International Journal of Food Engineering

Volume 3, *Issue* 5 2007 *Article* 17

Strength and Elastic Properties of Cassava Tuber

Oladele Peter Kolawole* Leo Ayodeji Sunday Agbetoye†
A. S. Ogunlowo‡

*International Institute of Tropical Agriculture, Ibadan, p.kolawole@cgiar.org
†Federal University of Technology, Akure, Nigeria, lasagbetoye@yahoo.com
‡Agricultural Engineering Department, Federal University of Technology Akure, Ondo State, Nigeria, a_ogunlowo@yahoo.com

Strength and Elastic Properties of Cassava Tuber*

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Abstract

In this study, some engineering properties of cassava tuber samples were determined experimentally under five moisture content levels of 70 %, 65 %, 60%, 55 %, and 50 %wet basis. The properties measured were tensile strength, compressive strength and elasticity. Three experimental tools were designed and fabricated using spring balance, hose-clips, and 12Volts motor with reels and rope for the investigations. The IITA improved cassava variety TMS 4(2) 1425 was used in the experiments. Results of the tests indicated that all the properties measured were influenced by the moisture contents of the tuber.

KEYWORDS: cassava tuber, tensile strength, compressive strenght, elasticity

*The authors wish to acknowledge the support of IITA management and staff. Also the assistance given by Messrs FK Alude, J.J. Ben, Paul Ilona, S. Agbaje and I. Oladejo during the fabrication and validation of experimental tools.

1. INTRODUCTION

The cassava plant has its origin in South America where its swollen roots have been used as food down the ages. It is a major staple food grown exclusively as food in about thirty-nine African countries. It accounts for a third of all staple foods produced in sub-sahara Africa (F.A.O, 1986). Industrial products such as perfume and pharmaceutical products can be extracted from cassava. Previous known industrial products are alcohol and starch (Onakunle, 1990). In seeking an alternative for Nigerians future needs, products of cassava can be found useful in engineering application such as fuel, glue and fibers. Researchers are exited by cassava's potentials as an income-generator as well as food and new industrial uses are being developed from it (Obafemi, 1998).

The first step in processing cassava into any product begins with the peeling of the tuber after manual harvesting, unfortunately harvesting and peeling constitute a serious bottleneck (Odighoh, 1991). A great deal of research effort is still being carried out and a lot of interest is shown in the mechanization of its production. Traditional peeling and processing methods are time wasting. Techniques used by farmers are still very crude which largely account for inefficiency in the system, developing appropriate tools and equipment to addressing the constraint in handling the crop is a task for design engineers (Halos-Kim, 1998). The design of equipment for handling and processing cassava requires a thorough understanding of the engineering properties of cassava tuber.

Scientists have conducted the study of some engineering properties of agricultural materials, in order to improve their mechanization, and commercial value; Cassava's physical properties influence the level of damage sustainable by it during handling operations. Notable damages are crushing, bruises, cracks or breakages Gakwaya (1990).

The ever-increasing need to mechanize handling and processing of cassava call for this study. To this end, some physical properties of cassava tuber in qualitative terms similar to those used to describe the engineering properties of steel, wood, and concrete was adequately described in this study. The objectives of this study therefore are to fabricate an experimental tool for the evaluation then determine mechanical strength and elasticity properties of cassava tuber and present the effect of the tuber moisture content on the magnitude of the properties mentioned.

2. LITERATURE REVIEW

Previous work has been done to determine the properties of various crops. The prediction of the resistance of crop to damage during mechanized operation of harvesting and processing was reported by Agbetoye (1999) Gakwaya(1990).

Anazoda and Norris (1979) studied the mechanized properties of corncob in radial compression. Similarly, Baryeh (1990) determined the tensile, compressive and shear strength, and degree of elasticity of cocoyam corms at various moisture contents. McRandal and McNuty (1978, 1980) studied the process of impact cutting for optimum design of rotary mowers and concluded that the minimum blade velocity of impact cutting was independent to the blade type but shear properties of various grasses became importance for the cutting operation. Kushwala et al, (1983) concluded that there was no linear relation between the shear strength and the moisture content of straw, as non-liner relationship was observed in two phases, he reported first that the increasing phase where shear strength increased with the moisture content of straw and the second that is the constant with increase in the moisture content.

2.1 Theoretical Background

Tensile strength, Compressive strength, and Modulus of elasticity are important parameters that materials possess, with today's wealth of information the task of measuring those parameters is becoming easier. Evaluation of these engineering properties of agricultural products was needed because it is important in the optimum design and performance of harvesting and processing machines, an external force applied to a material creates stress within the material; this stress causes the material to deform. The amount of deformation, as a fraction of the original size, is the strain. The maximum amount of stress a material can withstand before becoming permanently deformed is the elastic limit. The ratio of stress to strain is the elastic modulus, and the elastic limits of a material are determined by the molecular structure of the material. For the purposes of this work, the following definitions and equations were adopted and applied.

Stress σ = Tensile or compressive load Divided by Cross-sectional area

$$\sigma = F/A \; (N/m^2) \tag{1}$$

Normal strain ε = Change in length Divided by Original length

$$\varepsilon = e/L \tag{2}$$

Modulus of elasticity Y = Stress Divided by Strain

$$Y = \sigma / \varepsilon \tag{3}$$

The Degree of elasticity as defined from the force-deformation measurement (Mohseing, 1970)

$$D = Dr / Dc \tag{4}$$

Where Dr = distance recovered by sample after the load is removed Dc distance the sample is compressed.

If a load **P** is applied which acts in a straight line, together with an equal and opposite load of the same magnitude as **P**, the two forces being distance ΔY apart, then the body is said to be in shear.

Using Shear $q = P / A$ (5)

Where P = load, A= Cross Sectional Area

Hawke's et al; (1981) observed that double shear is mechanically sounder

Average shear: Load applied divided by the total area under shear

$$q = P/2A \quad (6)$$

3. MATERIALS AND METHODS

3.1 Description of Experimental Equipment

Separate equipment was fabricated to measure the properties of the cassava tuber sample.

3.1.1 Equipment for Tensile Tests

The equipment consists of a wooden base of 1.05 m long with 75 mm wide and 20 mm thick, a motorcycle throttle cable used as a string, an electrically controlled devise at a constant speed rate of 20cm per minute was used to pull the cable and two hose clamps for securing the sample. The strings were carefully fixed into the hose clamps with one end to the weighing balance and the weighing balance to a rigid support. The other hose clamp string secured into pressure devise, the two hose clamp secured the sample firmly as load is applied by winding the reel with an electric powered and the applied load monitored from the weighing scale under tension.

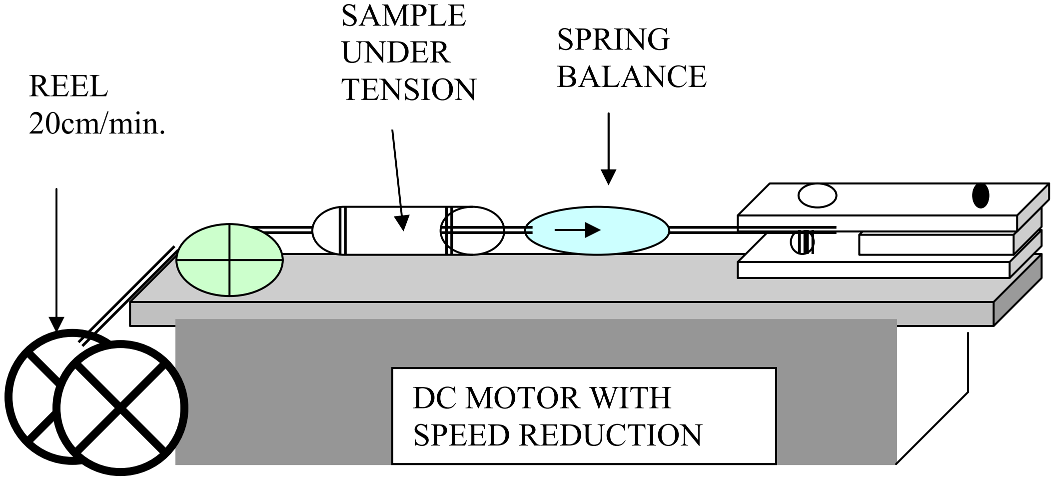

Figure 1. Tensile test equipment

3.1.2 *Equipment for Compressive Tests*

It was made with mild steel and very handy, it allows applied load to be measured through a weighing balance attached. (Figure 2.)

Downward movement exerts pressure on the sample and this is placed on a balance suspended by the weighing balance handle.

A scaled rule made to measure the height of the sample inform of a “go and no go” assisted in determining when the sample must have gone down its height to 90% of original height.

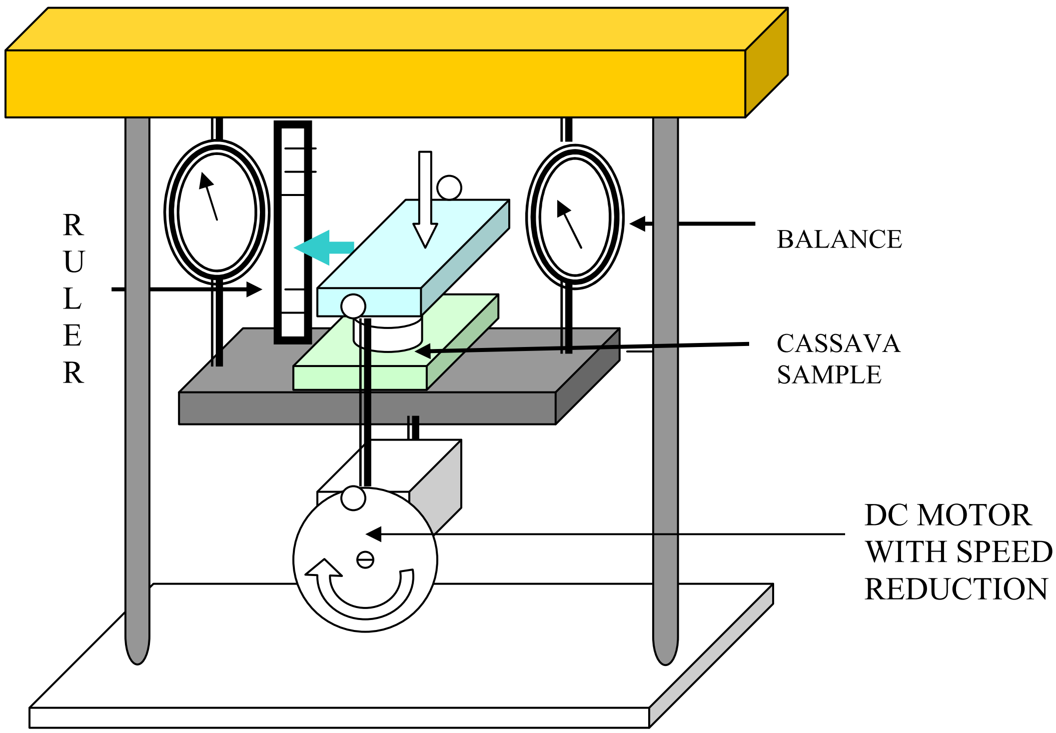

Figure 2. Compressive Test Equipment

3.1.*3Equipment for Shear Test*

This principle was based on double shear application (Figure 3). In place of clevis pin a cassava sample is subjected to a condition known as double shear i.e. the shear in two areas. This means that the available area is doubled and thus the stress is halved for equal diameter. A condition of double shear is obviously mechanically sounder than a single shear (Hawks, et al, 1981).

To provide this tool a transparent glass like plastic material was used. Four pieces with 12 mm thickness, and area of 200 mm by 100 mm. A 25 mm hole was drilled with the center at 25 mm from one end; three out of the four pieces had this hole, the centered piece had a 7 mm hole drilled at one end for string wire attachment. The four pieces was set up as shown in diagram below providing space and support for the clevis.

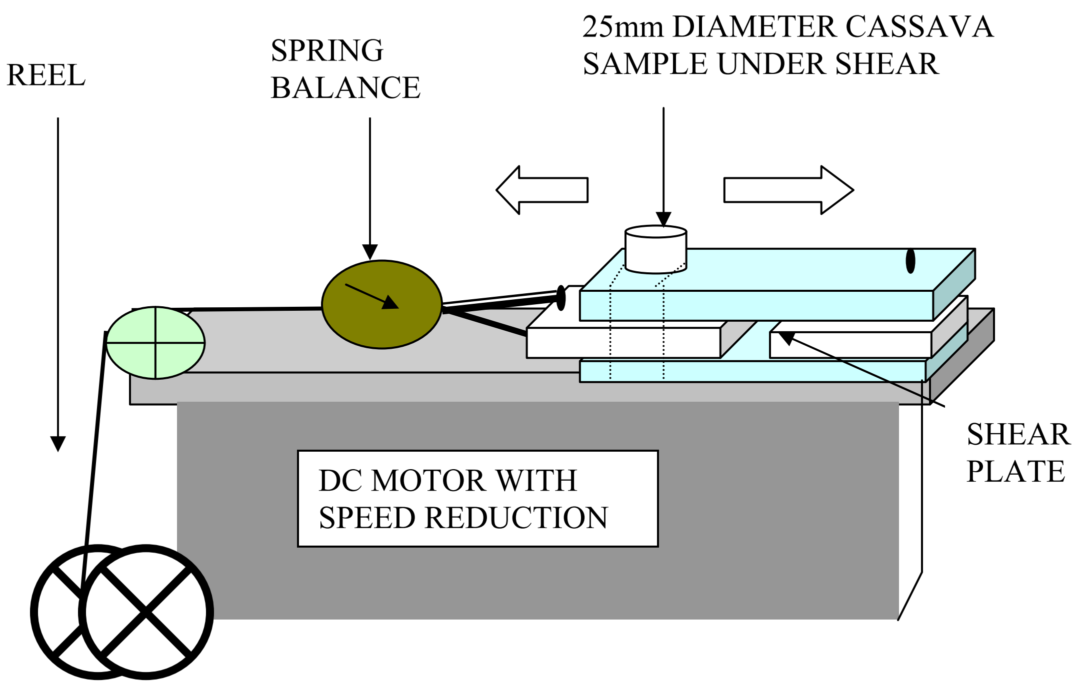

Figure 3. Shear Test Equipment

Uniformly applied load and forceful withdrawal of the shear plate piece, thereby putting the cassava sample in shear.

3.2 Experimental Procedure

To evaluate the strength of cassava tuber, freshly harvested one-year-old improved cassava from International Institute of Tropical Agriculture (IITA) cultivars TMS 4 (2) 1425 peeled normally and cut into sizes of about 30mm to 96 mm by 30 to 96 mm on each required sizes in cubes, cylindrical and at a base diameter and breath of 25 mm. roots were sorted out from the oven for each type of treatment. The samples were at various moisture contents for each treatment. Dried at 100^0c in a Try-Temp Hot pack oven and were re-weighed after 30 min, 1 hr., 1.5 hr and 2 hrs. All the samples were tested 10 times at given moisture content of each i.e. 50, 55, 60, 65 and 70% moisture content wet basis. Ten samples were used in each case.

Fresh samples were taken in ten replicates from the known moisture content. Experiments were carried out at 70%wb, 65%wb, 60%wb, 55%wb and 50%wb. Technically weighed using the oven sample pans, and their weight recorded. After proper labeling the samples were placed randomly in the oven for 30 min, 1 hour, 1.5 hours, 2 hours and 24 hours. The control sample was left for 24 hours, this help to determine the moisture content of the fresh cassava sample. The **compressive tests** were carried out on the ten samples with the compressive force. The spring balance measures the force applied. The **tensile test** was done with the aid of a pivoted string holding the sample with two clips of 25mm diameter and length of 80mm samples were held between the weighing balance and the force applied the readings were also taken from 10 treatments each case at different moisture content.

To determine the degree of elasticity, the samples were compressed to 90% of their original length using and other samples for tensile extended to 110%.

The degree of elasticity was calculated using the equation 4. Where Dr is the distance recovered by sample and Dc distance the sample was compressed or extended.

Conducting **shear tests** is for the toughness and resistance to bruises, sample was made cylindrically with diameter 25 mm and height of 50 mm. A force was applied to the shear plate; two areas took the shear load. Cassava shear strength therefore was calculated using the formula below Css = P/2A

Where CSS is cassava strength, P as force applied and A as the Area $\pi d^2/4$

4. DISCUSSION

4.1 Strength and elasticity

Greater strength was recorded in tension then in compression. The results of the tensile and compressive tests shown in Table 1 and 2 present relationship between stress and strain for both the tensile and compressive tests.

The crop seems stronger under tension than compression at 70% moisture content wet basis than at lower moisture levels presented (Figure 4-5).

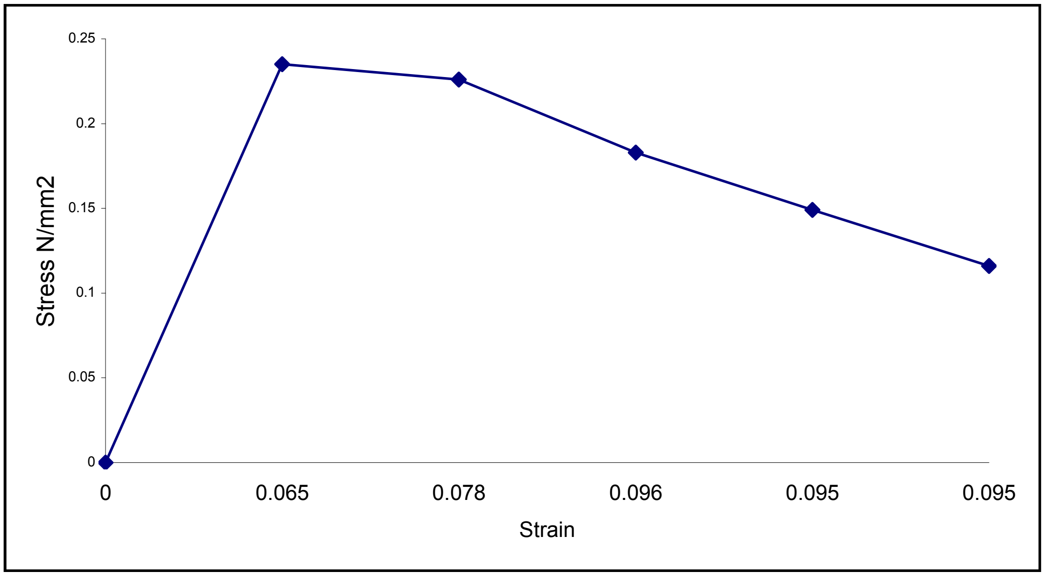

Figure 4: Tensile stress against strain graph

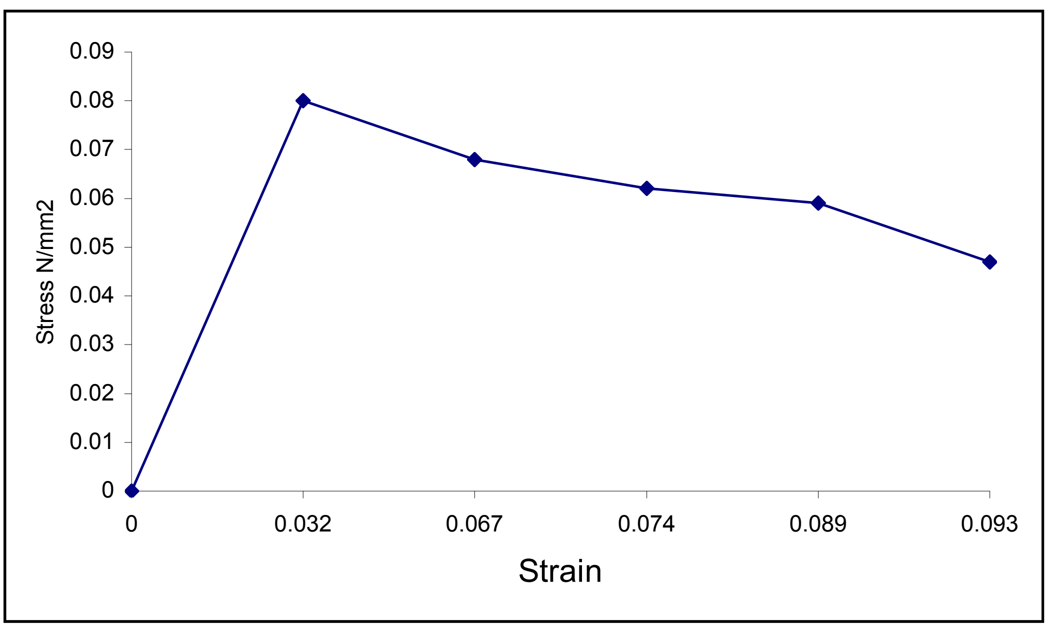

Figure 5: Compressive stress against strain graph

Table1: Cassava Tuber Tensile Test Result

M.C. % wb	Stress N/mm^2	Strain, mm/mm	Elasticity degree	Elasticity modulus N/mm^2
70	0.235	0.065	0.519	3.615
65	0.226	0.078	0.242	2.316
60	0.183	0.096	0.039	1.916
55	0.149	0.095	0.040	1.257
50	0.116	0.095	0.055	1.254

Table 2: Cassava Tuber Compressive Tests Result

M.C. % w.b	Stress N/mm^2	Strain, mm/mm	Elasticity degree	Elasticity modulus N/mm^2
70	0.080	0.032	0.680	2.497
65	0.068	0.067	0.328	1.018
60	0.062	0.074	0.260	0.842
55	0.059	0.089	0.111	0.667
50	0.047	0.093	0.068	0.500

Table 3: Cassava Tuber Shear Tests Result

MC (%wb)	Shear Stress N/mm^2)	Shear Strain, mm/mm
70	0.187	0.140
65	0.163	0.064
60	0.122	0.060
55	0.118	0.052
50	0.112	0.048

The lesson here is that handling and packaging could be done, as this is when the crop is likely to undergo more compression than tension. Implication for harvesting is that a machine need to uproot the crop by pulling the stem and will put the root under tension. Average modulus of elasticity values of 2.497 N/mm^2, 1.018 N/mm^2, 0.84N/mm^2, 0.7 N/mm^2, and 0.5 N/mm^2 obtained at different moisture content on compression, indicates that at higher moisture content the crop strength is higher. Cracks being to appear at 0.032 strain followed by rupture.

The crop exhibits different degree of elasticity in the tensile and compressive situation at all moisture content considered. Therefore, if the elasticity of the crop is important in it's handling, then it will be advisable to do most of the handling when the crop has 60 to 70% moisture content. These results on show that the crop required grater force to shear at higher moisture contents.

5. CONCLUSION

Studies were conducted using simple fabricated equipment. The properties investigated include strength, (shear tensile and compressive) and elasticity, the studies shown that tensile, compressive and shear strength of cassava reduces as the moisture content of the tuber decreases. The degree of elasticity decreases within the range. There is every indication that above statement can be otherwise at moisture content lower than 50% w.b.

It was also found that the lower the moisture content the harder the crop is and the more it resists cutting and abrasion. Meaning that cassava tuber mechanical property is moisture content dependent.

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