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Research Paper

Investigation of cassava tuber physical characteristics and their relationships

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Jinyemiema TK[1], Igboanugo AC[2] and Ariavie GO[3]

[1]Department of Mechanical Engineering, Ken Saro Wiwa Polytechnic, Bori, Rivers State.
[2]Department of Production Engineering,
[3]Department of Mechanical Engineering, University of Benin, Benin City. Edo State

*Corresponding author. E-mail: kurotamuno2000@yahoo.com.

ABSTRACT

This paper investigates cassava tuber characteristics with a view to inform researchers on the relationships that exist between these parameters, which may assist in designing an efficient and effective cassava peeling machine. Tubers were collected from different locations in Rivers and Abia States, Nigeria and the length, diameters at the head, mid-section and tail sections were measured as well as, peel thickness. The investigation revealed that an irregular relationship exist between the length and diameters at the different sections. However, the research also revealed that a polynomial of second order relationship exist between the diameter and peel thickness with a governing equation: $y = -15.92x^2 + 123.51x - 146.75$, with R2 value of 0.8571. Tubers collected from part of Rivers and Abia fit into Fourier relationships in the MATlab code denoted as: $y = 2.869 + 0.8025\text{Cos}(0.04878x) - 0.3073\text{Sin}(0.04878x)$, $y = 3.003 + 0.2758\text{Cos}(0.0371x) - 1.006\text{Sin}(0.0371x)$ and $y = 2.48 + 0.4703\text{Cos}(0.0895x) + 0.3684\text{Sin}(0.08985x)$ for the head, mid and tail sections respectively, with R^2 values of 0.9449, 0.9556 and 0.9328 for the corresponding sections. A trial with polynomial of third order with same did not show any relationship of that order.

Key words: Peel, relationships, thickness, tuber, cassava, diameter, length.

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-Sahara 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 of the reasons for investigating the physical and 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

Figure 1: Picture of cassava tubers show peeled sections.

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 post-harvest 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 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, 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 firsthand 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) Physical characteristics measurement which include:

i) Diameter;

ii) Length;

iii) Peel thickness.

Table 1: Measured values of cassava tuber characteristics from RUST, Port Harcourt, Rivers State.

S/N	Length (mm)	Head diameter (mm)	Tail diameter (mm)	Peel thickness	
				Head, t_1	Tail, t_2
1	211.400	61.325	34.375	2.736	2.402
2	251.225	56.150	29.000	2.976	2.435
3	264.000	52.350	29.250	2.778	2.439
4	228.225	60.500	25.225	2.802	2.256
5	274.225	49.275	34.050	2.378	2.226
6	307.150	45.325	29.900	2.554	2.089
7	210.100	43.100	36.200	2.568	2.432
8	218.775	49.835	35.000	2.537	2.417
9	221.850	44.900	25.400	2.437	2.080
10	248.400	50.350	27.425	2.390	1.692
11	235.050	54.150	27.150	2.163	1.503
12	229.950	45.875	25.000	2.268	1.893
13	191.850	67.100	40.250	3.677	2.411
14	280.000	60.875	21.300	2.350	2.411
15	220.000	58.400	33.150	2.150	1.897
16	228.200	56.600	46.250	2.588	1.785
17	248.100	68.250	49.200	2.845	2.415
18	215.300	65.000	42.100	2.513	2.067
19	235.050	53.825	32.350	2.520	1.667
20	288.050	72.225	28.900	3.078	2.167

b) Relationship between physical properties which include:

i) Length- diameter relationship;
ii) Peel thickness against diameter relationship;
iii) Derivatives of the properties and their relationship; this includes relationship between the ratios of lengths, diameters and peel thickness.

Determination of physical properties of cassava tubers

The essence of a study on tuber properties is to aid the design of a peeling machine that may relate machine parameters to tuber characteristics. Since the focus in this work is peel removal from the tuber, the objectives in this chapter are focused on peel thickness, length and diameter, which are:
- Identify the variance in diameter and peel thickness;
- Establish a relationship between the above parameters where possible;
- To transfer these relationships to the cassava peeling machine cutting or peeling surface.

MATERIALS AND METHODS

Several cassava tubers were collected from different parts of Rivers State (Nonwa and Port Harcourt) and Abia State. Thereafter, the following measurements were taken with the corresponding instrument: (a) Length: For short samples, vernier caliper was used. For long one, a measuring tape; (b) Diameter: Both vernier calipers and micrometer screw gauge were employed. The large diameters respond to vernier calipers while for smaller diameters, micrometer screw gauge was used; (c): All peel thicknesses were measured with electronic micrometer screw gauge.

For diameters and peel thicknesses, two to three points along the length of the tuber were measure depending on the length of the tuber, while peel thickness were measured corresponding to measured diameter positions. Figure 1 shows images of peeled sections of cassava tubers.

RESULTS AND DISCUSSION

Tables 1 to 3 shows that the peel thickness ranges between 1.55 to 4.175 mm for the samples measured. The maximum and minimum diameters of the cassava samples were 118.050 and 19.750 mm respectively. Again, the maximum and minimum lengths of tubers were 510.00 and 141.050 mm respectively.

The results showed that the length and peel thickness are not related in any form; the same applies to minimum

Table 2: Measured values of cassava characteristics from Nonwa, Tai LGA, Rivers State.

S/N	Length (mm)	Head diameter (mm)	Tail diameter (mm)	Peel thickness	
				Head, t_1	Tail, t_2
1	510.000	88.430	21.408	4.057	2.002
2	336.000	100.355	20.074	3.005	2.045
3	348.005	77.205	27.350	3.034	2.065
4	318.500	92.665	29.075	3.547	2.523
5	265.000	94.035	46.050	4.175	3.003
6	335.010	82.460	39.150	2.835	2.045
7	297.015	98.250	62.500	3.525	3.014
8	420.004	87.020	26.125	3.507	2.005
9	393.000	78.355	34.025	2.541	2.016
10	394.000	87.195	36.350	3.539	2.036
11	355.005	65.645	22.523	2.533	1.955
12	480.010	55.250	27.500	2.520	2.085
13	345.000	32.750	19.750	1.930	1.750
14	350.020	46.050	20.050	2.080	1.830
15	185.125	90.095	62.175	3.755	3.438
16	313.250	48.050	28.040	2.185	2.162
17	210.000	77.195	29.350	2.898	2.121
18	270.650	70.850	40.300	2.764	2.276
19	186.945	64.150	33.275	2.503	1.892
20	209.300	73.050	41.200	2.936	2.086
21	212.175	59.325	28.700	2.562	2.058
22	208.150	55.350	21.400	2.492	1.831
23	149.325	53.100	31.800	2.465	2.108
24	224.300	66.050	29.800	2.775	2.018

Table 3: Measured values of cassava characteristics from Abia State.

S/N	Length (mm)	Tuber diameter (mm)			Peel thickness (mm)		
		Head	Mid	Tail	Head, t_1	Mid, t_2	Tail, t_3
1	266.100	94.200	94.825	59.450	3.004	3.024	2.858
2	270.500	85.150	81.150	51.100	2.509	2.300	2.205
3	225.875	96.300	84.200	53.000	2.429	2.216	2.035
4	237.300	117.300	102.100	71.800	4.006	3.042	2.504
5	322.100	88.950	84.850	43.975	3.012	3.006	2.007
6	239.000	90.125	74.200	49.075	3.001	2.515	2.041
7	236.050	84.075	66.200	54.000	3.012	2.503	1.840
8	290.200	100.875	78.150	48.850	3.039	2.522	2.046
9	228.300	68.125	65.075	44.075	2.031	2.544	2.017
10	293.150	102.225	74.325	58.950	3.544	3.033	2.505
11	202.350	107.300	93.050	48.900	3.537	3.040	2.025
12	172.225	83.000	77.225	61.000	3.004	2.535	2.030
13	186.425	94.400	91.005	63.225	3.433	3.544	3.027
14	170.000	99.325	91.010	69.325	2.530	2.528	2.028
15	168.275	95.000	78.350	53.050	2.537	2.046	1.520
16	141.300	85.000	-	58.275	3.036	-	2.080
17	222.010	90.350	94.950	75.350	3.031	3.511	3.033
18	261.010	118.050	96.200	58.150	3.726	3.200	2.521
19	190.225	78.900	74.150	49.150	3.042	2.502	2.200

Table 3 Cont:

20	304.075	72.100	67.150	45.400	2.223	2.036	2.022
21	434.225	117.000	102.100	59.200	3.527	3.467	2.540
22	175.150	116.000	91.325	44.000	3.529	3.538	2.542
23	141.050	90.300	90.500	55.400	3.254	3.521	3.023
24	204.950	107.450	101.200	59.450	3.517	3.007	2.519
25	221.050	110.375	110.300	79.150	3.531	3.005	2.731
26	159.500	107.100	96.300	-	3.527	3.018	-
27	133.150	89.735	-	68.325	2,530	-	2.030
28	150.000	69.150	58.100	44.275	2.493	2.029	2.004
29	235.000	67.000	74.950	63.350	2.025	2.514	2.503
30	110.400	53.100	-	45.000	2.512	-	2.035

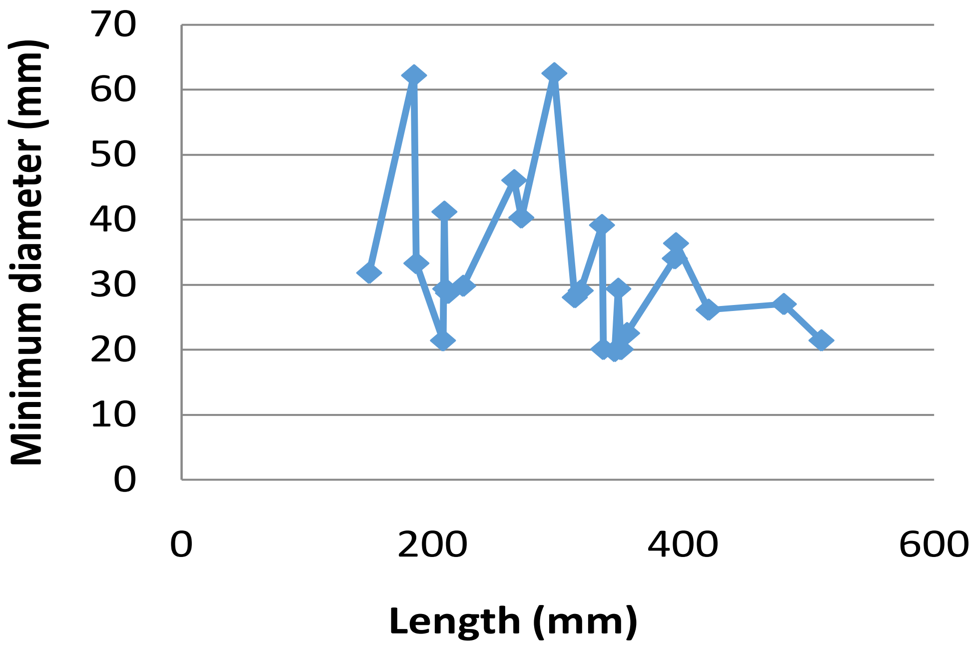

Figure 2: Minimum cassava diameter vs. length.

and maximum diameter values. It was also observed that the length in particular neither influences the diameters size nor the peel thickness. This can easily be deduced from the zig-zag or irregular curve in Figures 2 and 3. The curves suggest a random relationship between the diameter and the length. Also, the peel thickness follows the same pattern of relationship with the length (Figures 2, 3 and 4).

However, based on the experimental data the diameter has a relationship with the peel thickness (Figure 5). The results showed that the peel thickness either increases or decreases as the diameter for a particular tuber. For all samples measured, this was consistent. It implies that for the same cassava tuber, the peel thickness varies as the diameter, that is, regions of larger diameters have larger peel thickness and vice versa.

A plot of diameter against cassava length showed a near zig-zag curve indicating a random curve with some form of periodic flow (Figures 2 and 3). In addition, Figure 4 shows a curve of maximum tuber diameter against minimum diameter. Again, the Microsoft excel plot of the data suggest to a curve that showcase some random characteristics with some suggestions of exponential connotations with an R^2 value of 0.6141, $y = 43.009e^x$ (Figure 5).

Further investigation of the relationships between the physical parameters was carried out using MatLab application. Although, the MatLab application tries to give polynomial curves to these values, it is observed from Figures 10 to 13 that there is no polynomial relationship of third order between the tuber diameter and the peel thickness, but a polynomial of second order relationship

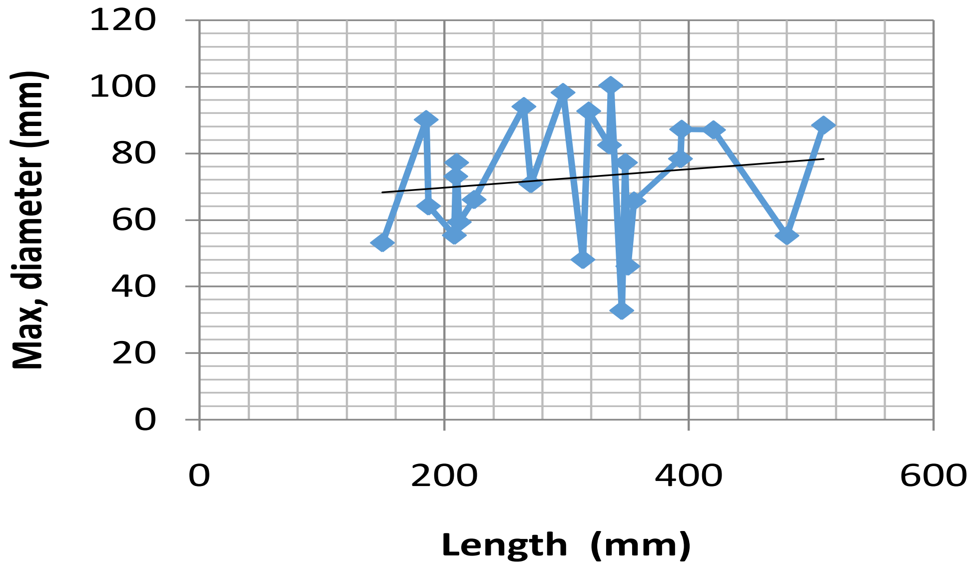

Figure 3: Maximum diameter vs. length of cassava.

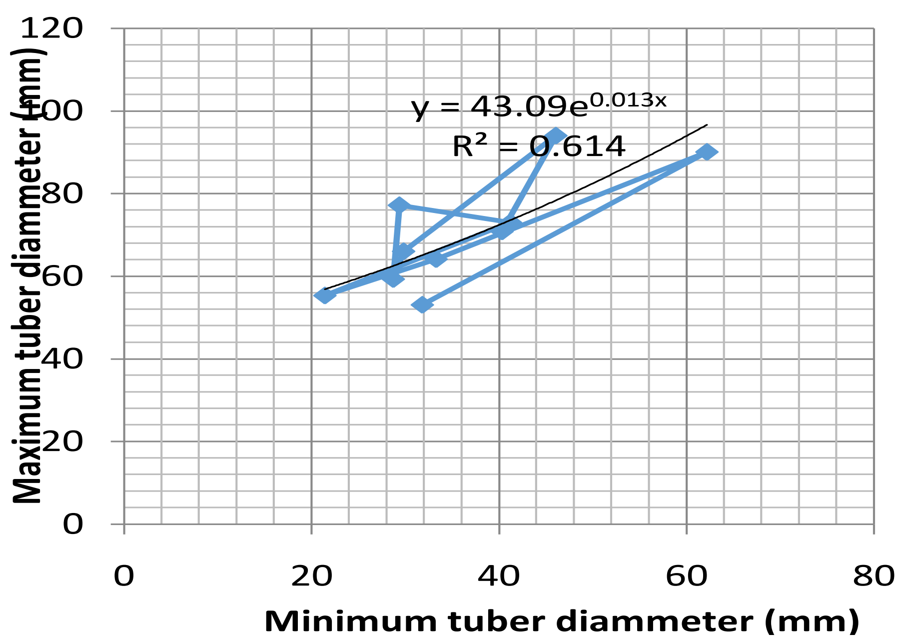

Figure 4: A plot of cassava maximum tuber diameter vs. minimum diameter.

exist as shown in Figure 5. Whereas the tubers obtained from Nonwa (Rivers State, Nigeria) gave rise to a polynomial of second order with a curve governed by the equation: $y = -15.92x^2 + 123.51x - 146.75$ and R^2 value of 0.8571, others from Abia State and parts of Port Harcourt, Nigeria did not showcase polynomial behavior but Fourier kind of relationship (Figures 6, 7, 8 and 9). The polynomial curve of second order in Figure 5 representing tubers from Nonwa, Rivers State has a maximum point at 92.5 (turning point).

Although no tuber was examined with respect to species behaviour of the different tubers from the different locations as shown from the aforementioned curves; some factors (not investigated) may have influenced the relationship which could be location or specie or any other factor. Since tuber characteristics curves showcase different relationships on the scale and software package, thus, it can easily be deduced that location is one of the factors that influences tuber parameters relationship. R^2 value is the root square value of the equation earlier

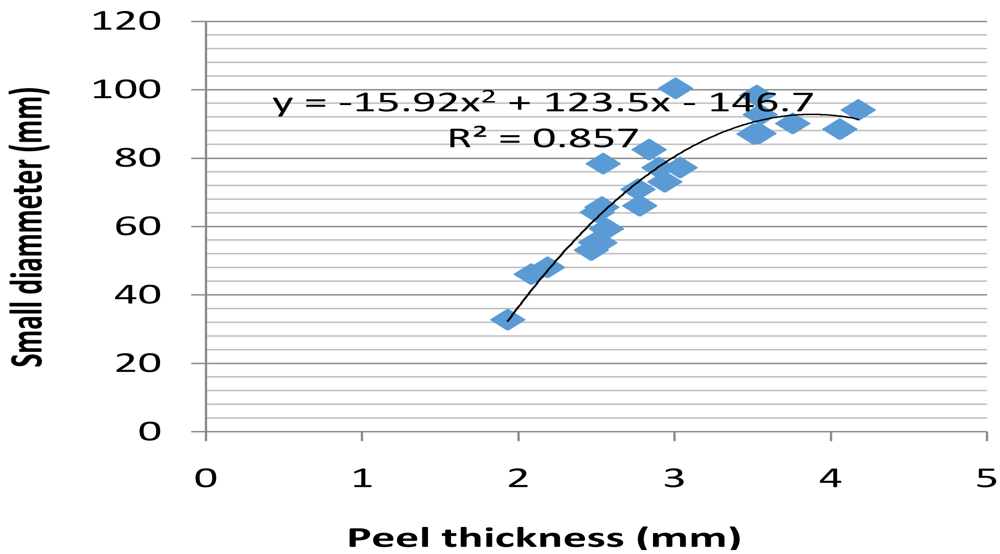

Figure 5: Small cassava diameter vs. peel thickness.

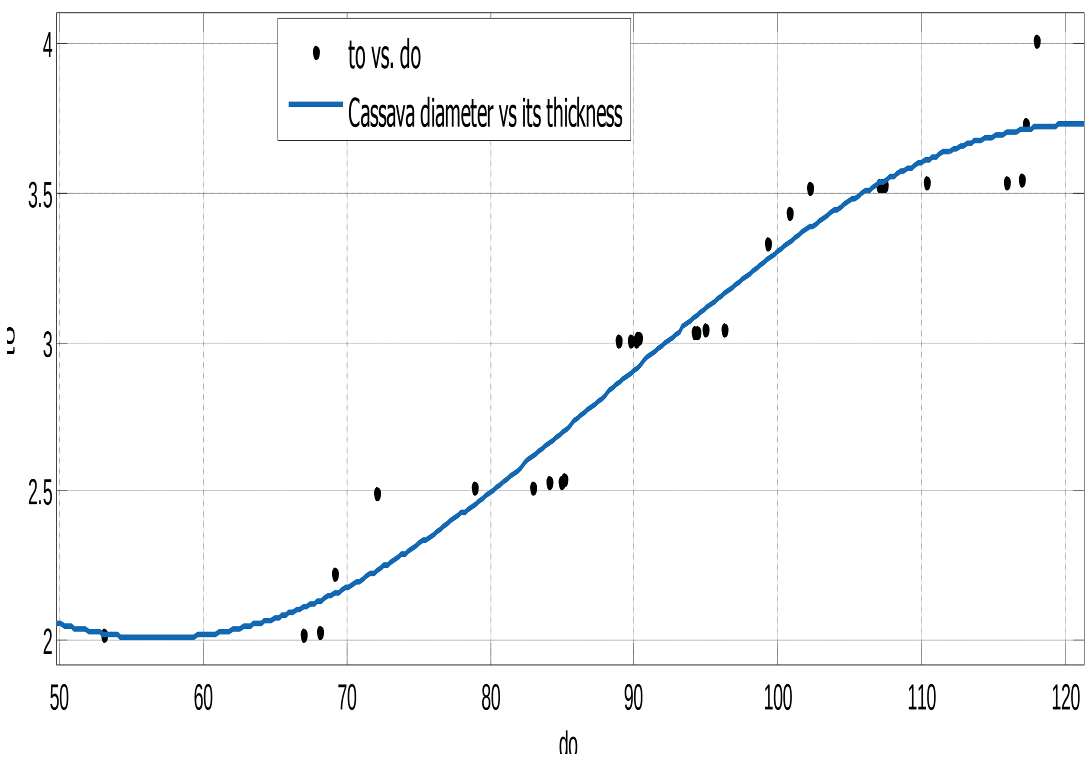

Figure 6: Fourier plot of cassava diameter thickness vs. thickness (mid-section). The Fourier model for Figure 6 is given as: y = 2.869 + 0.8025 Cos (0.04878x) – 0.3073 Sin (0.04878x).

mentioned and as suggested by the program, it gives an interpretation of the relationship that exist between the tuber parameters.

From the investigations on physical properties of cassava tubers, the following inferences can be drawn:

- Peel thickness on a particular tuber is not uniform, but increases with diameter and vice versa;
- Relationship between length of tuber and diameter is a near random Brownian kind of relationship;
- Peel thickness ranges from 1.50 to 5.0 mm which agrees with previous researches.
- Diameter and peel thickness have both Fourier and Polynomial of second order relationships and the location has some influence on these relationships.

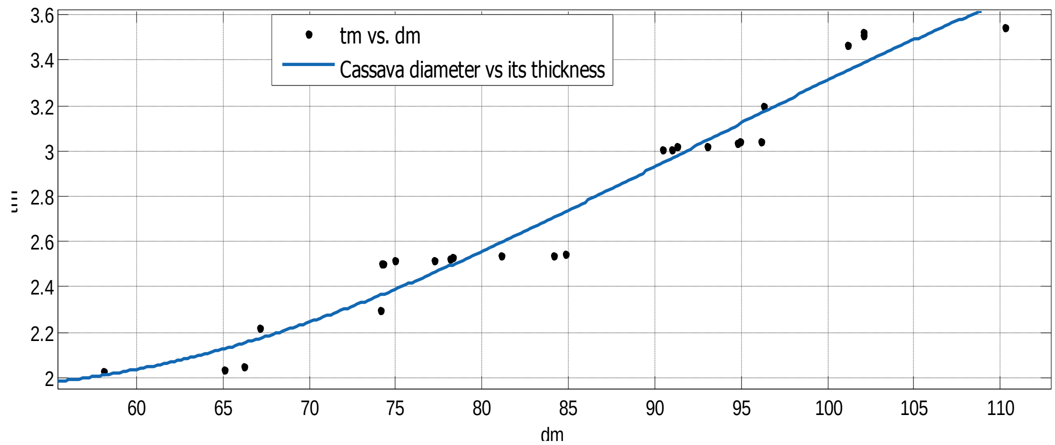

Figure 7: Fourier plot of cassava diameter (head-section). The Fourier model for Figure 7 is given as: y = 3.003 + 0.2758 Cos (0.0371x) – 1.006 Sin (0.0371x).

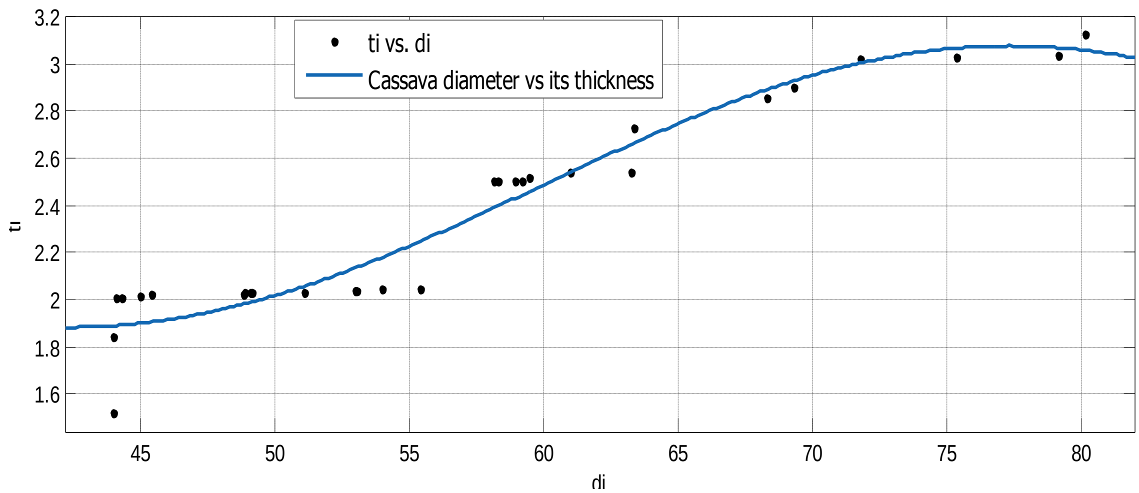

Figure 8: Fourier plot of diameter vs. thickness (tail section). The Fourier model for Figure 8 is given as: y = 2.48 + 0.470 Cos (0.0898x) + 0.368 Sin (0.0898x). The confidence bound is 95%; Goodness of fit: R^2 = 0.9328 and MATLAB version used is 8.1, 2013

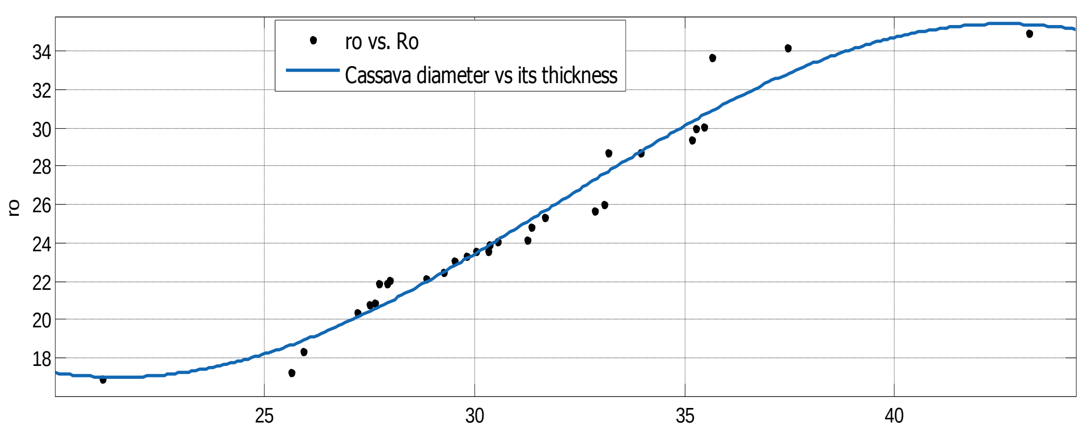

Figure 9: Adjusted Matlab plot of cassava diameter vs. thickness. The Fourier model for Figure 9 is given as: y = 26.21 + 9.174 Cos (0.1488x) + 0.5328 Sin (0.1488x). The confidence bound is 95%; R^2 = 0.9604 and RMSE: 0.9827.

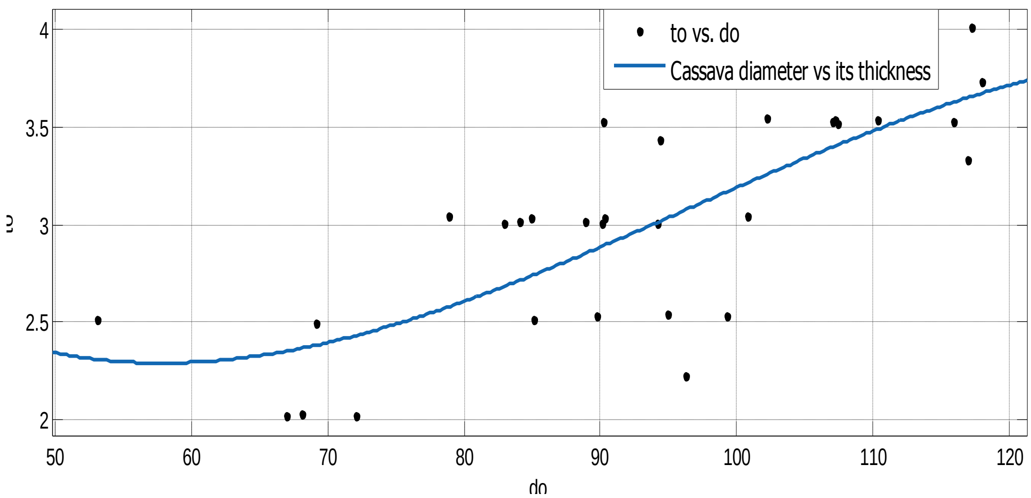

Figure 10: Polynomial plot of cassava diameter vs. thickness (head section). The Fourier model for Figure 10 is given as: $y = 6.858 \times 10^{-6} x^3 + 0.001984^2 - 0.1607x + 6.275$. The confidence bound is 95%. Goodness of fit: SSE: 3.507; R^2: 0.5938; Adjusted R^2: 0.5469; RMSE: 0.3673

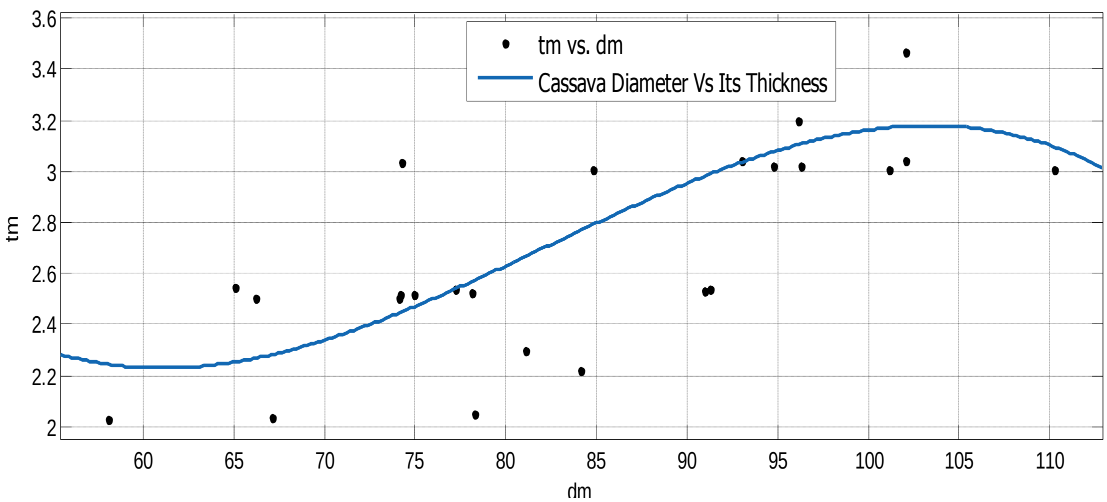

Figure 11: Polynomial plot of cassava diameter vs. thickness (mid-section). The Fourier model for Figure 11 is given as: $y = -2.498 \times 10^{-6}x^3 + 0.00616x^2 + 0.473x + 13.83$. The confidence bound is 95%. Goodness of fit: SSE: 2.742; R^2: 0.5091; Adjusted R^2: 0.445 and RMSE: 0.3453.

For the tubers considered in this research, the Fourier model of Matlab curves gave better relationship. This indicates that the cassava diameter and peel thickness relationship for most cassava tubers in Port Harcourt and parts of Abia state obey Fourier model type of relationship with a model equation of the kind: $y = 2.869 + 0.8025 \cos(0.04878x) - 0.3073 \sin(0.04878x)$, for the head section, $y = 3.003 + 0.02758 \cos(0.0371x) - 1.006 \sin(0.0371x)$ for the mid-section and $y = 2.48 + 0.4703 \cos(0.08985x) + 0.3684 \sin(0.08985)$ for the tail section.

The tubers from Port Harcourt environment and Abia State do not fit into polynomial functions of third order (Figures 10, 11, 12 and 13) and Fourier models (Figures 6, 7, 8 and 9) curves have a better fit.

Conclusion

The investigation carried on cassava parameters showed that a relationship exists between the tuber diameter and peeled thickness. This result showed that the tubers from different locations exhibit different relationships and it is expected that some factors from these regions influenced tuber diameter and peel thickness relationship because tubers obtained from Nonwa, Rivers State obeyed polynomial of second order relationship, while those collected from Rivers State, University of Science and Technology, Port Harcourt and Abia State obeyed Fourier function relationship. Therefore, it can be deduced that environmental factors also influence some tuber

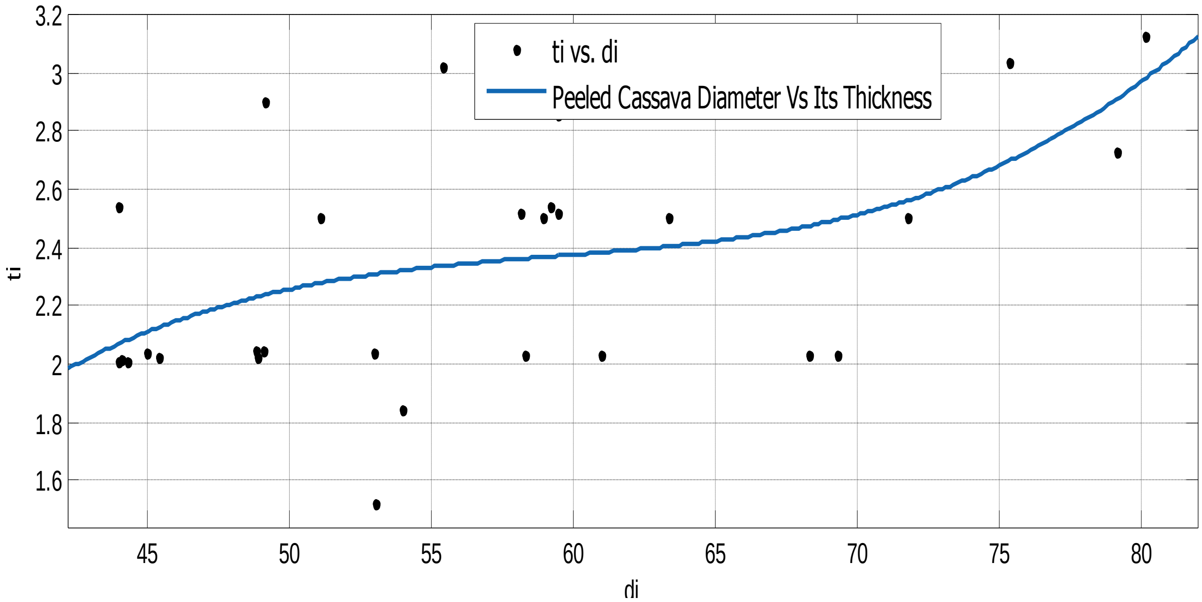

Figure 12: Polynomial plot of cassava diameter vs. thickness (Tail section). The Fourier model for Figure 12 is given as: $y = 5.032 \times 10^{-5}x^3 - 0.008963x^2 + 0.5398x - 8.617$. The confidence bound is 95%; Goodness of fit: SSE: 3.808 and R^2: 0.2698.

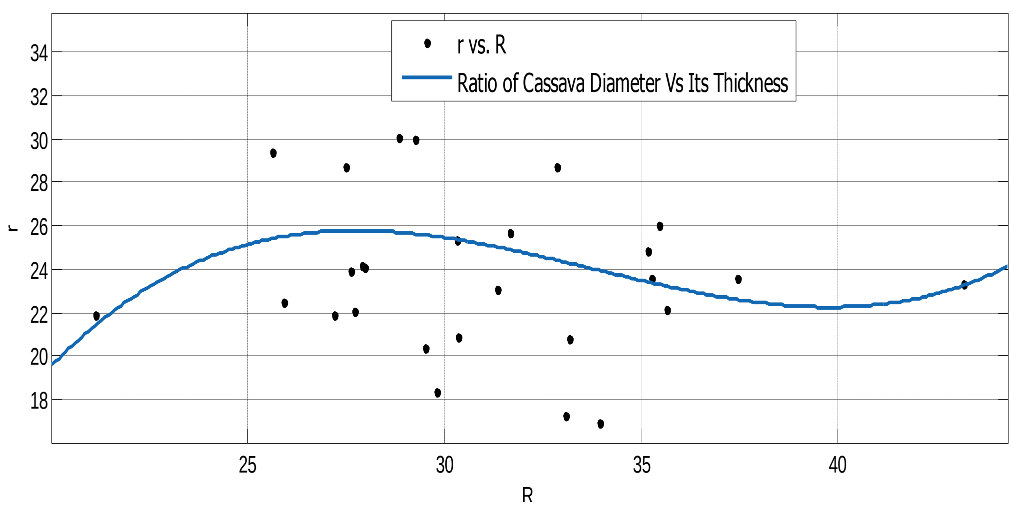

Figure 13: Polynomial curve of vs. thickness ratio. The Fourier model for Figure 13 is given as: $y = 0.004032x^3 - 0.4084x^2 -13.35x -116.4$. The confidence bound is 95%; Goodness of fit: SSE: 594.7 and R^2: 0.06154.

characteristics as proposed by Odigboh (1978). The information from the analysis showed that an irregular relationship exist between the tuber length and the diameter. This information on cassava tuber characteristics can be helpful in designing an appropriate cassava peeling machine.

REFERENCES

Adetan DA, Adekoya LO, Aluko OB (2003). Characterisation of some properties of cassava root tubers, J. Food Eng. 59:349-353.

Agodzo SK, Owusu FA (2002). Crop coefficient determination of a six-month variety cassava. J. Agric. Eng. Technol. 10: 1- 6.

Ejovo ON, Oboli S, Mgbeke ACC (1988). Studies and preliminary design for a cassava tuber peeling machine. Transactions of the American Society of Agric. Engineers 31(2):380-385.

Emadi B (2006). Experimental studies and modelling of innovative peeling processes for tough-skinned vegetables.

Emadi B, Abbaspour-Fard MH, Yarlagadda HPKV (2009). Mechanical properties of melon measured by compression, solar and cutting modes, Int. J. Food Pro. 12:780-790.

Emadi B, Kosse V, Yarlagadda P (2007). Abrasive peeling of pumpkin, J. Food Eng. 79:647-656.

Emadi B, Kosse V, Yarlagadda PKDV (2005). Mechanical properties of pumpkin, Int. J. Food Pro. 8:277-287.

Kolawole PO, Agbetoye I, Ogunlowo SA (2010). Sustaining world food security with improved cassava processing technology: The Nigeria experience, Sustainability 2(12):3681-3694.

Odigboh EU (1976). A cassava peeling machine: development, design and construction. J. Agric. Engr. Res., 21: 361-369.

Odigboh EU (1978). Cassava production, processing and utilization. In Chan. Jnr., H.T., Edition. Handbook of tropical foods, Marcel Decker Pup. Inc., 270, Madison Avenue, New York, 145-200.

Ugwu KC, Ozioko RE (2015). Development and Performance Test of cassava Peeling and Washing Machine. *Int. J. sci. eng. Res.* 6 (6):1572-1583

Uthman F(2011), Design and fabrication of cassava lump breaking and sieving machine. *Oasis J. Res. Dev.* 1(2): 42-50.

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