American Journal of Food Science and Technology, 2017, Vol. 5, No. 6, 233-237
Available online at http://pubs.sciepub.com/ajfst/5/6/2

DOI:10.12691/ajfst-5-6-2

Influence of Some Physical Properties of Cassava Tubers on Mechanical Compressive Cracking force of TMS 30572 and TMS 4(2)1425 Cassava Varieties

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Abstract The influence of some physical properties of cassava tubers on the mechanical compressive cracking force of TMS 30572 and TMS 4(2)1425 cassava varieties were investigated. 1200 tubers were freshly harvested from the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria. Each of the cassava cultivars was about 1.5 years old. The tubers were cleaned and sliced into different lengths ranging from 25 – 150 mm in steps of 25 mm. Slices of a particular length were sorted into 8 diameter groups: 21 – 30, 31 – 40, 41 – 50, 51 – 60, 61 – 70, 71 – 80, 81 – 90, and 91 – 100 mm, for each variety. The compressive cracking force of the sliced tubers was determined using an adapted Tensometer. The mechanical compressive cracking force required to break the tubers of the two cassava varieties (TMS 30572 and TMS 4(2)1425) increases with increase in length and peel thickness of tubers while it decreases with increase in diameter of tubers. Thus, these physical properties must be given a serious attention in the design and development of cassava peeling machine.

Keywords: *cassava varieties (TMS 30572 and TMS 4(2)1425), compressive cracking force, lengths of tubers, diameters and peel thickness of tubers*

Cite This Article: Ilori Olutosin O., Adetan Dare A., Soji-Adekunle Ayowumi R., Ojo Oluwaseun O., Adeleke Kehinde M., and Towoju Olumide O., "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*, vol. 5, no. 6 (2017): 233-237. doi: 10.12691/ajfst-5-6-2.

1. Introduction

Cassava (*Manihot esculenta Crantz*) is gaining wider acceptance and adoption as wonder crop by the day particularly in developing economies of the world. Nigeria is reported to be the highest producer of the crop in the world with production level estimated at 49 million tons per year [1]. Cassava has been primarily produced for food as it is consumed on daily basis, its importance as a major cheap source of calorie intake for both human and livestock in many tropical countries has been widely acknowledged. It is mostly processed traditionally into *gari, lafun, fufu, abacha* and *akpu* in Nigeria, *kokonte* and *agbelima* in Ghana [2] while the sweet varieties are boiled and pounded into dough and consumed with vegetable soup. There are many varieties of cassava in the world today which are differentiated from one another by their botanical characteristic and the level of hydrocyanic acid that causes toxicity in the root. This toxicity vary from place to place (a bitter variety may become sweet or vice versa). This is as a result of environmental factors such as soil type, soil moisture, soil fertility, tillage practice and vegetation of the farm [3,4]. Soil factors also influence shape and size of the tuber which constitutes major bottleneck in cassava peeling [5].

Cassava processing operation consist of peeling, grating, washing, drying, milling, pressing, sieving, frying and pulverizing. Virtually all of these operations are still being done manually and are usually labour intensive, arduous in nature, time consuming and unsuitable for large scale production [2,6] due to their low output capacity among other negative attributes. Cassava processing operations are mostly preceded by peeling which makes a very important operation. Peeling operation remains the most important un-mechanized process which has constituted a serious global challenge in food industries. This has invariably slow down medium-large scale utilization of the crop.

However, there is no efficient cassava peeler presently in the market [6,7,8,9]. [10] reported that the peeling machines developed to date face problems of high tuber losses and moderate peeling efficiency which means that the peel is not removed accurately or totally due to the high variability of the root sizes and its thickness. Also, efforts at mechanizing the peeling operation has been acknowledged but not to be fully developed yet [11]. This has been attributed to the irregularity in the shape of the tubers as well as the wide variations in the thickness of the peel, tuber size and dimension across the different varieties of the crop [12,13]. Hence, this study examined the influence of some physical properties of cassava tubers on the mechanical compressive cracking force of two cassava varieties.

2. Materials and Method

Fresh cassava tubers were harvested from the teaching and research farm of the Obafemi Awolowo University, Ile-Ife, Nigeria. They were commonly grown cassava cultivars (TMS 30572 and TMS 4(2)1425) and were about 1.5 years (18 months) old at the time of harvest. The tubers were made ready for the test by washing off all the soil particles adhering to them. The moisture content of the two varieties was determined and was found to be about seventy-four per cent (74%) before the experiment was carried out. The tubers were sliced through the transverse section into different lengths ranging from 25 mm to 150 mm in steps of 25 mm. For each cassava variety, the tuber slices of a particular length were sorted into eight (8) diameter groups: 21 – 30, 31 – 40, 41 – 50, 51 – 60, 61 – 70, 71 – 80, 81 – 90 and 91 – 100 mm. The diameter of each specimen was measured using a pair of vernier caliper. A tape measure was used to measure the lengths of tubers. Also, the peel thickness was determined using a micrometer screw gauge.

An adapted Tensometer was used to measure the resistance of the tubers to breakage by compression. Each of the tuber slices was inserted in the holding device as shown in Figure 1, mechanical load was then applied by a gear driven screw pressing the holding device into the specimen. This was done till the specimen made internal cracking sound (Figure 2); the compressive cracking force was noted at the point the specimen made the cracking sound. The speed at which the compressive load was applied was low that it could be taken as a static load [14,15]. This test was conducted on the two varieties of 8 diameter groups under each of which we have 7 different samples.

2.1. Model Specification

The mechanical compressive cracking force output (F_c) of the cassava tubers was assumed to be a function of three (3) independent variables, namely; length of tubers, diameters of tubers and peel thickness of tubers. A model was therefore specified mathematically as follows;

$$F_c = f\left(L, d_t, t_p\right) \quad (1)$$

where:
F_c = Compressive cracking force
L = Length of tubers
d_t = Diameter of tubers
t_p = Peel thickness of tubers

The impacts of the explanatory variables on mechanical compressive cracking force outputs were estimated using linear functional relationship between one dependent and three independent variables as shown below:

$$F_c = a_o + b_1 L + b_2 d_t + b_3 t_p. \quad (2)$$

where:
a_o = Constant term/ intercept
b_i = Regression coefficients of the variables (where i = 1,2,3)
L, d_t, t_p = Independent variables.

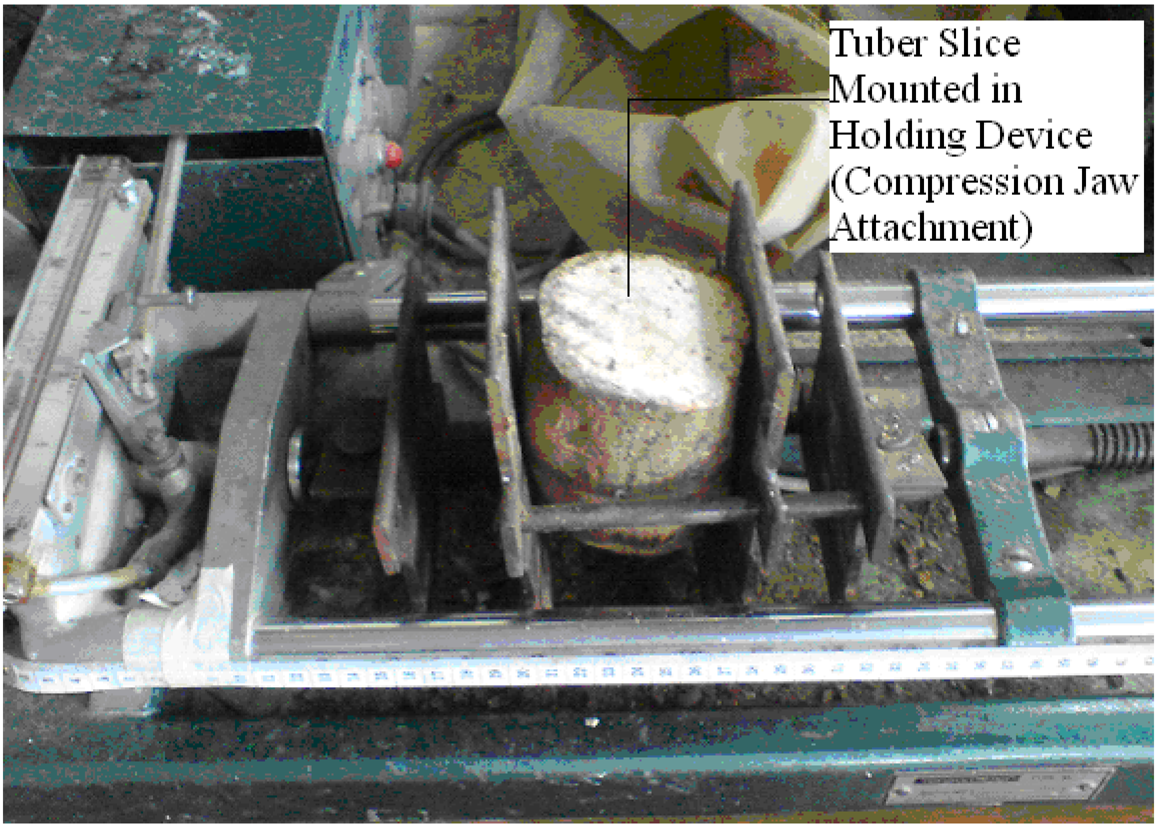

Figure 1. Length of tuber slice inserted in the holding device of the adapted Tensometer

Figure 2. The point of breakage of a certain tuber slice

2.2. Data Analysis

A multiple regression analysis was used to establish a linear functional relationship between mechanical compressive cracking force and the physical properties of cassava tuber considered.

3. Results and Discussion

Table 1 and Table 2 display the average results obtained during the experiment for the two cassava varieties TMS 30572 and TMS 4(2)1425. These results were further analysed using a linear multiple regression to examine the influence of each of the physical properties on mechanical compressive cracking force for both varieties. The linear multiple regression analysis on the values of F_c, L, d_t and t_p provided the following relationship among them for TMS 30572 cassava variety (Table 3):

$$F_c = 12.08L - 20.57d_t + 106.13t_p + 789.72 \tag{3}$$

where F_c in (N) is the compressive cracking force, L in (mm) is the length of tubers, d_t in (mm) is the diameter of tuber and t_p in (mm) is the peel thickness. The correlation coefficient (r) value is 0.9970 and the coefficient of determination (r^2) value is 0.9940 (Table 4). This shows that 99.40% of the compressive force at the stated condition is explained by the relationship. A test of significance of correlation shows that this linear relationship is significant at 0.05 significance level. Thus, F_c increases with increase in L and t_p while it decreases as d_t decreases. Therefore, the value of compressive breaking force can be predicted using eqn (3) for a given length of tuber, diameter and peel thickness with 99.40% confidence level.

Table 1. Average Values of Physical Properties and Compressive Cracking Force for TMS 30572

Length of tuber L (mm)	Average diameter of tuber D_m (mm)	Average peel thickness t_p (mm)	Average compressive cracking force F_c (N)
25	44.0	2.76	505
50	49.0	3.00	654
75	55.0	3.42	975
100	59.0	3.98	1164
125	62.0	4.34	1499
150	65.0	4.72	1770

Table 2. Average Values of Physical Properties and Compressive Cracking Force for TMS 4(2)1425

Length of tuber L (mm)	Average diameter of tuber D_m (mm)	Average peel thickness t_p (mm)	Average compressive cracking force F_c (N)
25	41	2.20	505
50	45	2.69	618
75	48	2.97	926
100	53	3.55	1235
125	58	3.80	1350
150	62	4.29	1722

Table 3. Regression Analysis for TMS 30572 (Coefficients)

Model	Beta (B)	Standard error	T
(Constant)	789.72	1445.34	0.546
Length of tuber	12.08	8.19	1.475
Diameter of tuber	-20.57	24.54	-0.838
Peel thickness of tuber	106.13	383.52	0.277

a. Dependent variable: Compressive cracking force

Table 4. Regression Analysis for TMS 30572 (Model Summary)

R	R Square	Adjusted R square	Standard error of the estimate	F Change	Significance F change
0.997[a]	0.994	0.984	61.065	104.866	0.009

b. Predictors: (Constant), Length of tuber, Diameter of tuber and Peel thickness of tuber.

Table 5. Regression Analysis for TMS 4(2)1425 (Coefficients)

Model	Beta (B)	Standard error	T
(Constant)	216.41	2800.11	0.077
Length of tuber	7.66	15.43	0.496
Diameter of tuber	-14.60	74.26	-0.197
Peel thickness of tuber	283.06	637.40	0.444

a. Dependent variable: Compressive cracking force.

Table 6. Regression Analysis for TMS 4(2)1425 (Model Summary)

R	R Square	Adjusted R square	Standard error of the estimate	F Change	Significance F change
0.991a	0.983	0.958	95.424	38.660	0.025

b. Predictors: (Constant), Length of tuber, Diameter of tuber and Peel thickness of tuber.

Also, for TMS 4(2)1425 cassava variety, the multiple regression analysis on F_c, L, d_t and t_p gave the following relationship among them (Table 5):

$$F_c = 7.66L - 14.60d_t + 283.06t_p + 216.41 \quad (4)$$

where F_c , L, d_t and t_p are as previously defined. The correlation coefficient (r) value is 0.9910 and the coefficient of determination (r^2) value is 0.9830 (Table 6). This shows that 98.30% of the compressive force at the stated condition is explained by the relationship. A test of significance of correlation shows that this linear relationship is significant at 0.05 significance level. Thus, F_c also increases with increase in L and t_p while it decreases as d_t decreases for TMS 4(2)1425. We can also predict the value of compressive force using eqn (4) for a given length of tuber, diameter and peel thickness with 98.90% confidence level.

3.1. Effect of Length of Cassava Tubers on Compressive Cracking Force

The average compressive cracking force for TMS 30572 ranges from 505 N for length of tuber 25 mm to 1770 N for the 150 mm tuber slice. Also for TMS 4(2)1425, F_c ranges from 505 N for length of tuber 25 mm to 1772 N for the 150 mm tuber slice. This implies that as the length of tuber slices increases, the average root breaking compressive force for the varieties (TMS 30572 and TMS 4(2)1425) also increases. This is justified by equations 3 and 4; a unit increase in the length of tuber increases the compressive cracking force for both varieties by 12.08 and 7.66 units respectively. Ilori and Adetan [15] reported the variations of average compressive cracking force (F_c) with the lengths of tuber for the two cassava varieties and established that the mean root radial compressive cracking force of cassava tubers increases significantly with tuber length. The F_c for TMS 30572 is slightly higher than the F_c for TMS 4(2)1425 at most lengths of tubers possibly because TMS 30572 has tougher starchy flesh covered by tuber peel than tuber samples for TMS 4(2)1425.

3.2. Effect of Diameter of Tuber on Compressive Cracking Force

The changes in average compressive cracking force (F_c) at different levels of average diameter of tuber (d_t) for TMS 30572 and TMS 4(2)1425 are shown (Table 1 and Table 2). The linear multiple regression analysis shows that the diameter of tuber slices for both varieties have negative impact on compressive cracking force, which is significant. A unit increase in diameter of tubers for both varieties decreases the compressive cracking force by -20.57 and -14.60 units respectively. This means that the compressive force required to crack the sliced tuber decreases as the diameter of tuber increases. This validated the report by [15] that cracking force drops as the diameter of tuber increases because some of the big diameter roots are so matured that naturally before harvesting them, they had already developed inner central cracks which served as easy crack initiation points. But differed with the report of earlier works that establish the cassava root strength properties generally increase with increase in tuber diameter because tubers increase in diameter and fibre content with age of plants [6,11] and also, that it may be due to the fact that growth and development of the root are a function of climatic conditions and type of soil [16,17].

3.3. Effect of Peel Thickness of Cassava Tubers on Compressive Cracking Force

The average peel thickness (t_p) ranges from 2.76 mm to 4.72 mm and 2.20 mm to 4.29 mm for TMS 30572 and TMS 4(2)1425 respectively. The t_p for both varieties are within the range reported by [18]. Although t_p in this work are slightly higher than the ones they reported, even though the TMS 30572 cassava variety (18 months old) was one of the three varieties used in their experiments. The beta coefficients of peel thickness for the two varieties in equations 3 and 4 indicate that a unit increase in t_p increases the compressive cracking force by 106.13 and 283.06 units. The compressive cracking force was more sensitive to changes in peel thickness among the three physical properties considered. Thus, the compressive force to crack the sliced tuber increases tremendously as the peel thickness increases. This implies that the peel thickness increased with the age of the tubers just like the diameter and length of tubers [18].

4. Conclusion

The study has established that the length of cassava tubers, diameter of tubers and peel thickness have significant effect on the mechanical compressive cracking force for TMS 30572 and TMS 4(2)1425 cassava varieties considered. The mechanical compressive cracking force increases with increase in length and peel thickness of tubers while it decreases with increase in diameter of tubers. Thus, these physical properties must be given a serious attention in the design and development of efficient cassava peeling machine.

Statement of Competing Interests

The authors have no competing interests.

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