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Effect of Pre-Cooling and Waxing on Quality and Shelf-Life of 'Galia' Cantaloupes (Cucumis melo var. Cantaloupensis)

Abu-Bakr A. Abu-Goukh, Al Fadil M. Baraka and Mustafa M.A. Elballa

Department of Horticulture, Faculty of Agriculture, University of Khartoum, Shambat 13314, Sudan

Abstract: The effect of pre-cooling and waxing of three 'Galia' cultivars was evaluated with regard to fruit quality and shelf-life at 18 ± 1°C and 85%- 90% relative humidity. Pre-cooling and/or waxing reduced moisture loss, delayed fruit ripening, maintained quality and extended shelf-life of the three cultivars. Pre-cooling and/or waxing delayed the onset of the climacteric peak, rind color development, fruit softening and TSS accumulation by one to four days. Weight loss was reduced by an average of 6.5% in the pre-cooled, 15.8% in the waxed and 27.4% in the pre-cooled and waxed fruits.

Key words: Cantaloupe; pre-cooling; waxing; quality; shelf-life

INTRODUCTION

Cantaloupes (*Cucumis melo* var. *Cantaloupensis*) are among the important fruit vegetables that are grown in Sudan. They have gained importance as an export commodity since 1975. Now they rank first in exported vegetables and only second to mangoes in Sudanese total horticultural exports, in terms of revenue (AOAD 2008).

During the last few years, farmers failed to harvest and keep their product in a way to comply with export requirements and about 40% to 55% of the total yield was classified as local market grade (Abbas 2004). Records from Wafra and Arab Company for Agricultural Production and Processing (ACAPP) showed that a significant portion (25-30%) was discarded from the packed melons before shipment (SHEC 1999). That was attributed to water loss, shriveling and physiological and pathological disorders. Importers feed-back also indicated that a considerable part of the product was discarded at destination for poor quality, due to improper harvesting maturity, fruit softening and shriveling (MACK 1999; Rustenburg Co. 1999).

High temperatures at harvest build-up high field heat in the fruits. Cantaloupes are generally harvested every two days or less, depending on daily heat patterns. If mature cantaloupes are exposed to direct sun and heat, they are easily sunburned. There are also moisture losses of up to 3-4% which is indicated by shriveling around the stem-end and softening of the fruit (Ware and McCollum 1980).

Cantaloupes harvested during the peak of the season are at about 30ºC or even more, on arrival at the packing shed. At such high temperatures, melons rapidly ripen and lose sugars and moisture (Ryall and Lipton 1979). Pre-cooling of melons, especially when they are picked during hot weather, is of vital importance (Salunkhe and Desai 1984). Cantaloupes should be cooled to 10-15°C as rapidly as possible, because cooling reduces the rate of ripening, shriveling and sugar losses (Ryall and Lipton 1979).

Waxing was reported to delay fruit ripening, reduce water loss and extend shelf-life in mango (Mohamed and Abu-Goukh 2003), guava (Mohamed-Nour and Abu-Goukh 2013), tomato (Ahmed and Abu-Goukh 2003), lime (Ayoub and Abu-Goukh 2009; Abdallah and Abu-Goukh 2010) and grapefruit (Abu-Goukh and Elshiekh 2008). The effect of waxing seems to lie mainly on preserving appearance of the fruit and color development, although the other aspects of ripening are also affected. Mohamed and Abu-Goukh (2003) found that waxing significantly decreased respiration rate, water loss and fruit softening, delayed the onset of the climacteric peak and fruit ripening, retained ascorbic acid, maintained fruit quality, reduced post-harvest losses and extended shelf-life of mango fruits.

This study was conducted to investigate the effect of pre-cooling and waxing on quality and shelf-life of 'Galia' Cantaloupes.

MATERIALS AND METHODS

Experimental Material

A field experiment was conducted during winter at Silate Agricultural Scheme, Khartoum North (15°40´ N, 32°22´ E). Land preparation and cultural practices were carried out as follows. Chicken manure and triple super phosphate fertilizer (43% P_2O_5) were applied during land preparation, at the rate of 14 tons and 50 kg per hectare, respectively. The soil was then disc-harrowed, leveled and made into beds of 1.75m wide. The field was then subdivided into plots, each 10 meters long with four beds.

Seeds of ‘Galia F_1 Standard’ and ‘Galia F_1 MN-318’ were provided by Pop Vriend Seed Company and seeds of ‘Galia F_1 Solar King’ were obtained from Nunhem Seed Company, USA. Two seeds per hole were sown during the first week of October, on both sides of the bed at 25cm inter-row spacing. Fifty kilograms of urea (46% N_2) were applied 15 and 45 days after sowing. The crop was irrigated at seven-day intervals until flowering and then was extended to 10-day intervals till harvesting time. Insecticides and fungicides were applied as needed to control insect pests and powdery mildews during the growing season. Fruits were harvested at the mature-green stage when they were fully developed, with complete netting and abscission layer was formed with slight yellowing at the fruit stem-end.

Fruit Treatment

Pre-cooling was done by dipping the fruits into iced water at 7°C for 15 minutes and then air dried. Food-grade wax (Flucka AG, CH-9470 Buchs) was used for wax treatment. The wax was applied in a thin layer by brushing over the surface of the fruit. The treatments were: untreated fruits (control), pre-cooled fruits, waxed fruits, and pre-cooled and waxed fruits of three ‘Galia’ cantaloupe cultivars; namely. ‘Galia F_1 Standard’, ‘Galia F_1 MN-318’ and ‘Galia F_1 Solar King’ The fruits were then packed in carton boxes and kept in a cold room at 18 ± 1°C and 85% - 90% relative humidity. A randomized complete block design (RCBD) with four replications was used.

Parameters Studied

Respiration rate (in mg CO_2/ kg - hr) was determined daily on six fruits from each replication using the total absorption method (Mohamed-Nour and Abu-Goukh 2010). Rind color was determined daily in 10 fruits from each replication. The color score used was, mature-green (= 0), trace yellow on rind (= 1), 20% yellow (= 2), 40% yellow (= 3), 60% yellow (=

4), 80% yellow (= 5) and 100% yellow (= 6). Weight loss was determined daily on the same 10 fruits used for rind color determination according to the formula: $W_1 = [(W_0-W_t)/W_0] \times 100$; where W_1 is the percentage weight loss, W_0 is the initial weight of fruits at harvest and W_t is the weight of the fruits at the designated time. Fruit flesh firmness was determined daily on three fruits picked randomly from each replication, other than those used for respiration rate, rind color and weight loss determination. It was measured by the Magness and Taylor firmness tester (D. Ballauf Meg. Co.), equipped with an 8 mm-diameter plunger tip. Two readings were taken from opposite sides of each fruit after the rind was removed and firmness was expressed in kg/cm^2. Total soluble solids (TSS) was determined daily for 12 days, on the same fruits used for flesh firmness determination. TSS was determined directly from the fruit juice extracted by pressing the fruit flesh in a garlic press, using a Kruss hand refractometer (Model HRN-32). Two readings were taken from each fruit and mean values were calculated and corrected according to the refractometer chart.

Statistical Analysis

Analysis of variance and Fishers protected LSD Test with a significance level of $P \leq 0.05$ were performed on the data (Gomez and Gomez 1984).

RESULTS AND DISCUSSIONS

Pre-cooling and waxing reduced moisture loss, delayed fruit ripening, maintained quality and extended shelf-life of fruits of the three ‘Galia’ cantaloupe cultivars. Since deterioration occurs much more rapidly at warm temperature than at low temperature, the more quickly field heat is removed after harvest, the longer the produce can be maintained in good marketable condition in storage (Hardenburg *et al*. 1986). Wax treatment was reported to retard moisture loss, delay fruit ripening, maintain quality and extends shelf-life of mango (Mohmed and Abu-Goukh 2003), guava (Mohamed-Nour and Abu-Goukh 2013), papaya (Abu-Goukg and Shattir 2012), tomato (Ahmed and Abu-Goukh 2003), lime (Ayoub and Abu-Goukh 2009; Abdallah and Abu-Goukh 2010) and grapefruit (Abu-Goukh and Elshiekh 2008). These effects were reflected in changes in respiration rate, rind color, weight loss, flesh firmness and total soluble solids.

Effect on Respiration Rate

The respiration curves of the three 'Galia' cultivars exhibited a typical climacteric pattern of respiration (Fig.1). This is in line with previous reports that cantaloupes have a moderate rate of respiration and a climacteric rise with fruit ripening (Kader 2002; Abu-Goukh *et al.* 2011). Respiration rate was significantly higher in 'Solar King' with climacteric peak of 128 mg CO_2/kg-hr, followed by the 'Standard' and 'MN-318' cultivars, with equal peaks of 93 mg CO_2/kg-hr. The untreated fruits reached the climacteric peak after three days in the three cultivars (Fig. 1).

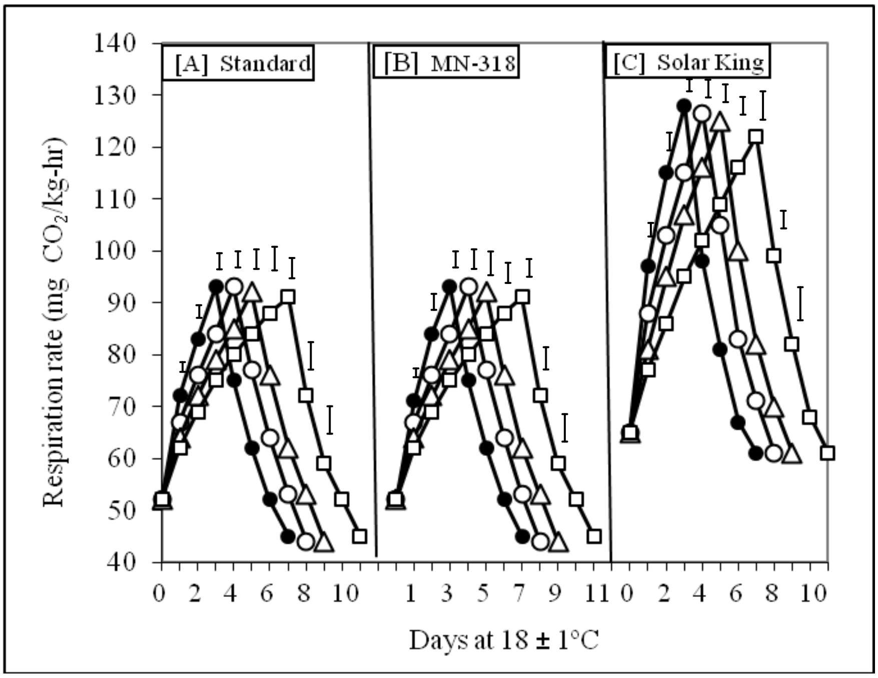

Fig. 1. Changes in respiration rate of 'Galia F_1 Standard' [A], 'Galia F_1 MN-318' [B] and 'Galia' F_1 Solar King' [C] cantaloupes, pre-cooled (○), waxed (Δ) or pre-cooled and waxed (□), compared with uncooled and unwaxed fruits (control) (•) at 18 ± 1ºC and 85% - 90% relative humidity. Vertical bars represent LSD (5 %).

This peak was delayed by one day in the pre-cooled fruits, by two days in the waxed fruits and by four days in the pre-cooled and waxed fruits of the three cultivars, compared to the untreated fruits. The pre-cooling and wax treatments slightly decreased the peak of respiration in the three cultivars (Fig. 1). Low temperature significantly retards respiration and other metabolic activities (Hardenburg *et al.* 1986, Wills *et al.* 1998). Waxing was reported to decrease respiration rate in mango (Mohamed and Abu-Goukh 2003), guava (Mohamed-Nour and Abu-Goukh 2013), papaya (Abu-Goukg and Shattir 2012), tomato (Ahmed and Abu-Goukh 2003), lime (Abdallah and Abu-Goukh 2010) and grapefruit (Abu-Goukh and Elshiekh 2008). Waxing has been shown to influence respiration rate by decreasing carbon dioxide content in the internal atmosphere of the fruit (Irving and Warren 1960).

Effect on Rind Color

Rind color score continuously increased during storage of the three ‘Galia’ cantaloupe cultivars (Fig. 2). Carotenoids begin to increase prior to the onset of respiration climacteric and chlorophyll content drops gradually as the fruits develop, with a final rapid decline coinciding with ripening (Pratt 1971). The untreated fruits reached the full yellow stage (color score = 6) after three days in ‘Solar King’ and after five days in ‘Standard’ and ‘MN-318’ cultivars.

Pre-cooling and waxing treatments significantly delayed rind color development in the three cultivars. Rind color was delayed by one day in the pre-cooled, two days in the waxed and four days in the pre-cooled and waxed fruits. Goodwin and Goad (1970) reported that carotenoids formation in ripening fruits is a function of oxygen, light and temperature. Waxing and surface coating materials significantly alter permeability of the skin to gases, and the commodity, through respiration, is used to reduce oxygen and increase carbon dioxide. Under such restricted air-exchange conditions, a modified atmosphere may be generated and some benefits of the modified atmosphere may be achieved (Kadar 2002). The delay in color development in the treated fruits might be due to changes in temperature, oxidation systems, pH and chlorophyllase enzyme activity (Wills *et al.* 1998).

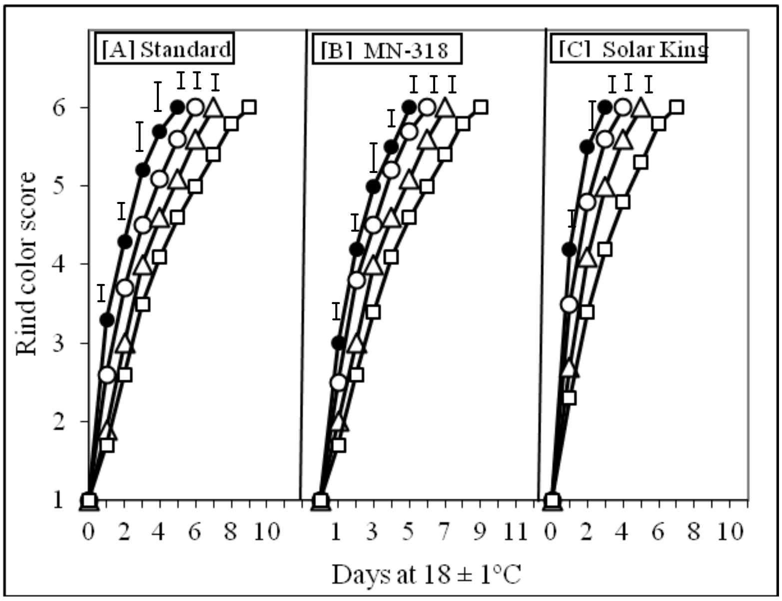

Fig. 2. Changes in rind color of 'Galia F_1 Standard' [A], 'Galia F_1 MN-318' [B] and 'Galia' F_1 Solar King' [C] cantaloupes, pre-cooled (○), waxed (Δ) or pre-cooled and waxed (□), compared with uncooled and unwaxed fruits (control) (•) at 18 ± 1ºC and 85% – 90% relative humidity. Vertical bars represent LSD (5 %).

Effect on Weight Loss

Weight loss progressively increased with storage period. Significantly lower percentages of weight loss were obtained in the pre-cooled and waxed fruits than the control in the three 'Galia' cultivars (Fig. 3). Weight loss in the untreated fruits was 22% after six days in storage in the three cultivars. At that time, weight loss was reduced by an average of 6.5% in the pre-cooled, 15.8% in the waxed and 27.4% in the pre-cooled and waxed fruits (Fig. 3).

The amount of weight loss during storage is influenced by internal commodity factors, such as morphological and anatomical characteristics, surface-to-volume ratio, surface injuries and maturity stage, and environmental factors, such as temperature, relative humidity, air movement and atmospheric pressure inside the storage facility (Ben-Yehoshua *et al.* 1979). There is a limited scope for modifying the tissue structure to reduce the rate of water loss. The most important method of reducing water loss from the produce primarily involves lowering the capacity of the surrounding air to hold additional water. This objective is achieved by lowering the temperature and/or raising the relative humidity. An alternative to raising the relative humidity is to provide a barrier to water loss by waxing or other hydrophobic coating or plastic films (Wills *et al.* 1998).

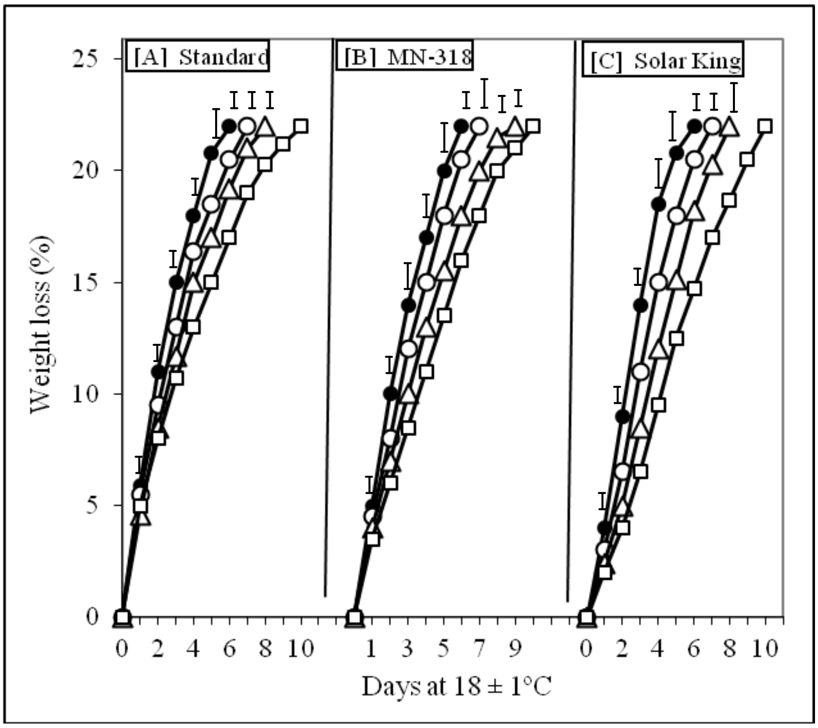

Fig. 3. Changes in weight loss (%) of 'Galia F_1 Standard' [A], 'Galia F_1 MN-318' [B] and 'Galia' F_1 Solar King' [C] cantaloupes, pre-cooled (○), waxed (Δ) or pre-cooled and waxed (□), compared with uncooled and unwaxed fruits (control) (•) at 18 ± 1ºC and 85% – 90% relative humidity. Vertical bars represent LSD (5 %).

Similar results were reported due to waxing in mango (Mohamed and Abu-Goukh 2003), guava (Mohamed-Nour and Abu-Goukh 2013), papaya (Abu-Goukh and Shattir 2012), tomato (Ahmed and Abu-Goukh 2003), orange (Martinez *et al.* 1991), lime (Ayoub and Abu-Goukh 2009) and grapefruit (Abu-Goukh and Elshiekh 2008). Wills *et al.* (1998) reported that the rate of water loss can be reduced by 30% to 50% in waxed fruits, under commercial conditions.

Effect on Fruit Flesh Firmness

Fruit flesh firmness decreased steadily during storage of the three 'Galia' melon cultivars (Fig. 4). 'Solar King' was more firm at harvest and took longer to soften than the other two cultivars. The untreated fruits reached the final soft stage (0.08 kg/cm^2) in six days in 'Standard' and 'MN-318' and eight days in 'Solar King' melons. Most of this decline occurred during 3-4 days following day-two in storage. Similar drop in flesh firm ness was reported in banana (Abu-Goukh *et al*. 1995), mango (Mohamed and Abu-Goukh 2003), guava (Bashir and Abu-Goukh 2003) and tomato (Ahmed and Abu-Goukh 2003; Ali and Abu-Goukh 2005).

Pre-cooling and waxing significantly delayed fruit softening during storage in the three cantaloupe cultivars. The final soft stage (0.08 kg/cm^2) was delayed by one, two and four days in the pre-cooled, waxed, and pre-cooled and waxed fruits, respectively, compared to the control (Fig. 4). Similar delay in fruit softening due to waxing was reported in mango (Yagi and Salih 1983; Mohmed and Abu-Goukh 2003), papaya (Abu-Goukg and Shattir 2012), guava (Mohamed-Nour and Abu-Goukh 2013), orange (Martinez *et al.* 1991) and tomato (Ahmed and Abu-Goukh 2003).

Effect on Total Soluble Solids

During storage, total soluble solids (TSS) progressively increased in the three 'Galia' melon cultivars. The maximum TSS percentages reached by the untreated fruits were 11.5%, 12.0% and 13.0% in 'Standard', 'MN-318' and 'Solar King' fruits, respectively, after six days in storage for the three cultivars (Fig. 5).

Pre-cooling and wax treatments significantly delayed accumulation of TSS in the fruits. The maximum TSS values reached were delayed by

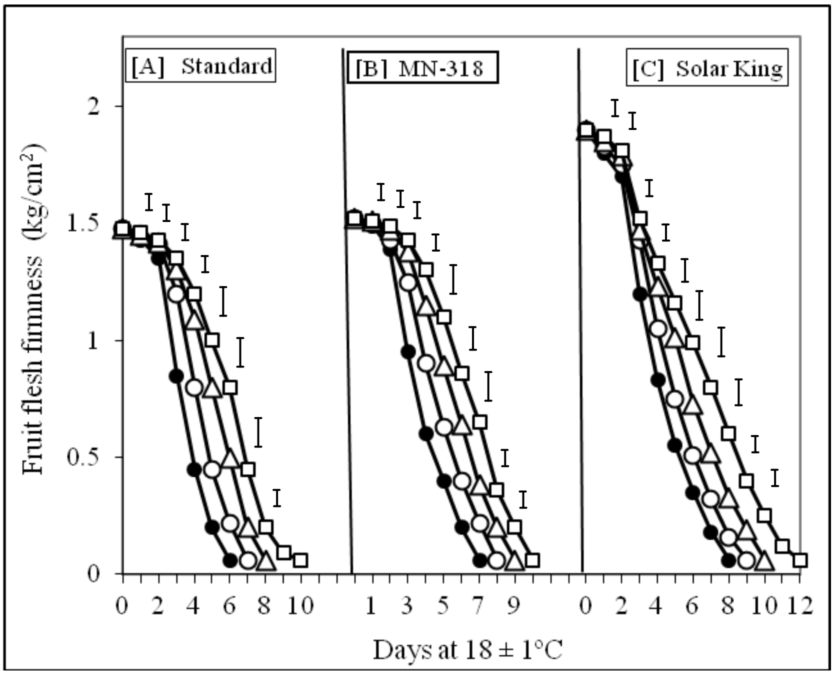

Fig. 4. Changes in fruit flesh firmness (kg/cm^2) of 'Galia F_1 Standard' [A], 'Galia F_1 MN-318' [B] and 'Galia' F_1 Solar King' [C] cantaloupes, pre-cooled (○), waxed (Δ) or pre-cooled and waxed (□), compared with uncooled and unwaxed fruits (control) (•) at 18 ± 1ºC and 85% - 90% relative humidity. Vertical bars represent LSD (5 %).

one, two and four days in the pre-cooled, waxed and pre-cooled and waxed fruits, respectively, compared to the untreated fruits. Low temperature significantly retards respiration, ethylene production and compositional changes (Wills *et al.* 1998; Kader 2002). Waxing was reported to decrease TSS accumulation during ripening and storage of mango (Yagi and Salih 1983; Mohamed and Abu-Goukh 2003), papaya (Abu-Goukg and Shattir 2012), guava (Mohamed-Nour and Abu-Goukh 2013), tomato (Ahmed and Abu-Goukh 2003), orange (Martinez *et al*. 1991)), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010).

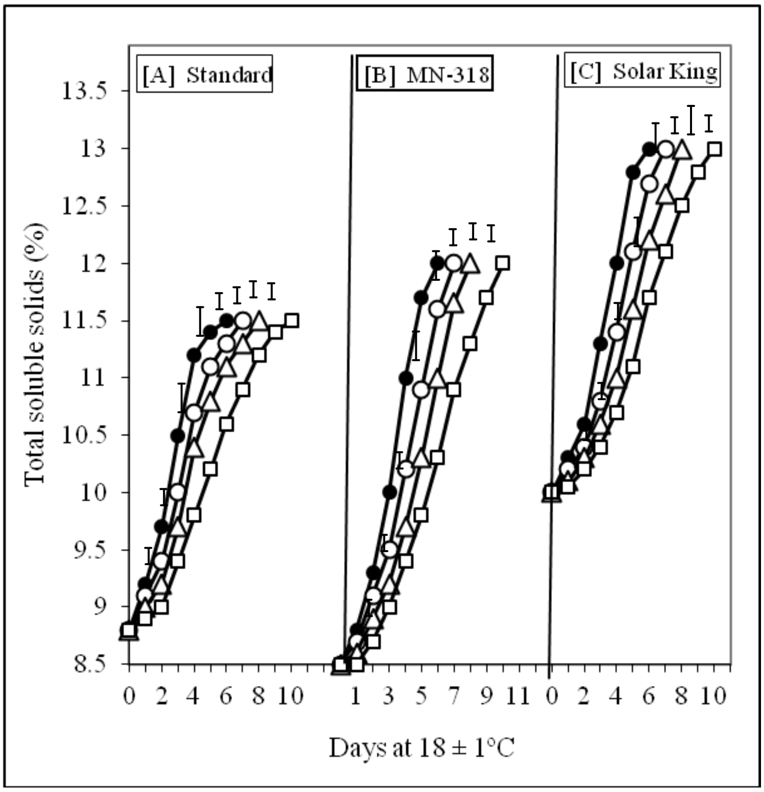

Fig. 5. Changes in total soluble solids (TSS %) of ‘Galia F_1 Standard’ [A], ‘Galia F_1 MN-318’ [B] and ‘Galia’ F_1 Solar King’ [C] cantaloupes, pre-cooled (○), waxed (Δ) or pre-cooled and waxed (□), compared with uncooled and unwaxed fruits (control) (•) at 18 ± 1ºC and 85% – 90% relative humidity. Vertical bars represent LSD (5 %).

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تأثير التبريد المبدئى والتشميع على الجودة والعمر التسويقى لثمار الشمام 'القاليا'

أبوبكر علي أبوجوخ والفاضل محمد بركة ومصطفى محمد علي البله

قسم البساتين – كلية الزراعة – جامعة الخرطوم، شمبات 13314 - السودان

المستخلص: تم تقويم تأثير التبريد المبدئى والتشميع على الجودة والعمر التسويقى لثلاثة أصناف من ثمار الشمام 'القاليا' عند درجة حرارة 18±1°م ورطوبة نسبية 85%-90%. أدت معاملات التبريد المبدئى والتشميع أو كليهما معاً إلى تقليل فقد الوزن وتأخير نضج الثمار والمحافظة على الجودة وإلى إطالة العمر التسويقى فى الأصناف الثلاثة. أخرت معاملات التبريد المبدئى والتشميع وصول الثمار إلى ذروة التنفس وتلوين القشرة وسرعة ليونة الثمار وتراكم المواد الصلبة الذائبة الكلية فيها لمدة يوم إلى أربعة أيام. إنخفضت نسبة فقد الوزن بمقدار 6.5 % فى الثمار التى تم تبريدها مبدئياً و 15.8 % فى الثمار التى تم تشميعها و27.4 % فى الثمار التى تم تبريدها مبدئياً وتشميعها فى آن واحد.