Time and Moisture Dependent Mechanical Properties of Freshly Harvested Cassava (*Manihot esculenta*) Tubers

Jaiyeoba, Kehinde F.[1], Fadele, N. T.[2], Adegbokan, O. B.[2], Aremu, David O.[2], and Ogunlade, Clement A.[3]

[1.] Department of Agricultural Engineering, Adeleke University, Ede, Osun State. Nigeria
[2.] Department of Agricultural Engineering, Federal College of Agriculture, Moor Plantation, Ibadan, Nigeria.
jaiyeoba_k2007@yahoo.com

Abstract: Cassava is extensively cultivated as annual crop in tropical and subtropical regions for its edible starchy tuberous root, it is a major source of carbohydrates. It pounds food security during conflicts when the invader cannot easily destroy or remove the crop, since it conveniently grows underground. The objective of the project was to determine the mechanical properties of freshly harvested cassava tubers as affected by time and moisture content. The mechanical properties determined using Universal testing machine include tensile strength, compressive strength, compressive load at maximum compressive stress and thickness all determined at an interval of three days and duration of five times for 4 locally grown cassava tubers (*odogbo, ita, idileru and oko iyawo*) in Nigeria. Result showed that there was significant different in the level of moisture, time duration and varieties of the freshly harvested cassava at 5% probability level using Duncan Multiple Range Test. *Idileru* variety has the highest percent moisture content at the fifth week (77.74a) while *Odogbo* variety has the highest compressive strain at maximum compressive 1.60a.

[Jaiyeoba, K. F., Fadele, N. T., Adegbokan, O. B., Aremu, D. O., Ogunlade, C. A. **Time and Moisture Dependent Mechanical Properties of Freshly Harvested Cassava (*Manihot esculenta*) Tubers.** *N Y Sci J* 2016;9(11):79-84]. ISSN 1554-0200 (print); ISSN 2375-723X (online). http://www.sciencepub.net/newyork. 12. doi:10.7537/marsnys091116.12.

Keywords: Cassava tubers, time, moisture content, variety, mechanical properties

1. Introduction

Cassava *(Manihot esculenta)* is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, it a major source of carbohydrate. A transverse section of the tuber shows that it consists of central core called the pith which is surrounded by the starchy flesh that forms the bulk of the tuber and constitutes the main storage region. It is white or cream in colour and surrounded by a thin cambium layer. Covering the cambium layer is the tuber peel which consists of a corky periderm on the outside which is dark in colour and can be removed by brushing in water as it is being done in the washers of large factories. The inner pat of the peel contains the cortex. The cortical region is usually white in colour (Adetan *et al., 2003*). Cassava roots are very rich in starch and contain significant amounts of calcium (50 mg/100g), phosphorus (40 mg/100g) and vitamin C (25 mg/100g). However, they are poor in protein and other nutrients, the leaves are good sources of protein (rich in lysine) but deficient in the amino acid. World production of cassava root was estimated to be 184 million tonnes in 2002, rising to 230 million tonnes in 2008 (FAO, 2011). The majority of production in 2002 was in Africa, where 99.1 million tonnes were grown; 51.5 million tonnes were grown in Asia; and 33.2 million tonnes in Latin America and the Caribbean. Nigeria is the world's largest producer of cassava. However, based on the statistics from the FAO of the United Nations, Thailand is the largest exporting country of dried cassava, with a total of 77% of third highest yield of carbohydrates per cultivated area among crop plants, after sugarcane and sugar beets. Cassava plays a particularly important role in agriculture in developing countries, especially in sub-Saharan Africa, because it does well on poor soils and with low rainfall, and because it is a perennial that can be harvested as required. Its wide harvesting window allows it to act as a famine reserve and is invaluable in managing labor schedules. It offers flexibility to resource-poor world export in 2005. The second largest exporting country is Vietnam, with 13.6%, followed by Indonesia (5.8%) and Costa Rica (2.1%).

In 2010, the average yield of cassava crops worldwide was 12.5 tonnes per hectare. The most productive cassava farms in the world were in India, with a nationwide average yield of 34.8 tonnes per hectare in 2010. Cassava, yams *(Dioscorea spp.*) and sweet potatoes (*Ipomoea batatas*) are important sources of food in the tropics. The cassava plant gives the farmers income because it serves as either subsistence or a cash crop (Stone, 2012). Starch is a polysaccharide composed by the amylose, a linear or sparsely branched polymer, and the amylopectin, a highly branched Polymer (Mali *et al.,* 2005, Fama *et al.,* 2005). This biopolymer could be interesting in the edible film technology because it is produced abundantly around the world, and it could be considered as inexpensive. An important starch source is cassava, which is a tropical root crop. Cassava starch is able to form transparent coatings (Vicentini and Cereda, 1999) and flexible films (Vicentini *et al.,* 2005) without any previous chemical treatment, neither plasticizer addition. However, for the production of edible films with good workability, a plasticizer such as the glycerol is usually used. The plasticizer modifies the interactions between the macromolecules, resulting in an increase in the chains mobility and consequently, causing a reduction in the glass transition temperature of the system.

A property may be a constant or may be a function of one or more independent variables, such as temperature. Materials properties often vary to some degree according to the direction in the material in which they are measured (Degermo *et al.,* 2003), a condition referred to as anisotropy. Materials property that relate two different physical phenomena often behave linearly (or approximately so) in a given operating range, and may then be modeled as a constant for that range. Some materials are used in relevant equations to predict the attributes of a system. Materials properties are most reliably measured by standardized test methods. We have many properties which acoustical, atomic chemical, electrical, environmental, magnetic, mechanical, optical, thermal properties and so on. Freshly harvested cassava tubers are susceptible to a lot of damage during processing and to reduce these damages, handling of freshly harvested cassava tubers must be minimized. This can be achieved by determining the mechanical properties of the tubers especially when freshly harvested. Mechanical properties like bending, elongation and tensile strength will help in the design of processing machines and handling equipment. Thus, the main objective of this study was to determine the effect of time on some mechanical properties of different varieties of freshly cassava tubers.

2. Material and Methods

Materials used for the study include ruler, weighing balance, mortar, pestle, oven, desiccators and Universal testing machine.

Sampling and Experimentation: four locally grown varieties of cassava tubers were identified and selected, they are *Idileru, Oko-iyawo, Ita, Odogbo.* One sample from each of the varieties of cassava was peeled and cut into 3cm through the same orientation on the Instron testing machine. Mechanical properties determined include impact, thickness, compressive strain, and compressive load at maximum compressive stress. Samples were tested at every three day interval to represent one week each, all experiments were carried out thrice and average values were recorded.

Moisture Content Determination: samples from each of the varieties were crushed with mortar and pestle and weighed. The samples were placed in cans and in the oven at *100*^{0}□ 100^{0}C to dry to a constant weight of 24hours.

Statistical Methods for Analysis: Analysis of variance (ANOVA) of two factors Completely Randomized Design (CRD) was used to evaluate the effect and significance of each level of each duration on the mechanical properties 95% confidence level.

3. Results

The results of the mechanical analysis and the moisture content of the freshly harvested cassava tubers for five times and 3 days interval are shown in Table 1:

Cassava variety A (*Idileru*) has the highest moisture content of 77%, variety B (*Odogbo*) has the highest maximum compressive stress of 1.59826MPa, the Compressive strain at Maximum Compressive stress of 0.31210 mm/mm and also has the highest Compressive load at Maximum Compressive stress of 479.44870N at the first week of harvest. Second week result shows that cassava variety C (*Ita*) has the highest moisture content of 71.3%, variety B (*Odogbo*) has the highest maximum compressive stress of 1.59826MPa, the Compressive strain at Maximum Compressive stress of 0.31210mm/mm and also has the highest Compressive load at Maximum Compressive stress of 479.44870N also, the third week analysis shows that cassava variety A (*Idileru*) has the highest moisture content of 72.5%, variety D (*Oko-Iyawo*) has the highest maximum compressive stress of 0.95178MPa, the highest Compressive load at Maximum Compressive stress of 285.51754N, while variety C (*Odogbo*) has the highest Compressive strain at Maximum Compressive stress of 0.36746mm/mm. After the fourth week, cassava variety A (*Idileru*) has the highest moisture content of 73.3%, variety D (*Oko-Iyawo*) has the highest maximum compressive stress of1.38067MPa, the highest Compressive load at Maximum Compressive stress of 414.17663N, the highest Compressive strain at Maximum Compressive stress of 0.30088mm/mm and the fifth week analysis shows that cassava variety A (*Idileru*) has the highest moisture content of 74.7%, variety D (*Oko-Iyawo*) has the highest maximum compressive stress of0.57507MPa, the highest Compressive load at Maximum Compressive stress of 172.51158N, while variety B (*Odogbo*) has the highest Compressive strain at Maximum Compressive stress of 0.19791mm/mm.

Table 1: Mechanical Properties of freshly harvested cassava as affected by Time and Moisture Content

Variety	Moisture Content **mcwb %**	Maximum Compressive stress (MPa)	Compressive strain at Maximum Compressive stress (mm/mm)	Compressive load at Maximum Compressive stress(N)
IDILERU				
Week 1	77.74162	0.88332	0.26738	264.98099
Week 2	73.43625	69.73268	0.57063	0.15076
Week 3	72.59048	0.49459	0.15268	148.36881
Week 4	73.32504	0.93220	0.18187	279.64419
Week 5	74.77766	0.43735	0.12029	131.19611
ODOGBO				
Week 1	63.21294	1.59826	0.31210	479.4487
Week 2	63.45395	1.59826	0.31210	479.44870
Week 3	64.64833	0.78969	0.36746	236.89272
Week 4	64.64833	0.55495	0.27007	166.47625
Week 5	68.02249	0.37102	0.19791	111.29936
ITA				
Week 1	62.26549	0.81338	0.22004	243.9984
Week 2	71.34189	0.60299	0.20818	180.88727
Week 3	65.06861	0.80955	0.22517	242.84962
Week 4	68.66926	0.90388	0.27944	271.14781
Week 5	68.20473	0.46036	0.11387	138.10004
OKO IYAWO				
Week 1	74.68275	0.8785	0.22517	263.53424
Week 2	70.71340	0.69251	0.16166	207.74207
Week 3	58.31897	0.95178	0.20785	285.51754
Week 4	57.81677	1.38067	0.30088	414.17663
Week 5	66.07554	0.57507	0.13856	172.51158

Compressive strain at Maximum Compressive stress:

Table 2 shows high significant difference at 5% level of probability by Duncan Multiple Range Test (DMRT) of each level of duration of the mechanical properties. The result of Duncan's test presented in Table 3 indicates that the first week of the analysis of the freshly harvested cassava has the highest percentage of the compressive strain at maximum compressive stress of 1.74a while that of fifth week of the analysis has the least compressive strain at maximum compressive stress of 0.45c while Table 4 shows that sample 4 which is (*Oko-Iyawo*) has the highest compressive strain at maximum compressive stress of 0.89a while sample 1 (*Idileru*) has the least compressive strain at maximum compressive stress of 0.66b.

Table 2: Analysis of Variance (Compressive strain at Maximum Compressive stress)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Samples	0.60	3.00	0.20	3.87	0.02
Duration	2.48	4.00	0.62	12.00	0.00
Samples * Duration	2.79	12.00	0.23	4.52	0.00
Error	2.06	40.00	0.05		
Corrected Total	7.93	59.00			

Table 3: Mean Effect of Duration on Mechanical properties and Moisture Content

Duration	Maximum Compressive stress	Compressive strain at Maximum Compressive stress	Energy at Maximum Compressive stress	Compressive load at Maximum Compressive stress	Moisture
7	17.32	1.04a	0.26a	312.97a	69.48a
14	17.32	0.76b	0.20ab	227.07b	68.81a
21	17.32	0.76b	0.24a	228.41b	65.16b
28	17.32	0.94ab	0.26a	282.86ab	66.60b
35	17.32	0.45c	0.14b	138.28c	69.27a
	Ns				

Ns; not significant Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)

Table 4: Mean Effect of Sample on Mechanical properties and Moisture Content

Samples	Maximum Compressive stress	Compressive strain at Maximum Compressive stress	Energy at Maximum Compressive stress	Compressive load at Maximum Compressive stress	Moisture
1	17.32	0.66b	0.17b	199.07b	73.63a
2	17.32	0.88a	0.28a	268.52a	65.52c
3	17.32	0.72ab	0.22ab	215.40b	67.11b
4	17.32	0.89a	0.21b	268.68a	65.19c
	Ns				

Ns; not significant. Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)

Energy at Maximum Compressive stress:

Table 5 shows that there is high significant difference at 5 % level of probability by Duncan Multiple Range Test (DMRT) of each level of samples of the mechanical properties. The result of Duncan's test as shown in Table 3 indicates that the first week of the analysis of the freshly harvested cassava retained the highest percentage of the energy at maximum compressive stress of 0.26a while that of the fifth week of the analysis of the harvested cassava has the least of 0.14b. However, Table 4 shows that (*Odogbo*) has the highest energy at maximum compressive stress of 0.28a while sample 1 (*Idileru*) has the least energy at maximum compressive stress of 0.17b.

Table 5: Energy at Maximum Compressive stress

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Samples	0.08	3.00	0.03	4.04	0.01
Duration	0.12	4.00	0.03	4.25	0.01
Samples * Duration	0.07	12.00	0.01	0.83	0.62
Error	0.27	40.00	0.01		
Corrected Total	0.54	59.00			

Compressive load at Maximum Compressive stress:

Table 6 shows that there is high significant difference at 5% level of probability by Duncan Multiple Range Test (DMRT) of each level of samples of the mechanical properties. Duncan's test presented in Table 7 indicates that the freshly harvested cassava retained the highest percentage of the compressive load at maximum compressive stress of 312.97a at the first week and the least percentage of the compressive load at maximum compressive stress of 138.28c at the fifth week. Table 4 shows that (*Oko-Iyawo*) has the highest compressive load at maximum compressive stress of 268.68a while sample 1 (*Idileru*) has the least energy at maximum compressive stress of 199.07b.

Table 6: Compressive load at Maximum Compressive stress

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Samples	58485.15	3.00	19495.05	4.35	0.01
Duration	213475.72	4.00	53368.93	11.90	0.00
Samples * Duration	242821.07	12.00	20235.09	4.51	0.00
Error	179454.67	40.00	4486.37		
Corrected Total	694236.61	59.00			

Table 7: Mean of interaction effect between duration and varieties

Sample	Period	Maximum Compressive stress	Compressive strain at Maximum Compressive stress	Energy at Maximum Compressive stress	Compressive load at Maximum Compressive stress	Moisture
1	7	17.32	0.88cdefg	0.27	264.98cdef	77.74a
2	7	17.32	1.60a	0.31	479.45a	74.68ab
3	7	17.32	0.81 cdefg	0.22	244.00cdefg	62.27j
4	7	17.32	0.88cdefg	0.23	263.46cdef	63.21hi
1	14	17.32	0.57 defgh	0.15	171.18 defgh	69.73defg
2	14	17.32	1.16bc	0.24	348.49bc	70.71cdef
3	14	17.32	0.60 defgh	0.24	180.89 defgh	71.34bcde
4	14	17.32	0.69defgh	0.16	207.74defgh	63.45hi
1	21	17.32	0.49efgh	0.15	148.37efgh	72.59bcd
2	21	17.32	0.79 cdefg	0.37	236.89cdefgh	58.32h
3	21	17.32	0.81 cdefg	0.24	242.85cdefg	65.07ghi
4	21	17.32	0.95cd	0.21	285.52cd	64.65ghi
1	28	17.32	0.93cde	0.18	279.64cde	73.32bc
2	28	17.32	0.56 defgh	0.27	166.48 defgh	57.82h
3	28	17.32	0.91cdef	0.28	271.15cde	68.67efg
4	28	17.32	1.38ab	0.30	414.17ab	66.61fgh
1	35	17.32	0.44gh	0.12	131.20gh	74.78ab
2	35	17.32	0.30h	0.20	111.29h	66.08fghi
3	35	17.32	0.48fgh	0.11	138.10fgh	68.20efg
4	35	17.32	0.57 defgh	0.14	172.51 defgh	68.02efgh
		Ns		Ns		

Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)

Moisture content:

Table 8 shows that there is high significant difference at 5% level of probability by Duncan Multiple Range Test (DMRT) of each level of samples of the mechanical properties. Duncan's test result (Table 3) shows that the freshly harvested cassava has the highest moisture content of 69.48a at the first week and the least moisture content of 65.16b at the third week. *Idileru* has the highest moisture content of 73.63a while sample 1 (*Oko-Iyawo*) has the least moisture content of 65.19c (Table 4).

Table 8: Analysis of Variance (Moisture content)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Samples	697.50	3.00	232.50	50.65	0.00
Duration	172.66	4.00	43.16	9.40	0.00
Samples * Duration	797.64	12.00	66.47	14.48	0.00
Error	183.60	40.00	4.59		
Corrected Total	1851.40	59.00			

Conclusion:

The effect of time and variety on some mechanical properties of cassava tubers was investigated, duration and variety of cassava has a great effect on mechanical properties and the moisture content. *Odogbo* variety has the highest compressive strain and Compressive load at Maximum Compressive stress while *Idileru* variety has the highest moisture content. *Odogbo* retained the highest percentage of compressive strain at Maximum compressive stress and compressive load at Maximum Compressive stress while *Idileru* has the greatest moisture content.

Acknowledgements:

Authors are grateful to the Department of Agricultural Engineering, Federal College of Agriculture, Moor Plantation, Ibadan, Department of Agricultural Engineering, Adeleke University, Ede, Osun State, Nigeria and Obafemi Awolowo University for the instrumentation in the course of carrying out this work.

Corresponding Author:
Dr. Jaiyeoba, Kehinde Folake
Department of Agricultural Engineering
Adeleke University, Ede, Osun State, Nigeria
E-mail: jaiyeoba_k2007@yahoo.com

References

1. Adetan, D. A., Adekoya, L.O. and Aluko, O.B. (2003): Characterization of some properties of cassava root tubers, *Journal of food Engineering*. 59 pp.349-353.
2. FAO (2011). FAOSTAT. Food and Agriculture organisation of the United Nations.
3. Mali S, L. S, Sakanta, F Yamashita, MVE Grossmann (2005): Water Sorption and mechanical properties of cassava starch films and their relation to plasticizing effect carbohydrate polymers 60:283.
4. Fama L, Rojas, M., Groyers,S. and Gershenson, L. (2005): Mechanical properties of tapioca starch edible films containing sorbates. LWT 38:631.
5. Vicentinni, NM, MP Cereda (1999). Uso de filmes de fecula de mandiocaem pos-colheita de pepino (cucumis satires L.) Brazilian J Food Tech 2 p.87.
6. Vincentinni, N. M, N Dupuy, M Leitzelman, M.P Cereda, and P. J.A Sobral (2005): Prediction of cassava starch edible film properties by chemometric analysis of infrared spectra. Spectroscopyletters 38: p 749.
7. Degermo, P.E, Black T.J and Kosher A.R (2003): ‘’Material and processing in manufacturing’’, Chap. 21-23, Ninth Edition, John Wiley & Sons (ASIA) Pte Ltd India 2002, p.31.

11/25/2016