperature (°C)	**Constants**			R^2
	a	**b**	**c**	
5	4×10^{-6}	- 0.0001	0.1751	0.985
10	3×10^{-6}	- 0.0014	0.2143	0.994
15	7×10^{-6}	- 0.0018	0.3356	0.996
Room Temperature	1×10^{-5}	- 0.0039	0.4483	0.998

Table 6: The constants a, b, c and coefficient of determination for hardness change at the different wax solution concentrations and the different storage temperatures.

average of hardness change rate decreased from 1.079 ± 0.107 to 0.530 ± 0.032 N h^{-1} when the wax concentration changed from 0 to 100%. The overall average of hardness change rate ranged from 0.687 ± 0.024 to 1.511 ± 0.093 N h^{-1} depending on the storage temperature (5 to 25°C).

Regression analysis was carried out to find a relation between the fruit hardness change and both wax solution concentrations and storage temperatures. Equation (11) shows the most appropriate form for the relationship between the fruit hardness change and wax solution concentrations at different storage temperatures. Equation (12) shows

the most appropriate form for the relationship between the fruit hardness change and storage temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 6.

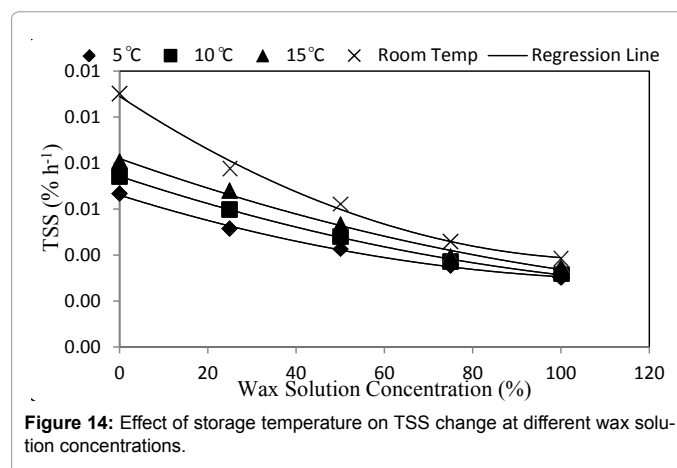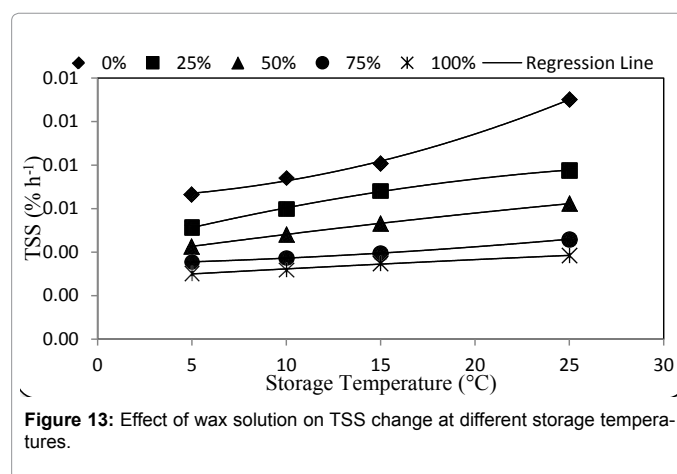$$H= a\ WX^2 + b\ WX + c \qquad (11)$$

$$H= a\ T^2 + b\ T + c \qquad (12)$$

Where:-

H is the hardness change (% h^{-1})

Effect of wax coating and storage temperature on total soluble solids (TSS) in cucumber fruits: Figures 13 and 14 show the effect of different wax solution concentrations and storage temperatures on TSS change in cucumber fruits. The results indicated that the TSS decreases with increasing wax concentrations but it increases with increasing temperature storage, where, it decreased from 0.008 to 0.003% h^{-1} when the wax solution concentrations increased from 0 (control) to 100%. On the other hand, TSS change increased from 0.005 to 0.007% h^{-1} with the storage temperatures increased from 5 to 25°C (room temperature). These results agreed with those obtained by [17]. The overall average of TSS change decreased from 0.008 ± 0.0016 to 0.003 ± 0.0004% h^{-1} when the wax concentration changed from 0 to 100%. The overall average of TSS change ranged from 0.005 ± 0.001 to 0.007 ± 0.002% h^{-1} depending on the storage temperature (5 to 25°C).

Regression analysis was carried out to find a relation between the

Figure 13: Effect of wax solution on TSS change at different storage temperatures.

Figure 14: Effect of storage temperature on TSS change at different wax solution concentrations.

Cucumber TSS change				
Wax Solution Concentrations (%)	Constants			R^2
	a	b	c	
Control	7×10^{-6}	1×10^{-5}	0.0065	0.997
25	$- 3 \times 10^{-6}$	0.0002	0.0041	0.999
50	$- 8 \times 10^{-7}$	0.0001	0.0037	1
75	1×10^{-6}	2×10^{-5}	0.0034	0.999
100	$- 2 \times 10^{-7}$	5×10^{-5}	0.0118	0.988
Temperature (°C)	Constants			R^2
	a	b	c	
5	2×10^{-7}	6×10^{-5}	0.0066	0.997
10	2×10^{-7}	$- 6 \times 10^{-5}$	0.0074	0.999
15	2×10^{-7}	$- 7 \times 10^{-5}$	0.0082	0.991
Room Temperature	6×10^{-7}	0.0001	0.0109	0.995

Table 7: The constants a, b, c and coefficient of determination for TSS change at the different wax solution concentrations and the different storage temperatures.
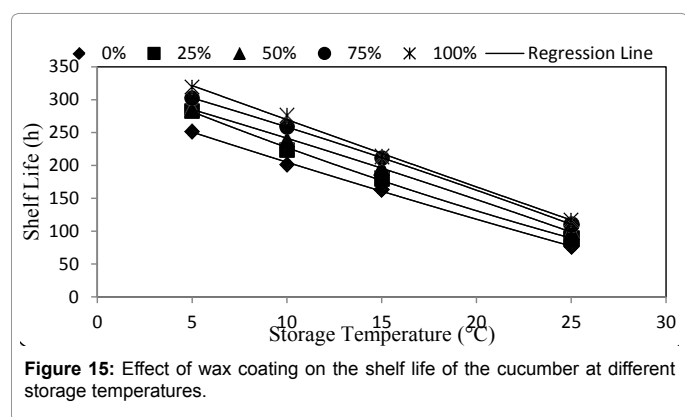
Figure 15: Effect of wax coating on the shelf life of the cucumber at different storage temperatures.
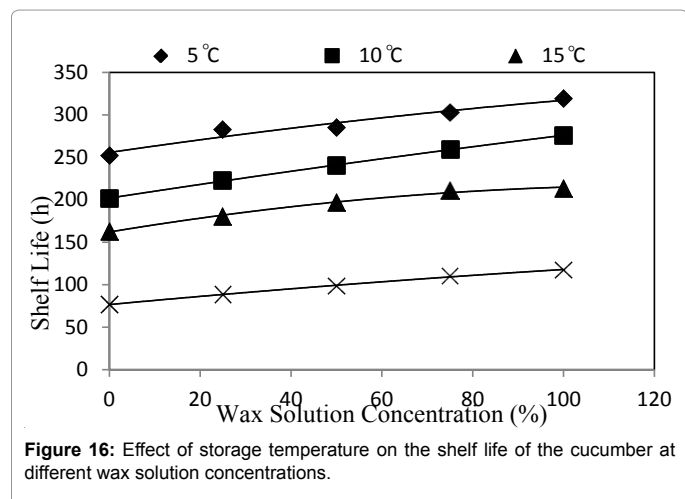
Figure 16: Effect of storage temperature on the shelf life of the cucumber at different wax solution concentrations.

fruit TSS change and both wax solution concentrations and storage temperatures. Equation (13) shows the most appropriate form for the relationship between the fruit TSS change and wax solution concentrations at different storage temperatures. Equation (14) shows the most appropriate form for the relationship between the fruit TSS change and storage temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 7.

$$TSS = a\ WX^2 + b\ WX + c \tag{13}$$

$$TSS = a\ T^2 + b\ T + c \tag{14}$$

Where:-

TSS is the cucumber TSS change (% h^{-1})

Effect of storage temperature on the shelf life of the cucumber coated with different wax solution percentage: Figures 15 and 16 show the effect of storage temperature on the shelf life of the cucumber coated with different wax solution percentage. The results indicated that the shelf life increases with increasing wax solution concentrations meanwhile, it increases with increasing temperature storage, where, it increased from 173.4 to 231.6 h when the wax solution concentration increased from 0 (control) to 100%. On the other hand, the shelf life in cucumber fruits increased from 98.40 to 288.48 h when the storage temperature increased from 5 to 25°C (room temperature). These results were in agreement with those obtained by [16]. The overall average of shelf life decreased from 288.48 ± 22.38 to 231.60 ± 75.77 h when the wax concentration changed from 0 to 100%. The overall average of shelf life change ranged from 288.48 ± 22.38 to 98.40 ± 14.64 h depending on the storage temperature 5 to 25°C.

Regression analysis was carried out to find a relation between the fruit shelf life and both wax solution concentrations and storage temperatures. Equation (15) shows the most appropriate form for the relationship between the fruit shelf life and wax solution concentrations at different storage temperatures. Equation (16) shows the most appropriate form for the relationship between the fruit shelf life and storage temperatures at different wax solution concentrations. The constants of these equations and coefficient of determination are listed in Table 8.

$$SL = a\ WX^2 + b\ WX + c \tag{15}$$

$$SL = a\ T^2 + b\ T + c \tag{16}$$

Where:-

SL is the cucumber shelf life (h)

Summary and Conclusions

The experiment was carried out to study the effect of wax coating (control, 25, 50, 75 and 100%) and storage temperatures (room temperature, 15, 10 and 5°C) on cucumber fruits quality, (diameter change, length change, volume change, area change, weight loss, hardness change rate and TSS change on cucumber fruits). Shelf life of the cucumber was also studied. The obtained results can be summarized as follows:

Cucumber Shelf life				
Wax Solution Concentrations (%)	Constants			R^2
	a	b	c	
0 (Control)	0.0327	- 9.6589	298.23	0.999
25	0.0851	- 12.172	340.43	0.997
50	-0.0393	- 8.1469	326.79	0.993
75	-0.0524	- 8.0465	344.2	0.996
100	0.0087	- 10.499	373.83	0.988
Temperature (°C)	Constants			R^2
	a	b	c	
5	0.0016	0.779	255.7	0.997
10	-0.0008	0.8215	202.01	0.999
15	-0.0036	0.8846	162.1	0.991
25 (Room Temperature)	-0.0008	0.4951	76.731	0.995

Table 8: The constants a, b, c and coefficient of determination for shelf life at the different wax solution concentrations and the different storage temperatures.

- The diameter change decreased from 0.053 to 0.017 mm h^{-1} when the wax solution increased from 0 to 100%. On the other hand, loss of diameter increased from 0.021 to 0.049 mm h^{-1} with the storage temperature increased from 5 to 25°C.

- The length change decreased from 0.199 to 0.0054 mm h^{-1} when the wax solution concentrations increased from 0 to 100%. On the other hand, the length change increased from 0.074 to 0.168 mm h^{-1} with the storage temperature changed from 5 to 25°C.

- The volume change decreased from 0.349 to 0.113 cm^3 h^{-1} when the wax solution increased from 0 to 100%. On the other hand, loss of volume cucumber fruit increased from 0.154 to 0.300 cm^3 h^{-1} with the storage temperatures increased from 5 to 25°C.

- The surface area change decreased from 0.419 to 0.111 cm^2 h^{-1} when the wax solution concentrations increased from 0 to 100%. On the other hand, change of surface area increased from 0.151 to 0.358 cm^2 h^{-1} with the storage temperatures increased from 5 to 25°C.

- The weight loss decreased from 0.020 to 0.005% h^{-1} when the wax solution increased from 0 to 100%. On the other hand, weight loss increased from 00073 to 0.017% h^{-1} with the storage temperatures increased from 5 to 25°C.

- The hardness change rate decreased from 1.079 to 0.530 N h^{-1} when the wax solution concentrations increased from 0 to 100%. On the other hand, the hardness in cucumber fruits increased from 0.687 to 1.511 N h^{-1} with the storage temperature increased from 5 to 25°C.

- The TSS decreased from 0.008 to 0.003% h^{-1} when the wax solution concentrations increased from 0 to 100%. On the other hand, TSS change increased from 0.005 to 0.007% h^{-1} with the storage temperatures increased from 5 to 25°C.

The shelf life increases with increasing wax solution but it increases with increasing storage temperature. It increased from 173.4 to 231.6 h when the wax solution concentration increased from 0 to 100%. On the other hand, the shelf life in cucumber fruits increased from 98.40 to 288.48 h with the storage temperature increased from 5 to 25°C.

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