

A Study of the Peel Penetration Pressure of Two Cassava Varieties

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Abstract: The pressure required to penetrate the peels of two cassava varieties (TMS 30572 and TMS 4(2)1425) of about 1.5 years old, using stainless steel knives was determined. A hand held penetrometer was calibrated, its conical head was replaced by knife-edges and it was used to determine the peel penetration force. The pressure required to penetrate the peels without damage to the tubers of the two cassava varieties increased as the peel thickness and tuber diameter increased. The study also showed that for TMS 30572 cassava variety, at knife-edge thickness 1.5 mm, the peel penetration pressure obtained ranged from 2.20 to 3.65 N/mm². Also, for knife-edge thickness 2.0 mm, the peel penetration pressure obtained ranged from 2.0 to 2.64 N/mm². Similar results were also observed for TMS 4(2)1425 cassava variety. There was no significant difference between the peel penetration forces for the two cassava varieties while using a knife edge of the same thickness.

Key words: Cassava varieties (TMS 30572 and TMS 4(2)1425) • Peel penetration pressure • Peel penetration force • Peel thickness • Tuber diameter

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a tropical plant which has a fibrous root system; some of these roots develop into tubers by the process of secondary thickening. These roots develop radially around the base of the plant forming five to ten tubers per plant. Typically, the root tapers from the end closer to the base of the plant (the proximal end) to the end farther away from the base of the plant (the distal end). Nigeria has been the world leading producer of cassava with an estimated annual production of 2.6 million tonnes from an estimated area of 1.7 million hectares of land [1, 2].

Cassava is mainly utilized as food in the producing nations; however, a sizable portion of the production is also utilized as raw material in the starch, plywood, paperboard, textile, pharmaceutical and many other industries. In Nigeria for example, an estimated 10% of the total cassava root produced in 2001 was used as chips in the animal feeds industry, 5% was processed into syrup concentrate for soft drinks and less than 1% was processed into high quality cassava flour used in biscuits and confectionery, dextrin pre-gelled starch for adhesives, starch and hydrolysates for pharmaceuticals and

seasonings [3]. The remaining 84% was consumed as human food. NEPAD [4] reported that 70% of total cassava production is processed into *gari*, *lafun* and *akpu*, three of the major food products obtainable from cassava root tubers.

In recent years, cassava production and processing received a major boost due to emerging areas of its utilization particularly in the oil and gas sector and its consequent adoption by many developing countries as a crop for enhanced food security, foreign exchange earning and a tool for rapid industrialization. Indeed, cassava has the potentials to contribute significantly to the transformation of rural African economies and thus improve livelihoods [4]. However, the potentials of the crop can only be fully realized through adequate processing because cassava is extremely highly perishable and the harvested tuber must be processed promptly to curb post-harvest losses [5-8].

There have been a number of research attempts at determining the properties of cassava that are relevant to its handling and processing as well as designing appropriate mechanical devices and systems for these operations. Adetan *et al.* [9] observed that the diameter of cassava root tubers varied between 18.8 and 88.5 mm

while the peel thickness ranged from 1.20 to 4.15 mm. Onwueme [10] and Ohwovoriole *et al.* [11] gave an earlier report that while tuber length varied between 150 and 1000 mm, the weight lies between 0.5 and 2.0 kg. The work of Ohwovoriole *et al.* [11] also showed that the diameter of tubers ranged from 16 to 83 mm and peel thickness ranged from 0.8 to 2.8 mm. This thickness of peel increased with tuber diameters even for the same tuber. The average peel-wood, peel-steel and peel-aluminium coefficient of friction reported by Ohwovoriole *et al.* [11] are 0.663, 0.577 and 0.404 respectively. Igbeka [12] also observed that the shear strength of cassava tuber increased from its centre to its peel with that of the peel being 3 to 4 times that of the centre. While the observed shear strength of the cassava tuber centre varied between 0.0218 and 0.087 N/mm², that of the peel varied between 1.5276 and 2.433 N/mm² depending on root moisture content. However, Adetan *et al.* [9] reported that the peel shearing stress of cassava ranged from 1.543 to 6.571 N/mm². The range is comparable to the 0.676-9.6 N/mm² reported by Odigboh [13].

Before the cassava tuber is processed into any of its food and some of its non-food products, it must be peeled. Peeling is simply the removal of the cassava peel (made up of the outer corky periderm and cortex) from the rest of the tuber. In the food industry, the peel must be completely removed without removing the useful tuber flesh.

For most processes, attempts at designing machines that will replace human labour usually focus on simulating the motion of the human hand during such processes. However, manual peeling of cassava by shearing with a knife has been shown not only to be inefficient but also wasteful [14]. Consequently, a need arises to examine the possibility of using methods other than one that simulates manual peeling by shearing with a knife.

Chemical peeling (using a hot solution of sodium hydroxide to loosen and soften the skin of roots), which is well developed for peeling sweet potatoes in processing industries, has been considered. A major reason why this method will not be suitable for cassava peeling is that a higher temperature and more root immersion time will be required for cassava tubers because they have peels that are tougher than those of potatoes. This will result in the formation of an objectionable heat ring (dark colour) on the surface of the useful tuber flesh and the gelatinization of starch in the cassava root [12]. Such roots are obviously unsuitable for the production of gari (granulated roasted cassava),

industrial starch, beverages, cassava flour and animal feed. For similar reasons, steam peeling is also ruled out for the peeling of cassava tubers.

Various models of abrasive drum batch peelers have also been tried. They are simple to fabricate and operate but they all have a common shortcoming: it is difficult for the abrasive surfaces to enter into the crevices and depressions on tuber surfaces. A tuber may be reduced to a cylinder of uniform radius with much wastage of useful flesh before satisfactory peeling is done. Otherwise, hand trimming is required to finish incompletely peeled tubers.

Ohwovoriole *et al.* [11] reported on a simple manual rig that works on the principle of peel-flesh separation through compression followed by peel penetration and removal with knives. With freshly harvested tubers, they reported no loss of useful flesh. Adetan *et al.* [15] developed an experimental mechanical peeling machine based on this peeling concept. It was observed during experimentation with this machine that sometimes, some of the tubers got crushed during the process of compression. However, the work confirmed that this principle has high promises for the cassava peeling mechanization problems. This study determined the force required to penetrate the peels of two commonly grown cassava varieties using stainless steel knives without tuber damage.

MATERIALS AND METHODS

The cassava tubers used for this study were freshly harvested from the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria. The varieties used were the commonly available cassava cultivars (TMS 30572 and TMS 4(2)1425) which were about 1.5 years (18 months) old at the time of harvest. A total of 1200 tubers of each of the cassava cultivars, freshly harvested from the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria, were used for the study. The tubers were cleansed manually to remove the impurities by picking out the large particles and thereafter washing with water to eliminate the presence of any trace of soil particles adhering to them.

Different types of measuring tools were used to carry out different measurements on the tubers. A tape measure was used to measure the lengths of tubers. The diameters of the tubers were measured using a pair of vernier calipers and the peel thickness was determined using a micrometer screw gauge. Knife edge thickness was also established using the micrometer screw gauge.



Fig. 1: Flat-pan head penetrometer



Fig. 2: Penetrometer with dead loads added in step of 2N

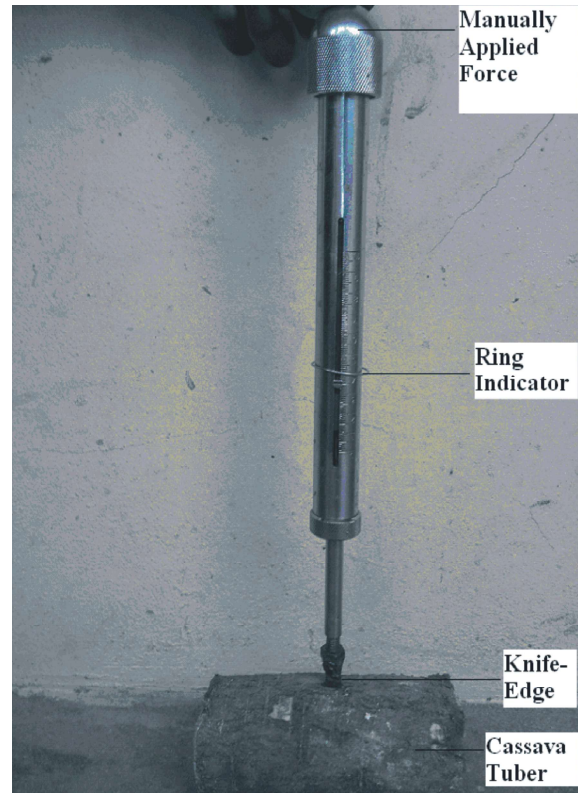


Fig. 3: Penetrometer with knife-edge after penetrating into the tuber peel

The force required to penetrate into the tuber peel with two stainless steel knife-edges having the same width, 7.0 mm, but different thicknesses, 1.5 and 2.0 mm were taken by an adapted hand-held penetrometer. The penetrometer was calibrated by replacing the conical head with a flat-pan head and clamping the penetrometer vertically in a vice (Figure 1). Dead loads were then placed on the pan in steps of 2 N and the reading indicated on the penetrometer by the movable ring indicator was noted at each step of loading (Figure 2). The readings obtained from the movable ring indicator were recorded and a penetrometer calibration graph was plotted out of these readings.

To measure the peel penetration pressure such that it could be related to the tuber diameter, a longitudinal line was marked on the tuber surface and transverse division marks were made along this line at intervals of 25 mm starting from the proximal to the distal end of the tuber. Each tuber was clamped between the jaws of a vice. The penetrometer's flat pan head (used for calibration) was replaced with a knife-edge head and the sharp edge of the penetrometer's knife-edge was placed normal to the tuber surface between two division marks. Force was then

applied manually to the penetrometer until the knife-edge penetrated the peel of the tuber (Figure 3). The position of the ring indicator was noted and the corresponding peel penetration force was read off from the penetrometer calibration graph. The diameter midway between the two transverse division marks was taken as the diameter at the point of measure of the peel penetration force. Thereafter, the tubers were sliced along the transverse marks, each slice was peeled off and the thickness of the peel was taken. In this way, peel penetration force was measured at intervals of 25 mm along the length of the tuber and at varying diameter values. Multiple regression analysis was used to establish mathematical relationships between the properties of the cassava tubers.

RESULT AND DISCUSSION

Peel Thickness: The peel thickness (t) ranged from 2.30 to 4.14 mm while the average value obtained was 3.35 mm for TMS 30572. For TMS 4(2)1425, peel thickness (t) observed ranged from 2.20 to 4.29 mm while the average value was 3.20 mm. Adetan *et al.* [9] reported peel thickness range of 1.20 - 4.15 mm and average value, 2.21 mm for TMS 30572 using a micrometer screw guage. Also, for an unspecified cassava variety, Ohwovoriole *et al.* [11] reported a range of peel thickness of 0.80 - 2.80 mm using a pair of vernier caliper.

Tuber Diameter: The range of diameter of tubers observed for TMS 30572 was 21 to 99.5 mm. This seems to agree closely with the values reported by Adetan *et al.* [9]. For TMS 4(2)1425, the range of diameter of tubers (d) observed is 21.5 to 99 mm. These values agree closely with the values reported by Adetan *et al.* [9] and Ohwovoriole *et al.* [11].

Peel Penetration Force: For TMS 30572 cassava variety and with a knife-edge of 1.5 mm thickness, the peel penetration force per unit length of knife edge (F_p) varied between 3.30 and 5.47 N/mm and had an average value of 4.35 N/mm. These values were converted to peel penetration pressure (P_p) by dividing them by 1.5 mm, the thickness of the knife-edge mounted on the penetrometer used for measuring peel penetration force (F_p). The peel penetration pressure (P_p) obtained ranged from 2.20 to 3.65 N/mm² and had an average value of 2.90 N/mm².

Similarly, when a knife-edge of thickness 2.0 mm was used for TMS 30572, the peel penetration force per unit length of the knife-edge (F_p) varied between 3.99 and 5.27 N/mm and average value of 4.64 N/mm. These values, when converted to peel penetration pressure (P_p) by

dividing them by 2.0 mm, (knife-edge thickness), resulted in peel penetration pressure (P_p) ranging from 2.0 to 2.64 N/mm² and having average value of 2.32 N/mm². This is comparable to the result of the work done by Adetan *et al.* [9] who reported a peel penetration pressure range of 1.543 - 6.571 N/mm².

For TMS 4(2)1425 cassava variety, with a knife-edge thickness (K_t) of 1.5 mm, the peel penetration force per unit length of the knife-edge (F_p) varied between 2.42 and 3.78 N/mm and had an average value of 2.97 N/mm. When the values were converted to peel penetration pressure (P_p), P_p obtained ranged from 1.61 to 2.52 N/mm² and average at 1.98 N/mm². With knife-edge thickness of 2.0 mm, F_p varied between 2.70 and 4.61 N/mm and had an average value of 3.45 N/mm. These values, when converted to peel penetration pressure (P_p), gave a range from 1.35 to 2.31 N/mm² and an average value of 1.73 N/mm². These ranges are also comparable to the values reported by Adetan *et al.* [9] and Odigboh [13].

Further analysis shows that at 0.05 significance level, there was no statistically significant difference in the penetration force obtained for TMS 30572 using knife thicknesses 1.5 and 2.0 mm. Similarly, there was no significant difference between the knife-edges of thicknesses 1.5 and 2.0 mm with respect to penetration force for cassava variety TMS 4(2)1425. Furthermore, at 0.05 significance level, when a knife-edge of the same thickness (1.5 or 2.0 mm) is use, there was also no significant difference between the two cassava varieties with respect to peel penetration force.

Variation of Peel Penetration Force per Unit Length of Knife-Edge with Peel Thickness and Diameter: For the cassava variety TMS 30572, a multiple regression analysis of F_p on t and d for knife thickness $K_t = 1.5$ mm gave the linear relationship of Equation (1) below.

$$F_p = 0.144t + 0.26d + 2.351 \quad (1)$$

where

F_p (N/mm) is peel penetration force per unit length of knife-edge, t (mm) is the peel thickness and d (mm) is the diameter of tuber slices.

The correlation coefficient (r) value is 0.9747 and the coefficient of determination (r^2) value is 0.9500. This shows that 95% of peel penetration force per unit length of knife-edge is explained by the relationship. The relationship is statistically significant at 0.05 significance level.

Similarly, a multiple regression analysis of F_p on t and d for knife-edge thickness K_t of 2.0 mm resulted in the following linear relationship of Equation (2) with a correlation coefficient (r) value of 0.9905 and a coefficient of determination (r^2) 0.9810.

$$F_p = 0.383t + 0.009d + 2.683 \quad (2)$$

This shows that 98.10% of peel penetration force per unit length of knife-edge is explained by this relationship. The test of significance of correlation also shows that this relationship is statistically significant at 0.05 significance level.

For TMS 4(2)1425 cassava variety, the regression analysis of the values of F_p on t and d resulted in the following Equations (3) and (4) for knife-edge thickness (K_t) values of 1.5 and 2.0 mm respectively.

$$F_p = 0.131t + 0.16d + 1.566 \quad (3)$$

$$F_p = 0.511t + 0.010d + 1.170 \quad (4)$$

The correlation and determination coefficients for Equation (3) are 0.9829 and 0.9660 respectively while those for Equations (4) are 0.9731 and 0.9469 respectively. Test of significance also shows that these equations (3) and (4) are also statistically significant at 0.05 significance level.

From Equations (1) through (4), it may be concluded that for both TMS 30572 and TMS 4(2)1425 cassava varieties, the peel penetration force per unit length of knife-edge increases with the tuber peel thickness and diameter. These equations would be very useful in predicting the value of F_p that will be enough to cause a knife-edge to just penetrate into the peel of the tuber of given diameter without applying excessive pressure that could result in tuber breakage prior to the removal of the peel.

CONCLUSION

The pressure required to penetrate the peels of cassava root tubers using stainless steel knives without damage to the tubers was investigated for two cassava varieties (TMS 30572 and TMS 4(2)1425). The results show that the peel penetration pressure increased linearly as the tuber peel thickness and diameter increased. It was also established that there was no significant difference between the peel penetration force values obtained while

using knife edges of thicknesses 1.5 and 2.0 mm. Further analysis showed that there was no significant difference between the two cassava varieties with respect to the peel penetration force while using a knife of given cutting edge thickness.

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