Direct Research Journal of Agriculture and Food Science (DRJAFS)
ISSN 2354-4147
Vol.7 (5), pp. 93-98, May 2019
DOI: https://doi.org/10.5281/zenodo.2671484
Article Number: DRJA70481932015

http://directresearchpublisher.org/journal/drjafs/
Research Paper

Compressive Behaviour of Cassava (*Manihot Esculentar*) Tuber under Static Quasi Compression Loading, as Influenced by Age and Variety

[*1]Nyorere, O., and [2]Iweka, C.

[1]Department of Agricultural and Bio-environmental Engineering Technology, Delta State Polytechnic, Ozoro, Nigeria.
[2]Department of Mechanical Engineering Technology, Delta State Polytechnic, Ozoro, Nigeria.
*Corresponding Author E-mail: nyoreref@gmail.com

Received 30 March 2019; Accepted 30 April, 2019

The influence of maturity age of cassava tubers on the mechanical compressive properties of TME 419, TMS 30001 and *Peter* cassava varieties was investigated in this research. The cassava tubers were harvested at two maturity stages (10 MAP and 15 MAP) from the research farm of the National Center for Agricultural Mechanization (NCAM), Ilorin, Kwara state, Nigeria. The compressive properties (failure force, compressive crushing force, failure energy and crushing energy) were determined using Universal Testing Machine (Testometric model). From the results, the maturity age and cassava variety had significant (P<0.05) effect on the compressive properties of the cassava tubers. The mechanical compressive crushing force and energy required to break the tubers of the three cassava varieties increases with an increase in maturation of the tubers. Likewise, the samples failure force and failure energy increased across the three cassava cultivars as maturity progresses from 10 MAP to 15 MAP. Thus, these compressive parameters must be given serious attention in the design and development of cassava harvesting and peeling machines.

Keywords: TME 419, TMS 30001, *Peter,* crushing force, failure force

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an imported staple crop widely cultivated in Nigeria, believed to originate from Brazil. There are several cassava varieties which are differentiated by their botanical characteristic and the level of hydrocyanic acid in their leaves and root, which are at times affected by environmental factors (soil type, farming method, rainfall, sunlight, temperature) (Ademosun *et al.*, 2012; Ilori *et al.*, 2017). Cassava tuber is rich in carbohydrate, but poor in protein and vitamins. The use of cassava root as bio fuel, feed feeds, and industrial starch production is increasing lately. Cassava root contains about 0.1–0.5% crude fat, 1–3% crude proteins, and 80 to 90% carbohydrate (Ferraro *et al.*, 2016). Carbohydrate content in cassava root is higher than in potato tuber, but less than in wheat, rice, yellow corn, and sorghum (Gil and Buitrago, 2002). According to FAO data, Nigeria is the highest cassava producer in the world. Nigeria (59.49 million tonnes), Democratic Republic of the Congo (31.6 million tonnes), Indonesia (19.05 million tonnes) and Brazil (18.88 million tonnes) which were the highest beans production countries, account for about 44 percent of the world's total production (292 million tonnes) in 2017 (FAOSTAT, 2019).

Cassava roots processing unit operation mainly consist of peeling, washing, grating, pressing, drying, milling, sieving and frying. Most of these arduous processing operations are still being done manually, even though they are labour intensive, time consuming and unsuitable for large scale production (Quaye *et al.*, 2009; Ilori *et al.*, 2017). Cassava root peeling, a vital processing operation, remains one of the un-mechanized processing operations, constitutes a serious challenge in cassava processing industries. Mechanization of cassava root processing operation is aimed at reducing drudgery, enhancing process efficiency and avoiding operation hazards associated with the traditional processing techniques (Quaye *et al*., 2009).

Mohsenin, (1986) defined damage as the failure of the product under excessive deformation when it is forced through fixed clearance or excessive force when it is subjected to impact. Mechanical damages in agricultural products are due to external forces under static or dynamic conditions or to internal forces. Damages due to internal forces can be the result of physical changes, such as variation in temperature and moisture content, or chemical and biological changes. Mechanical damages due to external forces are mechanical injuries in fruits and vegetables, grains, and so on. In terms of intact agricultural products, failure is usually manifested through a rupture in the internal or external cellular structure of the material. Injuries could be classified as postharvest mechanical injuries (bruises, cuts, and punctures), pre-harvest mechanical injuries (healed lesions caused by rub injury or pest attacks), physiological disorders (badly misshapen fruit, growth cracks, or cracking), pre-harvest diseases (rust and shot-hole), and postharvest diseases (rots, including brown rot) (Amorim *et al*., 2008). External appearance is the main quality aspect that each consumer is confronted with when buying food products (Nicolaï *et al*., 2009). Internal quality is important at the moment of product consumption. Apart from other characteristics, the absence of damage is one of the most important signs of quality of an agricultural product. Mechanical damages appear due to impacts and compressions produced during harvesting, transport, and manipulation processes. Damages can appear at the moment at which the impact or compression takes place, or later, during storage. These damages have a direct effect on loss of quality and reduce sale prices. Baritelle *et al*. (2001) proposed an equation to evaluate the relationship between impact bruising and commodity conditioning. This relationship would estimate bruise threshold as a function of commodity tissue impact properties, Poisson's ratio, and specimen mass and radius of curvature for impacts on a flat, rigid surface.

The knowledge of mechanical properties, such as stress, strain, hardness and compressive strength is vital to engineers handling agricultural products (Balami *et al*., 2012). Several researchers had studied the engineering properties of cassava root, including the design and fabrication of its processing machines/equipment. Egbeocha *et al*. (2016) reported that the most cassava peeling machines developed so far are faced with the problems of high root losses and average peeling efficiency, which can be attributed to the high variability of the root sizes and shapes. Olukunle and Jimoh, (2012) suggested that it is essential and to design and develop a good, efficient and time conserving cassava peeling machine with low tuber loss to reduce the energy expended in cassava peeling. Adejumo *et al*. (2011) in a review underscored the importance of detailed information such as root age and varieties, among other things, in the study of cassava starch quality as these are some of the major factors that greatly affect the quality of starch products. The age of root considerably influenced the starch granule size, granule structure, granule size distribution and hydration properties (Sriroth *et al*., 1999). Nwandikom, (1990) carried out an extensive work with some cultivars of yam in Nigeria, by using different mechanical techniques: impact load resistance, tissue fracture and compression of tuber tissue. Kolawole *et al*., (2007) researched into some strength and elastic properties of cassava tubers using TMS 4(2) 1425 cassava, and reported that the tensile stress of the tuber from 0.235 to 0.116 N/mm^2 as at the moisture content range from 50 to 70 (% wb).

From literature search, these varieties of commonly cultivated cassava (TMS 30001, TME 419 and *Peter*) in Nigeria have been less studied, compared to other fruits crops. Therefore, the objective of this study was to evaluate the influenced of age on the compressive behaviour of the above-mentioned cassava varieties.

MATERIALS AND METHODS

Samples collections and preparation

The fresh cassava tubers were harvested from the National Center for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria. Three popular cassava cultivars (TME 419, TMS 30001 and *Peter*) planted under organic farming were used for this research. The cassava tubers were harvested at two maturity stages, 10 months after planting (MAP) and 15 MAP. The tubers were washed to remove all soil and foreign materials adhering to them, before they were selected based on uniformity of size and shape. Based the selection criteria, the tubers length ranged between 297.7 and 350.4 mm, while the tuber middle diameter perimeters ranged between 120 and 133.8 mm.

Determination of the compressive properties

The quasi-static compression tests on the cassava tubers were performed with a Universal Testing Machine (Testometric model, series 500-532) equipped with a 500 N compression load cell and integrator, with measurement accuracy of 0.001 N. During the test, each cassava tuber was placed in the machine under the flat compression tool, ensuring that the centre of the loading cell was in position with the peak of the curvature of the cassava tuber. A compression loading rate of 20 mm/min was applied on the cassava tuber during the test. As the loading progressed, a load-deformation curve was plotted automatically by the machine in relation to the

Plate 1. Cassava Tuber undergoing quasi compressive test using Universal Testing Machine (Testometric model).

cassava tuber response to the compression up to the rupture point. At the end of compression, the following parameters were calculated by the micro-processor of the machine and displayed on the screen (Plate 1).

(i) Bioyield force
(ii) Bioyield energy
(iii) Crushing force
(iv) Crushing energy

Rupture point (also expressed as the crushing point) corresponds to the macrostructure failure of the cassava tuber, while bioyield point corresponds to the microstructure failure of the cassava tuber (Sahin and Sumnu, 2006; Steffe, 1996). The Bioyield point is equivalent to the failure point as stated by Steffe, (1996).

Experimental design and statistical analysis

The results gotten from this research will be subjected to analysis of variance (ANOVA) using the Statistical Package for Social Statistics (SPSS version 20). The means will then be separated using the Duncan's New Multiple Range at 95% significance level.

RESULTS AND DISCUSSION

Effect of cassava variety and age on failure force of the tubers

Cassava variety and age significantly influenced ($P < 0.05$) the failure force of the cassava tubers studied in this research, portraying that they had appreciable effects on failure force of the cassava tubers. (Figure 1) describes the relationship between failure force and maturity age for the three cassava varieties under quasi compressive loading. The plots show that failure force increased with increase in maturation for both cassava varieties; highest in TMS 30001 variety than the other two varieties. Similar results were reported by Ilori *et al*. (2017) and Kolawole *et al.* (2007) on various cassava varieties.

Effect of cassava variety and age on compressive crushing force of the tubers

The average compressive crushing force for the three cassava varieties increases from TME 419 to *Peter*, while TMS 30001 had the highest crushing force (Figure 2). This could be attributed to the different cellular structure of the three cassava varieties. Ilori and Adetan, (2013) reported the variations of average compressive crushing force for the two cassava varieties (TMS 30572 and TMS 4(2)1425), they established that the mean root radial compressive rupture force of cassava tubers increases significantly with tuber length and variety.

Effect of cassava variety and age on failure energy of the tubers

The cassava maturity age had significant ($P<0.05$) effect on the failure energy of the cassava tubers across the three cassava varieties. As shown in (Figure 3), the average failure energy of the cassava tubers increases from TME 419 to *Peter*, while TMS 30001 had the highest value. This can be attributed to the change of the bean textural and material structures as the cassava tuber matures. Longer photoperiods may also result in greater production of phtosynthates and to increase biomass, growth efficiency, duration of crop and yield per plant and thus mitigating source limitations. This tendency was probably due to the gradual change in the integrity of the cellular matrix (Gupta and Das, 2000).

Effect of cassava variety and age on the crushing energy of the tubers

The average compressive crushing energy for the three cassava varieties increases from TME 419 to *Peter*, while

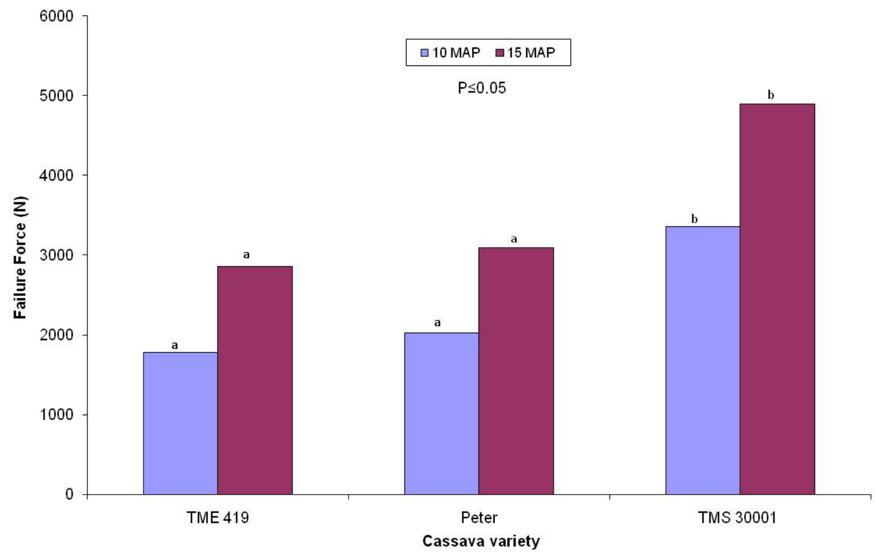

Figure 1. Effect of cassava variety and maturity age on the failure force of cassava tuber. Columns with the same common letter not significantly different (P < 0.05) according to Duncan's multiple ranges test.

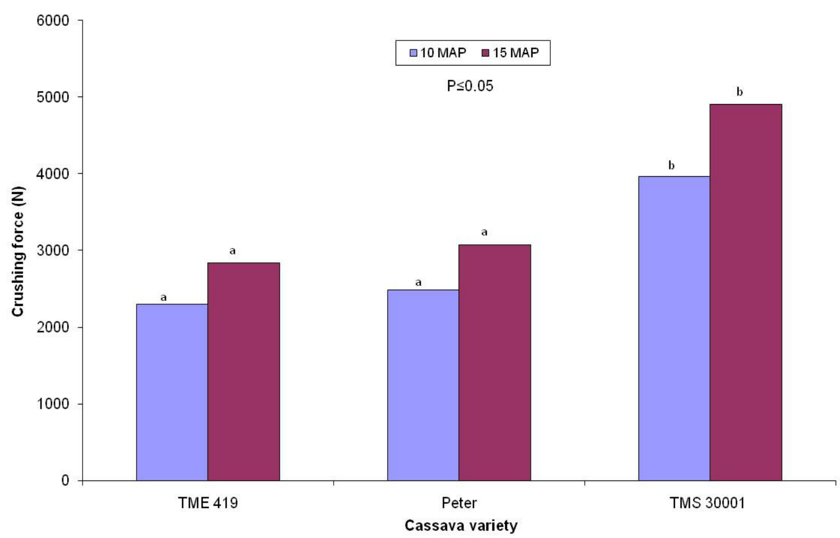

Figure 2. Effect of cassava variety and maturity age on the crushing force of cassava tuber. Columns with the same common letter not significantly different (P < 0.05) according to Duncan's multiple ranges test.

TMS 30001 had the highest crushing force (Figure 4). This could be attributed to the different cellular structure of the three cassava varieties during maturation. From the results, it can be seen that cassava tubers gradually attain viability and vigour during maturity, the increase in the crushing force of the tubers as maturation progresses reflects the accumulation of non-structural carbohydrates, reducing sugars and fibre. From the results, it was observed that all the seeds harvested earlier than 10 MAP required lesser crushing force and energy. Similar results were reported by Ilori *et al*., (2017) and Kolawole *et al*., (2007) on three various cassava varieties.

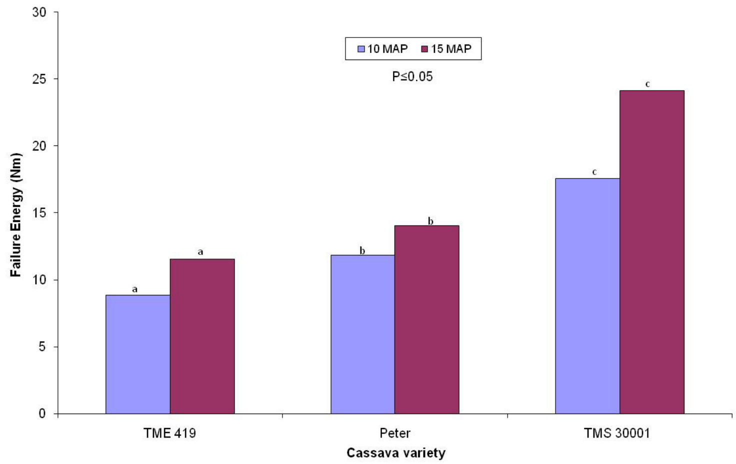

Figure 3. Effect of cassava variety and maturity age on the failure energy of cassava tuber. Columns with the same common letter not significantly different (P < 0.05) according to Duncan's multiple ranges test.

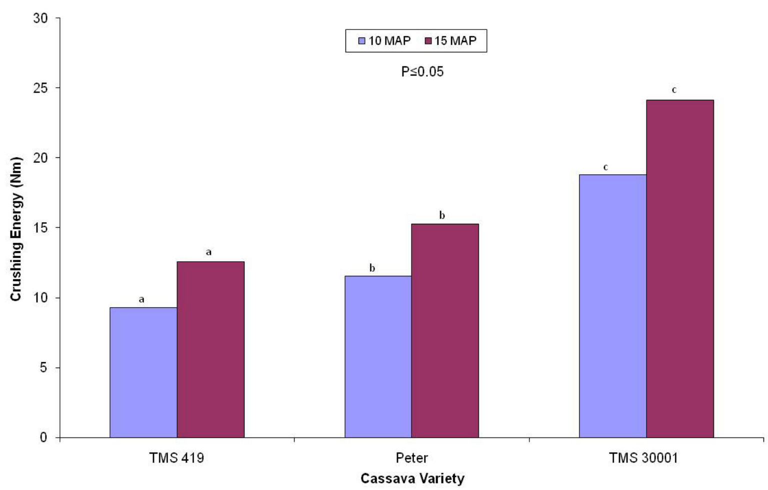

Figure 4. Effect of cassava variety and maturity age on the crushing energy of cassava tuber. Columns with the same common letter not significantly different (P < 0.05) according to Duncan's multiple ranges test.

The mechanical properties were failure, compressive crushing force, failure energy and compressive crushing energy, which are vital in the scientific design and development of processing, handling and processing equipment for cassava tubers.

Conclusions

This work focuses on effect of maturity age and cassava variety on some mechanical properties of three common cassava varieties grown in Nigeria. Based on the results of this research work, the following conclusions can be established:

(a) The age of cassava tuber is an important factor influencing the compressive parameters of cassava tuber and thus must be given a serious attention in the design and development of cassava processing, handling, packaging and transportation equipment.
(b) Crushing force and energy increased with increase in maturation of the cassava tubers in both cassava varieties.

(c) There was significant difference in the mechanical properties between the three cassava varieties tubers.

Authors` Declaration

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

REFERENCES

Adejumo AO, Oradugba OB, Ilori TA, Adenekan MO (2011). Development and evaluation of a cassava chipping machine. *Journal of Engineering and Applied Sciences*, 3: 43-51.

Ademosun OC, Jimoh MO, Olukunle OJ (2012). Effect of physical and mechanical properties of cassava tubers on the performance of an automated peeling machine. International Journal of Development and Sustainability, 1(3):810-822.

Amorim L, Martins M, Lourenço SA, Gutierrez ASD, Abreu FM, Gonçalves FP (2008). Stone fruit injuries and damage at the wholesale market of São Paulo, Brazil. *Postharvest Biology and Technology* 47: 353–357.

Balami AA, Adebayo SE, Adetoye EY (2012). Determination of some engineering properties of sweet potato (*Ipomoea batatas*). *Asian Journal of Natural and Applied Sciences*. 1(1):67 – 77.

Egbeocha CC, Asoegwu SN, Okereke NAA (2016). A review on performance of cassava peeling machines in Nigeria, *Futo Journal Series (FUTOJNLS)*, 2(1):140-168.

Baritelle A, Hyde GM, Fellman JK, Varith J (2001). Using 1-MCP to inhibit the influence of ripening on impact properties of pear and apple tissue. *Postharvest Biol. Technol.* 23: 153–160.

FAO FAOSTAT database. (2019). World Cassava production. Available at: http://www.fao.org/faostat/en/#data/QC

Ferraro V, Piccirillo C, Tomlins K, Pintado ME (2016). Cassava (*Manihot esculenta* Crantz) and yam (*Dioscorea* spp.) crops and their derived foodstuffs: safety, security and nutritional value. *Critical Reviews in Food Science and Nutrition*, 56(16):2714-2727, DOI: 10.1080/10408398.2014.922045.

Gil JL, Buitrago AJA (2002). *La yuca en la alimentacion animal.* In: B. Ospina, H. Ceballos, Eds., La Yuca en el Tercer Milenio: Sistemas Modernos de Produccion, Procesamiento, Utilizacion y Comercialización, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia: 527-569.

Gupta RK, Das SK (2000). Fracture resistance of sunflower seed and kernel to compressive loading. *Journal of Food Engineering* 46 (1): 1–8.

Ilori OO, Adetan DA, Soji-Adekunle A, Ojo OO, Adeleke KM, Towoju OO (2017). Influence of some physical properties of cassava tubers on mechanical compressive cracking force of TMS 30572 and TMS 4(2)1425 cassava varieties. *American Journal of Food Science and Technology*, 5(6):233-237.

Ilori OO, Adetan DA (2013). A study of the radial compressive cracking force of two cassava varieties. *Journal of Food Science and Engineering*, 3:541-549.

Kolawole OP, Agbetoye LAS, Ogunlowo AS (2007). Strength and elastic properties of cassava tuber. *International Journal of Food Engineering*, 3 (5): 1 – 10.

Mohsenin N N (1986). Physical properties of plant and animal materials. New York: Gordon and Breach Publishers.

Nicolaï BM, Bulens I, De Baerdemaeker J, De Ketelaere B, Hertog ML, Verboven P, Lammertyn J (2009). *Non-destructive evaluation: Detection of external and internal attributes frequently associated with quality and damage.* In Postharvest handling: A systems approach, ed. Robert L. Shewfelt and Stanley E. Prussia. Oxford: Academic Press.

Nwandikom G I (1990). Yam tuber resistance to mechanical damage. *Agricultural Mechanization in Asia, Africa and Latin America,* 21: 33 -36.

Olukunle OJ, Jimoh MO (2012).Comparative analysis and performance evaluation of three cassava peeling machines. *International Research Journal of Engineering Science, Technology and Innovation (IRJESTI),* 1(4):94-102.

Quaye W, Gayin J, Yawson I, Plahar WA (2009). Characteristics of various cassava processing methods and the adoption requirements in Ghana. *Journal of Root Crops*, 35(1):59-68.

Sahin S, Sumnu G (2006). *Physical properties of foods,* Springer Science + Business Media, LLC., New York, p.258.

Sriroth K, Santisopasri V, Petchalanuwat C, Piyachomkwan K, Kurotjanawon K, Oates C (1999). Cassava starch granule structure- functional properties: influence of time and condition at harvest on four varieties of cassava starch. *Carbohydrate Polymers*, 38 (2): 161 – 170.

Steffe JF (1996). *Rheological Methods in Food Process Engineering*. (Second Edition). Freeman Press, USA. 1996, 72-90.