Investigation of Mechanical Properties of Cassava Tubers

Jinyemiema, Tamuno K
Department of Mechanical Engineering
Ken Saro Wiwa Polytechnic, Bori, Rivers State
tjinyemiema@gmail.com, kurotamuno2000@yahoo.com

Abstract:
This paper investigates the mechanical properties of cassava tubers. Cassava were collected from Uselu market in Benin City, Edo state, Nigeria for the purposes of this experiment. The mechanical properties of cassava tubers such as coefficient of dynamic and static friction, compressive strength and crushing strength were investigated. The investigation revealed that, the coefficient of friction which is 2,24Ns/m^2 is ten times higher than the value (0.21Ns/m^2) from smooth surfaces. Some tubers obeys partly second order polynomial relationships, others Fourier. Compressive stress and friction coefficient values obtained were 3.445KPa and 0.175-0.235Ns/m^2 for the static and dynamic cases, but on rough surfaces 2.24Ns/m^2 was obtained

Keywords: compressive, properties, coefficient, values, smooth, rough

1.0: INTRODUCTION

Cassava (*Manihot Esculenta Crantz*) is a perennial crop commonly grown in most tropical regions of the world, because it flourishes sufficiently in areas of moderate rainfall (that is, 200 to 2000 mm of rainfall) and full sun, but it is susceptible to cold weather and frost, Agodzo and Owusu (2002). Due to the aforementioned properties of cassava, it is mostly cultivated in regions such as sub-Saharan Africa, West Indies, Brazil, Indonesia, Philippines, Malaysia, Thailand and china. According to Ugwu and Ozoiko (2015), cassava native Brazil was introduced into Central Africa by the Portuguese around 1558. It is believed to have made its entry into Nigeria through the Islands of Sao Tome and Fernando Po in the 17th century and as one of the earliest crops domesticated has since increase in popularity in the country (Adetan, 2010). Today, in Nigeria, cassava is grown in all the geo-political regions, which has eventually earn the country the largest producer in the world with an estimated production capacity of 49 million tons per year (Uthman, 2011), there is little or no database on cassava physical properties and their relationships for designers of processing machines.

However, this research investigates tuber physical properties and the relationships that exist between these characteristics. Properties like tuber diameters and length to peel thickness relationship were investigated and determined. One major reason for investigating the mechanical properties of cassava tubers is the improvement of the efficiency of processing machines, especially mechanical peelers. Other factors, for undertaking such a study may include, having an insight into the relationship between these properties for better post-harvest handling and understanding basic functional characteristics of cassava tubers. The tissues of most fruits, vegetables and tubers are subjected to different wanted and unwanted mechanical forces and strains during the post harvesting stage. The wanted mechanical loading takes place basically in food processing equipment such as slicers and peelers and is always accompanied by unwanted loads (Emadi, 2005, 2007). Furthermore, the unwanted mechanical loads such as compression, impact and vibration are the main causes of bruising of products during post-harvest operations Brusewitz et al. (1991). A good knowledge of the physical and mechanical properties of products will be useful for the purpose of increasing the effect of wanted and decreasing the effects of unwanted, mechanical loading.

Some researchers made attempts to investigate the various properties of root tubers (including cassava), but to find useful published data on physical and mechanical properties of cassava tubers have been unsuccessful. This study was carried out in response to three main reasons: - Cassava varieties are too numerous, to the extent that Odigboh (1978) identified about 200 species. Values sometimes obtained are based on single specie which may not be comprehensive for a database. This effort is to contribute to the much needed database for cassava tuber properties, give an insight to the differences that exist between tuber characteristics and the differences that exist in such properties among various species.

Knowledge of tuber properties as investigated is a key to making relevant conclusion and recommendation in postharvest processing of cassava tubers. Though not all varieties are captured in these investigations, tubers are collected from different parts of the country for the analysis (Figure 1 for samples used for the experiment). - Secondly, most data collected were

Figure 1. Samples of cassava tubers used for the experiment

Figure 3: Showing Compressive Test Apparatus with cut Tuber Sections

studied in a hurry to collate data for processing equipment design and development (Oriola and Raji, 2013). Despite all these attempts made by researchers, there is still this demand for expansion of the frontiers of knowledge on engineering properties of the tubers, since no two varieties exhibit similar properties (Odigboh, 1976). Again, newer varieties are still emerging due to rigorous research work across the different institutions, application of newer fertilizers, changes in climatic conditions, soil conditions and the likes. According to Odigboh (1976) and Kolawole et al. (2010), factors that contribute to the physical characteristics of cassava tubers such as shape, water content, and weight and peel thickness etc are numerous. This implies that any change in soil condition period of harvesting and time of harvesting etc can affect such properties. This further buttress the fact that regular update of physical and mechanical properties of cassava tubers is very important in achieving success in this area of study. The essence of the study is to compliment previous effort in providing updated data for further research. - Thirdly, a good understanding of cassava properties is needed for this research. It will not only enrich the thesis but also provide a first-hand knowledge of cassava. Having a good knowledge of the tuber properties, refreshes the researchers mind and give a positive direction to the work. Again, physical and mechanical properties give guidance to the choice of materials for the construction of compatible machines. It is on this note that the determination of physical and mechanical properties becomes imperative in this research.

The characteristics measured and investigated were:

a) Mechanical characteristics measurement which include:

i) Coefficient of friction on galvanised surface both smooth and rough.

ii) Compressive strength of tubers.

b) Relationship between these properties

2.0: Determination of Mechanical Properties

2.1: Compressive Test of Cassava Tubers

Researchers in Sub-Sahara African, Latin America and Asia are regularly making efforts in ascertaining the physical and mechanical properties of cassava roots. All these are attempts at developing a functional relationship between these properties and machine parameters, in an effort to develop appropriate processing machines for cassava tubers. This investigation was carried out to ascertain the compressive strength of cassava tubers, which has so much to do with the shear strength of cassava tubers.

2.1.1: Materials and Method

Fresh cassava tubers were collected from Uselu market in Benin City, a place designated for selling fresh cassava products. The tubers were cut at some sections that almost gave a round configuration (see Fig 2). This was carried out carefully, to ease the calculation of tuber area for the experiment. The instrument for the testing of compressive stress is a modified hydraulic pressure which has a gauge that reads the applied stress directly (Fig 3). The diameter of each cassava tuber was measured using a vernier and recorded as shown on Table (4). Thereafter, a compressive force is applied using the handle until a prop sound that signifies cracking of the tuber is heard, signifying the limit of compressive strength of the tuber. In Figure 3 a modified hydraulic press is used for the compressive/ cracking test.

2.2: Friction Experiment

Friction experiment is key to the peeling process, because, there is need to have a dependable contact for the abrasive surface. It enables us to have appropriate values of both the dynamic and static friction. These value are relevant for the predictive mathematical modelling of the machine operation, which is an integral part of this research. It was in this regard that the need for friction experiment became necessary.

2.2.1: Materials and Methods

The apparatus for cassava tuber friction experiments are not well developed in this part of the world, but the principle of operation are the same, hence, using the regular inclined plane is the only viable option and besides the results obtained from using the inclined plane have not been contradicted by any other research in this subject area. The inclined surface was modified as shown in Fig. 4, the steel surface was replaced with a galvanized iron sheet (two surfaces were designed, rough and smooth surfaces). The emphasis is on the rough surface, peeling is effected by the rough surface and not on the smooth surface.

2.2.2: Experimental Procedure

Two separate friction experiments were conducted on the inclined plane. 1. for the smooth sheet surface and 2. for the rough surface. The procedure for this experiment is exactly the same as normal friction experiment. For each angle, the tuber is placed on the plane and weights are applied using a string as shown in the Figure 5. Readings were taken as the tuber begins to slide along the plane. This was repeated for several samples, readings corresponding to initial motion of tubers were tabulated. One major constraint to this experiment on the rough surface is the spinning and tilting of the tuber at some protrusion points. It affects the readings because, rather than tubers to slide along the surface, they either got hooked, spin or tilt over. However, some slide along the surface with high level of bruising of the peel as shown in section five (results and discussions).

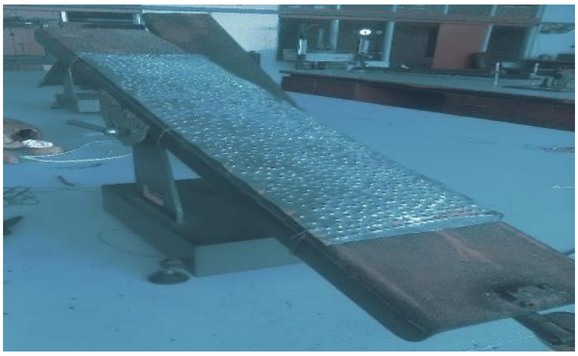

Fig. 4: Modified Inclined Surface for Friction Experiment

Fig. 5: Modified Friction Experiment Rig Showing string

3.0: Results and Discussions

3.1: Compressive Test Result

The essence of the comprehensive test is to have an insight into the required force for scratching the tuber surface for effective peeling and the force required to press the tuber against the drum surface. The result as presented in table 1 shows that; the tuber size does not influence the value of the compressive stress which remains constant at 3.445Kpa, except for serial number 3 that had a higher value. A closer look at the cross section of the tubers, shows a built-up point which may have resulted into a higher value than others. The value is consistent with values published by other authors like Kolawole (2010) and Ademosun (2012). The range of values published by these authors have slight variance but within the range published by both authors. The variance can only be attributed to difference in species, as cassava has several species within a particular region. Though the specie was not identified before the experiment, the results represents cassava specie as shown in Fig.1

Table 1. Compressive Strength Experiment Result

Tuber Diameter (cm)	Cracking stress psi	Stress kpa	Area (m^2) 10^{-3}	Force (N)
6.00	0.50	3.445	2.827	9.739
6.50	0.50	3.445	3.318	11.431
6.70	0.70	4.823	3.526	12.147
7.15	0.50	3.445	4.015	13.832
7.35	0.50	3.445	4.243	14.617
7.35	0.50	3.445	4.243	14.617

3.2: Friction Experiment

Friction experiment was carried out to identify a preferred abrasive surface for the peeling operation, hence two types of surface were developed for this purpose. The smooth and rough surfaces were experimented to identify contact surface effect on abrasive peeling of cassava tubers.

Values for different sizes of tuber obtained are tabulated in Table 2. These values were obtained at angle of 10^{o}, 15^{o} and 20^{o} respectively for both the smooth galvanised iron surface and smooth surface. Average values obtained for the smooth surface are 0.175, 0.217 and 0.235 for the dynamic coefficient of friction at the angles 10^{o}, 15^{o} and 20^{o} respectively. The Average values for the dynamic coefficient of friction obtained is 0.21Ns/m^2, which is in agreement with Ademosun's value of 0.22 Ns/m^2.

For the rough surface, the value is as high as 2.24Ns/m^2 but a more accurate value may be necessary as the tubers used for the experiment get pinned to the surface, which requires higher force value to crush them through the surface. The resulting surface is shown in Fig 7. The result produced on the surface experiment show excellent abrasive surface for peeling for peeling cassava tubers. Again, it also indicates that the sliding of the tubers will produce better peeling than rotation.

Table 3. Friction Experiment Result

S/N	Tuber weight (g)	Weight of blk	Angle inclination (^{0})
1	425	100	10
	425	850	15
	425	650	20
2	995	110	10
	995	900	15
	995	720	20
3	847	950	10
	847	750	15
	847	600	20
4	587	650	10
	587	550	15
	587	450	20
5	966	1150	10

Table 3.2: Average Dynamic Friction values (μ_d)

172.08	982.75	0.17
210.101	967.508	0.217
22.492	946.30	0.235

This result necessitated our machine design concept, which introduced a rocking motion in addition to rotation of the peeler drum and revolution of the top frame and drum subassemblies, almost generating a gyroscopic motion. This Figure 7. Shows a one-time sliding motion that removed both the periderm and the cortex of the cassava tuber.

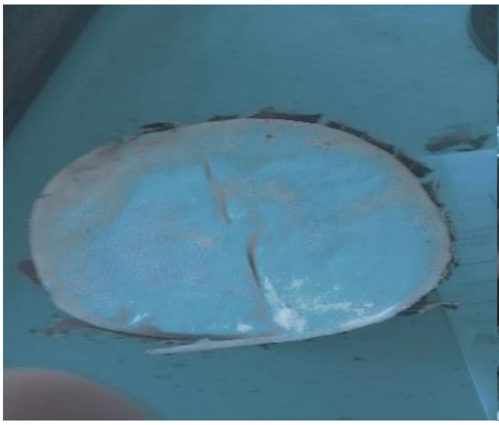

Fig. 6: Cassava Compressive Test Result Showing Crack Section **Fig. 7: Friction on Rough Surface Experiment Result**

4.0: CONCLUSION

From the experimental values, it obvious that the tuber size has no influence on the compressive stress of cassava, but built up edges increase the compressive strength, otherwise for all diameters tested, the value remains 3.445KPa. It can be deduced that the size of tuber does not influence the compressive of cassava, which is true for all engineering properties. Again, the friction values obtained agreed with earlier figures from Ademosun, though his work focused on smooth surfaces, the current effort considered rough surfaces which gave an insight into the possibility of using rough metal surfaces capacity to peel tubers. The figures shows a ten times increase in value from smooth to rough surface. From $0.22Ns/m^2$ to $2.24Ns/m^2$

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