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Cucumber Hydrocooling Treatment and its Relationship to Quality Properties during Cold Storage

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ABSTRACT

In the most countries, losses of fruits and vegetables during post-harvest process are of a wonderful concern to fruit-traders, farmers and consumers. The aim of this work is to study the effect of cucumber hydrocooling treatment 'HY' before putting cold room on its qualities and properties. 'HY' system conformed by putting cucumbers in cold water at "4 °C" with ratio of three units of water mass to one unit mass of ice and to one unit of cucumber mass (3:1:1). The cucumber "HY" treatment and non-hydrocooled (control, CR) were stored in cooling room under three different temperatures of 5.0; 9.0 and 13.0 °C, relative humidity of " 90±5 %" and five times of storage "3.0; 6.0; 9.0; 12 and 15 days". The changes in diameter, length and volume, firmness, mass, color parameters and total soluble solids (TSS) were determined as the most important factors affecting the cucumber quality during cooling. Results showed that, there are high significant differences between all treatments and the averages of all previous determinations such as changing in each of cucumber diameter, length, volume, firmness, mass loss, "TSS" and color parameters (L, a, b and ΔE). On the other hand, un-significant differences are found between the interactions of all treatments and the averages of mass loss and some color parameters of "a" (inner and outer) and b (outer). The "HY" treatment confirms a greatest higher on firmness and TSS. But it is recorded a slower loss of fresh mass, diameter, length and volume at comparing with "CR" method. Seven/eight cooling time "$TAT_{7/8}$", percentage of mass loss rate, lowest firmness and total color difference "ΔE" inner/outer" recorded at "HY" methods of" 7.5 m" ;"0.11% h^{-1} "; "10.44N" and "4.56/5.74' respectively, compared with "CR" method of "126 m";"0.19% h^{-1}"; "7.04N" and "5.04/ 5.44" at 13°C after 15 days of cold storage. But the highest mean value of "TSS" is found at "HY" system and recorded "3.89 ± 0.0013" at 5°C after 3 days of cold storage.

Keywords: Hydrocooling, cucumber, cooling storage, firmness, mass loss, color.

INTRODUCTION

Cucumber (*Cucumis sativus L.*) from family Cucurbitaceae is a local consumption and it is one of most favorite commodity exports for world markets. Also, it is represents one of the most important and economic vegetables in Egypt. For there more, cucumber include approximately 3.6% carbohydrates, 95% water, 0.65% protein and are low in calories (150 kCal kg^{-1}) (Thirupathi *et al.*, 2006). Also, it's a good source of nutrients (in mg kg^{-1}) such as vitamin C, magnesium, pantothenic acid Lucier and Jerardo, 2007). The consumption of fresh cucumber extended a range of health benefits include that, valuable antioxidant, anti-inflammatory, and anti-cancer benefits (Mukherjee *et al.*, 2013). Cucumber is grown in Egypt in the open field from March to November and under plastic houses from September to May. In Egypt, the cucumber cultivated area was about 28989 ha in 2018 according to the guides of CAPMS (2019).

Temperature control is the most used technique for postharvest maintenance of fruit and vegetables (Kader, 2002). Cooling related with cold storage helps in the maturity of the quality during marketable handling, which allows keep the shelf-life of fresh products (Chiabrando and Giacalone, 2011; Günther *et al.*, 2015). The cooling temperature under storage of fruit and vegetables is described by the acceptance to cold, which is a stress condition that can cause postharvest damage and loss of quality (Choi *et al.*, 2015).

Numerous cooling techniques are available, including vacuum cooling, forced air, cold air (passive) and hydrocooling. Each system varies regarding heat removal efficiency (Kalbasi, 2004). Hydrocooling is a fast, simple and a low-cost cooling method. The fresh product can be contact with water by sprinkling or washing, soaking and the cooling effect is sometimes quicker than conventional methods (Elansari, 2008; Jacomino *et al.*, 2011). Hydrocooling is an interesting technology, allowing high heat-transfer rates, which can result into three times shorter cooling times in comparison with products cooled by forced air, or ten times, when products are placed in conventional or storage room (Teruel *et al.*, 2004). Water encourages larger efficiency for field heat removal, as well as helps in the hygiene of the fruits, per remove dirt and microbial load coming from the field (Liang *et al.*, 2013; Tokarskyy *et al.*, 2015). The efficiency of the hydrocooling procedure depends on each of limitations of each product in order to be commercially applicable, relation temperature and refrigeration duration (Manganaris *et al.*, 2007). Water losses from a fruit or vegetable are driven by the gradient in incomplete pressure of water vapor between the boundary layer over the product surface and its immediate condition. While, the boundary layer of product surface is sometimes assumed to be saturated (a_w = 1.0) and the partial pressure at the evaporating surface isn't equivalent to the vapor pressure at the product surface temperature if there are broken up substances present as these lower the water activity at the evaporating surface (Eissa, *et al.*, 2017).

Choi, *et al.* (2015) observed that firmness decreased and water-soluble pectin increased with increasing water loss and that firmness remained high and water-soluble pectin concentration low if water loss was minimized.

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Fruits and vegetables components that may differentiate their impact on mass loss include fiber content, glycemic load (GL), and biologically active constituents like polyphenols and sugars. Higher fiber intake raises satiety, which in turn may reduce total energy intake and prevent mass gain (Mozaffarian, *et al*., 2011). Hydrocooling could be an option to maintain the cashew apples quality. The effects of the reduction of cooling time reflected in the maintenance of visual quality, in the conservation of firmness, and in lower PPO and POD activities in fruit (Edinaldo, *et al*., 2019). After 7 days of cold storage, lemon was lower percentages of firmness loss (26-40%) than stone fruits 55% (apricot, peaches, nectarine and plum), with 70-90% of loss in fruit firmness (Valero and Serrano, 2010).

Akdemir and Balb (2018) studied effect of cold-storage sensitive peaches "cv. Glohaven" in two different cooling systems and determine the quality parameter changes that occur during storage and resulted that variations in color factors values "L, a and b" which indicated that as maturity increased the peach fruits exhibited a more intense and less bright reddish yellow color. However, Valero and Serrano, 2010 indicated that no significant effects by the storage and level differences were observed on brightness. There was an increase in "a" values compared to the initial value (10.4). It is possible that the red color on the fruit skin became more visible. "b" values showed fluctuation. Research on the effects of hydrocooling have been carried out in many species, such as Cherry (Wang and Long, 2015), Blueberry (Carnelossi *et al*., 2004), lychee (Liang *et al*., 2013), Peaches, lettuce (França *et al*., 2015), strawberry (Tokarskyy *et al*., 2015), orange, plum and carrot (Teruel *et al*., 2004). However, little records have been found on the use of hydrocooling and its effects on the postharvest quality of Cucumber.

In most countries such as Egypt, cucumber fruits are often preserved and presented on the shelves in market places, resulting in increasing physiological damage associated with change in the nutritive values and quality parameters. It is required to reduce the physiological damage and improve the cucumber product. So, the following work is identified. The aim of this study is to determine the effect of cucumber hydrocooling treatment (HY) before cold storage on its quality and properties. Also, is to compare the physiological specification of cucumber under hydrocooling and non-hydrocooling (control) systems for different temperatures during storage in cooling rom.

MATERIALS AND METHODS

The cucumber (Cucumis sativus L.) was brought from the Faculty of Agriculture Farm, Menoufia University after harvesting. The samples transported to the laboratory within 2.0 h of harvest. The cucumber were selected by color uniformity, size, appearance and absenteeism of damage with preform format for length of 146 mm, diameter of 29.5 mm and with average mass of 99.73 g. Two experiments were conducted. First, experiment is conducted to test the effect of the selected precooling by hydrocooling treatment on postharvest quality of cucumber. And a second, cucumber is storied in cold room at different cooling temperatures after hydrocooling treatment and non-hydrocooled (control), in the attempt to find the best cooling temperature without damages during cucumber storage.

Hydrocooling determination

Hydrocooling (HY) was carried out by immersing cucumber fruit in cold water at 4 °C, maintained during cooling by addition of ice. Approximately 3 kg of cucumber were used for each treatment. Cucumber was hydrocooled in 30 L circular plastic water tanks, and it was with sodium hypochlorite (NaOCl; 5.65–6.00% Fisher Scientific) added to water, to yield final concentrations of 200 mgL^{-1} (pH adjusted to 6.5 ± 0.05). Water temperature was continuously monitored and maintained constant with thermocouples (±0.5 °C) by adding crushed ice when necessary. A volume ratio of 3: 1: 1 of water, ice and cucumber mass, respectively, used as recommended by (Hardenburg *et al*., 1990; Kitinoja and Gorny, 1999). Cucumber temperatures were monitored with T-type thermocouples (1 mm diameter, precision ± 0.2 °C). Isolated sensors were introduced length-wise in the product pulp, and local temperature history of three different cucumbers within the system was recorded every five seconds per treatment. The pulp temperature before cooling was 25.5 ± 4 °C (initial temperature).

Cold room storage

The hydrocooling (HY) and un-hydrocooled (control, CR) treatments of cucumbers were stored at three different temperature 5.0, 9.0 and 13 °C with relative humidity of 90±5 % in cold room per five storage times of 3.0, 6,9,12 and 15 days. The dimensions of cold room are 1.2 m length, 0.7 m in width and 1.2 m height.

It prefabricated from isolated panels with thickness of 80 mm. The both sides of insulation panel covered with pre-coated fiber glass sheet. Inside foam trays cucumbers were arranged in single layers. Thermocouples were used to monitor the temperature decrease in cucumber fruit pulp.

Cooling time (cooling rate)

Cooling time is a parameter used to evaluate the efficiency of fast-cooling systems for commercial and/or research purposes. Two terms related to cooling time are considered, namely half cooling time ($TAT_{1/2}$), and seven-eight cooling time ($TAT_{7/8}$). This parameter (time) can be determined by the Dimensionless Temperature Rate (TAT) according to Teruel *et al.* (2004) as shown equations 1 and 2. They were defined as the time required cooling the pulp in 1/2 or 7/8 of the difference between the initial temperature of the product and the temperature of the cooling fluid (Carnelossi *et al*., 2013).

$$TAT_{1/2} = \frac{T_p - T_a}{T_i - T_a} = 0.5 \qquad \text{---1}$$

$$TAT_{7/8} = \frac{T_p - T_a}{T_i - T_a} = 0.125 \qquad \text{---2}$$

Where: T_p is the temperature measured in the product during cooling, T_i is the initial temperature of the cucumber fruit, and T_a is the temperature in the cooling medium (water at 4ºC). The hydrocooling commercial temperature under experiment is 5 °C as recommended by (Moura *et al*., 2013).

Evaluation of Cucumber parameters

Cucumber dimensions

The axial dimensions of "100 samples" of cucumbers fruits were identified, namely: length and diameter were measured using a digital Vernier caliber with sensitively of 0.01 mm. the cucumber volume recorded relative to cylindrical principle equation.

Mass loss per unit time

Four cucumber fruit from each cooling time and temperature cold room treatment were weighed using a digital balance (GP4102 Model, Germany). Mass loss per unit time or per unit hour recorded at the beginning of the experiment (w_i) per every 3 days during storage till the end of the storage period (w_f). The results were expressed as the percentage losses of initial mass per unit hour. Cumulative mass losses were expressed as percentage loss of the original fresh mass as the following equation 3.

$$\text{Mass loss } \% = \frac{\text{Initial mass } (w_i) - \text{Final mass } (w_f)}{\text{Initial mass } (w_i)} \times 100 \qquad \text{---3}$$

Firmness

Firmness was measured using a digital penetrometer (model FHT-1122 hardness tester CT3, China), fitted with a 5 mm probe. The maximum force necessary to penetrate 3.5 mm into the pulp was recorded and expressed in Newton (N). Firmness was measured twice in each of cucumber fruit at each cooling time and temperature cold room treatment.

Color determination

Cucumber color was determined with a WR-10 colorimeter. Chroma values were the means of three determinations for each cucumber fruit along the equatorial axis. The lightness considers "L", "a" and "b" values. The L value is a useful indicator of darkening during storage, either resulting from oxidative browning reactions or from increasing pigment concentrations. The enzymatic browning at the cut surfaces of peaches could be monitored by measuring changes in reflectance" L", "a" and "b" values seemed to be unrelated to the extent of browning.

The change in the surface color of the sample was referred to total color difference. Then, the total color difference (ΔE) was determined using the following equation:

$$\Delta \mathbf{E} = \sqrt{(\Delta \mathbf{L})^2 + (\Delta \mathbf{a})^2 + (\Delta \mathbf{b})^2} \qquad \text{---4}$$

Total soluble solids

Total soluble solids (TSS) calculated according to the AOAC (1997) which determined using a digital refractometer (model HI 96801, Hanna Instruments, Romania).

Statistical analyses

The research was carried out in a completely randomized design in factorial scheme with two cooling methods, three cooling temperature (5, 9 and 13 ºC) and five storage time evaluations (3, 6,9,12, and 15 day). For the analysis of variance, the variable effects of cooling methods, cooling temperature, storage times and their interactions were analyzed. Data were generated in the program system software (SPSS, version 22) and were presented as means ± standard errors.

RESULTS AND DISCUSSION

Cooling time

Referring to mean initial temperature of cucumber of 25.5 ± 4 °C, the relationship between cooling times and temperatures of cucumber during hydrocooling (HY) under cold storage in cold room (CR) indicated that the half cooling ($TAT_{1/2}$) and seven eight cooling times ($TAT_{7/8}$) of cucumber were attained when they reached a temperature of approximately 15.1 °C and 6.75ºC for hydrocooling at resting time of 1.08 and 7.5 minute from beginning cooling respectively. On the other hand, the times required for $TAT_{1/2}$ and $TAT_{7/8}$ in cold room were 32 and 126 min, respectively. As the relationship between cucumber temperatures and cooling time were illustrated at the upper part of (Fig. 1) and the lower part connected the relationship between cooling time and the dimensionless of temperature rate under cucumber hydrocooled at 4 ºC and 5ºC cooling room.

At cooling rate (TAT7/8), cucumber in cold room required 19.38 times longer than that cucumber hydrocooling to reach 5ºC. Under this condition, temperature rapid decreases. It may be due to the high thermal conductivity of the cooling water, the agitation of the ice/water mixture and the uniform contact of the whole surface of the cucumber fruit (Fig. 1). These results were agreement with Liang *et al*., (2013) and Teruel (2004). Also, the cucumber fruit in cold room recorded total cold time of 126 minutes ($TAT_{7/8}$) achieved at 7.65 °C. While, the cucumber that hydrocooled at 5 °C with initial temperature of 25.5 °C, the cold temperature decreased to 6.75 °C for ($TAT_{7/8}$) per time of 6.5 minute.

Cucumber Quality and properties pre cold storage

Cucumber quality was determined and analysis of variance and the significant differences were summarized in Table 1. Results illustrated high significant differences among all treatments and each of averages values of deferments and interactions between treatments for all evaluation parameters.

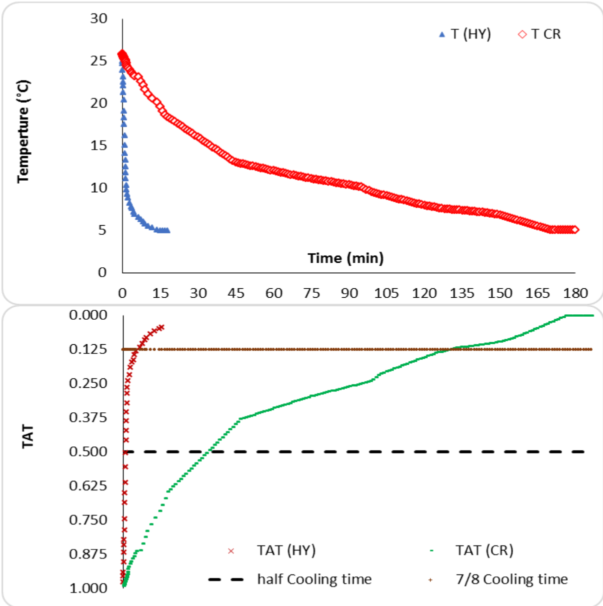

Fig. 1. The combination relationship among cooling time, cucumber temperature and dimensionless of cooling rate

Table 1. Analysis of variance (Mean square and significant) for Time, Cooling system (HY, CR), Temperature, °C and their interactions with treatment

			Time (day)	Cooling system (HY, CR)	Temperature, °C	Interaction
Diameter change, mmh^{-1}			0.004**	0.011**	0.005**	0.0009**
Length change, mmh^{-1}			0.080**	0.25**	0.049**	0.00**
Volume change, mm^3h^{-1}			0.623**	1.516**	0.705**	0.002**
Firmness (N)			136.4**	356.4**	64.1**	0.30**
Weight loss, $\%h^{-1}$			0.025**	0.030**	0.007**	0.0001 ns
Color		inner	159.3**	9.27**	221.5**	0.36**
	L	outer	65.0**	0.78**	211.5**	1.87**
		inner	10.85**	3.11**	0.74**	0.00 ns
	a	outer	17.67**	10.25**	1.33**	0.00 ns
		inner	62.97**	131.4**	297.5**	0.34 ns
	b	outer	75.41**	223.2**	60.23**	0.21**
		inner	10.93**	7.90**	8.13**	0.01**
	ΔE	outer	5.94**	6.14**	9.48**	0.04**
TSS (%)			4.30**	7.36**	3.78**	0.00**

(**), significant at level P≤ 0.01 (*), significant at level P≤ 0.05 (ns), non-significant

Change in cucumber diameter rate

Figure 2 shows the effect of different cooling system (HY and CR) and storage temperatures on change in cucumber fruit diameter. The results indicated that the diameter increases with increasing cold storage temperature, meanwhile, the change of diameter was less with cucumber hydrocooling treatment than cucumber cold room at all storage time. Where, it decreased from0.054 to 0.026 mm h^{-1} at 5 °C, from 0.069 to 0.046 mm h^{-1} at 9 °C and from 0.085 to 0.066 mm h^{-1} at 13 °C after 15 days from cold storage with non-hydrocooled (control, CR) and hydrocooling treatment (HY) respectively.

On the other hand, loss of diameter increased from 0.0019 to 0.026 mm h^{-1} with the storage time increased from 3 to 15 days at 5°C cooling room for hydrocooling treatment (HY). While, it increased in average from 0.02 to 0.054 mm h^{-1} under the above conditions for non-hydrocooled (control, CR). The maximum loss of diameter was 0.066 and 0.085 mm h^{-1} achieved after 15 days at 13 °C for "HY" and "CR" respectively. Meanwhile, the minimum loss of diameter achieved after 3 days, was 0.002 and 0.02 mm h^{-1} at 5 °C with "HY" and "CR" respectively. These results are agreement with (Bahnasawy and Khater, 2014). Finally, the cucumber loss in diameter was 8.6, 17.7 and15.1% and 22.8, 21.0 and 28% at 5.0, 9.0 and 13 °C after 15 day with "HY" and "CR" respectively.

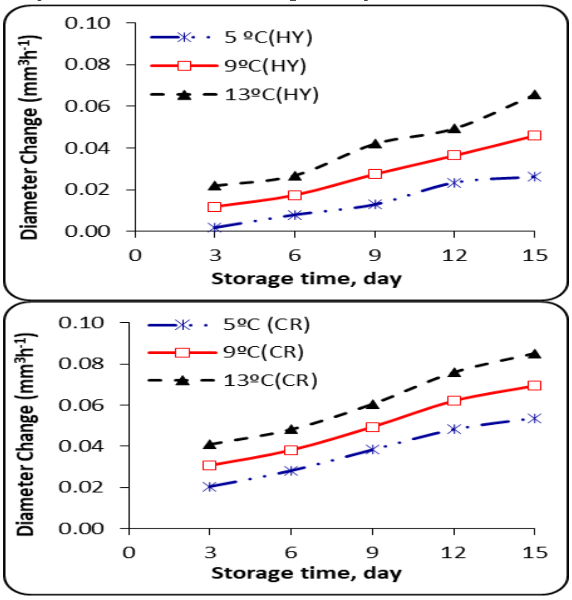

Fig. 2. Effect of cooling system (HY and CR) on cucumber fruit diameter

Rate of cucumber length change

Figure 3 shows the effect of different storage temperatures on change rate of cucumber length at "HY" and "CR". The results indicated that the length change rate increases with increasing storage temperature. Meanwhile, the change of length was less for "HY treatment than that for "CR" of cucumber at all storage time. Where, it decreased in average from "0.28 to 0.11 mm h^{-1}" at 5 °C, from "0.31 to 0.17 mm h^{-1} " at 9 °C and from "0.34 to 0.21 mm h^{-1}" at 13 °C after 15 days for (CR) and (HY) respectively. On the other hand, loss of length increased from "0.03 to 0.11 mm h^{-1}" with the storage time increased from 3 to 15 days at 5°C for "HY". While, it increased from "0.05 to 0.28 mm h^{-1}" with the storage time increased from 3 to 15 days at 5°C for "CR". The maximum loss of length was "0.21 and 0.34 mm h^{-1}"achieved after 15 days at 13 °C for "HY" and "CR" respectively. Also, the minimum loss of length achieved after 3 days, was 0.003 and 0.05mm h^{-1} at 5 °C with HY and CR respectively. These results agreed with those obtained by (Bahnasawy and Khater, 2014).

Rate of cucumber volume change

Figure 4 shows the effect of different storage temperatures on cucumber fruit volume change at "HY" and "CR" of cucumber. The results indicated that the volume change increases with increasing storage temperature; meanwhile, the change of cucumber volume was less with "HY" than that for "CR" for all storage time. Where, it is decreased in average "from 0.39 to 0.37 mm^3 h^{-1}" at temperature of 5 °C; "from 0.87 to 0.63 mm^3 h^{-1}" for cooling room temperature of 9.0 °C and "from 1.03 to 0.84 mm^3 h^{-1}" at 13 °C after 15 days from cold storage for "CR" and "HY" respectively.

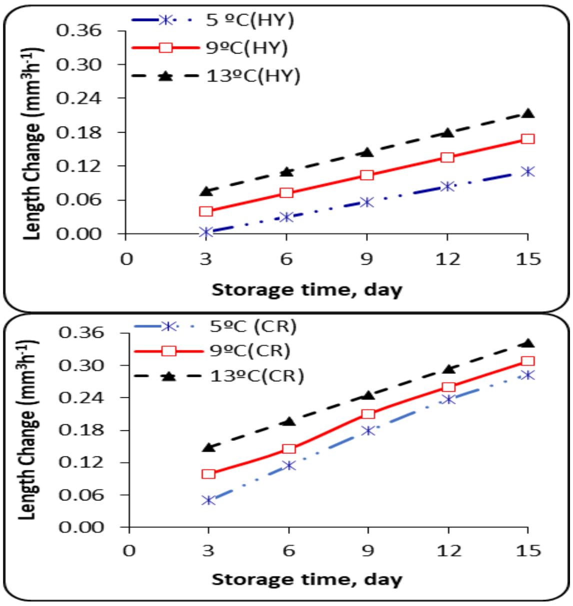

Fig. 3. Effect of cooling system (HY and CR) on cucumber fruit length

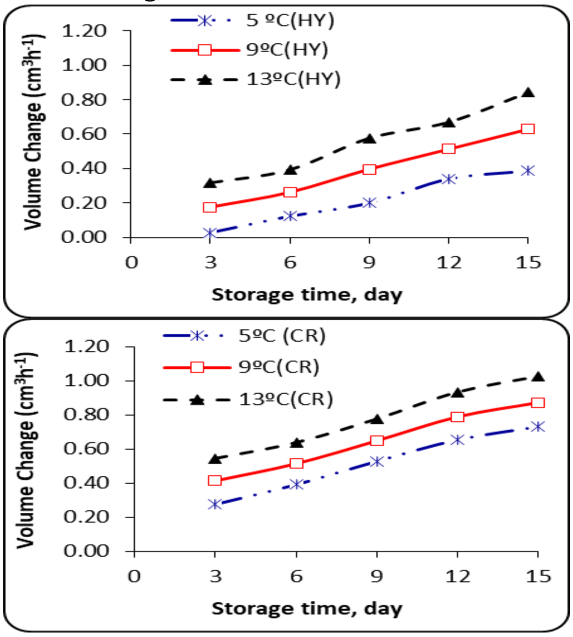

Fig. 4. Effect of cooling system (HY and CR) on cucumber fruit volume

On the other hand, loss of volume increased from 0.03 to 0.39 mm^3 h^{-1} with the storage time increased from 3 to 15 days at 5°C for "HY". While, it increased "from 0.54 to 1.03 mm^3 h^{-1}" for the storage time increased from 3 to 15 days at 5°C with CR. The highest loss of volume was 0.84 and 1.03 mm^3 h^{-1} achieved after 15 days at 13 °C with HY and CR respectively. Also, the minimum loss of volume achieved after 3 days, was 0.03 and 0.27 mm^3 h^{-1} at 5 °C for "HY" and" CR" respectively. These results agreed with those obtained by (Tsuchida *et al.*, 2010).

Rate of mass loss (m % h^{-1})

The rate of mass loss (m, % h^{-1}) of cucumber after 15 days was extrapolated based on the mass loss rate every 3 days until end of storage period for cucumber cold storage. There was a significant between "HY", "CR" treatments and storage time on mass loss. Also, un-significant effect was found between interaction "HY", "CR" treatments, temperature and storage time (Table 2). Figure 5 shows the effect of storage temperatures on cucumber mass loss ($\%h^{-1}$) change with HY and CR. The initial mass of cucumber was 99.73 g. The cucumber with HY showed lower weight loss than CR during cold storage. The highest mass loss (0.11% h^{-1}) was observed in cucumber fruits treated with HY followed by the control cucumber CR (0.19 % h^{-1}) at 13°C after 15 days cold storage. Percentage mass loss of cucumber increased with increasing storage temperature and time. Where, it increased from "0.09" to "0.12 % h^{-1} " at "5 °C", from "0.1" to "0.16 % h^{-1} " at "9 °C" and from "0.11" to "0.19 % h^{-1}" at "13°C" after 15 days from cold storage for "CR" and "HY" respectively, as shown figure 6. On the other hand, loss of mass loss increased from 0.02 to 0.09 % h^{-1} and from 0.03 to 0.12 % h^{-1} with the storage time increased from 3 to 15 days at 5°C with HY and CR respectively. Meanwhile, decreasing of mass loss increased from 0.03 to 0.11 % h^{-1} and from 0.06 to 0.19 % h^{-1} with the storage time increased from 3 to 15 days at 13°C with HY and CR respectively. The percentage of mass loss of cucumber was 6.5 and 8.9%, 7.4 and 11.2%, 7.9 % and 13.4% at 5, 9 and 13 °C after 15 day with HY and CR respectively. Loss of mass in fresh fruits and vegetables is mainly due to the loss of water caused by transpiration and respiration processes (Zhu *et al.*, 2008). Where after harvesting, water supply to the plant is chopped off, and transpiration becomes responsible for promoting water loss. In the present study, fresh mass loss may be related to the water flow in the cucumber. Also, cucumber mass loss during postharvest handling is caused by the vapor pressure deficit between the fruit interstitial air space (100% RH) and the surrounding air (<100% RH), and by metabolic processes of respiration during postharvest handling and storage (Joo *et al.*, 2011). Weight fix or decreasing slowly in HY cucumber was mainly due to free water on the fruit surface, although small amounts may have been absorbed through the cucumber stem scar. This is one of the main benefits of HY, the prevention of water loss during the cooling process. Generally, it is found the loss in volume of cucumber had an extreme positive relationship with the loss in mass of its fruits (weight loss caused changing in size of the fruit and, therefore, the volume).

The cucumber firmness is considered the shelf life and quality of cucumber. It is presented in figure7 at different temperature under "HY" and "CR" treatments. There was a high significant interaction between "HY", "CR" treatment, temperature and storage time on firmness (Table 2). The results proved that the "HY" treatment is maintained the low firmness of cucumber, same trend was reported by Edinaldo *et al.*, (2019). Also, it showed the firmness in extreme relationship with the total mass loss of cucumbers. However, the "HY" treatment have lower mass (m % h^{-1}) during the storage time. It confirmed a higher firmness value at the end of storage period and storage temperature.

The relationship between firmness of cucumbers and storage period at three storage temperatures for "HY" and "CR" was presented graphically in figure 6. The results of the comparison between the firmness, (N) for "HY" and "CR" versus the storage period and temperature, showed that the firmness of treatment "HY" is higher at the end (after stored 15 days) than that for "CR".

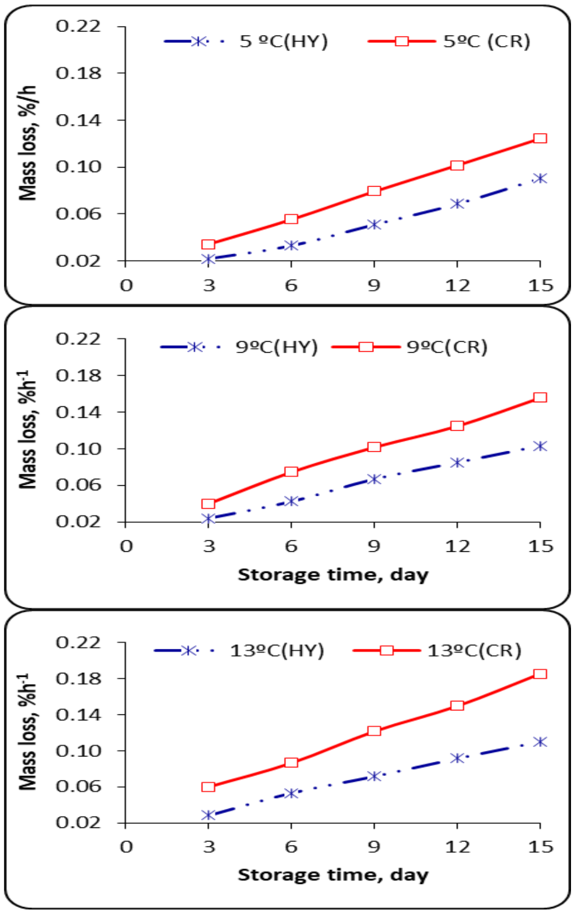

Fig. 5. Effect of storage temperatures on rate of cucumber mass loss (m% h^{-1}) change with HY and CR. Firmness

Table 2. Mean and standard error (±) of some quality properties for cucumber per times, cooling system (HY, CR) and temperature, °C

Items	day	TSS, %	Color parameter							
			L		a		b		ΔE	
			inner	outer	inner	outer	inner	outer	inner	outer
Time	3	3.79±0.002	63.05±0.06	27.98±0.059	-5. 4±0.009	-7. 0±0.006	24.5±0137	25.9±0.011	2.79±0.008	2.99±0.009
	6	3.08±0.002	60.02±0.06	28.27±0.059	-4.9±0.009	-7. 3±0.006	23.3±0.137b	26.5±0.011a	3.54±0.008	3.80±0.009
	9	3.03±0.002	58.88±0.06	29.94±0.059	-4.14±0.009	-7.9±0.006	22.5±0.137c	27.9±0.011	3.95±0.008	3.85±0.009
	12	2.77±0.002	56.7±0.06	31.86±0.05	-3.95±0.009	-8.5±0.006	21.2±0.137d	29.1±0.011	4.39±0.008	3.89±0.009
	15	2.48±0.002	55.35±0.06	32.13±0.05	-3.33±0.009	-9.6±0.006	19.67±0.137d	30.9±0.011	4.81±0.008	4.62±0.009
Cooling system	HY	3.3±0.0013	62.1±0.04	28.7±0.037	-4.0±0.006	-7.7±0.004	23.4±0.087 a	26.5±0.007	3.6±0.005	3.1±0.005
	CR	2.7±0.001	56.45±0.04	30.2±0.037	-4.6±0.006	-8.4±0.004	21.0±0.087 b	29.6±0.007	4.2±0.005	4.0±0.005
Storage temperature °C	5	3.4±0.002	61.8±0.049	27.4±0.046	-4.1±0.007	-7.9±0.005	25.7±0.106	27.0±0.008	3.4±0.006	3.3±0.007
	9	2.96±0.002	58.1±0.049	30.2±0.046	-4.3±0.007	-7.95±0.005	21.2±0.106	27.5±0.008	3.49±0.006	3.8±0.007
	13	2.7±0.002	56.5±0.049	32.7±0.046	-4.4±0.007	-8.3±0.005	19.7±0.106	29.7±0.008	4.4±0.006	4.46±0.007

The lowest firmness (10.44 N) was observed in cucumber fruits treated with "HY" followed by the control cucumber "CR" (7.04 N) at 13°C after 15 days cold storage. Cucumber firmness decreased with increasing storage temperature and time. Where, it decreased from "13.93" to "10.53 N" at 5 °C, from "11.86 to 8.46 N" at 9 °C and from "10.44 to 7.04 N" at 13 °C after 15 days from cold storage for "HY" and "CR" respectively, as shown figure 6.

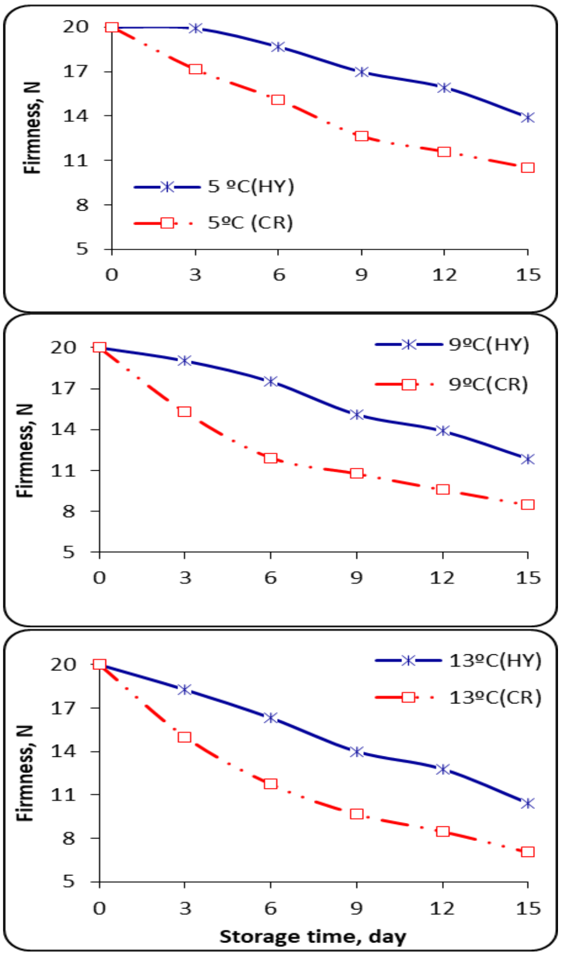

Fig. 6. Effect of storage temperatures on cucumber firmness (N) with HY and CR.

On the other hand, cucumber firmness decreased from “19.92 to 13.93 N” and from “17.16 to 10.53 N” as storage time increased from “3 to 15” days at” 5°C” for “HY” and “CR” respectively. This suggests that the mass loss is associated with firmness of cucumber during cold storage. These results are agreement with Shiekh *et al*., (2013); Rab *et al*. (2013) and Makwana *et al*. (2014).

Color parameter

Plate 1 shows the effect of cooling system for “HY”, “CR” treatments and storage temperature on appearance and outer color of cucumber after 15 days in cold room. The color changes in inner and outer cucumber as influenced by storage temperature and time for “HY” and “CR” as shown in Table 1. There was high significant change ($p \geq 0.01$) in lightness “L” (inner and outer) values of the cucumber treated by “HY” and “CR” during the period of storage (15 days) at different storage temperatures. Similarly, high significant change ($p \geq 0.01$) in “b” (outer) and ΔE (inner and outer) values of the cucumber treated with “HY” and “CR” under above conditions.

However, nun significant differences were observed between the “a” (inner and outer) and “b” (outer) values of the treated “HY” and “CR” cucumber as the storage days progresses at storage temperatures. The evaluation considered the appearance color, the lightness (“L” value), green/red components (“a” value), and blue/yellow components “b” value. The mean value and stander error of color parameters (inner and outer) affected by time, cooling system and temperature illustrated in table 2.

At initial “L” value of 65.08, the mean value for color parameters “L” (inner) ranged from “63.05±0.06” after 3 days to “55.35±0.06” after 15 days. Also, it ranged from “61.8±0.049” to “56.5±0.049” at 5 days and 13 °C respectively. Meanwhile, it ranged from “62.1±0.04” to “58.45±0.04” for “HY” treatment and “CR” respectively. The lowest mean value of “L” (outer) “32.13±0.059” was observed in cucumber fruits treated with CR at 13°C after 15 days cold storage.

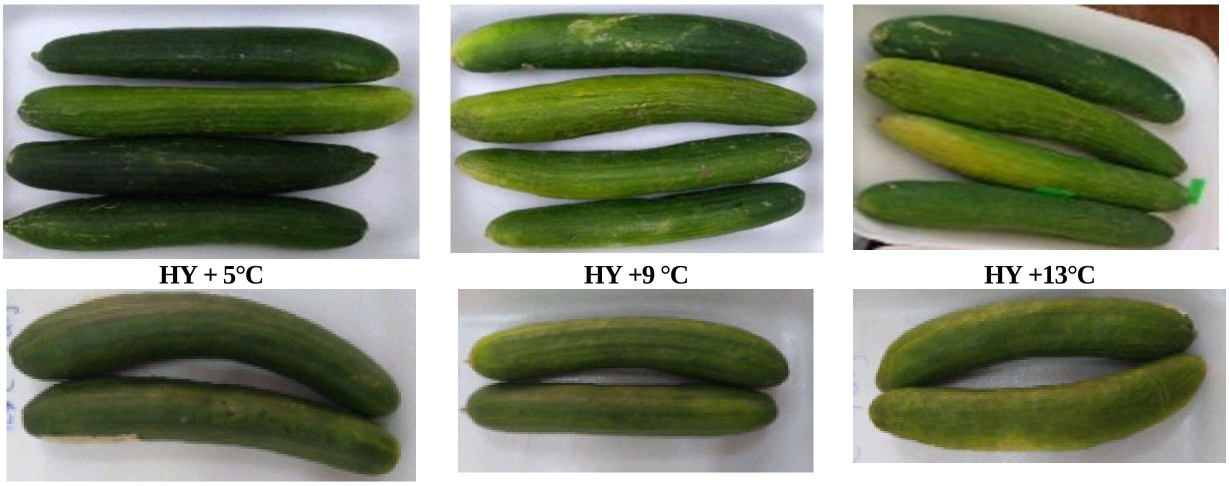

Plate 1. The “HY”; “CR” treatments and storage temperature as affecting appearance and outer color of cucumber after 15 days in cold room

The values of “a” (inner) and (outer) increased with increasing storage time and decreased with increasing temperature for “HY” and “CR”. Also. The lowest mean values of “a” (inner and outer) recorded “-4.4±0.007” and “-8.3±0.005” were observed at 13°C. While, there recorded after 15 days “-3.33±0.009” and “-9.6±0.006”. In addition, mean value of “a” (inner) was ‘-4.0±0.006” and “-4.6±0.006” but, mean value of “a” (outer) was “-7.7±0.004” and “-8.4±0.004” for “HY” and “CR” respectively.

The values of “b” (inner and outer) decreased with increasing storage time and temperature for “HY” and “CR”. Mean values of “b” (inner) and (outer) were “23.4±0.087”; “21.0±0.087” and “26.5±0.007”; “29.6±0.007” for “HY” and “CR” respectively.

Variation in color parameters during storage period may be to the burst of ethylene gas and increase generate respiration rate that signals genes to transform chloroplasts.

The chlorophyll gradually replaced by the carotenoids. This phenomenon was agreement with Keshek *et al.* (2018).

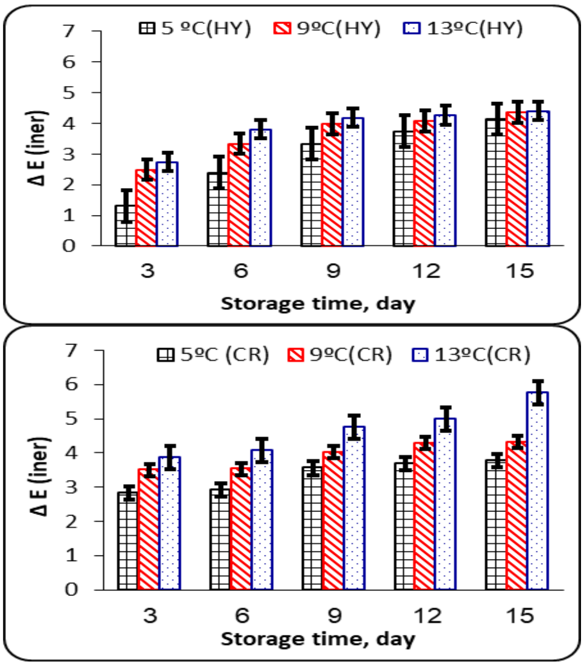

Fig. 7. Effect of storage temperatures on cucumber ΔE (inner) for "HY" and "CR" tratments

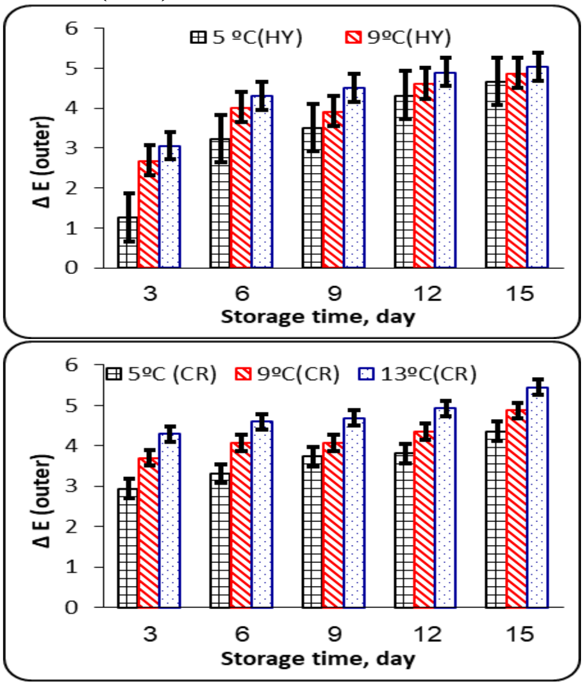

Fig. 8. Effect of storage temperatures on cucumber ΔE (outer) with HY and CR.

The color change (ΔE) of cucumber as influenced by storage time and temperature for "HY" and "CR" is shown figures 7 and 8. The total color change (ΔE inner) during the storage period for cucumber was in the range from "1.26 to 4.14" and from "2.38 to 4.17" occurred after 15 days of cold storage at 5 °C for "HR" and 'CR" respectively. While ΔE (outer) ranged from "1.31 to 4.67" and from "2.95 to 4.36" under above conditions respectively. The maximum value of ΔE inner and outer were "4.56 and 5.74" and "5.04 and 5.44" after 15 days at 13 °C for "HR" and "CR" respectively. This indicates that, the HY treatment of fresh cucumber before cold room resulted in reducing of texture quality degradation over the sample storage period.

Total soluble solid (TSS)

The mean value and stander error of TSS affected by time, cooling system and temperature are in table 2. The initial of "TSS" was "4.25". The value of "TSS" decreases by increasing storage time and temperature for "HY" and "CR". The lowest mean value of TSS was "2.7±0.001" observed for cucumber fruits treated with "CR" at "13°C" after 15 days cold storage. Meanwhile, the highest mean value of "TSS" was "3.89±0.0013" observed for cucumber fruits treated with "HY" at 5°C after 3 days cold storage.

CONCLUSION

- Cucumber quality plays an important role in determining consumer acceptance. These results suggest that, cucumbers could be hydrocooled using cold water at temperatures of 4°C and the recommended storage temperature at 5°C. Generally, the quality properties of cucumber under hydrocooled (HY) were better than non-hydrocooled (CR) in room storage. Cucumbers in cold room required 19.38 times longer than that hydrocooling to reach 5ºC.
- Mass losses were "0.11 and 0.19 % h^{-1} "for cucumber fruits treated by "HY" and "CR" at 13°C after 15 days cold storage. The lowest firmness "10.44 N" was observed in cucumber fruits treated with "HY" against "7.04 N" for "CR" under the sane above conditions.
- The maximum value of ΔE "inner and outer" were recorded "4.56 - 5.74" and "5.04 - 5.44" at 13°C after 15 days cold storage for "HY - CR" respectively.

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المعالجة المائية للخيار وعلاقته بخصائص الجودة أثناء التخزين البارد

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في معظم البلدان ، تعتبر خسائر الفاكهة والخضروات خلال عملية ما بعد الحصاد مصدر قلق كبير لتجار الفاكهة والمزارعين والمستهلكين. لذا فإن الهدف من هذا العمل هو دراسة تأثير المعالجة المبردة للخيار "HY" قبل وضعه فى غرفة التبريد وتأثير ذلك على خواصه. يتوافق نظام "HY" بوضع الخيار في الماء البارد عند "4 درجات مئوية" بنسبة ثلاث وحدات من كتلة الماء إلى وحدة كتلة واحدة من الجليد ووحدة واحدة من كتلة الخيار (3: 1: 1). حيث تم تخزين الخيار المبرد "HY" وغير المبردة بالماء (الكنترول، CR) في غرفة التبريد تحت درجات حرارة (5.0؛ 9.0 و 13.0 درجة مئوية) وعند الرطوبة النسبية "90±5٪" وفترات تخزين "3.0؛ 6.0؛ 9.0؛ 12.0 و 15.0 يوم". وقد تم قياس التغيرات في القطر، الطول والحجم، الصلابة، الكتلة، معاملات اللون والمواد الصلبة الذائبة الكلية (TSS) كأهم العوامل التي تؤثر على جودة الخيار أثناء التبريد. أظهرت النتائج وجود فروق ذات دلالة إحصائية عالية بين جميع المعاملات ومتوسطات جميع التحديدات السابقة مثل التغيير في كل من قطر الخيار، الطول، الحجم، الصلابة، الفقد فى الكتلة، "TSS" ومعاملات اللون (L، a، b و ΔE). من ناحية أخرى، وجد لأنه لا يوجد فروق معنوية بين تفاعلات جميع المعاملات ومتوسط الفقد فى الكتلة وبعض معاملات اللون "a" (الداخلية والخارجية) و"b" (الخارجي). حققت المعاملة "HY" أعلى درجات الصلابة و TSS، وأقل فقد فى الكتلة والقطر والطول والحجم بالمقارنة مع طريقة "CR". وقت تبريد "TAT 7/8"، النسبة المئوية لمعدل فقد الكتلة ، أدنى صلابة وفرق اللون الكلي "ΔE" داخلي / خارجي تم تحقيقه عند " HY " والتى تبلغ" 7.5 م "؛" 0.11٪ h-1 "؛ "N10.44" و "4.56 / 5.74" على التوالي مقارنة بطريقة "CR" لـ "126 m"؛ "0.19٪ h-1"؛ "N7.04" و "5.04 / 5.44" عند 13 درجة مئوية بعد 15 يومًا من التخزين المبرد. ولكن أعلى قيمة متوسطة لـ "TSS" حُققت مع نظام "HY" وسجلت "3.89±0.0013" عند 5 درجات مئوية بعد 3 أيام من التخزين البارد.