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Effect of Boiling Time on Selected Engineering Properties of Cassava

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Abstract

The engineering properties of cassava boiled at different times (20, 30 and 40 minutes) were investigated. The engineering properties of the tubers investigated include moisture content, density, %peel, hardness, compressive strength, stiffness moduli, toughness, shear strength, and coefficient of static fiction on ply wood, mild steel and aluminium surfaces. As boiling time increased, the moisture content and stiffness moduli were seen to increase while all other properties measured were observed to decrease. The result from the study showed that boiling time had no significant effect ($p>0.05$) on the density, % peel, hardness, coefficient of static friction, stiffness moduli and shear strength. However, the moisture content, compressive strength, toughness and shear strength were significantly influenced ($p<0.05$) by the boiling time.

Keywords: *Cassava, boiling, physical properties, mechanical properties,*

1.Introduction

Cassava tubers are raw materials used for producing various products. Cassava is consumed only in its processed form due to its high hydrogen cyanide content which can be toxic to humans (Onwueme, 1978). These products include *fufu, garri,* chips, *abacha*. A lot of research has gone into processing of cassava into starch, garri, fufu, (Etejere and Bhat, 1985) but not enough has been done in the processing into *abacha*. The unit operations involved in the processing into *abacha* includes boiling, peeling, slicing/shredding, washing and drying. This work aims at determining the effect of boiling times on the engineering properties of the tubers. This is to enable food engineers design and construct suitable slicing/shredding machine. This traditional technology of processing *abacha* slices involves a lot of drudgery with low throughput which reduces the market availability of the products. These desirable traits are being exploited by the farmers which probably accounted for the present position of Nigeria as the world leading cassava producing nation ((Kolawole et al., 2007)). It is usually processed, locally, into *gari, lafun, fufu, abacha and akpu* in Nigeria, and, *kokonte* and *agbelima* in Ghana ((Quaye et al., 2009)).

The rising significance of agricultural products simultaneously with the complexity of modern technology for their processing need a better knowledge of their engineering properties so that machine's processing operations can be designed for maximum efficiency and the highest quality of the final end products ((Mohsenin, 1970). For instance, the application of physical properties such as shape which is an important parameter for stress distribution in materials under load is important in developing processing machines (Eşref and Halil, 2007). It is important to have an accurate estimate of shape, size, volume, density, surface area and other engineering parameters for a given biomaterial. Knowledge of mechanical properties such as, shear strength and compressive strength is vital to engineers in the design of processing equipment.

The successful design and development of postharvest handling and processing operations of the tubers, depends on comprehensive understanding of the engineering properties of the cassava root (Adetan et al., 2003; Kolawole et al., 2007). Therefore shredding has potentials to improve cassava products quality, even though the process is not widely used in cassava processing. Cassava shreds known within the Eastern parts of Nigeria as i*ghu*, n*sisa* or a*bacha* are is a local delicacy. It is made from peeled and shredded cassava tubers, after steaming and fermentation for about 24 hours. The product is then washed and eaten as a snack or made into a main meal or dried for storage. Cassava shredding is still done manually. Peeled and steamed cassava is moved vigorously by hand over metallic shredding plates to effect the shredding action, or by the use of kitchen knives. The mechanization of cassava shredding introduces changes in the quality characteristics of the shreds produced. The nature of these changes will depend on the interaction of the machine, process and raw material variables. Therefore, a rational approach to the design of agricultural processing equipment (e.g. cassava shredding machine) will involve the knowledge of the engineering properties of the boiled tubers.

The objective of this study is to determine the effect of processing (boiling) times on some selected engineering (physical and mechanical) properties of cassava TME 419 grown in Crop Science Department, University of Nigeria, Nsukka, Enugu State, Nigeria, to establish a convenient reference data for their mechanization and processing. The knowledge of the engineering properties is useful for both engineers and food scientists; plant and animal breeders and it is also important in data collection in the design of machines, structures, processes and controls; and in determining the efficiency of a machine or an operation.

2.Materials and Method

A given variety of cassava, TME 419, was selected from Crop Science Department, University of Nigeria, Nsukka, Enugu State. One hundred and twenty (120) cassava tubers of this variety were randomly selected. Sixty three samples were randomly selected for physical properties test; fifty four samples were randomly selected for mechanical properties test. Three groups were created for each engineering property tests (physical and mechanical), with three different boiling times of 20, 30 and 40 minutes respectively for each group. Each group contains six cassava tuber samples, except for coefficient of static friction, which contains three tuber samples in each group. The tubers in each group were peeled using a knife, washed thoroughly and boiled at their different time intervals using a cooking pot, and a stove as a source of energy and allowed to cool. The volume of water that was used to fill the cooking pot for boiling was the same. The samples were given identification marks to avoid the repeat of experiment. All experiments were carried out under standard laboratory conditions. All calculated values for physical properties test were rounded up to four decimal places.

2.1 Moisture content

Moisture content of the eighteen samples selected were determined using standard methods for oven drying as described by (Razavi et al., 2007). Six samples of boiled tubers were randomly selected across the three groups. A mass of 10g weighed using a weighing scale (Mettler Toledo JL 620-GLA01) of the six boiled samples randomly selected from group A, after boiling for twenty minutes and allowed to cool, were then oven dried to constant weight. The mass loss on oven drying of the 0.001kg boiled tuber samples in an oven at a temperature of 105°C for 18 hours were then measured and recorded as described by (Obi and Offorha, 2015; Razavi et al., 2007). The moisture content of these boiled tuber samples were determined, and an average value was taken. This process was carried out in group B, and C with boiling times 30 and 40 minutes respectively. The moisture contents (%) were calculated on wet basis using eq. 1;

$$mc = \frac{m_1 - m_2}{m_1} \times 100 \qquad (1)$$

Where, $mc =$ %moisture content (wb)

$m_1 =$ initial mass when boiled (wet sample) (kg)

$m_2 =$ final mass when oven dried (dry sample) (kg)

2.2 True Density

The mass m(kg) of the tubers were determined after boiling them at their appropriate times using an electronic weighing balance (SHIMADZU BZ 32 OH, Japan) with an accuracy of 0.01g and the volume V(m^3) was gotten using liquid displacement method. The densities (ρ) of the six boiled tuber samples used for size tests, selected across the three groups were calculated using eq. 2.

$$\rho(kg/m^3) = \frac{m\ (kg)}{V\ (m^3)} \qquad (2)$$

2.3 Proportion by weight of peel

Proportion by weight of peel for the six boiled tuber samples selected for this test, across the three groups of eighteen boiled tuber samples were determined. The six boiled tuber samples in group A of 20 minutes boiling time, their mass (kg) before and after peeling were measured using electronic weighing balance as described by (Adetan et al., 2003). This process was repeated for group B and C for 30 and 40 minutes respectively. Proportion by weight of peel was calculated using eq. 3;

$$w_p = \frac{m_{up} - m_p}{m_{up}} \qquad (3)$$

Where,

$w_p =$ proportion by weight of peel (%)

$m_{up} = mass\ of\ unpeeled\ cassava (kg)$

$m_p = mass\ of\ peeled\ cassava\ (kg)$

2.4 Coefficient of static friction

Three surfaces (plywood, aluminium sheet and mild steel) were used to determine the static coefficient of friction. The three boiled tuber samples selected from group A were boiled for 20 minutes and cooled, and were placed (horizontal and vertical positions) on a small rectangular frame containing the different surface materials, positioned on an adjustable tilting surface. The surface was then raised gradually until the filled rectangular frame starts to slide down (Adetan et al., 2003; Dutta et al., 1988; Razavi and Milani, 2006). This process was repeated for group B and C with boiling times of 30 and 40 minutes respectively. The coefficient of static friction was calculated using the eq. 4;

$$\mu = \tan \theta \quad (4)$$

Where, $\mu =$ coefficient of static friction
$\theta =$ angle of tilt of table (°)

2.5 Hardness test
Grain hardness tester (Wenzhou Tripod) with ±1N precision was used to obtain the hardness of the six boiled tuber samples selected for this test, across the three different boiling time group. For group A of 20 minutes boiling time, the upper part of instrument slot was screwed downward to press 10mm diameter of the six boiled tuber samples individually. The first sound made by each tuber sample when tightly pressed indicates its hardness. The counter reading was taken when the sample was not making a total contact with the tester. Average values were taken. This process was carried out in group B and C of 30 and 40 minutes boiling times respectively.

2.6 Compressive strength and shear strength
The major diameters of the three boiled tuber samples for both loading positions for the three boiling time groups for compressive and shear strength tests were measured. The boiled samples were fixed on the compressive and shear chambers in their various loading positions respectively, and locked up. The mercury level was initialized and zero to the working fluid level. A gradual but continuous load was applied through the longer handle as the pulleys turn the attached machine graph round the graph drum. At intervals, the slider pin was pressed down to initiate the different force positions of the testing material. At rupture point, the material was removed and zero to the mercury level. The graph was then removed from the drum. The result was then read and interpreted for the various leading positions (Aluko and Koya, 2006). The beam used was 250kgf (2500N).
2.7 Tuber stiffness moduli and toughness
The force–deformation curves obtained from each compression test of the three boiled tuber samples in the vertical and horizontal loading positions for their different boiling times were subsequently analyzed to determine stiffness moduli and material toughness. For each sample, stiffness was determined as the slope of the apparent linear elastic portion of the force–deformation curve and toughness, the area under the curve.
2.8 Statistical analysis
A completely randomized design (CRD) was employed in this work while analysis of variance (ANOVA) was used to analyse the data obtained. Means were separated using least significant difference.

3.Results And Discussion

The results of the boiling time on the engineering properties of cassava (TME 419) are discussed below. The boiling time ranged from 20 to 40 minutes.
3.1 Effect of boiling time of physical properties
The mean values recorded for the physical properties of boiled cassava are shown in Table 1. For moisture content, it was observed that it increased as boiling time increased. This could be as a result of moisture absorbed during boiling. The density of the tuber was observed to decrease as the boiling time increased, The %peel reduced as the boiling time increased; it ranged between 14 to 17% which falls within the range reported by (Adetan et al., 2003). And also the hardness decreased as the boiling time increased.
The analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) carried out revealed that there was no significant difference ($p>0.05$) between the moisture content of cassava boiled at 20 minutes and 30 minutes but there was a significant difference ($p<0.05$) between the samples boiled at 40 minutes and those of 20 and 30 minutes respectively. However, there was no significant effect ($p>0.05$) of the boiling time on the density, %peel and hardness of the tuber.

Table 1 Physical properties of cassava at different boiling times

Time (mins)	MC	Density (kg/m^3)	% peel	Hardness (kg)
20	55.93[a]	1287.5[a]	17.73[a]	2.07[a]
30	58.86[a]	1140.5[a]	16.06[a]	1.46[a]
40	63.09[b]	1002.40[a]	14.41[a]	1.23[a]

3.2 Effect of boiling time on frictional properties of the tuber
As shown in table 2, the coefficient of static friction increased with boiling time when positioned vertically against plywood and mild steel and when placed horizontally against mild steel. However, no clear trend was observed when it was placed against aluminium and horizontally against plywood. This suggests that there is no effect of boiling time on the coefficient of static frictions against these materials.
The analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) done shows that there was no significant difference between the frictional

properties of the tuber when boiled at the different times.

Table 2 Coefficient of static friction

	Plywood		Mild steel		Aluminium	
	H	V	H	V	H	V
20	0.86a	0.22a	0.61a	0.21a	0.63a	0.25a
30	0.79a	0.28a	0.68a	0.28a	0.98a	0.36a
40	1.2a	0.48a	1a	0.41a	0.86a	0.33a

3.3 Mechanical properties

As shown in tables 3 and 4, as boiling time increased, it was observed that the horizontal and vertical compressive strengths of the tuber decreased. This was the same for other mechanical properties measured except the horizontal stiffness moduli which increased as the boiling time increased.

The analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) done revealed that there was a significant effect ($p<0.05$) of the boiling time on the horizontal compressive strength but no significant difference ($p>0.05$) was shown in the vertical compressive strength

Table 3 Mechanical properties (horizontal loading)

Time (mins)	Comp strength H (N)	Stiffness moduli H (N/mm)	Toughness H (J)	Shear strength H (N)
20	425^{a}	150.57^{a}	1840.9^{a}	145.83^{a}
30	316.67^{b}	255.33^{a}	1479.4^{a}	139.58^{a}
40	225^{c}	338.9^{a}	446.33^{b}	95.83^{a}

Table 4 Mechanical properties (vertical loading)

Time (mins)	Comp strength V (N)	Stiffness moduli V (N/mm)	Toughness V (J)	Shear strength V (N)
20	195.83^{a}	145.37^{a}	659.63^{a}	120.83^{a}
30	175^{a}	120.37^{a}	454.97^{ab}	104.17^{a}
40	141.67^{a}	80.57^{a}	285.17^{b}	95.83^{a}

4. Conclusion

The effect of boiling time on the engineering properties of cassava boiled were investigated using cassava TME 419 specie. Some properties such as density, %peel, hardness, coefficient of static friction, stiffness moduli and shear strength were seen not to be significantly affected ($p>0.05$) by the boiling time. However, the boiling time is seen to have a significant effect on the moisture content, compressive strength and toughness.

The knowledge of the effect of boiling time on cassava could be used in the design of processing and handling equipment for the processing of *abacha* and cassava snacks.

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