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# Compositional Changes during Muskmelon Fruit Ripening

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**Abstract:** The objective of this study was to investigate compositional changes during ripening of three Galia $F_1$ muskmelon cultivars for export; namely, 'Galeb', 'Seeren' and 'Green Star' at 18±1ºC and 85%-90% relative humidity. The fruits of the three cultivars exhibited a typical climacteric pattern of respiration during ripening. Fruit flesh firmness was declined progressively in a similar manner in the three cultivars. Rind colour, total soluble solids (TSS) and weight loss steadily increased and cellulose content decreased with fruit ripening. Total protein increased up to the climacteric peak of respiration and then decreased.

**Key words:** Muskmelon fruit; compositional changes; fruit ripening

## INTRODUCTION

Muskmelons (*Cucumis melo* L.) are among the major vegetable crops grown in Sudan. The demand for fresh muskmelons is increasing for their excellent flavour, attractive fragrance, beautiful colour, delicious taste and health giving properties (Salunkhe and Desai 1984). Muskmelons have gained importance as an export commodity since 1975. They rank first in exported vegetables and second to mango in Sudanese horticultural exports in terms of revenue (AOAD 2009). 'Galia' is the only melon cultivar grown for export in Sudan (Baraka *et al.* 2011).

Muskmelons are typical climacteric fruits that exhibit characteristic rise in ethylene production and respiration rate during ripening (Kader 2002). The high rates of respiration and ethylene production, which are usually associated with a short shelf-life (Wills *et al.* 1998), soft texture and high

moisture content, make muskmelons a very perishable commodity that requires absolute care during handling, ripening and transportation.

During ripening, the fruit passes through a series of overt changes in colour, texture and flavour, indicating that compositional changes are taking place. Attainment of maximum eating quality of the fruit necessitates the completion of such chemical changes (Wills *et al.* 1998). The quality of muskmelons depends on colour, texture of the flesh and absence of fibrous materials, along with characteristic aromatic flavour and sweetness (Salunkhe and Desai 1984).

Although Sudan has a great potential to produce and export high quality muskmelons, the post-harvest handling practices are still not taken care of by many producers and distributors. These practices need a lot of improvement. Therefore, improvement of handling techniques and control of fruit ripening are crucial for the development of a sound muskmelon industry in Sudan.

This study was carried out to investigate the compositional changes during muskmelon fruit ripening, and to provide base-line information regarding these biochemical changes, to assist in the development of sound programs for controlling muskmelon fruit ripening and/or loss of flesh firmness during transportation and storage.

## MATERIALS AND METHODS

### Experimental material

Three important export Galia $F_1$ muskmelon cultivars, namely 'Galeb', 'Seeren' and 'Green Star' were selected for this study. Mature-green Galia $F_1$ muskmelon fruits of the three cultivars, at half-slip stage, were obtained from a private farm at El-Silait, Khartoum North (15º40′ N, 32º 22′ E). Fruits were selected for uniformity of size, colour and freedom from blemishes. About 120 fruits of each of the three Galia $F_1$ muskmelon cultivars were washed by tap water to remove latex and dust, treated with sodium hypochlorite (52.5 ppm) as a disinfectant and air dried. The fruits were packed in carton boxes (6 fruits each), arranged in a completely randomized design with four replicates and ripened at 18±1˚C and 85% - 90 % relative humidity.

### Studied parameters

Respiration rate, weight loss and rind colour were determined daily during the ripening period on six fruits from each replication. Respiration rate was determined by the total absorption method (Mohamed-Nour and Abu-Goukh 2010) and was expressed in mg $CO_2$/ kg-hr. Weight loss (%) was determined daily on the same six fruits used for respiration rate determination. A digital sensitive balance was used and weight loss was calculated 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 the fruits and $w_t$ is the weight of the fruits at the designated time. Rind colour was determined daily during fruit ripening on the same six fruits from each replication used for respiration rate and weight loss determinations. The colour score used: mature-green (= 0), 20% yellow on rind (= 1), 40% yellow (= 2), 60% yellow (= 3), 80% yellow (= 4) and 100% yellow (= 5). Flesh firmness, TSS, total protein and cellulose content were determined daily on two fruits picked randomly from each replicate, other than those used for respiration, weight loss and rind colour determinations. Magness and Taylor firmness tester (D. Ballauf Meg. Co.), equipped with 8 mm

diameter plunger tip, was used. Three readings were taken on three sides of each fruit after the rind was removed. Flesh firmness was expressed in $kg/cm^2$. Total soluble solids (TSS) were determined on fruit juice extracted by pressing the fruit pulp in a garlic press on the same fruits used for flesh firmness using Kruss hand refractometer (model HR-32). Three readings were taken from each fruit and mean values were calculated and corrected according to the refractometer chart.

After determination of flesh firmness and TSS, about half of the fruit samples were labeled and stored at -12ºC for further determination of total protein and the other half of the samples were oven dried at 75ºC for three days for determination of cellulose content.

The frozen fruit samples from each replicate were thawed separately for 90 minutes at room temperature for determination of total protein. Thirty grams of fruit pulp were homogenized in 100 ml of distilled water for one minute in a Sanyo Solid State blender (model LM 242) and centrifuged at 10,000 rpm for 10 min in a Hettich centrifuge (EBA 20). The volume of the supernatant, which constituted the pulp extract, was measured. Total protein was determined in the pulp extracts according to the protein-dye binding procedure described by Bradford (1976) and was expressed as mg/100g fresh weight.

Cellulose content was determined on fruit pulp. The dried samples (DM) were ground using a mechanical grinding in a mill and stored dry in polyethylene bags. Cellulose was determined by the difference between acid detergent fiber (ADF) and acid detergent lignin (ADL) according to the method of Abdulrazak and Fujihara (1999). Cellulose was expressed as mg/100g dry weight.

The acid detergent fiber (ADF) is a rapid method for determination of lignocelluloses. Two grams of the dried pulp samples were put in a 250 ml conical flask. One hundred mls of acid detergent solution (84 ml of conc. $H_2SO_4$ + 2.916l ml of distilled water + 60 g of acetyl-trimethyl

ammonium bromide). The flask with its contents was placed on a hot refluxing apparatus and heated to boiling (5-10 min) and then adjusted to gentle boiling for one hour at about 60ºC. The end sample was filtered using a filter paper and rinsed with a small amount of distilled water.

Then the sample was put in a previously weighed crucible (X) and dried in an oven at 105ºC. After drying, the weight of the crucible and sample (Y) was determined. Acid detergent fiber (ADF) was calculated according to the formula: ADF (%) = [(Y-X)/weight of sample] × 100%.

The sample, resulting from ADF determination was put in a coach crucible. An amount of 72% $H_2SO_4$ to cover the sample was added, stirred with a glass rod, and the coach crucible was left to stand for 3 hours with frequent stirring while adding the acid to it every hour. The sample was rinsed primarily with hot water, and then with tap water until all the acid was washed. The sample was oven dried at 105ºC and the weight of the crucible with sample after drying ($Y_2$) was determined. The sample was then ignited at 550 ºC for 3 hours in a muffle furnace and the weight of the crucible with the sample (ash) (Z) was recorded. The ADL was determined according to the formula: ADL (%) = [($Y_2$-Z)/weight of sample] × 100 %. Finally cellulose content of the sample was determined as follows: Cellulose (%) = ADF (%) – ADL (%), and cellulose content was expressed in mg/100g dry weight.

## RESULTS AND DISCUSSION

Fruit ripening progressively increased in the three muskmelon cultivars. During ripening, a fruit passes through a series of overt changes in colour, texture and flavour, indicating that compositional changes are taking place (Wills *et al.* 1998). Fruit ripening rate was faster in 'Galeb', followed by 'Seeren' and slower in 'Green Star'. This was reflected in changes in respiration rate, rind colour, weight loss, flesh firmness, total soluble solids, total protein and cellulose content.

### Changes in respiration rate

The respiration curves of the three muskmelon cultivars exhibited a typical climacteric pattern during ripening (Fig.1). This agrees with earlier reports that muskmelons have moderate rate of respiration and with a climacteric rise observed with fruit ripening (Kader 2002; Abu-Goukh *et al.* 2011). 'Galeb' had significantly higher rate of respiration at harvest (50.4 mg $CO_2$/ kg-hr) and during ripening with climacteric peak of 57.7 mg $CO_2$/ kg-hr., followed by 'Seeren' (43.1 mg $CO_2$/ kg-hr at harvest) and with peak of 49.4 mg $CO_2$/ kg-hr and last came 'Green Star' (38.9 mg $CO_2$/ kg-hr at harvest) and with a peak of 46.1 mg $CO_2$/ kg-hr (Fig. 1). Fruits of 'Galeb' reached the climacteric peak after 6 days, while 'Seeren' and 'Green Star' reached the climacteric peak after 7 days at 18±1 ºC. This higher rate of respiration in 'Galeb' may indicate a shorter shelf-life of 'Galeb', compared to the other two cultivars, since high rate of respiration is usually associated with short shelf-life (Wills *et al.* 1998).

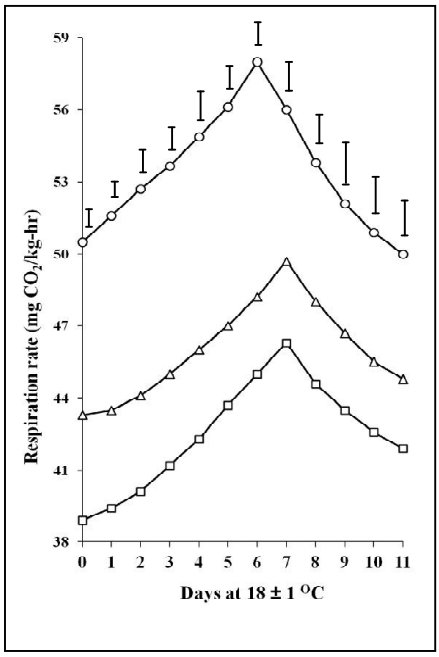


Fig.1. Changes in respiration rate during ripening of 'Galia $F_1$ Galeb' (o), 'Galia $F_1$ Seeren' (Δ) and 'Galia $F_1$ Green Star' (□) muskmelon cultivars at 18 ±1ºC and 85% - 90% relative humidity. Vertical bars represent LSD (5 %).

**Changes in weight loss**

Weight loss progressively increased during ripening of the three muskmelon cultivars (Fig. 2-A). At the end of the 11 days ripening period, weight loss was 12.4 %, 11.5% and 10.9% in fruits of 'Galeb', 'Seeren' and 'Green Star' cultivars, respectively. 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 (Ben-Yehoshua *et al.* 1979). During ripening of fleshy fruits, changes in tissue permeability and cellular compartmentation occur (Wills *et al.* 1998). Since the ripening rate was faster in 'Galeb' followed by 'Seeren' and slower in 'Green Star' as indicated in changes in respiration rate (Fig. 1), rind colour (Fig. 2-B) and

TSS (Fig. 3-B), tissue permeability would change accordingly and weight loss would be more in fruits of 'Galeb' followed by 'Seeren' and least in 'Green Star'.

**Changes in rind colour score**

Rind colour progressively increased during ripening in the three muskmelon cultivars (Fig. 2-B). Rind colour of muskmelon fruits changes from dark-green to grayish-green and then to yellowish-green as the melon fruit approaches maturity (Salunkhe and Desai 1984). The yellow colour development was fastest in 'Galeb' muskmelon cultivar and reached the full yellow colour (colour score 5) after 10 days, followed by 'Seeren' which reached colour score 5 after 11 days (Fig. 2-B). 'Green Star' showed great variability in colour development and after 11 days it only reached about 70% yellow (colour score 3.5). This might be due to genetic variability. Similar variation among cultivars was reported during growth and development (Abu-Goukh *et al.* 2011). Muskmelon cultivars show great variability in rind and flesh colour (Salunkhe and Desai 1984).

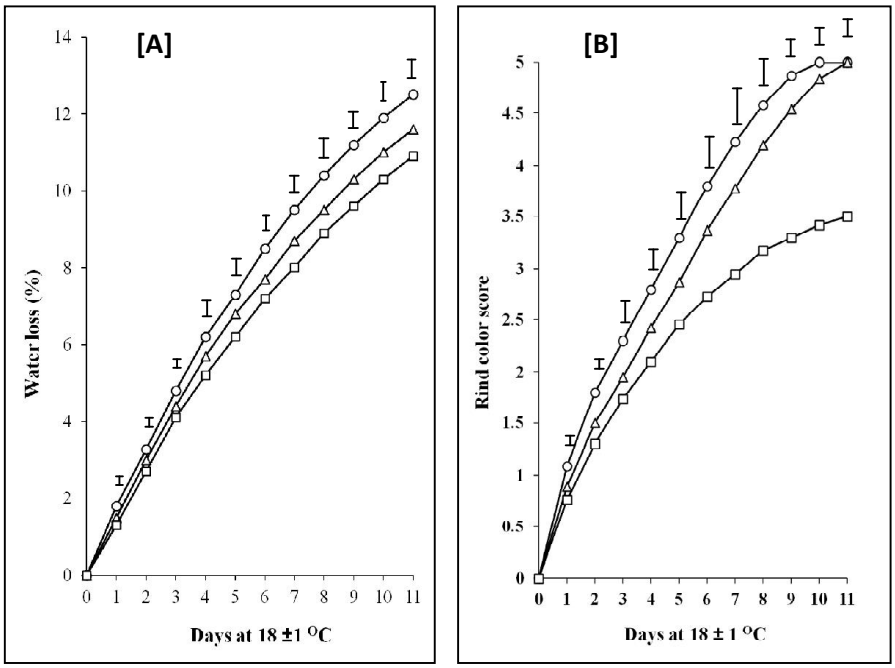


Fig. 2. Changes in water loss [A] and rind colour [B] during ripening of 'Galia $F_1$ Galeb' (o), 'Galia $F_1$ Seeren' (Δ) and 'Galia $F_1$ Green Star' (□) muskmelon cultivars at 18 ±1ºC and 85% - 90% relative humidity. Vertical bars represent LSD (5 %).

**Changes in flesh firmness**

Fruit flesh firmness decreased steadily during ripening of the three muskmelon cultivars (Fig. 3-A). Most of this decline occurred during four days following day-two during ripening. Similar drop in flesh firmness was reported in banana (Abu-Goukh *et al.* 1995), mango (Abu-Goukh and Abu-Sarra 1993; Mohamed and Abu-Goukh 2003), guava (Bashir and Abu-Goukh 2003), tomato (Ali and Abu- Goukh 2005), papaya (Shattir and Abu-Goukh 2012), and cantaloupes (Baraka *et al.* 2011). Although 'Galeb' had a higher rate of respiration than the other two cultivars, which may indicate shorter shelf-life, it was more firm at harvest and took longer to soften, compared to the other two cultivars.

**Changes in total soluble solids**

Total soluble solids (TSS) progressively increased during ripening in the three muskmelon cultivars (Fig. 3-B). 'Galeb' was the highest in TSS at harvest and during ripening, followed by 'Seeren' and then 'Green Star'. At the end of the ripening period, TSS values were 18.1%, 12.3 % and 11.7 % for the three cultivars, respectively (Fig. 3-B). Similar increase in TSS was reported in banana (Ibrahim *et al.* 1994), mango (Abu-Goukh and Abu-Sarra 1993; Mohamed and Abu-Goukh 2003), guava (Bashir and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), grapefruit (Abu-Goukh and Elshiekh 2008) and cantaloupes (Abu-Goukh *et al.* 2011). Total soluble solids (TSS) contents have long been used as an indicator of melon quality, sweetness, flavour, acceptability and maturity.

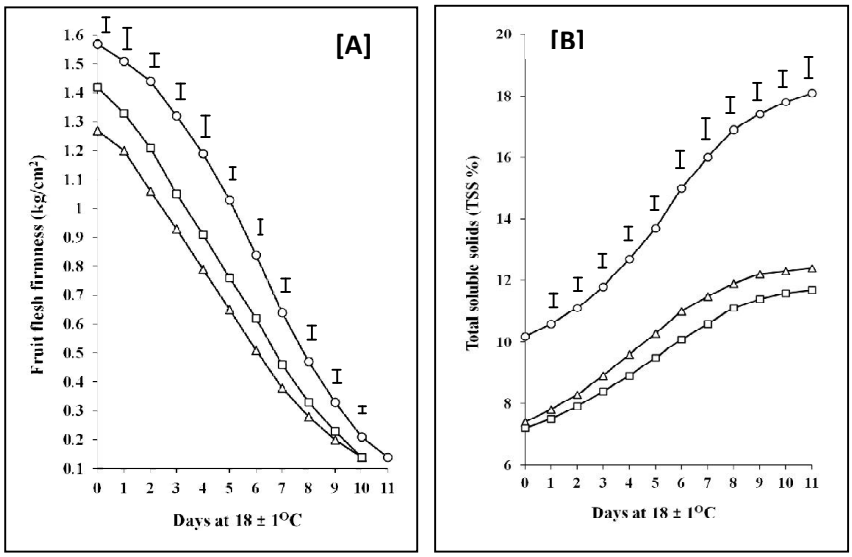


Fig. 3. Changes in fruit flesh firmness [A] and total soluble solids (TSS) [B] during ripening of 'Galia $F_1$ Galeb' (o), 'Galia $F_1$ Seeren' (Δ) and 'Galia $F_1$ Green Star' (□) muskmelon cultivars at 18 ±1ºC and 85% - 90% relative humidity. Vertical bars represent LSD (5 %).

The level of TSS reflects not only stage of maturity, but also quality and grade of the melon (Rosa 1982). The increase in sugars renders the fruit to be much sweeter, and therefore more acceptable (Wills *et al.* 1998). According to Bianco and Pratt (1977), 97% of the TSS in muskmelon fruits is soluble sugars, with sucrose accounting for 50% of the total soluble sugars.

**Changes in total protein**

Total protein increased systematically up to the climacteric peak and subsequently decreased in the three cultivars (Fig. 4-A). Total protein was significantly higher in 'Galeb' cultivar with a peak at 330 mg/100g, followed with 'Seeren' (peak at 133 mg/100g) and slowest in 'Green Star' (peak at 117 mg/100g). Quantitative changes in soluble protein during fruit ripening have been repeatedly demonstrated (Mattoo and Modi 1969). Abu-Goukh and Abu-Sarra (1993) reported that the total protein in the pulp and peel of three mango cultivars increased up to the full-ripe stage and then decreased at the over-ripe stage. Similar results were reported in guava (Bashir and Abu-Goukh 2003), tomato (Ali and Abu-Goukh 2005) and cantaloupe (Abu-Goukh *et al.* 2011). The increase in protein content during the climacteric phase coincided with increased activity of polygalacturonase, pectinesterase and cellulase in mango (Abu-Sarra and Abu-Goukh 1992), guava (Abu-Goukh and Bashir 2003), tomato (Ali and Abu-Goukh 2005) and muskmelon (Elhassan 2009). The decline in protein content at the over-ripe stage was explained as breakdown of protein during senescence, which again supported the view that proteins in ripening fruits are mainly enzymes required for the ripening process (Frenkel *et al.* 1968; Ali and Abu-Goukh 2005; Abu-Goukh *et al.* 2011).

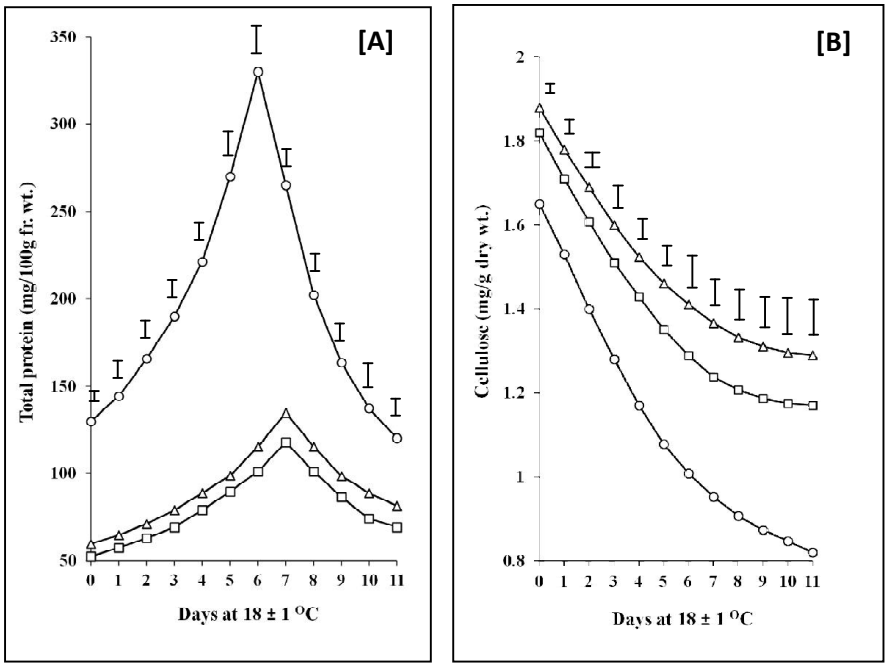


Fig. 4. Changes in total protein [A] and cellulose [B] during ripening of 'Galia $F_1$ Galeb' (o), 'Galia $F_1$ Seeren' (Δ) and 'Galia $F_1$ Green Star' (□) muskmelon cultivars at 18 ±1ºC and 85% - 90% relative humidity. Vertical bars represent LSD (5 %).

**Changes in cellulose content**

Cellulose content progressively declined during ripening of the three muskmelon cultivars (Fig. 4-B). 'Galeb' had the lowest cellulose content at harvest and during the ripening period, followed by 'Green Star' and then 'Seeren' with the highest cellulose content. Cellulose had decreased from 1.65, 1.83 and 1.87 mg/g dry weight at harvest to 0.82, 1.16 and 1.27 mg/g dry weight at the end of the ripening period in 'Galeb', 'Green Star' and 'Seeren' cultivars, respectively (Fig. 4-B). This is in agreement with previous reports that the amount of fiber which, consists of cellulose,

hemicellulose and lignin, decreased during maturation and ripening of dates (Mustafa *et al.* 1986). The cellulose in the ripening dates is converted into glucose (Barrevelled 1993). Tahir and Malik (1977) reported that cellulose and hemicellulose contents in mango fruit did not show appreciable changes during ripening, therefore, appear to have insignificant importance in textural changes during ripening. However, cellulose and hemicellulose were reported to change substantially during softening of dates (Coggins *et al.* 1967; Hasegawa and Smolensky 1971) and banana (Barnell 1943).

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