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Full-Length Research Paper

Biochemical Characterization of Okra (*Abelmoschus esculentus L.*) Pods, Cultivated under Different Soil Condition

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ABSTRACT: Soil biochemical properties have been shown to have a significant impact on agricultural products and nutritional properties. The purpose of this study was to investigate the effect of soil biochemical properties on the biochemical qualities of okra (*Abelmoschus esculentus* L.) pods. The soil in which the okra plants were grown was subjected to four different treatments. Treatment 1 (T1) received no amendment and was referred to as the control; treatment 2 (T2) received organic manure applied at a rate of 3000 kg/ha; treatment 3 (T3) received potassium nitrate (KNO_3) fertilizer applied at a rate of 200 kg/ha; and treatment 4 (T4) received a combination of organic manure and KNO_3, mixed at a rate of 3000 kg/ha (organic manure) and 200 kg/ha (KNO_3) fertilizer (KNO_3). The okra pods were harvested 15 days after flowering and the concentrations of nitrate, protein, potassium, copper, and calcium were determined using standard approved procedures. The results of the tests revealed that the pre-harvest treatments had a significant (p 0.05) effect on the biochemical properties of the okra pods. The study's findings revealed that T1 okra pods had the lowest protein content (0.57 percent), while T4 okra pods had the highest protein content (0.57%) (0.97%). Similarly, the T1 pods had the lowest nitrate concentration (11.43 mg/kg), while the T3 pods had the highest (15.64 mg/kg). The results also revealed that the T3 pods had the highest calcium concentration (824.67 mg/kg), while the T1 pods had the lowest (439.67 mg/kg). In terms of copper concentration in okra pods, the results showed copper concentrations of 7.51 mg/kg, 8.42 mg/kg, 9.07 mg/kg, and 10.31 mg/kg in okra pods produced under T1, T2, T3, and T4 regimes, respectively. The T1 pods had the lowest potassium concentration (2088.00 mg/kg), while the T3 pods had the highest potassium concentration (5546.00 mg/kg). Because the T4 pod generated high protein content and low nitrate content, this study found that combination treatment is the preferable treatment method, because nitrate accumulation in edible plant parts is hazardous to humans.

Keywords: Biochemical qualities, clemson spineless, potassium nitrate, soil amendment, organic manure

INTRODUCTION

Okra (*Abelmoschus esculentus* L.), a member of the Malvaceae family, is a popular vegetable crop in Africa, particularly in Nigeria. In 2020, approximately 10 million tons of okra pods were produced globally, with Nigeria accounting for approximately 1.82 million tons (about 20%) of global okra pod production (FAOSTAT, 2020; Edafeadhe and Uguru, 2020). Okra pods and leaves have numerous nutritional and pharmaceutical benefits due to their high concentrations of essential vitamins and antioxidants (Zaharuddin et al., 2014; Oghenerukewve and Uguru, 2018; Liu et al., 2019). As a result, they're used to treat things like diarrhea, acute inflammation, gonorrhea and dysuria, diabetes, dental problems, bronchitis, and pneumonia, among other things.

Crop engineering qualities are influenced by cultivar, farming practice, climatic conditions, maturation stage, pre-harvest treatment, and other factors (Eboibi et al., 2019; Uguru and Iweka, 2019). The application of particular amendments (organic or inorganic) to the soil to improve soil fertility, crop productivity, and crop engineering qualities is a farming approach (Ijabo et al., 2019; Nwanze and Uguru, 2020; Bratte and Uguru, 2021). Organic manure, one of the most widely used soil amendments and pre-harvest treatment therapies, improves soil pH, fertility, and structure, hence improving crop productivity and biochemical characteristics (Ouédraogo et al., 2001; Eboibi et al., 2018).

According to Stony Brook University (2019), while conventional farming methods aim to maximize crop production, environmental health and human biosecurity are rarely negatively impacted. According to Ayeni et al. (2012), organic manure contains essential soil nutrients required for plant growth and development; however, these nutrients are in crude form and are released gradually into the soil. Several studies are currently being conducted to determine the effect of soil treatment on the biochemical and mechanical qualities of fruits and vegetables. According to Akpokodje and Uguru (2019a), calcium pre-harvest treatment increased the skin firmness of eggplant (cv. Africa beauty) fruits. The pre-harvest application of methyl jasmonate (MeJA) improved some mechanical properties of Fuji apple fruits (Altuntas et al., 2012). Furthermore, Akpokodje and Uguru (2019b) found that cassava roots treated with Maxi Calmag in the field had significantly higher calcium and nitrate concentrations (p 0.05) than cassava roots harvested from the control program. Idama and Uguru (2021) looked at how potassium nitrate (KNO_3) and organic manure affected the mechanical properties of tomato (Solanum lycopersicum Mill cv. UC82B) fruits. They discovered that tomato fruits grown with organic manure could absorb more compressive force, compressive energy, and deformation than tomato fruits grown with KNO_3. According to Zahirul et al. (2018), pre-harvest foliar application of potassium solution (at low concentration) increased the body mass and tissue firmness of cherry tomato (cv. Unicorn) fruits. When compared to the fruits produced under the control program, the mechanical properties of apple (cv. Fuji) fruit pre-harvest treated with potassium solution developed better mechanical properties during maturation (Zhang et al., 2017).

According to Dumas et al. (2003), one of the major factors influencing the biochemical and mechanical properties of agricultural products is farming method. Uguru and Obah (2020) found that pineapple leaves treated with calcium nitrate ($Ca(NO_3)_2$) had higher fibre firmness and cellulose content, and that the firmness and cellulose content increased progressively as the calcium nitrate concentrations increased from 0 mg/L to 300 mg/L. In their study, Li et al. (2001) discovered that calcium foliar application increased the ability of litchi (Litchi chinensis) fruits to absorb more compression force, thereby increasing the force required to rupture the litchi fruits. Calcium is essential for the development of plant cellular structures (Helper, 2005). Edafeadhe and Uguru (2018) investigated the effect of farming method on cucumber (Cucumis sativus L.) fruit mechanical performance. They discovered that pre-harvest treatment with $CaCl_2$ and $Ca(NO_3)_2$ via foliar application had a significant ($p \leq 0.05$) effect on the mechanical properties (failure force, failure energy, and shear force) of cucumber fruits. Despite the fact that several authors (Ajari et al., 2003; Tiamiyu et al., 2013; Molik et al., 2016; Edafeadhe et al., 2020) have studied the effect of organic and inorganic manure on the growth, yield, and mechanical properties of various okra cultivars, literature on the effect of organic and inorganic treatment on the biochemical qualities of okra pods is still scarce. As a result, the purpose of this research is to look into the effects of organic manure, inorganic manure (potassium nitrate fertilizer), and their combined treatment on the biochemical qualities of okra (cv. Clemson Spineless) pods.

MATERIALS AND METHODS

Materials

The okra (cv. Clemson Spineless) seeds were procured from the seed bank of the Department of Agricultural Engineering, Delta State University of Science and Technology, Ozoro, Nigeria.

Methods

Organic manure formation

The organic manure was formulated from poultry waste, cattle dung, and oil palm fruit bunch waste, mixed at the ratio of 3:5:2 (by weight), by adopting the passively aerated static pile composting method.

Treatment options

The pre-harvest treatment options adopted for the purpose of this study are summarized in (Table 1). The treatments options were randomized in three replicates, with each plot measuring 3 m x 2 m, and a spacing of 1 m x 1 m between the plots.

T1 (Control) - No pre-harvest amendment
T2 - Organic manure applied at the rate of 3000 kg/ha

Table 1: The ANOVA results of the effect of pre-harvest treatment on the biochemical qualities of okra pod.

Source		df	Mean Square	F. Stat	p-value
Treatment	Nitrate	3	9.64	98.47	1.17E-06*
	Protein	3	0.086	197.77	7.67E-08*
	Calcium	3	87394.78	3913.20	5.29E-13*
	Copper	3	4.15	398.36	4.79E-09*
	Potassium	3	7743060.08	106312.04	9.74E-19*

*significant at $p \leq 0.05$ according to Duncan's multiple range tests (DMRT)

Table 2: Biochemical content of okra pods which were treated by different treatment options.

Treatment	Nitrate (mg/kg)	Protein (%)	Calcium (mg/kg)	Copper (mg/kg)	Potassium (mg/kg)
T1	$11.43^{a}\pm0.49$	$0.57^{a}\pm0.02$	$439.67^{a}\pm6.66$	$7.51^{a}\pm0.08$	$2088.00^{a}\pm7.55$
T2	$12.53^{b}\pm0.19$	$0.86^{c}\pm0.02$	$527.33^{b}\pm3.21$	$8.42^{b}\pm0.18$	$2816.67^{b}\pm3.21$
T3	$15.64^{d}\pm0.30$	$0.76^{b}\pm0.02$	$824.67^{d}\pm3.79$	$9.07^{c}\pm0.04$	$5546.00^{d}\pm5.00$
T4	$13.57^{c}\pm0.18$	$0.97^{d}\pm0.02$	$686.33^{c}\pm4.51$	$10.31^{d}\pm0.02$	$4693.00^{c}\pm14.11$

±Mean and standard deviation; columns with the same common letter (superscript) are not statistically different according to DMRT at $p \leq 0.05$; n=5.

T3 -Potassium nitrate (KNO_3) fertilizer applied at the rate of 200 kg/ha
T4 -Organic manure applied at the rate of 3000 kg/ha + KNO_3 fertilizer applied
at the rate of 200 kg/ha

Pre-harvest treatment application

Four weeks prior to the planting of the okra seeds in the organic/combine treatment plots, the organic manure was ploughed into the soil. This is to enable the release of the nutrients form the organic manure into the soil, since the process is a very slow one. As for the inorganic fertilizer pre-harvest treatment, the KNO_3 was applied through ring application method, two weeks after the germination of the okra seedlings. Other variables such as: pest and weed control, environmental conditions, etc. were uniform in all the treatments during the okra growing period.

Okra pod sampling

The okra pods were harvested at 15 days after flowering. This is the stage when the pod is mostly consumed fresh, as the tissues are still soft and succulent. The pods were inspected, and all the pest infested pods were discarded.

Biochemical analysis of the okra pods

The protein content of the okra pods was determined by the Kjeldahl method; while the calcium content of the okra pod was determined by using the atomic spectrophotometry, after digesting the fruit with Trioxonitrate (V) acid and Perchloric acid, according to procedures as explained by Nichols *et al*. (1991). The nitrate concentration in the okra pods was determined by the colourimetric method, as described by Sjoberg and Alanko (1994); while the potassium and the copper concentration in the okra pods were determined using the atomic absorption spectrophotometer, according to AOAC Official Method 984.27 procedures.

Statistical analysis

Raw data obtained from this study were subjected to two-way Analysis of Variance (ANOVA) by using SPSS 20.1, to determine effect of pre-harvest treatment option on the biochemical qualities of okra (cv. Clemson Spineless) fruits. While the means were separated using Duncan's Multiple Range Tests (DMRT) at 95% confidence level ($p \leq 0.05$).

RESULTS

The effect of pre-harvest treatment option on the biochemical qualities of okra (cv. Clemson Spineless) fruits are presented in the ANOVA table given in (Table 1). The ANOVA results revealed that the treatment option had significant ($p \leq 0.05$) effect on the biochemical properties of the fruits. According to the mean separation presented in (Table 2), the control okra fruits had the lowest biochemical values.

DISCUSSION

Nitrate

From the study results presented in (Table 2), the nitrate concentration in the okra pods was significantly ($p \leq 0.05$) lowest (11.43 mg/kg fw) in the control pods (T1), while the okra pod produced with potassium nitrate (T3) had the highest nitrate concentration (15.64 mg/kg fw).

It was observed from the results that the nitrate concentration (12.53 mg/kg fw) of the fruits produced with organic manure (T2) was significantly ($p \leq 0.05$) lower than the nitrate concentration (13.57 mg/kg fw) in the okra pod fruits produced with the combined treatment (T4).

This higher nitrate recorded in the fruits produced with conventional and combined treatment, could be attributed to the nitrogen content of the treatment therapies. (Musa and Ogbadoyi, 2012; Akpokodje and Uguru, 2019) reported that soil nitrogen is one of the major factors that helped to elevate the nitrate content of the fruits and vegetables.

Furthermore, Boroujerdnia *et al*. (2007) reported that there is strong positive correlation between nitrogenous fertilizer/manure and nitrate accumulation in lettuce plant. The findings of this our investigations (Table 2) revealed that the nitrate concentration in the okra pods, regardless of the pre-harvest treatment, was below the maximum allowable limit of 2500 mg/kg approved by the WHO and FAO, for plants edible parts (Kirovska-Cigulevska, 2002).

Several researches and clinical studies (Bartsch et al., 1990; Prakasa Rao and Puttanna, 2000; Anjana *et al*., 2007) results had showed that nitrate toxicity includes: methaemoglobineamia, gastric cancer, stomach cancer etc.

Protein

The protein content of the fresh okra pods is presented in (Table 2). As shown by Table 2, the control okra pods had the lowest protein content (0.57%); while the okra pods produced with combined treatment had the highest protein content (0.97%).

Similarly, it was observed from the results that the protein content of the okra pods produced with organic manure was higher (0.86%), when compared to the okra pods produced with potassium nitrate (0.76%).

This result revealed that organic manure influences the protein content of the okra pods. Similar assentation was made by Aminifard *et al.* (2013), who stated that compost manure can facilitate protein synthesis and growth development in plants.

Asghari and Fard (2016) stated that organic manure caused a significant increment in the protein content of potato (*Solanum tuberosum* var. Agria).

Calcium

The findings of this study presented in (Table 2), revealed that treatment option had significantly ($p \leq 0.05$) influence the okra pod calcium concentration. Table 2 shows that okra pods treated with KNO_3 developed the highest calcium concentration (824.67 mg/kg fw); while the okra pods produced with control unit developed lowest calcium concentration (439.67 mg/kg fw). Additionally, the study revealed that the okra pod produced with combined treatment exhibited significant lower calcium concentration than the pods produced with pure inorganic treatment. The okra pods calcium concentration recorded in this study was higher, when compared to the pod concentration (2660 mg/kg fw) previously reported by Romdhane *et al*. (2020) for *Marsaouia* okra pods. This difference in the calcium concentration could be attributed to genetic, climatic conditions and planting conditions. According to Eboibi and Uguru (2017), climatic and soil conditions can significantly have altered the qualities of fruits and vegetables. Similarly, Baafi and Safo-Kantanka (2008) stated that the mechanical and biochemical properties of crops are highly dependent on the edaphic, bioctic and climatic condition of the location. The higher calcium concentration recorded in pods produced with inorganic and combined treatments (T3 and T4), could be attributed to the high potassium content in the treatment therapies. According to Rees *et al*. (2012), high potassium concentration in the soil helps in optimizing calcium assimilation in plants; hence increasing their calcium concentration and firmness. Similar results were reported by Peyvast et al. (2009), when calcium concentration of tomato (cv. Rada) fruits increases as the concentration of the potassium phosphate fertilizer increases. Similarly, Jifon and Lester (2009) in their investigation into the effect of pre-harvest treatment of muskmelon with foliar potassium fertilization observed that, potassium treatment therapy generally improved the calcium content in the muskmelon leaves and stem.

Copper

The copper concentration of the okra pods is presented in Table 2. It was observed from the results that irrespective of the treatment therapy, the copper concentration of the okra pods was higher than the value recorded in the control unit. The results revealed that apart from the control unit, the okra pods produced with organic treatment had lowest copper concentration (8.42 mg/kg fw), when compared to the okra pods produced with pure inorganic treatment and the combined treatment regime. As depicted by the results, the okra copper concentration (10.31 mg/kg fw) produced by the combined treatment was significantly (p ≤0.05) higher than the copper concentration (9.07 mg/kg fw) of the okra pod fruits produced with the single inorganic treatment. Similar result was reported by Romdhane *et al*. (2020) when the copper concentration of okra pods (cv. Marsaouia) was about 4.9 mg/kg fw. The difference observed between this study okra pods copper concentration and previous studies results could be attributed to the different okra cultivars, farming methods adopted and okra pod maturity stage.

Potassium

The result of the okra pods potassium concentration, as presented in Table 2, revealed that treatment option had significant effect on the okra pods potassium content. It was observed from the results of this study that the control okra pod had the lowest (2088.00 mg/kg fw) concentration. Regarding the treatment options, the results revealed that the okra pod produced with organic manure had the lowest potassium concentration (2816.67 mg/kg fw), while the okra pod produced with potassium nitrate had the highest potassium concentration (5546.00 mg/kg fw). Similar result was obtained by Islam *et al*. (2018) where tomatoes (cv. Unicorn) fruits pre-harvest treated with potassium nitrate recorded higher potassium content, when compared with other pre-harvest treatment options. Furthermore, when compared to the results of the okra pods produced with potassium nitrate, the findings of this study revealed that the okra pods produced with combined treatment therapy had lower potassium concentration (4693.00 mg/kg fw). According to the findings of this study, organic manure can cause a significant increase in the potassium content of plants' edible parts. This is consistent with a previous report by Belde et al. (2000), which stated that organic manure can cause a significant increase in soil organic matter, facilitating phosphorus, potassium, and nitrogen assimilation by plants from the soil. Results obtained from this study revealed that, the combination of organic manure and potassium nitrate fertilizer is the best pre-harvest treatment option of okra plant. Although the potassium, nitrate and calcium concentrations in the okra pods produced with the combined treatment were lower, when compared to the okra pods produced with potassium nitrate fertilizer. But the protein concentration of the okra pods produced with the combined treatment was higher, when compared to the okra pods produced with potassium nitrate fertilizer. Additionally, the lower concentration of nitrate in the okra pods produced with the combined treatment is an advantage, because high nitrate accumulation in plants edible parts is hazardous to human beings (Anjana *et al*., 2007). Protein has a wide range of functions in the body, which include enzymatic activity, transport of nutrients and other biochemical compounds across cellular membranes of the human body (Wu *et al*., 2014).

Conclusion

There is growing concern on the effect of soil amendment and pre-harvest treatment on the biochemical qualities of the edible parts of plants. This study was carried out to evaluate the effect of organic manure, potassium nitrate and their combination on some biochemical (nitrate, protein, copper, calcium and potassium) qualities of okra (cv. Clemson Spineless) fruits. Results obtained from the study indicated that pre-harvest treatment had significant effect on the biochemical qualities of the okra fruits. Generally, the okra pods produced under the control unit had the lowest biochemical qualities. In term of the treatment options, the results revealed that the okra pods produced with organic manure had the lowest nitrate, copper, calcium and potassium concentrations; while the okra pods produced with potassium nitrate fertilizer had the highest nitrate, calcium and potassium concentrations. Furthermore, the findings of this study revealed that the okra pods produced with combined treatment had the highest protein and copper concentrations. To conclude, the combined treatment is the better treatment option, when compared to the single treatment option, as the okra pod had the highest protein, copper and fairly low nitrate concentrations. This will help to minimize the accumulation nitrate, a poisonous compound at low concentration in edible okra pods.

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