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Physicochemical Characterization and Nutrient Composition Decide Harvest Maturity of *Cucumis melo* Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cucumis melo is a polymorphic taxon belonging to the family Cucurbitaceae, with several varieties based on ovary pubescence. *Cucumis melo* var. *momordica* and *Cucumis melo* var. *acidulus* are popularized and highly cultivated forms in South India. The characteristic of *C.melo* var.*momordica* is its fruit-cracking nature, which distinguishes the variety from others when it is ready to harvest. So, it would be a herculean task for the farmers to harvest ripened fruits before it gets cracked. Analysis of the ripening process's physicochemical attributes and nutritional composition is inevitable to understand and establish proper harvest management for the varieties. The current study was conducted in the experimental field of the Department of Botany, University of Kerala using two different melon varieties, *Cucumis melo* var. *momordica* (Roxb.) Duthie & Fuller (Snap melon) and *Cucumis melo* var. *acidulus* L. Naudin (culinary melon), from January to October 2021. Fruits were harvested at five developmental stages (S1: 5 days after pollination (DAP), S2: 10 DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP) and analysed for physical and biochemical characters.

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Results were analyzed statistically by using one way ANOVA (P≤0.05). Pomological characteristics such as fruit weight and length at different developmental stages showed a tremendous peak from S3 to S5 in both varieties. However, the firmness of the fruits decreased from the S4 to S5 stage in varieties, reducing sugar accumulated sharply from the S2 to S3 stage. Titratable acidity content in *Cucumis melo* fruits continuously increased from the S1 to S5 stage. On the other hand, the total carbohydrate, cellulose, protein, and amino acid content increased from S1 to S2 but decreased sharply in S3 and S5. Ascorbic acid, total phenolics, lipid peroxidation, and electrolyte leakage levels declined with fruit ripening in *Cucumis melo* varieties. As a result of all the quality parameters mentioned above, *Cucumis melo* fruit harvested at the S4 maturity stage was the ideal harvest maturity for long-distance transportation and had higher consumer acceptability before fruit cracking. Our findings showed that the physical-biochemical properties and nutritional composition of *Cucumis melo* varieties change dynamically during ripening. The study highlighted the significance of maturity stages for fruit quality and provided critical information for optimal harvest management of the fruits of C*ucumis melo* varieties.

Keywords: Cucumis melo var. acidulus; Cucumis melo var. momordica; physico biochemical attributes; fruit cracking; fruit quality.

1. INTRODUCTION

Melon (*Cucucims melo*) is an old-world warm-season cucurbit species that belongs to the family Cucurbitaceae. According to the FAO [1], 1.14 million ha of land produces 32 million t of melons annually. China (17.1 million tonnes) is the world's top producer of melons, followed by Turkey, Iran, and Egypt. Almost all cucurbit fruits contain significant amounts of cucurbitacin, vitamin C, provitamin A, and phenolic phytochemicals, apart from other beneficial nutrients for human consumption, including fibre and minerals [2,3]. The species differ widely, and numerous varieties, such as Hammer K [4], of these *C.melo* var. *Momordica* (Roxb.) Duthie. & J.B. Fuller and *C.melo* var. *acidulus* L, are the generally cultivated varieties in South India, which are selected for the study.

Melon fruit cracking is a major physiological problem that harms the production of high-quality fruits with principal consumer and commercial value. The cracks formed on the fruit surface quickly penetrate fungal spores and decrease moisture content, leading to excessive fruit shrivelling and decreasing fruit quality and shelf life. In this aspect, harvesting fruits before fruit cracking is inevitable. Nutritional factors responsible for fruit quality indices of melon include biochemical characteristics such as titratable acidity [5], carbohydrate [6], protein [7], amino acids [8], electrolyte leakage [9], cellulose [10], ascorbic acid, reducing sugar and phenol [11]. Reports were suggesting that long-distance transportation of commercially cultivating fruits such as tomato, Litchi, cherry and Akebia is possible only after harvesting them at semi-ripened stages [12,13] based on its physicochemical analysis. The maturity stage at harvest influenced the physicochemical properties of winter jujube, Akebia, during fruit ripening [14-18]. Similarly in the cultivation and transportation of melon varieties, it is crucial to determine the physical and chemical attributes of fruits at different maturity stages and explore the suitable fruit maturity stage with the best commercial value.

Nevertheless, little is known about the changes in physicochemical properties and nutritional composition of *C.melo* varieties at various stages of fruit maturity. Thus, this study aimed to look into changes in physicochemical properties and nutritional composition in the fruits of *C.melo* varieties at different stages of ripening. The findings in the present investigation can help to understand the fundamentals of dynamic fruit quality patterns and determine optimal harvest maturity stages of *C.melo* varieties with higher quality and longer marketability before fruit cracking.

2. MATERIALS AND METHODS

2.1 Plant Material

Fruits of two varieties of *C.melo* var. *momordica* and *C.melo* var. *acidulus*, which are free from pests, insects, and diseases, were randomly harvested at five developmental stages (S1: 5 days after pollination (DAP), S2: 10DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP) from the experimental farm at the Department of the Botany University of Kerala, India, which is located at 8.5°N latitude 76.9°E longitude and 29m above mean sea level (Fig. 1). Seeds of

both varieties were collected and sown in different areas of the experimental farm by following the procedure given by the Kerala Agricultural University (KAU) package of Practices Recommendations for Organic Farming Crops (2016) for the cucurbitaceous Vegetables from January to October 2021. Fresh fruits of both varieties were collected at different developmental stages to evaluate fruit length, fruit weight, Total Soluble Solids (TSS) and fruit firmness. Fruits pulp from three fruits was mixed into one biological replicate for Reducing sugar, Total carbohydrate, protein, amino acid, cellulose, ascorbic acid, total phenolics, Titratable Acidity, Electrolyte leakage, and lipid peroxidation, and the fruit pulp was stored at -80^{0}C until further analysis. Samples from each stage were immediately evaluated for fruit weight, length, and moisture on five fruits.

2.2 Experimental Methods

2.2.1 Estimation of Physico chemical parameters

Five fruits from each developmental stage were collected for average weight by an electronic balance and expressed in grams. Fruit length (FL) was determined using a digital caliper with 0.01 mm accuracy. Their values were expressed in millimeters. Flesh firmness of the fruit in different developmental stages of both varieties was measured using a texture analyzer (TA) HD plus (Stable microsystems the UK) using the compression mode test, and the result was expressed in Newton (N). Moisture content in the fruit at different maturity stages was calculated by oven drying at 70^0 for 48 hours.

An Erma hand refractometer was used to determine each sample's total soluble solids (TSS). Few drops of the well-homogenized sample were taken from the fruit's equatorial region and put on the prism of the refractometer. Direct reading was taken by reading the scale in meters and expressed in ^{0} Brix. Titratable acidity (TA) was determined by titrating 100 g of the sample against 0.1 N NaOH solution using phenolphthalein as an indicator until reaching pH 8.1. The result was expressed in percent anhydrous citric acid.

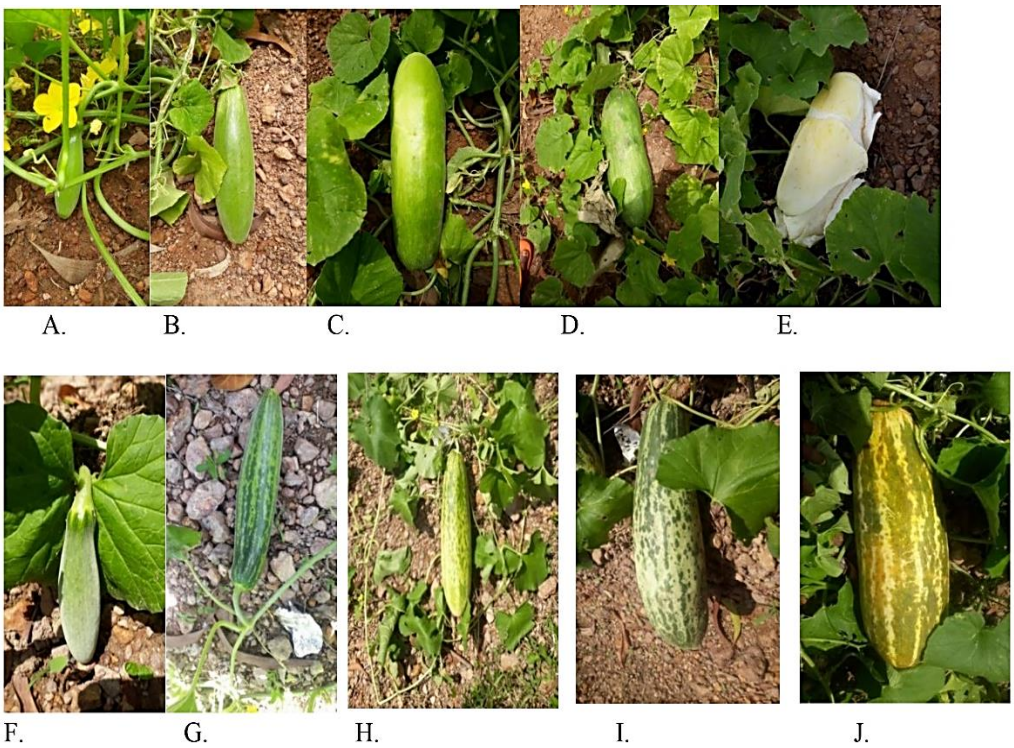


Fig. 1. The fruits of *C melo* varieties at different maturity stages. (A-E) the fruit of var. *momordica* at S1,S2,S3,S4 and S5 stages ,respectively. The pericarp is whitish cream when it cracks. (F-J) the fruit of var.*acidulus* at S1,S2,S3,S4 and S5 stages,respectively. (S1: 5 days after pollination (DAP), S2: 10DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP)

2.2.2 Biochemical characterisation

Estimation of reducing sugar: 100mg of the fruit pulp was weighed, and the sugars were extracted with hot 80% ethanol 5mL each time. A water bath evaporated the collected supernatant at 80°C. Then added 10mL of distilled water and dissolved sugars. Later pipette out 0.5 3mL extracts into the test tubes and equalizes the volume to 3mL with water in all the tubes. 3mL of DNS reagent was added and heated in a boiling water bath for 5 min. 1mL of 40% Rochelle salt solution was added to the warm test tubes, cooled, and read the intensity of dark red color at 510 nm.

Determination of cellulose: Added 3 ml of acetic/ nitric reagent to 1g sample in a test tube and mixed in a vortex mixer. Later, test tubes were placed in a water bath at 1000C for 30 minutes. Cooled and centrifuged the contents for 15 – 20 minutes. Discarded the supernatant and washed the residue with distilled water. Then added, 10 ml of 67% sulphuric acid and allowed to stand for 1 hour—diluted 1ml of the above solution to 100 ml. 1 ml of this diluted solution was mixed with 10 ml of anthrone reagent. For 10 minutes, place the tubes in a boiling water bath. The color was cooled and measured at 630 nm.

2.2.3 Estimation of total carbohydrate, protein, and amino acids

Weighed 100mg of the sample into a boiling tube and hydrolysed it by keeping it in a water bath for 3 hours with 5mL of 2.5 N-HCl and cooled it to room temperature. Then neutralized, it is with solid sodium carbonate until the effervescence ceases. Made the volume up to 100mL and centrifuged. Later collected, the supernatant and taken 0.5 ml and 1mL aliquots for analysis. Distilled water was added to all the test tubes, and the volume was one mL.4mL of anthrone reagent was added and heated for eight minutes in a boiling water bath. Cooled rapidly and read the green to dark green colour at 630 nm.

1 g of sample homogenized with 5 ml of Phosphate buffer saline (PBS). Now add 5 ml of diluted dye solution to all the test tubes, including the test tubes labelled 'blank' and 'unknown.' Mix the contents of the tubes by vertexing them for 30 minutes to develop colour. Then recorded the absorbance at 595 nm against blank.

Took 1 g of the samples in labelled test tubes. Then added, distilled water was to the test tube to make up the volume to 4 ml. Later, added 1 ml of ninhydrin reagent to all the test tubes labeled, and mixed the contents of the tubes by shaking the tubes. Covered the mouth of the tubes with aluminum foil and placed all the test tubes in a boiling water bath for 15 minutes. Cooled the test tubes in cold water, added 1 ml of ethanol to each test tube, and mixed well. Recorded the absorbance at 570 nm using a spectrophotometer.

2.2.4 Determination of ascorbic acid, total phenolics, lipid peroxidation, and electrolyte leakage

Ascorbic acid estimation was carried out by following the procedure of Bajaj and Kaur. In a test tube, 1g of fresh sample was placed. 4 mL of oxalic acid-EDTA extracting solution (5 g oxalic acid + 0.75 g EDTA in 100 mL distilled water) was added. Then 1 mL of orthophosphoric acid was added, followed by 1 mL of 5% sulphuric acid. 2 mL of 5% ammonium molybdate solution and 3 mL of water were added to this mixture. The solution was kept at room temperature for 15 minutes. After incubation, absorbance at 760 nm was measured using UV-visible spectrophotometry against a blank. A standard ascorbic curve was used to calculate the concentration of ascorbic acid in the samples. After the incubation period, absorbance at 760 nm was measured, and the standard graph was created.

The rate of Lipid peroxidation was measured by following the procedure of Carmak and Horst. The 1 g fruit sample was homogenized in 3 ml of 0.1% (w/v) TCA solution. Then centrifuged, the homogenate was for 15 minutes at 20,000 rpm. 0.5 ml of supernatant and 3 ml of 0.5% TBA were added to 20% TCA. This mixture was heated at 950 degrees C in a water bath for 25 minutes. Cooled the test tubes in an ice water bath and stopped the reaction. Samples were centrifuged at 10,000rpm for 10 minutes, and the absorbance was measured at 532 and 600nm. The absorption coefficient for calculating MDA concentration was measured as the difference in absorbance at 600 nm and 532 nm.

The sample's total phenol content was estimated with [19]. 1mg of the fresh fruit sample was weighed and made into a paste using a mortar and pestle with 5 ml of distilled water. 3 ml was put into a test tube from the prepared extract

pipetted out. Made the volume of each test tube to 3 ml with distilled water and mixed thoroughly with 0.5 ml of Folin – Ciocalteu reagent for 3 min. After that, 2 ml of 20% of sodium carbonate was added. Boiled the solution in a water bath for 10 minutes, cooled to room temperature, and measured absorbance at 650 nm. The results were given as mg of catechol equivalent per g fresh weight.

The percentage of electrolyte leakage was measured by [20]. Four pieces of 9mm melon cylinder from the equatorial part of the fruit were taken by a cork borer. Then added, distilled water and filtered by using Whatman filter paper. Later transferred, it was to a 50ml beaker, then added 30 ml of 500mM mannitol and measured the conductivity. Then incubated it for 5 hours and again measured the conductivity. Stored at 20 degrees for 24 hours, boiled for 15 minutes at 1000C, and cooled and measured the conductivity.

2.3 Statistical Analysis

Statistical analyses were carried out using IBM SPSS Statistics 24.0 software, and significant differences between means were determined using Turkey's highest significant difference (HSD) test at $p < 0.05$. The findings were presented as tukey's means± standard error.

3. RESULTS

3.1 Changes in Physical Parameters of *C.melo* Fruits at Different Developmental Stages

At the S4 time point, the fruits of var. *momordica* begins to soften to some extent with no fruit cracking. At the S5 time, the fruits begin to crack (about 90%), which was set as the fruit cracking time (Fig. 1 &b). *momordica* and var. *acidulus*) are shown in Table 1. It was found that fruit weight, length, and moisture content increased significantly with increasing maturity in both varieties. In *C.melo* var. *momordica*, the fruit weight increased from 52±5.8 g to 2169.6±51.17 g at S1 to S5 stage. However, in the case of *C.melo* var. *acidulus* showed an increase from 50±3.21 to 2524±126.15 at the S1 to S5 stages.

An increase in fruit moisture content was observed in the varieties, in *C.melo* var. *momordica*, it was 93.91±.07 % to 96.23±0.17 and 93.62±0.08% to 96.36±11% *C.melo* var. *acidulus* respectively. The fruit length in var.*momordica* increased significantly, *ie,* from 123.6±0.31mm to 253.3±3.41 mm and in var. *acidulus* it was 103.6±0.57mm to 326±0.64mm respectively. The moisture content in both varieties shows no significant difference was observed in the moisture content of both varieties from S1 to S3 stages, but from S4 to S5 stage there was a slight increment. The fruit firmness of *C.melo* varieties was significantly affected by the harvest maturity stages during fruit development. Fruit firmness in var. *momordica* increased significantly from the S1 to S3 stage (261.73 N, 279.39 N, 350.66 N), but there was a sudden decline from S4 to S5 (260.04N, and 54.94N). Similar pattern was observed in *C.melo* var.*acidulus* from the S1 to S3 stage but from S4 to S5 stage showed increased values.This result indicates that the rate of firmness is increasing in var. *momordica* goes faster than var. *acidulus* in the early maturity stages but declines when it matures.

Table 1. Effect of harvest maturity on physical parameters of two varieties of *C.melo*

Varieties	Maturity stages	Fruit Weight(g)	Fruit Length (mm)	Moisture content (%)	Flesh firmness (N)
C.melo var.momordica	S1	52±5.8 ^{e}	123.6±0.31 ^{e}	93.91±0.07^{de}	261.73±7.25^{c}
	S2	171.33±35.19 ^{d}	143±0 ^{f}	93.74±0.15^{ef}	279.39±25.34^{b}
	S3	894±206.03^{c}	192±0.3^{c}	93.22±0.09^{f}	350.66±29.59^{d}
	S4	1141.6±83 ^{b}	246±0.52 ^{bc}	95.67±0.13^{bc}	260.04±16.31^{c}
	S5	2169.6±51.17^{a}	253.3±3.41 ^{b}	96.23±0.17^{a}	54.94±4.45^{d}
C.melo var.acidulus	S1	50±3.21^{d}	103.6±0.57 ^{f}	93.62±0.08^{ef}	255.96±4.45^{c}
	S2	337.33±100.77^{d}	174±0.72^{e}	93.41±0.06^{ef}	264.9±17.73^{c}
	S3	587±111.44^{c}	241±0.69 ^{bc}	95.25±0.07^{c}	381.02±5.1^{a}
	S4	1140.33±87.6^{b}	287±0.64 ^{ab}	94.43±17 ^{d}	218.75±21.36^{b}
	S5	2524±126.15^{a}	326±0.64^{ab}	96.36±11^{a}	287.25±3.8 ^{c}

Data expressed here are the mean value of replicates of three independent analyses and SE. According to Tukey's test, means with different superscript letters in the same column are statistically different ($p < 0.05$) between varieties for each variable. (S1: 5 days after pollination (DAP), S2: 10DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP)

3.2 Changes in pH, Total Soluble Solids, Titratable acidity, and Ascorbic Acid Content During Developmental Stages

The P^H of melon varieties at different maturity stages showed a decreasing trend while ripening (Table 2). Fruits of var. *acidulus* displayed lower pH during the late stage of ripening than var. *momordica* as shown in Table 2. There is no significant difference in the TSS value of both varieties at the S3 and S4 stages. In var *momordica*, TSS content decreases from the S4 stage to the S5 stage as 20 Brix to 1.90Brix, but in var. *acidulus,* it increases from 2.530Brix to 3.70Brix.

As shown in the Table 2, the Titratable acidity (TA) content of fruits *of C. melo* varieties gave an increasing range of values from the S1 to S5 stage of fruit maturity in both varieties. The S3 and S5 stages of *C.melo* var. *momordica* showed higher values than its prior stages of maturity. While var. *acidulus* displayed higher values at the S3 and S4 stages of fruit maturity. The content of ascorbic acid declined from 6.8 mg/100g to 5.7 mg/100g during the maturity stages in var. *momordica*, but there was a slight increment in the value at the S5 stage of fruit ripening. Similarly, fruits of var. *acidulus* showed a decrease in ascorbic acid content from 6.3mg/100g to 5.2mg/100g at different maturity stages. However, no significant change was observed between the S4 and S5 stages.

Data expressed here are the mean value of replicates of three independent analyses and SE. According to Tukey's test, means with different superscript letters in the same column are statistically different ($p < 0.05$) between varieties for each variable. (S1: 5 days after pollination (DAP), S2: 10DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP)

3.3 Change in Total carbohydrate, Reducing Sugar and Cellulose Content During Maturity Stages

Total carbohydrate content in the two varieties of melon showed significant changes over the different maturity stages. The observed values are given in Fig. 2A. The carbohydrate content was found deceased from S1 to S3 stages and accumulated from S3 to S4.

For var. *acidulus* the total carbohydrate content increased from S3 to S4 stage. Similarly, cellulose content also increased from S3 to the s4 stage in var. *acidulus,* whereas in var. *momordica*, it decreased slightly from S3 to the S4 stage (Fig. 2C). But no significant changes were noticed in the reducing sugar present in both varieties (Fig. 2B).

3.4 Change in Total Protein and Amino Acid Content During Maturity Stages

The total protein content of var. *momordica* declines from S1 to S4 (5.09 -4.7mg/g). It reaches a minimum value at the S5 stage (3.9 mg/g), while the total protein content of var. *acidulus* showed significant increase from the S1 to S4 stage (2.8 mg/g -4.9 mg/g), followed by a sudden decrease at the S5 stage (0.9mg/g) (Fig. 3A).

Table 2. Effect of harvest maturity on chemical parameters of the two varieties of *C.melo*

Variety	P^H	TSS (°B)	TA (%)	Asa (mg/g)
Cucumis melo var *momordica*	S1 5.9±0.02^{b}	4.6±0.20^{ab}	5.5±0.02^{bc}	6.8±0.48^{a}
	S2 5.03±00^{e}	4.06±0.08^{bc}	4.3±0.02^{c}	5.9±0.28^{bc}
	S3 5.27±0.01^{d}	2.9±0.03^{d}	6.4±0.02^{abc}	5.5±0.02^{c}
	S4 4.44±0.01^{g}	2±0.05^{e}	5.4±0.04^{bc}	5.6±0.17^{c}
	S5 4.22±00^{h}	1.9±0.01^{e}	7.4±0.05^{ab}	5.7±0.17^{bc}
Cucumis melo var.*acidulus*	S1 6.01± 0.00^{a}	5.1±0.03^{a}	4.4±0.00^{c}	6.3±0.26^{bc}
	S2 5.63±0.02^{c}	2.7±0.03^{d}	5±0.08^{bc}	5.7±0.18^{bc}
	S3 5.34±0.01^{d}	2.96±0.06^{d}	6.6±0.11^{abc}	6.00±0.1^{bc}
	S4 4.57±00^{f}	2.53±0.028^{de}	8.2±0.02^{a}	5.2±0.2^{c}
	S5 3.92±0.01^{i}	3.7±0.019^{c}	0.82±0.02^{a}	5.2±.08^{c}

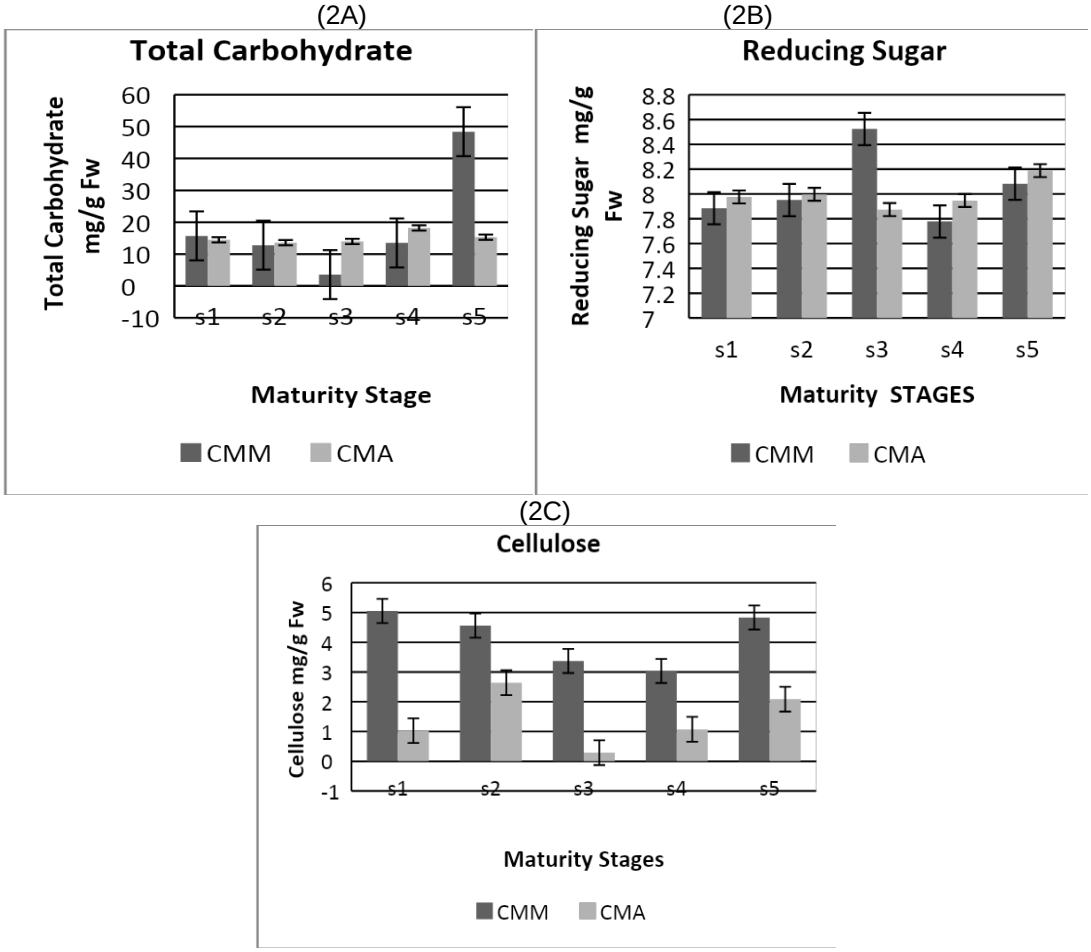


Fig. 2(A). Total Carbohydrate, (B) Reducing Sugar, and (C) Cellulose in varieties of *C.melo* fruit at five stages of ripening.CMM: *Cucumis melo* var.*momordica*; CMA: *Cucumis melo* var.*acidulus* . S1: 5 days after pollination (DAP), S2: 10DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP

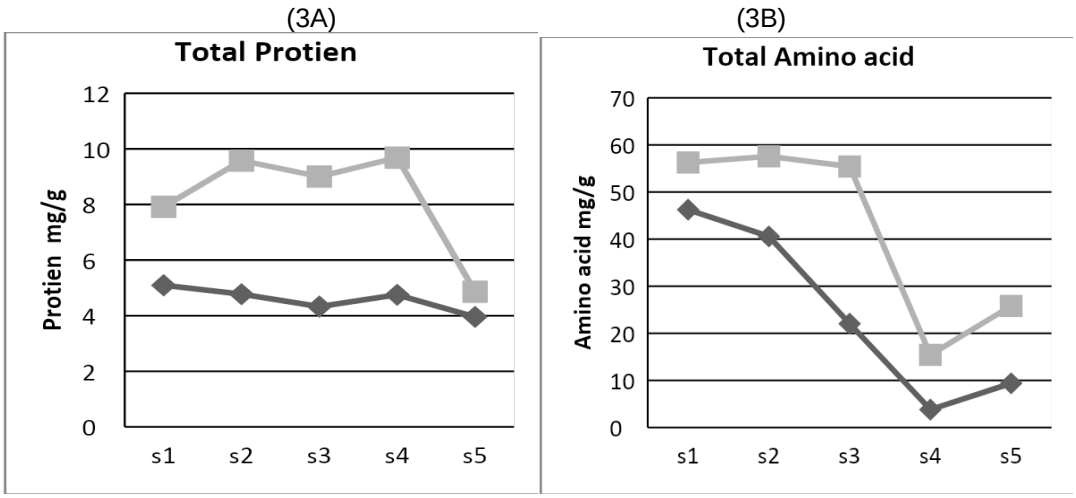


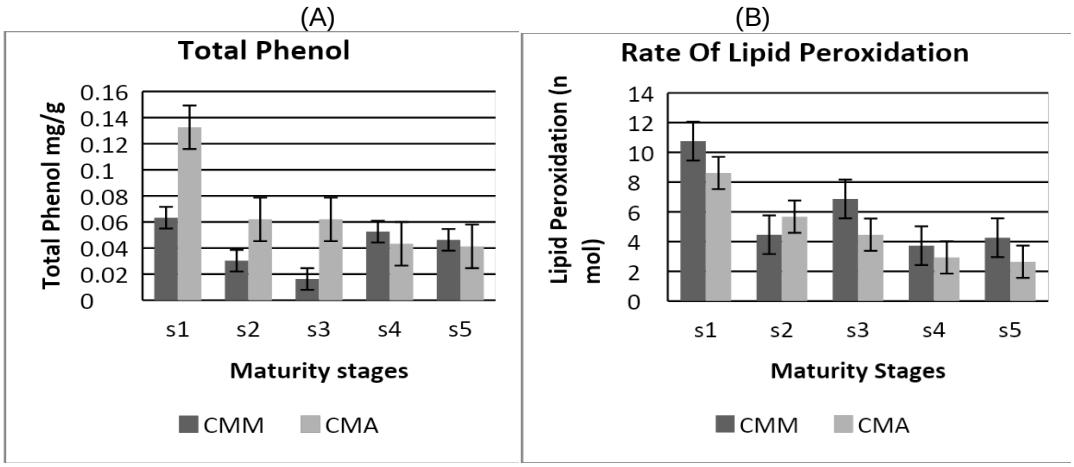
Fig. 3. (A) Total Protein and (B) Total Amino acid in varieties of *C. melo* fruits at five stages of ripening. CMM: *C. melo* var.*momordica*; CMA: *C.melo* var.*acidulus*. Error bars indicate standard error from 3 replicates. S1: 5 days after pollination (DAP), S2: 10DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP

The total amino acid content in var. *momordica* declined significantly from the S1 to S4 stage (46.23mg/g -3.8mg/g) and had a slight increment at the S5 stage (9.38mg/g).However, var. *acidulus* showed a slight increment from the S 1 to S4 stage (10.3- 11.6mg/g) with a sharp increment at the S3 stage (33.36mg/g) and the increment from S4 to the S5 stage is meager at later stage of fruit maturity Fig. 3B.

3.5 Change in Total Phenolics, Electrolyte Leakage and Lipid Peroxidation During Maturity Stages

The total phenolic content in melon varieties at five maturity stages is shown in Fig. 4A. Overall, the total phenolic content declines from the S1 to S5 stage. Compared with var. *momordica*, the phenolics content in var. *acidulus* was sharply decreased (0.132- 0.041 mg/g) from the S1 to S5 stage of fruit maturity. Rate of lipid peroxidation and electrolyte leakage on both varieties decreased from the S1 stage to the S4 stage of fruit maturity (Fig. 4 B&C).

The value of electrolyte leakage percentage (55.4%-75%) in var. *momordica* slightly increased from S4 to S5 stage, and in var. *acidulus*, it was (67.6%-71.4%). Whereas lipid peroxidation rate in var. *momordica* at the S4 and S5 stage is 3.7nmol and 4.2nmol respectively, whereas in var. *acidulus* a slight decrease from 2.9nmol to 2.64 n mol at the S4 to S5 stage was observed.



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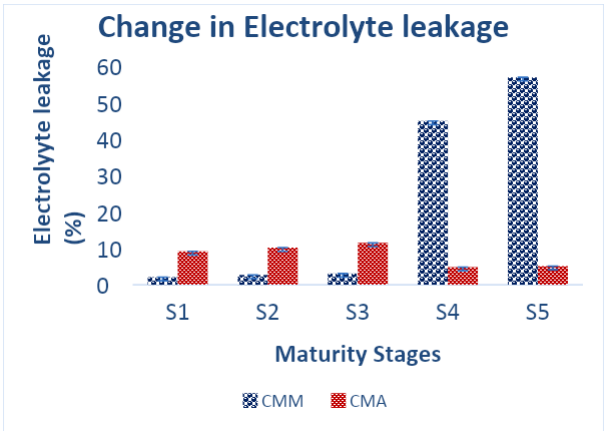

Fig. 4. Total Phenol(A), (B)Lipid peroxidatioin and (C) Electrolyte Leakage in varieties of *C.melo* fruits at five stages of ripening

CMM: Cucumismelo var.momordica;CMA: Cucumis melo var.acidulus. Error bars indicate standard errorfrom 3 replicates. S1: 5 days after pollination (DAP), S2: 10DAP, S3:15 DAP, S4: 20 DAP, S5: 25 DAP

4. DISCUSSION

The current study found that the maturity stage significantly impacted the physicochemical and nutritional properties of *C.melo* fruits. Fruit size increased when harvest maturity was postponed (fruit weight and length). At the S3, S4, and S5 stages, the fruit weight of *C.melo* var. *momordica* increased by 42%, 67%, and 90%, respectively. Fruit weight increased by 42%, 48%, and 54% in the var. *acidulus*. The fruit weight of var. *momordica* increased faster than that of var. *acidulus*. The highest rate of fruit length growth in var. *momordica* occurred at the S3 Stage (25.5%), followed by a gradual decline at the S4 and S5 stages (21.9% and 2.88%, respectively). Fruit length decreased from 27.8% to 11.9% in the var. *acidulus*. Both varieties rapidly increase fruit weight and length from S4 to S5. Previous research on commercially cultivated fruits shown that the maturity stage at harvest significantly impacts the quality of ripe fruit and its storage life [21-23]. Fruit growth in both varieties followed a sigmoid curve, consistent with previous reports of *Akeiba trifoliata* [24,13].

As a critical quality criterion, fruit firmness directly impacts fruit shelf life and consumer acceptance. With fruit ripening, the fruit of *C. melo* varieties begins softening and cracking, which is associated with easy rotting caused by bacterial infection and mechanical damage. Therefore, harvesting fruits before they soften and crack may be an effective way to extend the shelf life of melon varieties. In the current study, the firmness of var. *momordica* decreased with the delay of the harvest stage, whereas the firmness of var. *acidulus* increased. Fruit firmness of var. *momordica* decreased by 25.7% and 79.71%, respectively, from S4 to S5, indicating that fruit textural properties changed dramatically during the period. In *Akebia trifoliata*, Niu et al*.* [25] discovered that the cell wall becomes thinner and looser during fruit cracking, showing a significant breakdown in the pericarp of cracking fruit compared to noncracking fruit. Fruit moisture content is crucial in determining flavour, storage ability, and suitability for consumption of fruits. It is worth noting that the moisture content of both varieties increased significantly from the S3 to the S5 stages. As the fruit ripens, the increase in moisture content could be attributed to starch hydrolysis to sugars. Mulberry and cherry fruit have shown a similar increasing trend in moisture content with maturity [26-28,13].

PH was inversely related to acidity. The ripe sample with the lowest acid content had the highest p^H. Furthermore, when pineapple fruit reaches an advanced ripening stage, increased pH results less acidity. In the present study, var. *momordica* at the S4 Stage of fruit maturity was given a pH of 4.4. The pH of the different fruit fractions ranged from 4.27 to 5.29. Parveen et al. [29] discovered similar P^H variations in the *Ravi* melon variety. According to Bianchi et al. [30], the pH of melon varies from 5.2 to 6.5 depending on the cultivar used.

Titratable acidity (TA) indicates the fruit's acidity, which influences its flavour. Our study showed that in var. *momordica* and var. *acidulus*, the TA value decreases from the S1 to S5 stage of maturity. This outcome is comparable to the reports of Bianchi in differentmelontypes [31]. According to Woodward and Moing, titratable acidity increased during development but was lower in ripe fruits [32,33]. Ruban et al. reported that the titratable acidity of mango and cashew apple is high at the immature stage and low at the over-ripened stage [34]. Notably, the rise in acidity could be related to the fruit's low respiration rate (reducing the citric acid cycle) and the accumulation of organic acids from phloem unloading [35]. Titratable acidity (TA) is an essential genetic quality in peach fruit that influences both perceptions of sourness and sweetness, which vary depending on the ripening stage [36,37]. Our study noted that fruits of *C.melo* varieties have a low sweet taste due to less accumulation of Total Soluble Solids (TSS) and a high level of TA. As a result, the fruit's balance of sugars and acids may significantly impact its flavor. Other studies have documented TSS, TA, and TSS/TA changes at various maturity stages [38,39,32]. Firmness and TSS for *C.melo* varieties changed sharply between the S3 and S4 stages in var. *momordica* than in var. *acidulus*. Then, it tended to level off; firmness and TSS can be used as fruit maturity indicators for melon varieties. As a result, TSS, TA, and firmness are always regarded as the primary parameters for determining fruit quality.

Ascorbic acid is not only a necessary nutrient for humans, but it is also a potent antioxidant [33]. The AsA content in the fresh fruit weight of both varieties decreases from S1 to S5 stages. The analysis of results shows a slight increment from 5.2 to 5.7 mg/100 Fw in the S5 Stage of *var. momordica*, whereas, in var. *acidulus*, the value is 5.2 mg/100mg FW in both the S4 and S5 stages. This result indicates that AsA is rapidly synthesized before fruit ripening. Studies conducted by [40-42] in the South Indian melon landraces showed that AsA content increases up

to 9.0 mg 100 g-1 FW in the varieties. Tlili et al. say that the vitamin C content of many fruits (apple, mango, citrus) is higher when they are immature and declines as the fruits reach peak ripeness as they are respired or converted to sugars [43].

Fruit ripening and cracking are complex physiological processes that involve the transcription of many genes and the synthesis of large amounts of protein. The present study reveals that total protein content at different maturity stages decreases while ripening, but there is a slight increase from S3 to S4 Stage in var. *momordica*. In the same way, in var. *acidulus*, it increases from the S1 to S4 Stage, then at the S5 Stage, it declines abruptly. The decline in protein content from the S4 to S5 stage is explained by the ripening proteins used for the enzyme machinery [44]. Nevertheless, the increment in protein content at the S3- S4 Stage shows that these Stage fruits are metabolically stable and viable for long-term transport. Changes in amino acids indicate variations in metabolic activity during different growth phases. During the climacteric phase of many fruits, there is a decrease in free amino acids, which often reflects an increase in protein synthesis. In the present investigation, *Cucumis melo* var *momordica* shows a sudden decrease from the S3 to the S4 Stage. In var. *acidulus*, it increases from S1 to S4, which includes a gradual decrease from S3 to S4 stage. In summary, both varieties' increased protein and decreased amino acid content from S3 to S4 favour long shelf life and harvest maturity. This result is supported by [45] because free amino acids increase during ripening, as per their research. In contrast, protein content decreases due to exopeptidase and non-specific protease enzyme activity in the fruit.

Carbohydrates, sugar, and cellulose play a significant role in fruit physiology when the fruit is attached to the tree and after its harvest. The present study reveals that var. *momordica* gradually increased the total carbohydrate content from the S3- S4 Stage of maturity. However, in the var. *acidulus*, it is a gradual change. Nunez-Palenius et al. [46] have shown that the total carbohydrate content increases during the development of Cantaloupe melon fruit, ensuring the ripened fruits' quality attributes. The total cellulose content in var. *momordica* declines from the S3-S4 Stage of maturity to the S4- S5 Stage. However, var. *acidulus* increased from the S3 to S5 Stage of fruit maturity. A report states that the amount of fiber, consisting of cellulose, decreases during the maturation and ripening of Dates [47]. Evidence from the studies conducted in the three muskmelon cultivars shows cellulose content decreases during harvest maturity and increases at the over-ripened stage [48].

Numerous studies have reported sugar content in the melon fruit during fruit growth and ripening as soluble sugar accumulation, which determines fruit sweetness at harvest, an essential parameter of fruit quality [49-50]. In the present investigation reducing sugar decreases from S3 to S4 stage maturity in var. *momordica* but in var. *acidulus*, there is a slight difference in the reducing sugar at the S4 to S5 Stage in both varieties.

According to Shivapriya et al [51], quantitative analysis of sugars in muskmelon fruit showed consistency in reducing sugar content, which was high initially and decreased subsequently but increased in the pre-ripened stage. However, reducing sugars declined when the fruit attained the fully ripe stage. There are reports with the litchi cultivar, Gola, that the highest reducing sugars were significantly superior in quality attributes but also had the maximum fruit cracking than the rest of the others with less reducing sugars [52]. From this report, we could conclude that the S3-S4 Stage of maturity of var. *momordica* has superior fruit quality attributes than var. *acidulus*.

Phenolic compounds are important secondary metabolites in plant cells, which protect the cell from oxidative damage. Our work shows that total phenolic content decreases with maturity advancement in the fruits of *C.melo* varieties. However, if we compare the quantity of the compound from S3 to S4 Stages of ripening, var. *momordica* possesses slightly more than var. *acidulus*. This fact can be considered a quality-improved criterion of melon fruits, and such variations in phenolics have also been found in many fruit crops [53].

Melon fruit shows a progressive increase in membrane permeability, as measured by electrolyte leakage, as the fruit matures [54]. In this study, electrolyte leakage of var. *momordica* from the S3-S4 stages increases in percentage, reaching maximum at the S5 stage. In contrast, in var. *acidulus*, there is no prominent change in the percentage from S3 to S5 fruit maturity stage. Non-netted melon electrolyte leakage increased with ripening when comparing short and long

storage life. It was consistently higher in the short-storage cultivar, whereas the long-storage life cultivar had little increase in membrane permeability as the fruit ripened [55]. According to Bhatt et al*.* [56], electrolyte leakage is often regarded as a reliable tool to measure overall fruit quality because sometimes increased membrane permeability coincides with increased membrane viscosity [57,58].

Like electrolyte leakage, lipid peroxidation is a prominent feature of plant senescence and may impair membrane structure and function. Studies show lipid peroxidation is an early detectable process in fruit ripening. The free radicals induce lipid peroxidation, which initiates the deteriorative changes associated with fruit ripening. In this study, we observed that both melon varieties' lipid peroxidation rates decreased by half from the S3 to S4 fruit maturity stage. So, the lower the rate of lipid peroxidation, the higher the fruit quality [58,59].

5. CONCLUSIONS

Among the two varieties of *Cucumis melo* selected for the study, fruits of *Cucumis melo* var. *momordica* are highly perishable with a shorter market and shelf life than the *Cucumis melo* var. *acidulus*. The study found that the maturity stages significantly affect physicochemical parameters and nutritional properties during *C.melo* fruit ripening, with dramatic changes occurring between the S3 and S4 stages. The pH, TSS, TA, firmness, ascorbic acid, total carbohydrate, protein, amino acid, reducing sugar, total phenolics, and celluloses showed remarkable changes during the transition to physiological maturity. The fruit harvested before fruit cracking, the harder the fruit is, the more suitable for long-distance transportation and the longer shelf life.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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