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Full-Length Research Paper

Optimization of agricultural machines through the pre-harvest treatment of sweet paper (cv. Goliath) fruits

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ABSTRACT: Food wastage and shortage of workforce are some of the major problem militating against crop production. The purpose of this research was to improve the physical and mechanical properties of sweet pepper (cv. Goliath F1) fruits in order to optimize harvesting, handling, and processing machines. Goliath sweet pepper plants were pre-harvest treated with $CaCl_2$ and KCl solutions at 100 mg/L and 200 mg/L concentrations, respectively. The treatment was done twice weekly, starting from the fruits' flowering stage, till when they were harvested at the deep green maturity stage. All the fruits harvested subjected to physico-mechanical tests according to ASTM International procedures. Results obtained from the test revealed that the treatment options affected all the parameters (fruit weight, moisture content, spoilage rate and firmness) of the fruits, even during storage period. The study revealed that fruits produced with KCl had better body weight, and experienced lower physiological weight loss, than the fruits produced with $CaCl_2$ and the control. Likewise, the results revealed that the fruits produced with $CaCl_2$had better fruit firmness than the fruits produced with KCl and the control. This study results will be useful to engineers for the design and optimization of equipment for sweet pepper production.

Keywords: Sweet pepper, calcium chloride, Goliath F1, optimization, potassium chloride

INTRODUCTION

Pepper (*Capsicum* spp.) which belongs to the *Solanaceae* family is widely cultivated globally, and its' fruits are commonly used as spices. There are five species of *Capsicum*, which are: C. *annuum* (sweet type), C. *chinense* (chili type), C. *frutescens* (jalapeno type), C. *pubescens* (cayenne type), and C. *baccatum* (cherry type) (Moses *et al*., 2014). Pepper fruits contain a lot of essential minerals and vitamins, such ascarotenoids, vitamin C, capsaicinoids, etc. (Jeong *et al*., 2011; Bae *et al*., 2012). According to Karsha and Lakshmi (2012), pepper fruits have some medicinal values, as it is used to manage vertigo, colon toxins, obesity, congestion, fever, arthritic disorders, etc. Dereje (2003) reported that pepper fruit quality, is a complex one, as it includes its colour, physical characteristic, firmness, total soluble solid, acidity, moisture content, vitamin C concentration, etc. The mechanical properties of fruits are crucial factors to be considered during the design of fruits harvesting, handling, processing and packaging machines (Idama and Uguru, 2021). Research results had revealed that pre-harvest treatment of fruits and vegetables, greatly enhanced their mechanical properties. Li and Yu (2000) investigated the effect of chitosan pre-harvest treatment on the firmness of peach fruits, and observed that the fruits treated with chitosan recorded higher firmness, compared to the harvested from the untreated peach trees. Furthermore, Kirmani *et al*. (2013) reported that pre-harvest treatment plum fruits with $CaCl_2$ minimized their physiological weight loss during storage under ambient condition. Similarly, Edafeadhe and Uguru (2018) reported that pre-harvest treatment of cucumber fruits enhanced their mechanical properties, hence optimizing the performance of their harvesting and processing equipment. Taylor and Brannen (2008) reported that pre-harvest applications of calcium-based solutions, help in fruits' growth and development, increased their firmness and shelf life by reducing the fruits spoilage during storage. Zhang *et al*. (2017) observed that potassium helped to increase fruits firmness and sizes; thereby, leading to increase in fruits ability to absorb more puncture force during harvesting and handling operations. According to Myhan *et al*. (2012), fruits are exposed to several mechanical forces during harvesting, handling and processing operations. This mechanical stress can cause irreparable damage, if it is beyond the bearing capacity of the fruits. This damage makes the fruits highly susceptible to microbial attack; therefore, lowering their viability and shelf life (Linden *et al*., 2006; Uguru and Nyorere, 2019). Although several literatures had been cited on the impact of pre-harvest treatment on the mechanical properties of fruits and vegetables, there is no recorded literature on the effect of calcium based amendment, on the mechanical properties of sweet pepper fruits. Therefore, this research was aimed at investigating the influence of calcium chloride and potassium chloride on some physico-mechanical properties of sweet pepper (cv. Goliath F1) fruits. Results obtained from this research will enhance the design and optimization of sweet pepper harvesting, handling and packaging systems.

MATERIALS AND METHODS

The study was carried out at the research center of the Department of Agricultural and Bioenvironmental Engineering, Delta State Polytechnic, Ozoro, Nigeria. Ozoro is located in the rain forest vegetation region of Nigeria, on latitude 5.5 N, longitude 6.2 East and altitude 14 m above sea level (Ebiobi *et al*., 2019).

Materials

Pepper

The sweet pepper (*Capsicum annuum* L., cultivar Goliath F1) seeds used for this study were purchased from Technisem Seed Company, through the sales outlet in Kano State, Nigeria.

Calcium chloride

The calcium chloride ($CaCl_2$), which is a highly soluble compound and solid at room temperature, was purchased from a chemical store at Onitsha, Anambra State, Nigeria.

Potassium chloride

Potassium chloride (KCl), is a soluble compound, and was purchased from a chemical store at Onitsha, Anambra State, Nigeria.

Methods

Experimental design

The experiment consisted of 5 treatments, a control (distil water), 2 concentrations (100 mg/L, and 200 mg/L) of $CaCl_2$, and 2 concentrations (100 mg/L and 200 mg/L) of KCl. The treatments are summarized and tagged as shown below:

Treatment 1 (T1): Zero (0) treatment, which was referred to as the "Control";
Treatment 2 (T2): 100 mg/L $CaCl_2$;
Treatment 3 (T3): 200 mg/L $CaCl_2$;
Treatment 4 (T4): 100 mg/LKCl;
Treatment 5 (T5): 200 mg/LKCl;

The treatments were applied on the pepper plants twice weekly, starting from the flowering stage to the harvesting period. During the treatment application, each pepper plant was sprayed thoroughly, until the plant was completely wet, using the knapsack sprayer.

Pepper cultivation

The experiments were carried out from October 2019 through February 2020, at the research station of Delta State Polytechnic, Ozoro, Nigeria. The pepper plants were watered through sprinkler irrigation method. Systemic insecticide was applied when necessary to pervert insects' attack. Weeding was done manually, through the experimental period.

Pepper fruits collection

The peppers fruits chosen for the study were marked during their flowering stage, to evaluate how long it takes before they attain their full maturity stage. The pepper fruits were harvested at deep green (commercially ripe) maturity stage. All the harvested fruits were manually inspected to remove damage, deformed and pests infected fruits. The sorted pepper fruits were then taken to the biomaterials laboratory of Delta State Polytechnic, Ozoro, Nigeria, for storage and others laboratory analysis.

Pepper fruits storage

After the sorting, the fruits were gently washed under running tap water for 20 minutes to remove the field heat from the fruits. They were later stored under ambient laboratory conditions (29±4ºC, 70±10 RH, etc.), during the experimental period of 16 days.

Postharvest pepper fruits analysis

Physical characteristics

These physical parameters weight, moisture content, physiological weight loss, and spoilage rate of the fruits were determined.

Fruits weight

Individual weight of the fruit was taken with an electronic weighing balance, and the value recorded.

Physiological weight loss (%)

Twenty pepper fruits were selected and their weight taken using an electronic weighing balance and labeled. The fruits were stored under ambient laboratory conditions, and their weight retaken every experimental date (every four days). The weight loss was calculated using the formula presented in Equation 1.

$$\text{Weight loss } (\%) = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

Where:
W_1 = initial weight (g)
W_2 = weight at the experimental day (g)

Determination of moisture content

The fruit moisture content was determined in compliance with AOAC (2005) approved procedures, for moisture content determination. 20g of the fruit flesh was cut out, placed in a moisture can, and transferred into an electric laboratory oven, pre-set at 75±3^{0}C. The weights of the samples were taken even one hour, until a stable weight was attained. Moisture content of each sample was calculated by using the formula in equation 2.

$$M_c(\%wb) = \frac{W_w - W_d}{W_w} \times 100 \quad (2)$$

Where:
W_w = weight of wet sample (g),
W_d= weight of dried sample (g),
M_c = moisture content wet basis (%).

Mechanical properties

Pepper flesh firmness

The Magnus Taylor Puncture Probe (MTPP) set with WBST bottom platen, attached to the Universal Testing machine, was used employed for this test. A 6 mm diameter round end stainless steel probe was attached to the loading cell of the machine, was used to puncture the fruit to a pre-set depth (50% of the fruit's diameter) and swiftly returned to its original position (Figure 1). The Universal Testing Machine was pre-set with the following information: preload speed, 200 mm/min; testing-speed, 102 mm/min; and post-test speed, 0.5 mm/min; defection 50% strain. Firmness of the fruit's flesh was mined by the microprocessor attached to the machine and displayed on the screen.

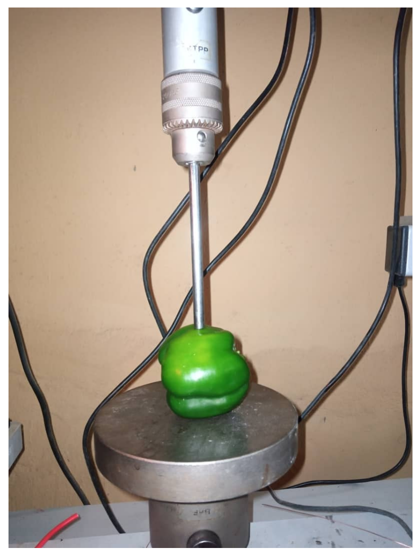

Figure 1: A sweet pepper fruit undergoing firmness test.

Statistical analysis

The data obtained from the study will be statistical analysis by using the Microsoft excel software.

RESULTS AND DISCUSSION

Sweet pepper fruits physical characteristics

Fruit moisture content

The moisture content of the pepper fruits presented in (Table 1) increased non-linearly during storage. Regardless of the treatment option applied, the moisture

Table 1: Sweet pepper physical characteristics

Parameter	Storage	Treatment				
		T1	T2	T3	T4	T5
Spoilage rate (%)	Day 4	11.0±0.9	5.7±0.6	4.7±0.3	6.3±0.6	5.3±0.6
	Day 8	35.7±2.5	19.3±2.6	10.3±1.5	16.7±1.6	7.7±1.6
	Day 12	61.0±3.2	34.3±3.2	29.3±2.4	32.4±3.0	26.1±2.1
	Day 16	75.3±3.5	60.3±3.5	50.7±2.5	56.3±3.6	45.2±2.3
	Mean	45.75	29.9	23.75	27.93	21.08
PWL (%)	Day 4	5.3±0.3	3.3±0.1	2.3±0.5	3.0±0.2	2.1±0.3
	Day 8	23.0±2.4	15.5±2.2	13.3±2.3	11.8±1.1	9.3±1.6
	Day 12	35.8±3.3	21.9±2.3	17.8±2.4	19.9±1.3	15.4±2.1
	Day 16	45.8±3.2	29.8±3.3	25.4±2.2	26.5±1.7	20.1±2.3
	Mean	27.5	17.6	14.7	15.3	11.7
Moisture content	Day 0	52.8±2.3	46.8±2.1	43.7±2.2	42.6±3.5	40.3±3.7
	Day 4	44.2±4.5	40.6±3.2	41.2±2.6	39.2±3.0	38.1±3.9
	Day 8	51.7±3.8	42.3±3.7	39.5±3.1	41.0±2.6	35.3±2.5
	Day 12	64.3±3.3	50.8±3.5	46.9±3.4	48.9±3.1	39.5±3.6
	Day 16	70.1±4.8	55.8±3.2	50.6±3.9	52.3±3.0	44.1±2.9
	Mean	56.6	47.3	44.4	44.8	39.4

± Standard deviation

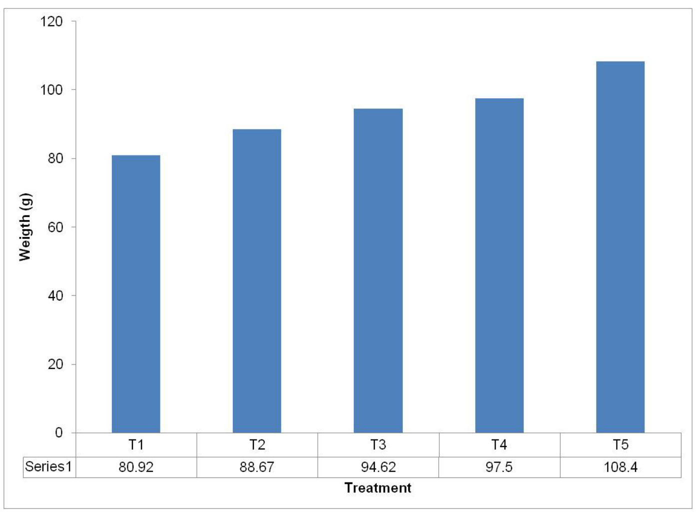

Figure 2: Fresh weight of sweet paper fruits at harvest day.

content reduced during the initial 4 storage day, before it started to increase again. The declined observed during the initial storage days could be attributed to the loss of water from the fruits through evaporation and transpiration (Gayed *et al*., 2017). Then as deterioration of the fruit sets in, carbohydrates and other dry matters of the fruits will breaks down, processing water in the process.

Fruit weight

This study revealed showed that the treatment options had greatly influenced the fresh weight of the sweet pepper fruits (Figure 2). It was observed from the results that the fruits' weight increased linearly as the treatment (KCl or $CaCl_2$) concentration increases from 100 mg/L to 200 mg/L. However, the fruits treated with KCl (T3 and T5) exhibited relatively higher body weight than those fruits treated with $CaCl_2$ (T2 and T3). This showed that potassium played an essential role in the fruit development. The higher fruits body weight recorded in the fruits produced with KCl further affirmed previous reports on the importance of potassium in crop production. According to Botella *et al.* (2017), potassium is an essential nutrient, and its application on crop will significantly increase the fruits body mass.

Table 2: Variation in sweet pepper firmness during storage

Storage	Treatment				
	T1	T2	T3	T4	T5
Day 0	84.6^{e}±3.7	99.3^{e}±3.8	108.2^{e}±3.5	94.8^{e}±2.9	99.8^{e}±2.7
Day 4	76.4^{d}±3.2	94.7^{d}±3.8	104.1^{d}±2.8	86.0^{d}±3.0	95.6^{d}±3.4
Day 8	55.9^{c}±2.6	79.8^{c}±2.5	92.8^{c}±2.1	69.5^{c}±2.7	81.1^{c}±2.7
Day 12	29.3^{b}±1.8	57.3^{b}±2.7	71.4^{b}±1.9	48.5^{b}±3.1	56.8^{b}±2.9
Day 16	20.2^{a}±1.9	28.4^{a}±1.9	42.2^{a}±2.2	23.5^{a}±2.6	29.7^{a}±1.6
Mean	53.3	71.9	83.72	64.52	72.62

± Standard deviation

Similarly, Jawandha *et al*. (2017) stated that potassium leads to the accumulation of photosynthates in fruits, hence increasing their body weight. Results obtained from this study are similar to those obtained by Sharma and Pratima (2018) and Kirmani *et al*. (2013) for peach and plum (*Prunussalicina* L.) fruits respectively.

Fruit spoilage rate and storability

The results presented in (Table 1) showed that pre-harvest treatment influenced the spoilage rate of the sweet pepper fruits. It was observed from the results that the sweet pepper treated with $CaCl_2$ and KCl had lower spoilage rate, when compared with the control fruits. Regardless of the treatment option, it was revealed by the results that, as the concentration of the treatment option increases, the spoilage rate of the pepper decreased. It can be deduced from the results that T5 (200 mg/LKCl) option, was the most effective treatment method of reducing spoilage in sweet pepper fruits. This affirmed previous report by Zahirul *et al*. (2018) that potassium helps in maintaining fruits' structural qualities during storage. In addition, Kirmani *et al*. (2013) reported that chloride based solutions can reduced physiological disorders in fruits and increased their resistance to infections; thereby, increasing their shelf life.

Physiological weight loss (PLW) (%)

The results of the PLW of the sweet pepper fruits are presented in (Table 1). It was observed that the control fruits (T1) had the highest PLW (27.5%), while the fruits produced with T5 had the lowest PLW of 11.7%. Irrespective of the treatment concentration, the fruits produced with $CaCl_2$ had a higher PWL, compared to the fruits produced with KCl. This verified the previous observations of Armstrong *et al*. (1998), who stated that K^+ helps to reduce fruits water loss; thereby maintaining its turgor was weight during storage. It was observed from the results that during storage, regardless of the treatment option applied, higher PWL was observed during the initial 8 storage days. These results are in conformity with the previous work of Zahirul *et al*. (2018) on cherry tomato fruits and Kirmani *et al*. (2013) on plum fruits. According to Zahirul *et al*. (2018), KCl helped in reducing physiological weight loss of cherry tomato fruits during storage under ambient conditions.

Sweet pepper mechanical properties

Firmness

The results of the sweet pepper fruit firmness as affected by the treatment options and storage duration are presented in (Table 2). As seen in the results, the fruit firmness was higher in the treated fruits, when compared with firmness values recorded in the control fruits. Regardless of the treatment concentration, the results indicated that fruits treated with $CaCl_2$ had superior firmness, which they maintained such throughout the 16 days storage period. This showed that $CaCl_2$ is a very effective in maintaining fruits firmness, when compared to other treatment options; confirming earlier reported of Kirmani *et al*. (2013) and Gayed *et al*. (2017) for plum and peach fruits respectively. In addition, Botella *et al*. (2017) observed that pre-harvest application of KCl had the ability of increasing the firmness of the pepper fruits. Additionally, the study results revealed general decline in the fruits firmness during the storage period (Table 2). It was observed that the fruits harvested from T1 (control) recorded the highest firmness decreasing rate; while the fruits harvested from T3 (200 mg/L $CaCl_2$) recorded the least decreasing rate during the 16 day storage period. This portrayed that pre-harvest treatment of the pepper plants with 200 mg/l $CaCl_2$, is the most effective option in producing sweet pepper fruits with good firmness during storage. El-Badawy (2012) reported that calcium, being and essential plant nutrient, helps in fruit's cellular structures development; hence, improving the fruits mechanical properties. Fruit firmness is a vital factor to be considered, during development of harvesting and handling systems. The knowledge of fruit firmness determines the maximum pressure the fruit will be subjected to, to avoid mechanical damage. As portrayed by the results, the fruits produced with $CaCl_2$ and KCl can absorbed more force than the control fruits, hence significantly reduce food wastage through mechanical damage. Kazemi and Gholamalizadeh (2015) stated that improving the mechanical properties of fruits and vegetables will help minimizing wastage of the agricultural products. This is because fruits with high failure point are able to withstand wide range of pressure and compression forces, during their harvesting, handling and packaging operations.

Conclusion

The influence of pre-harvest treatment of sweet pepper (cv. Goliath) fruitswas investigated in this study. Sweet pepper fruits were treated with KCl and $CaCl_2$in the field at the rate of 100mg/L and 200 mg/L. The physical characteristics and mechanical properties of the fruits were determined in accordance to ASTM International methods. Results of the laboratory tests revealed that both $CaCl_2$ and KCl, influenced all the parameters evaluated in this study. It was observed that the control fruits recorded the lowest body weight, while the KCl treated sweet pepper fruits had the highest fruit weight. Regardless of the treatment concentration, the study depicted that the fruits produced with KCl, had higher body weight than fruits produced with $CaCl_2$. Similarly, the results revealed that the control fruits had the lowest highest shelf life, while the $CaCl_2$ treated fruits recorded the highest shelf life. It was also observed from the study that fruits produced with KCL recorded the lowest PWL, while the control fruits recorded the highest PWL. In addition; the study revealed that the fruits produced with $CaCl_2$ had the highest firmness, which they maintained throughout the storage during. These results had shown that increasing the treatment concentration, helped to enhance the mechanical properties of sweet pepper fruits. This study results will be useful in optimizing sweet pepper harvesting and handling equipment, since unnecessary force that will cause mechanical damage will be avoided.

REFERENCES

Analysis of the Association of Official Analytical Chemists – AOAC (2006). Official Method 967.21. Ascorbic Acid inVitamin Preparations and Juices: 2,6-DichloroindophenolTitrimetric Method.Official Methods of Analysis of theAssociation of Official Analytical Chemists.

Armstrong DL, Griffin KP, Danner M (1998). Better Crops with Plant Food, Potash & Phosphate Institute, Norcross, GA.

Bae H, Jayaprakasha GK, Jifon J, Patil BS.(2012). Variation of antioxidant activity and the levels of bioactive compounds in lipophilic and hydrophilic extracts from hot pepper (*Capsicum* spp.) cultivars. *Food Chemistry*, 134: 1912-1918.

Botella MA, Arevalo L, Mestre TC, Rubio F, GarciaSanchez F, Rivero RM, Martinez V (2017). Potassium fertilization enhances pepper fruit quality.*Journal of Plant Nutrition*, 40(2): 145-155.

Dereje A. (2003). Screening *Capsicum annuum* Germaplasm for Variability in Ascorbic Acid, Total Soluble Solids and Dry Matter Content, Faculty of Agricultural, Food and Environmental Quality Sciences, The Hebrew University of Jerusalem, MSc Thesis

Eboibi O, Akpokodje O I, Uguru H. (2018). Growth performance of five bean (*Phaseolus* spp) varieties as influenced by organic amendment. *J. Appl. Sci. Environ. Manage.*, 22 (5): 759 – 763

Edafeadhe GOI, Uguru H. (2018). Influence of field practices on the performance of cucumber fruits harvesting and processing machines. *Direct Research Journal of Engineering and Information Technology*. 5 (5):42-47.

El-Badawy HEM. (2012). Effect of chitosan and calcium chloride spraying on fruits quality of Florida Prince peach under cold storage. *Research Journal of Agriculture and Biological Sciences,* 8(2): 272-281.

Gayed AN, Shaarawi SA, Elkhishen MA, Elsherbini NRM.(2017). Pre-harvest application of calcium chloride and chitosan on fruit quality and storability of 'Early Swelling' peach during cold storage. *Ciência e Agrotecnologia,* 41(2):220-231

Gil MI, Aguayo E, Kader AA. (2006). Quality Changes and Nutrient Retention in Fresh-Cut versus Whole Fruits during Storage. *J. Agric. Food Chem*. 54 (12):4284-4296.

Hortwitz W. (1960).Official and Tentative Methods of Analysis, vol. 9.Association of the Official Agriculture Chemist, Washington, DC, USA.

Idama O. Uguru H. (2021) Robotization of tomato fruits production to enhance food security. *Journal of Engineering Research and Reports*. 20(1): 67-75.

Jawandha SK, Gill PPS, Singh H, Thakur A. (2017). Effect of potassium nitrate on fruit yield, quality and leaf nutrients content of plum. *Vegetos- An International Journal of Plant Research*, 30(2):322-328

Jeong WY, Jin JS, Cho YA, Lee JH, Park S, Jeong SW, Kim YH, Lim CS, Abd El-Aty AM., Kim GS, Lee SJ, Shim JH, Shin SC. (2011). Determination of polyphenols in three *Capsicum annuum* L. (bell pepper) varieties using high-performance liquid chromatography–tandem mass spectrometry.Their contribution to overall antioxidant and anticancer activity.*Journal of Separation Science*, 34, 2967-2974.

Karsha P V, LakshmiBO. (2010). Antimicrobial activity of black pepper (*Piper nigrum* Linn.) with special reference to its mode of action on bacteria.*Indian J. Natural Prod. Resources* 1: 213-215.

Kazemi M, Gholamalizadeh S (2015). Evaluation of practical solutions in post- harvest to reduce waste of horticultural crops. *Journal of Agriculture and Natural Resources Engineering Disciplinary Organization,* 13(48): 13–17. (In Persian).

Kirmani SN, Wani GM, Wani MS, GhaniMY, Abid M, Muzamil S, Raja H, Malik AR (2013).Effect of preharvest application of calcium chloride ($CaCl_2$), gibberlic acid (GA3) and napthelenic acetic acid (NAA) on storage of plum (*Prunussalicina* L.), cv. Santa Rosa, under ambient storage conditions. *African Journal of Agricultural Research*, 8(9):812-818

Li H, Yu T. (2000). Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. *Journal of the Science of Food and Agriculture*, 81:269-274.

Linden VV, Scheerlinck N, Desmet M (2006). Factors that affect tomato bruise development as a result of mechanical impact. *Postharvest Biol. Technol*. 42: 260-270.

Moses M, Umaharan P, Dayanandan S (2014). Microsatellite based analysis of the genetic structure and diversity of *Capsicum chinense* in the Neotropics. *Genetic Resources and Crop Evolution,* 61:741–55.

Myhan R, Białobrzewski I, Markowski M (2012). An approach to modeling the rheological properties of food materials. *Journal of Food Engineering*, 111(2), 351–359.

Sharma S K, Pratima P (2018). Effect of pre-harvest gibberellic acid and calcium application on post-harvest behaviour of subtropical peaches. *Current Agriculture Research Journal*, 6 (1):78-84

Taylor KC, Brannen P (2008). Effects of foliar calcium application on peach fruit quality, shelf-life and fruit rot. Albion® Conference on Plant Nutrition, 1–11.

Uguru H, Nyorere O (2019). Failure behaviour of groundnut (SAMNUT 11) kernel as affected by kernel size, loading rate and loading position. *International Journal of Scientific & Engineering Research*, 10(2): 1209 – 1217

Zahirul I M, Young-Tack L, Akter MM, Ho-Min K (2018).Effect of pre-harvest potassium foliar spray and postharvest storage methods on quality and shelf life of cherry tomatoes. *Research Journal of Biotechnology*,13 (7): 49-54.

Zhang W, Zhang NS, Zhao JJ, Guo YP, Zhao ZY, Mei X (2017). Potassium fertilization improves apple fruit (*MalusdomesticaBorkh*. Cv. Fuji) development by regulating trehalosemetabolism. *Journal of Horticultural Science and Biotechnology*, 92: 1-12.