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Effect of physical and mechanical properties of cassava tubers on the performance of an automated peeling machine

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Abstract

Peeling of cassava tuber at all levels is still largely carried out manually; however, this work is presented with a view to investigate the effect of physical and mechanical properties of cassava tubers on mechanical peeling and hence provides a basis for cassava peeling mechanization. These properties include size of the tuber, t_l, proportion by weight of peel, w_p, average moisture content of the peel, m_{ap}, peel thickness, t_p, tuber diameter, t_d, tuber surface taper angle, α, peel penetration force, F, and peel shearing stress, t_s. The results showed that for S_{lmhf}; t_l ranged from 140-460mm, w_p ranged from 13.12-20.06%, m_{ap} was 76.27%, t_p ranged from 1.62-4.34mm, t_d ranged from 31.08-136.63mm, α ranged from 9.03-23.13^0, F ranged from 0.17-1.85N/mm, t_s ranged from 0.85-9.25N/mm^2 and quality performance of the machine, Q_{PE}, for this tuber ranged from 70.82-96.21%. Similarly, for S_{smlf}; t_l ranged from 125-362mm, w_p ranged from 10.52-16.66%, m_{ap} was 70.97%, t_p ranged from 1.22-4.12mm, t_d ranged from 18.86-99.29mm, α ranged from 5.20-12.29^0, F ranged from 0.13-1.54N/mm, t_s ranged from 0.65-7.70N/mm^2 and quality performance of the machine, Q_{PE}, for this tuber ranged from 67.27-92.25 %. The results confirm influence of physico-mechanical properties of cassava tuber on mechanical peeling.

Keywords: Cassava, Peeling, Properties, Performance, Machine

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1. Introduction

Cassava (Manihot esculenta, Crantz) is a tropical plant which has a fibrous root system. Some of these roots develop into root tubers by the process of secondary thickening. These roots develop radials around the base of the plant forming five to ten tubers per plant. These are the main economically useful parts of the plant (Ajibola, 2000). It usually elongated, has depressions and crevices along its length and tapers to one end. In most cases, the middle part has a fairly constant diameter. Whereas the head end has a relatively large diameter, the tail end has a considerably smaller diameter when compared with the middle part. The head and tail ends are generally referred to as the proximal and distal ends respectively. At its proximal end, the tuber is joined to the rest of the plant by a short woody 'neck' (Adetan et al., 2003). A transverse section of the tuber shows that it consists of central core called the pith. This 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 is surrounded by a thin cambium layer. Covering the cambium layer is the tuber peel. The peel 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 part of the peel contains the cortex. The cortical region is usually white in colour (Adetan et al., 2003).

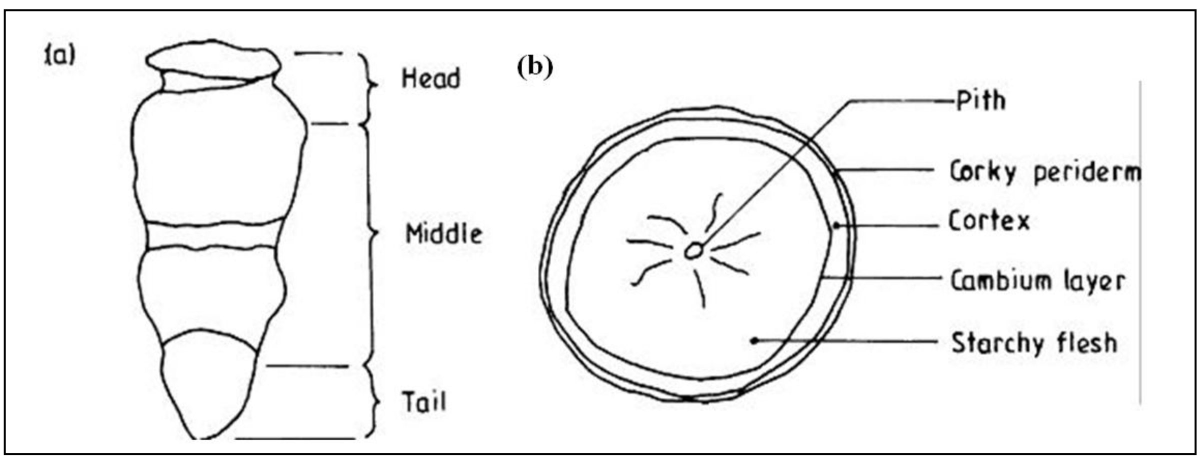

Figure1. Morphology of the casssava tuber: (a) general morphology and (b) transverse section (Adetan et al., 2003)

The loosening of the whole peel from the central part facilitates the peeling of the roots. As the tuber continues to increase in diameter, the continuity of the cork layer is broken, so that longitudinal cracks or fissures appear on the surface of the tuber. However, new corks soon form beneath the cracks to restore the integrity of the protective corky layer (Igbeka, 1984). Cassava is a popular, most important food energy and commercial crop in tropical countries. There are numerous varieties of cassava in the world today and these are usually differentiated from one another by their botanical characteristic and level of hydrocyanic acid which causes toxicity in the root. This toxicity vary from place to place, in many instances, a bitter variety may become sweet for example or vice versa. This is as a result of environmental factors such as soil type, soil moisture, soil fertility, tillage practice and vegetation of the farm. The numerous varieties of cassava are usually grouped in two main categories: Manihot palmate and Manihot utilissima, or bitter and sweet cassava (Grace, 2004). Olukunle and Oguntude, (2007) further reported that soil factors would also influence shape and size of the tuber which constitutes major bottleneck in cassava peeling.

Cassava has nutritive and commercial benefits which make it attractive especially to the local farmers. First, it is rich in carbohydrates and could be enriched with other food composition such as protein to obtain nourishment. Secondly, it is always available in all seasons, making it preferable to other more seasonal crops such as grains, peas, beans and other crops for food security. Compared to other crops, cassava is more tolerant to low soil fertility, and more resistance to pest and diseases. More importantly too, it produces very well on soil so depleted by repeated cultivation that has becomes unsuitable for other crops. It also tolerates environmental stresses such as short period of drought, strong and desiccating winds (Osundahunsi, 2005). All the unit operations involved in cassava processing such as grating, drying, milling, pressing, sieving, frying and extrusion have been mechanized successfully; however, peeling remains the only unmechanized process which has constituted a serious global challenge in food industries. This has invariably slow down medium-large scale utilization of the crop. The versatility of the crop call for scientific approach aiming at investigating effect of physical and mechanical properties of cassava tubers on the performance of an automated cassava peeling machine.

2. Materials and methods

2.1. Research materials

The cassava tubers (Manihot utilissima) used for this experiment were obtained from two different farm locations with different soil factors such as vegetation of the farm, soil type, soil water and soil nutrient. In the course of the experiment, the tubers were categorized into three different classes namely; small, medium and large sizes while the clustering criteria include the combined feature of length, weight and diameter. The tubers were harvested fully matured, the age at harvest was 18 months and the soil particles were washed off completely before the commencement of the test. The locations of the farm are;

a) Ibilo, Edo State Nigeria. The agricultural practice of this site is shifting cultivation with minimum of 4 years soil nutrient replenishment before next land clearing. The soil is characterized with sandy loams, moist, high fertility and good farm vegetation (S_{lmhf}).

b) Awo-Mmama, Imo State, Nigeria. Here, the agricultural practices is subsistence farming because of scarcity of land and about 90% of the farmers in this location engaged in cassava plantation. The soil is characterized with sand, moist, relatively low fertility and poor farm vegetation (S_{smlf}).

2.2. Machine description

An automated cassava peeling machine with variable speed was developed at the Department of Agricultural Engineering, Federal University of technology, Akure Nigeria. The design of the machine was based on the development and modification of the peeling tool of previous cassava peeling machines. This was aimed at achieving a good tool configuration to achieve 100% cassava tuber flesh recovery irrespective of the size, shape, variety and orientation of the tuber. The mail feature of the machine includes: peeling chamber, peeling tool, supporting frame, hopper and transmission system.

2.3. Measuring tools and instruments

A variety of tools and instruments were used to carry out different measurements on the root tubers. A tap measure was used to measure the lengths of roots while the diameters of the roots were measured using a pair of vernier caliper. The weights of roots before and after peeling and that of the peels were measured with an electronic weighing balance while the thickness of the root peel was measured by micrometer screw gauge.

2.4. Determination of physical and mechanical properties of cassava tuber

2.4.1. Grading of cassava tuber

Cassava tubers freshly harvested from each farm locations were graded into small, medium and large sizes. 20 tubers of each size range were considered during experiment. Length, t_l of each tubers was measured, average tuber length, t_{al} and its standard deviation, Sd were determined as shown in Table 1.

Table 1. Determination of tuber length

Size	**Tuber length (S_{lmhf} cassava)**			**Tuber length (S_{smlf} cassava)**		
	Range(mm)	*t_{al} (mm)*	*Sd*	*Range(mm)*	*t_{al}(mm)*	*Sd*
Small	$140<t_l<190$	159	6	$125<t_l<180$	148	6
Medium	$191<t_l<320$	253	8	$181<t_l<256$	215	7
Large	$321<t_l<460$	380	8	$257<t_l<362$	297	7

2.4.2. Determination of proportion by weight of peel in the tuber, (w_p)

The graded tubers were weighed separately and the weight of each tuber, w_1 was noted. Each of the tubers was then carefully hand-peeled such that no traces of tuber flesh were found on the peel. The weight of tuber flesh hand-peeled, w_2 was also noted. The proportion by weight of peel, w_p, average proportion by weight of peel, w_{ap}, and its standard deviation, Sd for each size range were also determined as shown in Tables 2 using expression:

$$w_p = \left[\frac{w_1 - w_2}{w_1}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Table 2. Determination of proportion by weight of peel

Size	Proportion by weight of peel (S_{lmhf} cassava)			Proportion by weight of peel (S_{smlf} cassava)		
	Range (%)	*w_{ap} (%)*	*Sd*	*Range (%)*	*w_{ap} (%)*	*Sd*
Small	$13.12<w_p<16.45$	14.88	0.15	$10.52<w_p<12.30$	11.14	0.12
Medium	$14.16<w_p<17.38$	15.91	0.17	$10.85<w_p<14.53$	12.56	0.13
Large	$15.43<w_p<20.06$	17.22	022	$13.38<w_p<16.66$	14.93	0.12

2.4.3. Determination of moisture content of the peel, (m_p)

The moisture content was determined by sun drying using dry base method. 5 freshly harvested tubers were selected at random from each of the farm locations. The peel of each tuber was carefully removed by knife in such a way that tuber flesh was intact and weighed, m_1, the peel was sun-dried until repeated weight, m_2 was obtained. Percentage moisture content, % m_p of the peel was determined as:

$$\%m_p(db) = \left[\frac{m_1 - m_2}{m_2}\right] \times 100 \ldots\ldots\ldots\ldots 2$$

Average moisture content of the peel, m_{ap} for each farm location was also determined.

2.4.4. Determination of peel thickness, (tp)

Another 60 tubers were collected and graded into small, medium and large sizes from each of the two farm locations. Transverse division marks were made on the surface of each tuber at interval of 50 mm from the proximal to the distal end. Each tuber was cut through along the mark and the diameter, t_d, average diameter, t_{ad}, and its standard deviation, Sd for each slice were determined along four different diametric lines approximately 45^0 to each other as shown in Table 3. The peel was carefully removed from the surface of each tuber slice and the thickness of the peel for respective slice was taken. From each of the farm locations, peel thickness, t_p, average peel thickness, t_{ap}, and its standard deviation, Sd for each size range were determined as shown in Table 4.

Table 3. Determination of tuber diameter

Size	Tuber diameter (S_{lmhf} cassava)			Tuber diameter (S_{smlf} cassava)		
	Range(mm)	t_{ad}*(mm)*	*Sd*	*Range(mm)*	t_{ad}*(mm)*	*Sd*
Small	$31.08<t_d<70.84$	50.45	11.53	$18.86<t_d<49.75$	35.17	7.56
Medium	$51.24<t_d<101.18$	80.01	12.55	$26.12<t_d<83.40$	45.27	10.23
Large	$74.03<t_d<136.63$	101.74	15.56	$33.47<t_d<99.29$	52.87	13.06

Table 4. Determination of tuber peel thickness

Size	Peel thickness (S_{lmhf} cassava)			Peel thickness (S_{smlf} cassava)		
	Range(mm)	t_{ap}*(mm)*	*Sd*	*Range(mm)*	t_{ap}*(mm)*	*Sd*
Small	$1.62<t_p<4.25$	2.59	0.79	$1.22<t_p<3.96$	2.13	0.36
Medium	$1.82<t_p<4.27$	2.67	0.58	$1.25<t_p<3.95$	2.36	0.32
Large	$1.88<t_p<4.34$	3.27	0.35	$1.26<t_p<4.12$	2.60	0.31

2.4.5. Determination of tuber surface taper angle, (α)

The shape of cassava slice at 50mm interval becomes frustum of a right circular cone as shown in Figure 2, where R is the radius of the upper base, r is the radius of the lower base, s is the slanting side, and h is the height of tuber slice. To determine the taper angle, α, the two slanting sides are projected further to meet at point O; angle subtended by the right circular cone at the point of interception is the tuber surface taper angle. Average taper angle, α_a, and its standard deviation, Sd, for each size range were also determined as shown in Table 5.

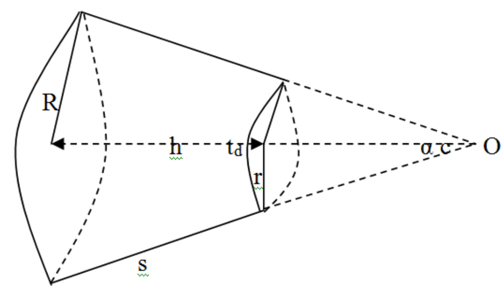

Figure 2. Schematic illustration of tuber surface taper angle determination

Table 5. Determination of tuber surface taper angle

Size	**Surface taper angle (S_{lmhf} cassava)**			**Surface taper angle (S_{smlf} cassava)**		
	Range (^{0})	*α_a (^{0})*	*Sd*	*Range (^{0})*	*α_a (^{0})*	*Sd*
Small	9.03<α<14.21	10.66	0.41	5.20<α<8.73	6.33	0.25
Medium	10.48<α<18.66	12.00	0.62	7.57<α<10.63	8.84	0.47
Large	14.95<α<23.13	16.52	0.96	9.78<α<12.29	10.31	0.60

2.4.6. Determination of peel penetration force, (F)

To determine peel penetration force per unit length of cutting blade, the sliced root to be peeled was considered as an approximate frustum of a cone. This was done to reduce the problem posed by tuber size and shape. The concept was to generate a force that will be sufficient to penetrate through the peel thickness during peeling process to achieve 100% useful tuber flesh recovery. Peel penetration force is calculated from the data obtained using the following mathematical expression:

$$F = K_s \left[\frac{t_{ap}}{w} \frac{F_p}{l_1} \right] \qquad \text{..........3}$$

where F is the force require to penetrate through root peel, t_{ap} is the average tuber peel thickness, F_p is the force in play as a result of pressure exerted by the tuber on the cutting tool during peeling, w is the difference between peel thickness and height of the cutting blade, l_1 is the length of line of contact of the cutting blade on the tuber, k_s is the constant proportionality, k_s = 0.207 (Adetan et al., 2006). Average force of penetration, F_a, and its standard deviation, Sd, were also determined as shown in Table 6.

Table 6. Determination of peel penetration force

Size	peel penetration force (S_{lmhf} cassava)			peel penetration force (S_{smlf} cassava)		
	Range (N/mm)	*F_a (N/mm)*	*Sd*	*Range (N/mm)*	*F_a (N/mm)*	*Sd*
Small	0.17<F<1.11	0.88	0.08	0.13<F<1.05	0.75	0.06
Medium	0.24<F<1.35	1.03	0.15	0.15<F<1.22	0.91	0.13
Large	0.59<F<1.85	1.21	0.23	0.36<F<1.54	1.10	0.17

2.4.7. Determination of peel shearing stress (t_s)

Tuber shearing stress is determined by dividing peel penetration force by 0.50mm, the thickness of the cutting blade on the cutting tool. The peel shearing stress, t_s, average peel shearing stress, t_{as}, and its standard deviation were determined as shown in Table 7.

Table 7. Determination of peel shearing stress

Size	Peel shearing stress (S_{lmhf} cassava)			Peel shearing stress (S_{smlf} cassava)		
	Range (N/mm²)	*t_{as}(N/mm²)*	*Sd*	*Range (N/mm²)*	*t_{as}(N/mm²)*	*Sd*
Small	$0.85<t_s<5.55$	4.40	0.40	$0.65<t_s<5.25$	3.75	0.30
Medium	$1.20<t_s<6.75$	5.15	0.75	$0.75<t_s<6.10$	4.55	0.65
Large	$2.95<t_s<9.25$	6.05	1.15	$1.80<t_s<7.70$	5.50	0.85

2.5. Determination of quality performance efficiency of the machine, Q_{PE}

Quality performance efficiency of the machine for each size range at feed rate; 10, 20, 30, 40 and 50 kg is determined for each location using the following mathematical expression:

$$Q_{PE} = [(I - M_D)(1 - P_R)] \ldots\ldots\ldots\ldots\ldots\ldots 4$$

where M_D is the mechanical damage and P_R is the peel retention.

3. Results and discussions

3.1. Results of physical and mechanical properties of cassava tuber

The data obtained from the experiment shows that cassava length, t_l in S_{lmhf} ranges from; 140-190 mm for small sizes, 191-320 mm for medium sizes, and 321- 460mm for large sizes. In S_{smlf}, the length ranges from; 125-180 mm for small sizes, 181-256 mm for medium sizes, and 257-362mm for large sizes. This revealed that cassava tubers from S_{lmhf} are taller than those from S_{smlf}, this is because of environmental factor. The observed diameter of the tuber, t_d in S_{lmhf} ranges from; 31.08-70.84mm for small sizes, 51.24-101.18mm for medium sizes, and 74.03-136.63mm for large sizes. In S_{smlf}, the diameter ranges from; 18.86-49.75mm for small sizes, 26.12-83.40mm for medium sizes, and 33.47-99.29 mm for large sizes. The tuber diameter in S_{smlf} seems to agree closely with the value 18.80-88.50 mm reported by (Adetan et at., 2003). The root surface taper angle, α in S_{lmhf} ranges from; 9.03-14.21^0 for small sizes, 10.48-18.66^0 for medium sizes, and 14.95-23.13^0 for large sizes. In S_{smlf}, the root surface taper angle ranges from; 5.20-8.73^0 for small sizes, 7.57-10.63^0 for medium sizes, and 9.78-12.29^0 for large sizes. It was observed that the tuber taper angle varied with respect to size of the tuber and this was higher in S_{lmhf}. This is important so as to determine the angle of inclination at which cutting blade or knife will be subtended for effective peel removal during mechanical peeling of cassava tuber.

The result of the experiment shows that the proportion by weight of peel, w_p of the tuber in S_{lmhf} ranges from; 13.12-16.45% for small sizes, 14.16-17.38% for medium sizes, and 15.43-20.06% for large sizes. In $S_{smlf,}$ the proportion by weight of peel ranges from; 10.52-12.30% for small sizes, 10.85-14.53% for medium sizes, and 13.38-16.66% for large sizes. The result in S_{lmhf} fall within the range reported by (Adetan et al., 2003) while that of S_{smlf} fall within the range reported by (Ezekwe, 1979). This shows that differences in environmental factor responsible for the divergence in crop properties. Average peel moisture content in S_{lmhf} observed in this work is 76.27% while in $S_{smlf,}$ it is 70.97%. This is important in designing speed of cutting tool and magnitude of impact on tubers during peeling process. The thickness of peel, t_p in S_{lmhf} ranges from; 1.62-4.25mm for small sizes, 1.82-4.27mm for medium sizes, and 1.88-4.34mm for large sizes. In $S_{smlf,}$ the peel thickness ranges from; 1.22-3.96mm for small sizes, 1.25-3.95mm for medium sizes, and 1.26-4.12mm for large sizes. The result in S_{smlf} is in accordance with (Adetan et al., 2003).

The observed peel penetration force per unit length of cutting blade in S_{lmhf} ranges from; 0.17-1.11N/mm for small sizes, 0.24-1.35N/mm for medium sizes, and 0.59-1.85N/mm for large sizes. In S_{smlf}, the peel penetration force per unit length of cutting blade ranges from; 0.13-1.05N/mm for small sizes, 0.15-1.22N/mm for medium sizes, and 0.36-1.54N/mm for large sizes. The result is slightly lower than the range of 0.54-2.30N/mm reported by (Adetan et al., 2003). However, a lot of damages would have been done to tubers flesh if they were to be peeled mechanically. This work is aimed at achieving 100% quality tuber flesh recovery. The peel shearing stress obtained in S_{lmhf} ranges from; 0.85-5.55N/mm^2 for small sizes, 1.20-6.75N/mm^2 for medium sizes, and 2.95-9.25N/mm^2 for large sizes. In S_{smlf}, the peel shearing stress ranges from; 0.65-5.25N/mm^2 for small sizes, 0.75-6.10N/mm^2 for medium sizes, and 1.80-7.70N/mm^2 for large sizes. This is in agreement to the result, 0.68-9.60N/mm^2 achieved by (Odigboh, 1983).

Table 8 (a). Determination of quality performance efficiency (S_{lmhf})

Size	**Speed (rpm)**	**Q_{PE} (%) at different feed rate**				
		10 kg	*20 kg*	*30 kg*	*40 kg*	*50 kg*
Small	100	79.79	71.91	71.13	70.88	70.82
	110	80.21	72.69	71.96	71.89	71.84
	120	81.20	73.44	72.58	72.31	72.25
	130	94.03	85.29	83.73	83.56	83.11
	140	91.24	83.31	82.77	82.55	82.28
Medium	100	81.40	81.81	80.03	82.68	82.34
	110	83.19	83.31	82.54	83.57	84.00
	120	85.13	84.68	84.33	83.77	85.33
	130	94.78	93.00	94.87	95.59	96.21
	140	92.56	91.86	94.14	95.21	95.79
Large	100	84.39	85.33	83.06	80.21	78.29
	110	87.52	87.93	85.24	81.87	79.70
	120	89.86	90.49	91.71	89.84	89.54
	130	94.18	93.93	93.39	92.39	91.58
	140	88.10	91.84	91.37	90.66	90.49

Table 8 (b). Determination of quality performance efficiency (S_{smlf})

Size	Speed (rpm)	Q_{PE} (%) at different feed rate				
		10 kg	*20 kg*	*30 kg*	*40 kg*	*50 kg*
Small	100	77.67	71.34	70.71	70.28	70.39
	110	78.06	71.13	71.25	71.06	71.07
	120	80.53	67.27	71.86	71.56	71.60
	130	84.94	75.12	78.43	73.00	71.54
	140	82.82	73.75	73.01	72.37	72.32
Medium	100	80.77	80.18	78.67	82.05	82.03
	110	81.55	82.25	81.89	82.73	83.45
	120	83.99	83.87	83.69	84.27	84.83
	130	87.61	91.18	84.88	85.00	85.39
	140	85.26	90.34	84.21	84.77	85.07
Large	100	83.48	84.06	82.43	79.55	77.49
	110	86.24	87.02	84.47	81.14	79.07
	120	88.14	89.51	87.32	83.33	80.81
	130	92.25	91.50	89.69	85.05	82.34
	140	90.47	88.65	88.20	83.81	81.28

3.2. Effect of tuber properties on quality performance of the machine

The trend in the results shows that properties of the tuber increases with size. During mechanical peeling of small tubers and as machine speed increases from100-130 rpm, at feed rate 10 kg; quality performance efficiency (Q_{PE}) increases from 79.79-94.03% and decreases to 91.24% as speed further increases to 140 rpm for S_{lmhf} while for S_{smlf}, it increases from 77.67-84.94% and decreases to 82.82% as speed increases to 140 rpm. At feed rate 20 kg; Q_{PE} increases from 71.91-85.29% and decreases to 83.31% as machine speed increases to 140 rpm for S_{lmhf}, it also increases from 71.34-75.12% and decreases to 73.75% as speed increases to 140 rpm for S_{smlf}. At feed rate 30 kg; it increases from 71.13-83.73% and decreases to 82.77% as speed further increases to 140 rpm for S_{lmhf}, it increases from 70.71-78.43% and decreases to 73.01% as speed increases to 140 rpm for S_{smlf}. At feed rate 40 kg; it increases from 70.88-83.56% and decreases to 82.55 as speed increases to 140 rpm for S_{lmhf}, it also increases from 70.28-73% and decreases to 72.37% as speed increases to 140 rpm for S_{smlf}. At feed rate 50 kg; Q_{PE} increases from 70.82-83.11% and decreases to 82.28 as speed further increases to 140 rpm for S_{lmhf}, for S_{smlf}, it also increases from 70.39-71.54% and increases to 72.32% as speed further increases to 140 rpm.

During peeling of medium sizes, and as speed increases from 100-130 rpm, at feed rate10 kg; Q_{PE} increases from 81.40-94.78% and decreases to 92.56% as speed further increases to 140 rpm for S_{lmhf}, it also increases from 80.77-87.61% and decreases to 82.82% as speed increases to 140 rpm for S_{smlf}. At feed rate 20 kg; Q_{PE} increases from 81.81-93% and decreases to 91.86% as speed increases to 140 rpm for S_{lmhf}, it increases from 80.18-91.18% and decreases to 90.34% as speed further increases to 140 rpm for S_{smlf}. At feed rate 30 kg; Q_{PE} increases from 80.03-94.87% and decreases to 94.14% as speed further increases to 140 rpm for S_{lmhf}, it also increases from 78.67-84.88% and decreases to 84.21% as speed further increases to 140 rpm for S_{smlf}. At feed rate 40 kg; Q_{PE} increases from 82.68-95.59% and decreases to 95.21% as speed increases to 140 rpm for S_{lmhf}, for S_{smlf}, Q_{PE} increases from 82.05-85% and decreases to 84.77% as speed further increases to 140 rpm. At feed rate 50 kg; Q_{PE} increases from 82.34-96.21% and decreases to 95.79% as speed increases to 140 rpm for S_{lmhf}, while for S_{smlf}, it increases from 82.03-85.39% and decreases to 85.07% as speed further increases to 140 rpm.

Mechanical peeling of large sizes of cassava tuber, and as speed increases from 100-130 rpm, at feed rate10 kg; Q_{PE} increases from 84.39-94.18% and decreases to 88.10% as speed further increases to 140 rpm for S_{lmhf}, it also increases from 83.48-92.25% and decreases to 90.47% as speed increases to 140 rpm for S_{smlf}. At feed rate 20 kg; Q_{PE} increases from 85.33-93.93% and decreases to 91.84% as speed increases to 140 rpm for S_{lmhf}, it increases from 84.06-91.50% and decreases to 88.65% as speed further increases to 140 rpm for S_{smlf}. At feed rate 30 kg; Q_{PE} increases from 83.06-93.39% and decreases to 91.37% as speed further increases to 140 rpm for S_{lmhf}, it also increases from 82.43-89.69% and decreases to 88.20% as speed further increases to 140 rpm for S_{smlf}. At feed rate 40 kg; Q_{PE} increases from 80.21-92.39% and decreases to 90.66% as speed increases to 140 rpm for S_{lmhf}, for S_{smlf}, Q_{PE} increases from 79.55-85.05% and decreases to 83.81% as speed further increases to 140 rpm. At feed rate 50 kg; Q_{PE} increases from 78.29-91.58% and decreases to 90.49% as speed increases to 140 rpm for S_{lmhf}, while for S_{smlf}, it increases from 77.49-82.34% and decreases to 81.28% as speed further increases to 140 rpm.

4. Conclusions

i. Clustering of cassava tubers is in right direction for quality peeling performance. This is because the shearing stress needed for large sizes would have deep into tuber flesh of smaller sizes. However, the performance is relatively low during S_{smlf} peeling simply because of poor environmental factors.
ii. Cutting of tubers into slices to form frustum of a cone addresses the problem posed by tuber size and shape so as to enhance effective quality peeling.

iii. Performance of the machine improves as its speed increases up to 130 rpm and declined as the speed further increases. This is because the shearing stress is exceeded.

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