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Full Length Research Paper

Calcium treatment and harvesting stage influence on textural quality of eggplant (cv. Africa black beauty) fruits

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Effects of foliar application of calcium (Ca^{2+}) fertilizer and maturity stage on texture quality of eggplant (cv. *Africa black beauty*) skin and flesh was evaluated in this study. The eggplant fruits were harvested at three maturity stages (30 DAF, 40 DAF and 50 DAF) and their skin and flesh firmness were tested for, using the Warner-Bratzler shear force (WBS) method, with the aid of the Universal Testing Machine (Testometric model) with accuracy of 0.001N. The results showed that calcium treatment had significant ($p \leq 0.05$) effect on the eggplant fruits' skin and flesh firmness. Calcium treated fruits skin firmness was higher (189.47 N) when compared to the control fruits skin firmness (158.63 N); while a flesh firmness of 93.85 N was recorded for the calcium treated fruits, which was higher than 78.68 N recorded for the control fruits. Fruit texture was significantly ($p \leq 0.05$) higher at the early maturity stage; as the fruit skin and flesh firmness decreased linearly as maturation of the fruits progressed. The results indicated that the texture quality of eggplant fruits is highly dependent on the soil amendment and harvesting stage. These findings will be useful in predicting the textural behaviour of eggplant fruits, and will be of great help in the fruits' processing industries.

Keywords: Eggplant, Africa black beauty, calcium, texture, firmness

INTRODUCTION

Eggplant (*Solanum melongena* L) belonging to the *Solanaceae* family is an important fruit crop cultivated in the tropical and subtropical regions of the world (Uthumporn *et al*., 2016). Eggplant thrives well in a well-drained and fertile soil which receives full sunlight, having soil pH of the range 6 to 7. Soil amendments such as organic manure and other synthesized fertilizers helps a lot during the growing and fruiting periods (Barnett, 2019). The higher the organic matters content in the soil, the better the performance of the plant. According to the 2017 FAO data, the world eggplant total production was about 53 million metric tons, with 1.9 million metric tons coming from Africa; while Asia was the largest eggplant producing continent, producing 49 million metric tons (FAOSTAT, 2019). When compared to other fruits cultivated in the African continent, African eggplant fruits have relatively higher carbohydrate (7.2 g/100g), crude fibres (2.0g/100g), calcium (28mg/100g), iron (1.5 mg/100), carotene (0.35 mg/100g) and ascorbic acid (8 mg/100g) (Hornal *et al*., 2007; Msogoya *et al.,* 2014). There are several cultivars of eggplants which are identified by their fruits colours, sizes, shapes and chemical compositions. Black Beauty eggplant is one of the most popular eggplant cultivars. It has high yield and large fruits of high nutritional and medicinal values. Black beauty eggplant fruit has a black bell-shaped shape with slight signature ribbing. Black beauty fruit has a deep purple colour, which becomes glossy when the fruit matures.

Harvesting operation of eggplants is complicated and time-consuming (Hayashi *et al*., 2002). Canakci and Akinci, (2006) reported that energy requirement for eggplant harvesting is significantly greater than that for tomatoes, peppers, and cucumbers. A major problem

associated with mechanical harvesting is the mechanical stresses which are imposed on fruit during the gripping process by robot fingers (Li *et al*., 2010; Li *et al*., 2011). Mechanical damage of agricultural products, which results from improper handling of the products will caused physiological responses on the point of impact; leading to complex physiological, metabolic, and enzymatic changes (Pérez-López *et al*., 2014; Umurhurhu and Uguru, 2019). Two main forces are encountered during eggplant handling operations; namely, compression force and puncture force. These forces are experienced either by the whole fruit or by a specific point on the fruit (Sirisomboon *et al*., 2012; Ashtiani *et al*., 2016). The knowledge of the mechanical properties of agricultural products will decrease their mechanical damage during harvesting and handling operations; conserve power and energy during processing operation and minimize wastage during handling, processing and storage operations. Mechanical behaviours of fruits and vegetables are highly dependent on the farming system, environmental factors, harvesting period, and cellular structure. Agricultural product's structure is heterogeneous and commonly anisotropic; therefore, mechanical stresses are distributed inhomogeneous within its tissues (Li *et al*., 2013).

Intensive researches have been going on in the past three decades on the effects of soil amendments on the engineering properties of agricultural products by many researchers. Altuntas *et al*. (2012) studied some mechanical properties of Fuji apple as affected by methyl jasmonate (MeJA) soil amendment; and reported that as the MeJA doses increased from 1,120 to 4,480 mg/L, the apple skin firmness linearly increased from 100.38 N to 112.60 N. Altuntas *et al*. (2013) studied the effects of maturity stage and methyl jasmonate application on the mechanical behaviours of plum fruits. They observed that the rupture force of the plum fruits increased with increase in maturation, but declined from 165.4 N to 129.6 N, as the MeJA concentration increased from 0 to 2,240 mg/L. The impact of Maxi Calmag soil amendment on some nutritional values of roots were investigated by Akpokodje and Uguru, (2019). They reported the Maxi Calmag significantly affected (about 50% increment) the Calcium and Nitrate contents of the cassava roots. Eboibi *et al*. (2018) in their study reported about 100% increment in the growth performance of five bean (*Phaseolus spp*) cultivars, in soil treated with organic manure. According to their results, the mean fresh weight of cowpea planted in un-amended (control) soil was 36.90 g as against 1266.4 g recorded in cowpea planted in organic manure amended soil. Calcium plays a vital role in the strengthening the cell wall. Its influence on diverse physiological and biochemical changes during fruit maturity and ripening had been reviewed by Poovaiah *et al*. (1988) and Stuckrath *et al*. (2008). Abbott *et al*. (1989) observed that calcium treatment significantly increased the tissue strength of apple fruits. However, studies conducted on the effect fertilizers containing Ca^{2+} and Mg^{2+} on some textural qualities of eggplant (cv. *Africa black beauty*) have not been studied. Thus, the objective of this study was to examine some textural qualities such as skin firmness and flesh firmness of *Africa black beauty* eggplant fruits, as affected by maturity stage and fertilizers containing Ca^{2+}.

MATERIALS AND METHODS

The study area

The study was carried out at the research station of Delta State Polytechnic Ozoro, Nigeria. Ozoro is located in the rain forest vegetation region of Nigeria, on latitude 5.544 North, longitude 6.232 East and altitude 14 Meters (45.93 Feet) above sea level. Rainfall distribution pattern in this region is bimodal with peaks in July and September and a short dry spell around mid-August (Eboibi *et al*., 2018).

Soil sampling and analysis

Topsoil (0-20 cm depth) samples were randomly taken from the experimental field before the land preparation. The soil samples were air dried in the laboratory under ambient temperature (27±5°C), after which they were sieved with a 2 mm stainless steel sieve. Soil physicochemical and heavy metals analyses were carried out on the soil samples in accordance to standards (AOAC, 2019; Akpokodje and Uguru, 2019).

Plant of interest

The Africa black beauty eggplant seeds obtained from Technisem seed company sales outlet, Kano State, Nigeria.

Seeds nursery and transplanting

The eggplant seeds were nursed at the Research Station of the Delta State Polytechnic, Ozoro, Nigeria. During the period, the seedlings were watered with sprinkler irrigation, at a very low pressure. Weeding was done through by handing picking, while systemic herbicide was used to prevent insects' attacks. The seedlings were treated with the Z-force fungicide (Active Ingredient, Mancozeb 80%WP). Transplanting of the eggplant seedlings was done 24 February 2019, at the age of five weeks.

Experimental setup

The soil amendment management (SAM) lasted for three

Table 1. Experimental setup.

Block	Method	Eggplant cultivar
Block1	Control	Africa black beauty
Block 2	Amendment	Africa black beauty

months, during which the eggplant plants were closely monitored. The experimental field was manually tilled, and divided two main blocks as indicated in (Table 1), and spaced 1 m apart in a square grid. To improve the soil fertility, compost manure was incorporated into the soil at the rate of 2 ton/ha, two weeks before transplanting of the eggplant seedlings.

Amendment block

In the amendment block, calcium based fertilizer with the trademark Maxi Calmag (manufactured by SQN, Santigo Chile) was applied to the eggplant plants at every two weeks interval, starting from four weeks after transplanting of the seedlings till the end of the experiment. The fertilizer was applied at the rate of 4 kg/ha through foliar application. In addition, boron salt solution was used to reinforce the calcium based fertilizer, during each foliar application at the rate of 1 g/16L. Boron salts facilitate the translocation of Ca^{2+} from the leaves to the fruits of plants. Most plants absorb mineral nutrient applied to their leaves in the form of foliar application and is most effective when the nutrient solution remains on the leaf as a thin film, mostly in the dry season (Taiz and Zeiger, 2006).

Control block

Control eggplants received no Maxi Calmag treatment throughout the growing period. Insects were controlled with systemic insecticides, while weeds control was carried was done manually in both blocks.

Eggplant fruits harvesting and sampling

The eggplant fruits were harvested in three maturity stages. The fruits were harvested at 10 days interval starting from 30 days after peak flowering (DAF). The harvested eggplant fruits were manually inspected to remove all pests/insets infested and rotten fruits. After this, they were randomly selected, and taken to the laboratory for textural analyses.

Instrumental texture profile analysis

Texture profile analysis, (TPA), of the intact Africa black beauty eggplant fruits was carried out using Warner-Bratzler shear force (WBS) method, with the aid of the Universal Testing Machine (Testometric model) with accuracy of 0.001N. The operating parameters were as follows: cylindrical puncture probe diameter = 8 mm, preload speed of 200 mm/min and test-speed = 105 mm/min (Eboibi *et al.,* 2019). The test probe was attached to the load cell of the machine, which was used to penetrate the fruit (sample) at the preset crosshead speed.

Test on the intact fruit skin firmness

To test the intact eggplant fruit skin firmness, a single intact eggplant fruit was placed in the machine, and punctured with the probe to a position of about 50% of the fruit's diameter, and then returned to the point where pre-load was reached on the first cycle. Then it waited for a short time which is supposed to represent the time between chews, before the second puncture (Nyorere and Uguru, 2018).

Test on the fruit flesh firmness

In order to test the fruit flesh, the eggplant fruit was cut into two halves along the longitudinal axis. Each slice was positioned intently under the probe and held firmly between two fingers until probe penetrated the slice at the preset crosshead speed (Ashtiani *et al*., 2016). The probe went to a position (about 50% of the slice diameter), and then returned to the point where pre-load was reached on the first cycle. Then it waited for a short time which is supposed to represent the time between chews, before the second puncture (Nyorere and Uguru, 2018). The firmness of the sample was calculated automatically by the computer attached to the machine and the results read from the screen. The firmness of the sample was carried out at ambient temperature (22 ± 5°C). Firmness is the maximum force the fruit can withstand during the first compression (Szczesniak, 1990; Eboibi *et al*., 2019). As suggested by ASABE Standards, (2008) all the mechanical tests were replicated 20 times, thus the mean values were recorded.

Statistical analysis

Data obtained from this study were subjected to analysis of variance (ANOVA) using IBM SPSS statistic software,

Table 2. Physico-chemical properties of the soil sample

Parameters	Level
Particle size distribution (%)	
Sand	40.5
Silt	33.2
Clay	27.3
Physiochemical analysis	
Soil pH (H_20)	7.25
Total nitrogen (mg/kg)	3.19
Available Phosphorus (mg/kg)	12.37
Nitrate (mg/kg)	8.36
Sodium (mg/kg)	510.74
Calcium (mg/kg)	415.07
Magnesium (mg/kg)	378.74
Extractable Potassium (mg/kg)	897.58
Heavy metal analysis	
Copper (mg/kg)	6.25
Lead (mg/kg)	0.85
Iron (mg/kg)	21.34

Table 3. The ANOVA of effect of treatment and maturity stage on the textural qualities of *Africa black beauty* eggplant fruit.

Source of variation	df	Skin firmness	Flesh firmness
Maturity stage	2	2.84E-05*	5.81E-05*
Treatment	1	2.49E-9*	4.43E-08*
Maturity x treatment	2	0.044*	0.012*

*Significant at P ≤ 0.05

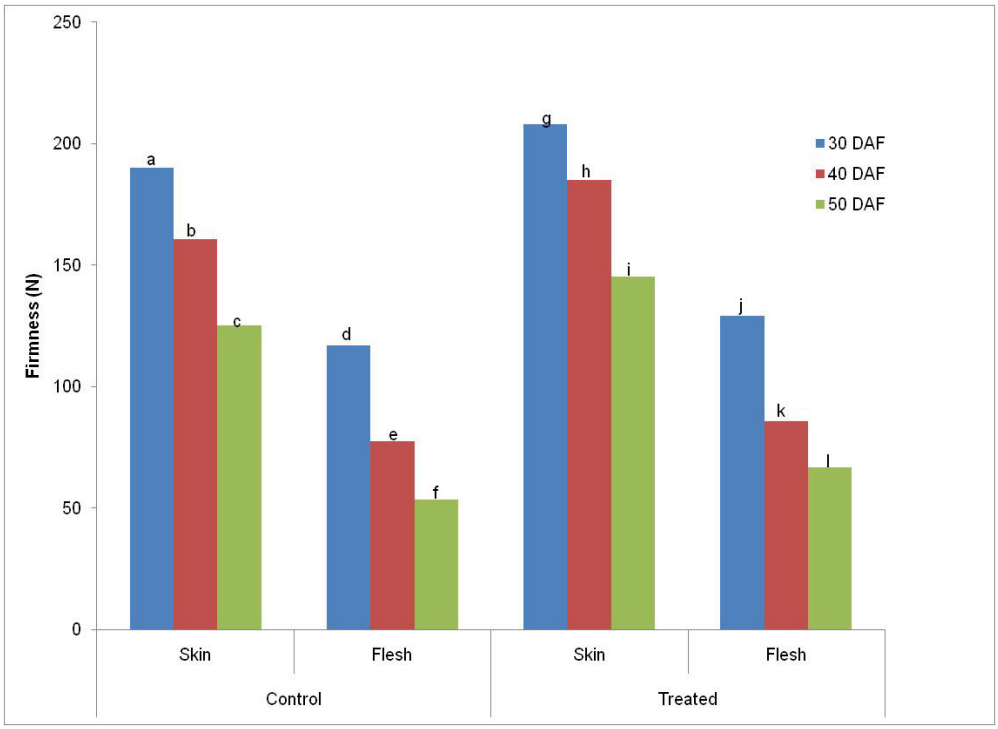

Figure 1. Firmness of raw eggplant fruits as evaluated by puncture test. Columns with the same common latter are not significantly different (p ≤0.05) according to Duncan's multiple ranges test.

version 20. The means of the results were separated by Duncan Multiple Range Test at 95% confidence level.

RESULTS AND DISCUSSION

The results of the soil physiochemical and heavy metals analyses are presented in (Table 2). According to the results (Table 2), the soil was alkaline, fairly rich in calcium and Potassium; but poor Nitrogen and phosphorus. The average atmospheric temperature during eggplant planting period was about 32°C; the average soil temperature was about 23°C in the morning and 36°C in the evening. The analysis of variance (ANOVA) result of the textural qualities of *Africa black beauty* eggplant fruit is presented in (Table 3). As shown in (Table 3), calcium treatment and maturity stage significantly influenced ($P \leq 0.05$) the two parameters (skin firmness and flesh firmness) investigated in this study. The mean values of the textural qualities investigated in this study are presented in (Figure 1).

Results of the study presented in (Figure 1) showed that Calcium fertilizer had significant ($p \leq 0.05$) effect of the skin and flesh firmness of the eggplant fruits. The average skin and flesh firmness of the eggplant fruits decreased from 30 DAF to 50 DAF. At the beginning of the maturity period there was a higher skin and flesh firmness, which reduces as the fruits matured (Figure 1). The fruit softening (lower firmness) of the eggplant fruits that occurred during development and maturity was primarily due to changes in the fruit cell wall carbohydrate metabolism and to the action of cell wall hydrolases. Pectin-degrading enzymes have received most attention as potential causal agents in the softening of ripening fruit (Serrano *et al*., 2002; Stuckrath *et al*., 2008). In addition, the results showed that calcium treated eggplant fruits were significantly ($p \leq 0.05$) firmer than the control eggplant fruits (Figure 1). The greater skin and flesh firmness of calcium treated eggplant fruits may result from calcium interacting directly with cell wall pectic substances, resulting in cell wall stiffening, as also observed by Stuckrath *et al*. (2008) for blueberry fruits. According to Carpita and McCann, (2000) calcium-pectate interactions make the cell wall of fruits firmer than the control fruits. Calcium is mostly associated with fruit quality, in general, and firmness in particular (Sams, 1999).

Previous researches have showed that Calcium had the capability of increasing the fruits skin firmness. Raese and Drake, (2000) reported that Calcium foliar application improved apple fruit firmness, increased juiciness and increased red skin colour; when compared with fruits harvested from control '*Red*' and '*Golden Delicious*' apples trees. According to Barrett *et al*. (1998) and Radzevičius *et al*. (2012) tomato variety, maturity stage, genetic modification, farming methods, environmental conditions (mostly sunlight and rainfall), processing conditions and calcium addition affect the textural integrity of tomato fruits. Bashir and Abu-Goukh, (2003) studied fruit flesh firmness in two guava cultivars, and observed a progressive declined in the fruits' firmness during ripening. The declined in the fruits' firmness was about eight-fold from the hard mature green stage to the final soft ripe stage.

Conclusion

This study was conducted to evaluate the effect of calcium treatment on some textural qualities of *Africa black beauty* eggplant fruits at three maturity stages. The results of the study indicated that the texture quality of eggplant fruits is highly dependent on the soil amendment and harvesting stage. The results showed that calcium treatment had significant ($p \leq 0.05$) effect on the eggplant fruits skin and flesh firmness. Calcium treated fruits skin firmness was higher (189.47 N) when compared to the control fruits skin firmness (158.63 N); while flesh firmness of 93.85 N was recorded for the calcium treated fruits, higher than 78.68 N recorded for the control fruits. Fruit texture was significantly ($p \leq 0.05$) higher at the early maturity stage; as the fruit skin and flesh firmness decreased linearly as maturation of the fruits progresses. Findings of this study will be useful in the design and development of eggplant fruits processing and packaging systems. But further research works are needed to investigate the effects probe size and shape on the textural qualities of eggplant fruits.

Authors' declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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