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Mechanical Properties of Tomato (*Lycopersicon Esculentem* Mill) Fruits Produced Under Different Field Practices

Nyorere, O[a,c]*, Eje, B.E[b]. and Ugwu, K.C[b]

[a]Department of Agricultural Engineering, Delta State University of Science and Technology, Ozoro, Nigeria

[b]Department of Agricultural and Bioresources, Enugu State University of Science and Technology, Enugu, Nigeria

[c]PhD Student, Department of Agricultural and Bioresource Engineering, Enugu State University of Science and Technology, Enugu, Nigeria

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Abstract

Sustainable crop production plays an essential role in addressing food insecurity problem. This research was carried out to enhance the mechanical properties of tomato fruits through soil treatment, to reduce mechanical injuries during harvesting and handling operations. The tomato fruits were cultivated under three soil treatments, plot 1 "consisting of purely calcium-based organic manure", plot 2 "consisting of purely NPK 15:15:15 fertilizer, and plot 3 "consisting of mixture of 50% calcium-based organic manure and 50% NPK 15:15:15 fertilizer. Tomato fruits from these experimental plots were harvested manually at pink maturity stage, and their mechanical properties determined in accordance with ASABE standards. The results depicted that the treatment options had substantial effect on the rupture force and energy of the fruits. The fruits produced with the organic manure, fertilizer, and mixture of manure and NPK fertilizer had rupture energy of 869, 821 and 845 N.mm, respectively. Likewise, the fruits sampled from the plots treated with organic manure, fertilizer, and mixture of manure and NPK fertilizer recorded rupture force of 98.4, 90.3 and 95.7 N, respectively. The observation that fruits produced through organic farming recorded the maximum mechanical properties is an interesting finding that can have implications for agricultural practices and food quality.

1.0. Introduction

Tomato (*Lycopersicon esculentem* Mill) fruits are a rich source of essential nutrients, including vitamins A and C, potassium, and antioxidants, and played a vital role in a balanced diet and contribute to overall health and well-being. Tomato production is an essential part of agriculture in Nigeria. Tomatoes are a versatile and widely consumed vegetable, used in various culinary applications [1, 2]. Tomato cultivation in Nigeria often involves manual labor for planting, cultivating, and harvesting; which has effect on the yield and storability of the fruits. Poor harvesting and handling operations can lead to mechanical damage of the tomato fruits; hence, reducing their overall quality and quantity of the fruits [3 -5]. High temperatures, sunlight duration, soil fertility, soil condition and tomato cultivar are some of the critical factors that significantly impact tomato production and yield. Tomatoes are sunlight-dependent plants, and adequate period of sunlight is essential for photosynthesis. Inadequate sunlight can lead to retard growth, delayed flowering, and poor fruits yields [6, 7].

Harvesting time and plant variety are some of the important factors that influenced the engineering properties and nutritional qualities of crops. Timely harvesting helps ensures that crops are harvested at their peak maturity stage, which will help to reduce food waste through mechanical damage and crop spoilage [8, 9]. Crops harvested at peak maturity stage have ideal balance of flavor, texture, and nutritional content. Pre-mature and overripe crops are more susceptible to food wastage associated with injuries, lower consumers' preference and microbial growth. Prolonging the harvesting time of crops beyond their optimal maturity period can have several negative consequences, impacting both the engineering properties and nutritional qualities of the harvested produce [10]. Over-maturity is a major problem for fruits and vegetables destined for food processing, as the processing equipment and machines will encounter lower firmness and structural integrity of crops tissues; hence, reducing the efficiency of the machine and quality of the finished product [9, 11, 12].

Tomato fruit harvesting is a complicated and time-consuming task, which could be attributed to the delicate nature of the fruits and indeterminate growth. Mechanical fruit harvesting tends to reduce the stress involved with tomato harvesting, but it comes with some challenges which include mechanical injuries to the fruits [13,14]. To mitigate the problem of mechanical damages using fruits harvesting and handling operations, many researches had explored various methods to enhance the mechanical properties of fruits through field practices and post-harvest treatments [15-18]. Crop treatment is a critical aspect of food value chain, as appropriate crop treatment technique enhances the product quality and quantity. These treatments play various roles, some increase the fruit's nutritional values while others improve the mechanical characteristics of the fruits [19]. Though previous research outcomes have revealed that farming methods has positive effects on the engineering properties of fruits and vegetables, there is still information dearth on the effects of hybridized soil treatments on the mechanical properties of tomato fruits. Therefore, the goal of this research is to investigate the influence of combined soil treatments (organic manure and fertilizer) on the mechanical properties of tomato fruits. The information obtained from this study will contribute immensely to the improvement of agricultural practices and crop quality.

2.0 Materials and method

2.1 Study area

This study was conducted in Ozoro community of Delta State, Nigeria. The region has an average annual rainfall amount of 1800 mm, and temperature that ranged from 21^oC to 35^oC [20]. Warm temperature provides suitable environment for tomato cultivation. Soil samples from the study area were collected at a depth of 0 to 0.25 meters for analysis of physicochemical properties. The chemical compositions were analyzed following the procedures outlined in the ASTM standards, as detailed by Eboibi [21].

2.2 Planting materials and experimental plan

The calcium-based organic manure and NPK 15:15:15 fertilizer were obtained from the farm structure laboratory of the Department of Agricultural Engineering, Delta State University of Science and Technology, Ozoro, Nigeria.

The tomato seeds were nursed at the research center of the Delta State University of Science and Technology, Ozoro, Nigeria. After 28 days of germination, the healthy and well-established seedlings were carefully transplanted to the main experimental field. The field was divided into four plots, and each plot was subjected to the treatment plan shown in Table 1.

The treatments were carefully selected to represent various soil management strategies. Throughout the tomato growing period, systemic insecticide was exclusively applied as needed, with manual weed protection measures implemented as necessary. There was no disease outbreak during the experimental period. Sprinkler irrigation was used as the irrigation method, and the water for irrigation was borehole water.

Table 1: Treatment plans

Sample code	Soil amendment
Control	0%
Amend 1	100% Calcium-based organic manure
Amend 2	100% NPK 15:15:15 fertilizer
Amend 3	50% Calcium-based organic manure + NPK 15:15:15 fertilizer

2.3 Tomato fruits sampling

The tomato fruits were harvested at pink maturity stage to ensure consistency in the experimental results. Tomatoes harvested at the pink maturity stage have a longer shelf life compared to those harvested at a more advanced ripeness - light-red and red maturity stage. The color of a tomato is a key indicator of its maturity and ripeness. To standardize the classification of tomato maturity stages, various color codes and systems have been developed, and this fruit maturity followed these order: mature green, breaker, turning, pink, light-red and red. The United States Department of Agriculture has endorsed these color codes for categorizing tomato fruits according to their stages of ripeness.

After harvesting, the tomato fruits were carefully examined to identify and discard damaged or pest infested fruits. Then the remaining fruits were selected based on their uniformity of size and shape, while extremely large and small fruits were discarded during this selection process. In accordance with the guidelines set forth by the American Society of Agricultural and Biological Engineers (ASABE), a sample of twenty tomato fruits was chosen for each mechanical property test.

2.4 Mechanical analysis of the tomato fruits

The Universal Testing Machine “UTM” (Testometric model) was used to determine the mechanical properties of the tomato fruits. For each testing operation, each tomato fruit was positioned inside the compression chamber of the UTM, where the movable upper compression jaw steadily compressed the fruit at a consistent rate of 20 millimeters per minute. The compression process halted automatically upon reaching the rupture point. While undergoing compression, the UTM microprocessor monitors the force and deformation necessary for the tomato to reach both the bio-yield and rupture points. The data obtained from this process is then utilized to evaluate the mechanical properties of the tomato [22]. For each treatment, the compressive force test was replicated 20 times, and the average value was recorded.

2.5 Statistical evaluation

The results obtained from the laboratory tests were analyzed using the Microsoft Excel, to evaluate the impact of field treatment on the mechanical properties of tomato fruit.

3.0 Results and discussion

3.1. Physiochemical characterization of the soil

The results of the physiochemical analysis of the study soil are as presented in Table 2. It can be seen from the results that the soil was relatively neutral with pH of 7.15, indicating that the soil is neither too acidic nor too alkaline. Also, the chemical composition results revealed that the soil contains poor concentrations of essential nutrients, and higher concentrations of non-essential nutrients. These poor concentrations of macro nutrients could negatively affect the growth and development of the tomato plants, as plants required large amount of macro nutrients for their development [23, 24].

Table 2: The soil physiochemical properties

Parameter	Concentration
pH	7.15
Electrical conductivity	3.77 dS/m
Nitrogen	0.35%
Nitrate	10.33 mg/kg
Potassium	4611 mg/kg
Phosphorus	3735 mg/kg
Calcium	2094 mg/kg
Iron	4184 mg/kg
Sodium	2118 mg/kg

3.2 Rupture force

Figure 1 shows the rupture force of the tomato fruits harvested from the various treatment plans. It was noted that the rupture force of the fruits produced under the control, Amend 1, Amend 2 and Amend 3 programs developed rupture force of 80.1, 98.4, 90.3 and 95.7 N, respectively. This is an indication that the application of soil amendment had a positive effect on the fruits, as it enhances the resistance of the fruits to mechanical stress. It can be observed from the results that the fruits grown under organic conditions exhibited the highest resistance to rupture force, whereas those cultivated under the control plan had the lowest rupture force. This observation supports the idea that organic cultivation practices, likely including the use of soil amendments mentioned earlier, contribute to the mechanical strength and resilience of the fruit [21, 25]. Similar results were reported by Ekruyota [26] on the influence of farming practices (soil treatments) on the mechanical properties of tomato fruits.

According to Jahanbakhshi [27], tomato plants cultivated under organic soil amendment were able to produce fruits with better (high) mechanical attributes, when compare with the tomato fruits produced with soil amendment. Increase in fruit rupture resistance could be linked to the elevated soil fertility resulting from organic matter treatment, thus promoting the growth and development of the tomato fruits [28,29,34]. Rupture force is one of the essential parameters considered during the design and development of tomato handling and processing machines. Adequate knowledge of fruits rupture force helps in the optimization of the performance of tomato handling and processing equipment/machine. This helps to reduce the occurrence of mechanical damage; thereby reducing food waste and maximizing the final products quality [17].

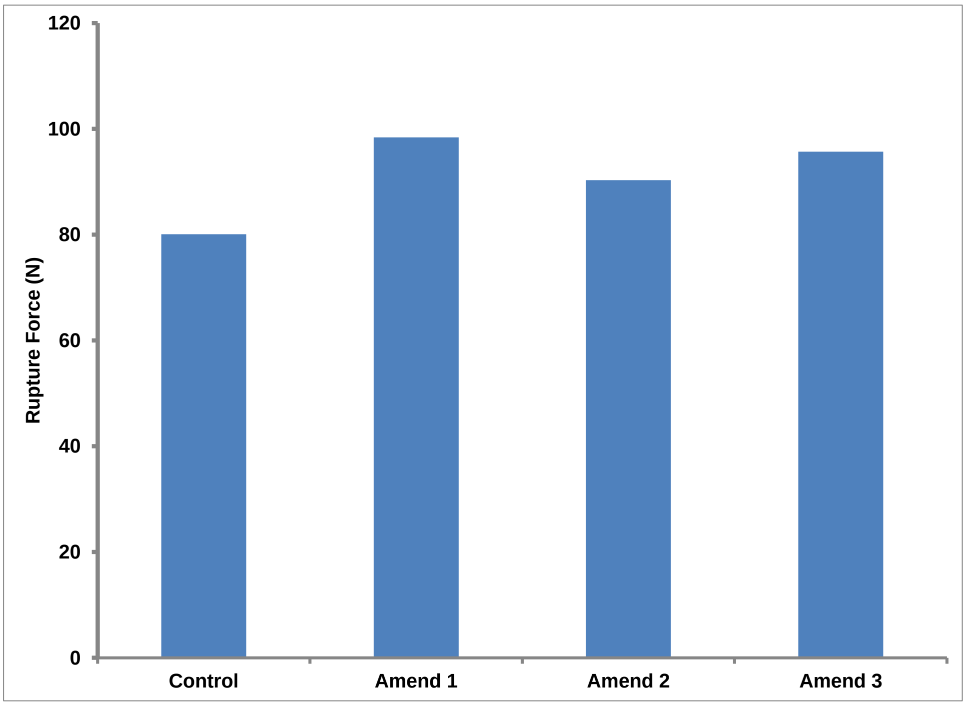

Figure 1: The rupture force of the tomato fruits

3.3 Rupture energy

The results of the rupture energy of the tomato fruits are presented in Figure 2. The findings indicated that the fruits sampled from the control, Amend 1, Amend 2 and Amend 3 treatment plans recorded rupture energy of 793, 869, 821 and 845 N.mm, respectively. This portrayed that the tomato fruits produced with organic manure were able to absorb more compression energy when compared to the fruits produced with inorganic fertilizer. This can be linked to their higher resistance characteristics of the organic fruits against mechanical damage [19]. Additionally, these findings aligned with previous reports of Jahanbakhshi [27] and Eboibi [21] on the impact of farming methods on the engineering properties of various tomato cultivars fruits.

This consistency in findings across different studies strengthens the evidence supporting the idea that farming practices have a significant impact on the mechanical characteristics of agricultural products. The enhancement noticed in the fruits produced with different soil treatments is beneficial to the development and performance of tomato fruits harvesting and handling machines, as it will minimize mechanical injures and improve the storability of the fruits. Fruit items having improved (higher) mechanical properties are less prone to mechanical injuries during harvesting and handling processes [30-33]. Agricultural products with enhanced mechanical behaviors are producers and consumers preference as they are less prone to mechanical damage. This reduces the occurrence of food wastage, leading to increase overall efficiency across the supply chain.

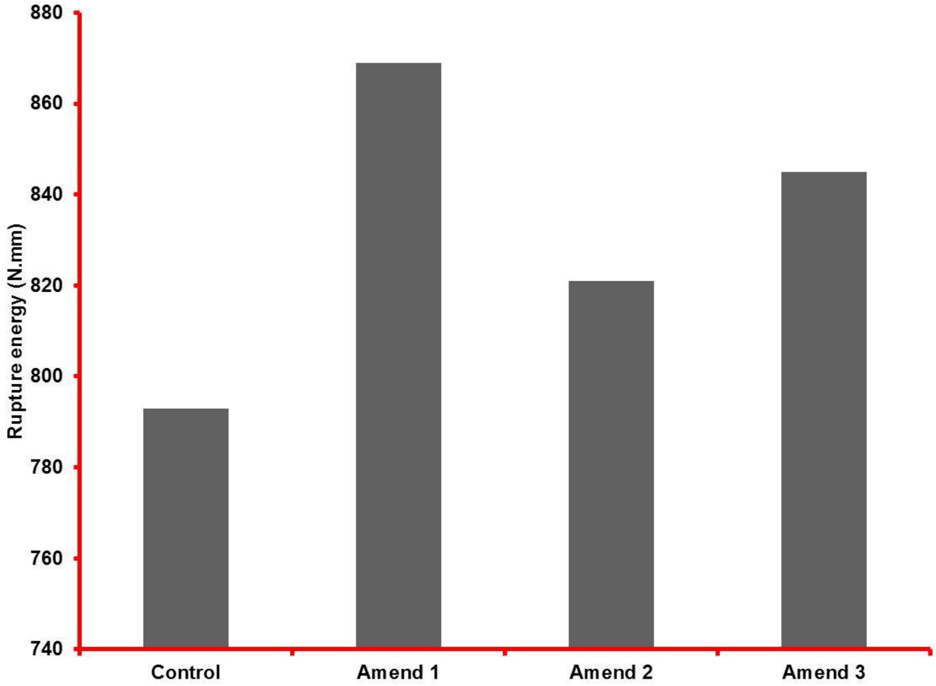

Figure 2: The tomato fruits rupture energy

4.0 Conclusion

This research was conducted to ascertain the impact of farming method on the mechanical properties of tomato fruits. The tomato was cultivated under organic, modified organic and convectional farming methods; and the mechanical parameters (rupture force and rupture energy) of the fruits were determined in harmony with ASABE procedures. The results revealed that farming method had significant effect on the rupture force and rupture energy of the tomato fruits, and fruits produced through the organic farming method recorded the maximum mechanical properties. The improvement observed in fruits resulting from various soil treatments is advantageous for the advancement and efficiency of harvesting and handling machines for tomatoes. This enhancement is expected to reduce mechanical injuries and enhance the storability of the fruits.

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