Analysis of Continuous Cassava Peeling Machine Design for Domestic and Commercial Use in Nigeria

E.K. Orhorhoro[1], O.W. Orhorhoro[2], A.E. Ikpe[3], A.Ngbeneme[3]

[1]Cemek Machinery Company, Technology Incubation Centre, Federal Ministry of Science & Technology, Benin City, Edo State, Nigeria
[2]Department of Electrical/Electronic Engineering, Delta State Polytechnic, Otefe-Oghara, Delta State
[3]Department of Mechanical Engineering, University of Benin, Benin City, Edo State, Nigeria

[1]Corresponding author:ejiroghene.orhorhoro@eng.uniben.edu;+2348064699781

Abstract

Analysis of Cassava peeling machine designed for domestic and commercial use in Nigeria was carried out. The cassava peeling machine was evaluated to determine its performance,machine through capacity, peeling efficiency, percentage of flesh loss, percentage of peels removed by machine and manually. The results obtained indicate that a peeling efficiency of 91.3%, average peeling time of 11.24minutes and 1.62minutes were calculated for manual peeling and machine peeling respectively. The percentage of mass of peels removed manually and by machine were approximately the same (9%). A machine through put capacity of 0.147kg/sec was obtained. The analysis of flesh lost shown that 0.6565% of useful cassava flesh was lost.Considering the results obtained, the machine can be used for domestic and commercial purpose in Nigeria.

Keywords: Cassava peeling machine, analysis, efficiency, machine through put capacity, Nigeria

Nomenclature			
Ave.	Average	S_1	Stage 1
d_1	Diameter of driver pulley	S_2	Stage 2
d_2	Diameter of driven pulley	S_3	Stage 3
D	Diameter	S_4	Stage 4
F	Force	*W*	Angular velocity
G	Acceleration due to gravity	T_1	Tension in the tight side of the belt
M	Mass of cassava tubers fed into the machine	T_2	Tension in the slack side of the belt
$M_3P_{machine}$	Percentage of mass of peels removed by machine	X	Distance between the two pulleys
M_1P_{manual}	Percentage of mass of peels removed manually	**Greek Symbols**	
n_t	Number of testing	θ	Angle of wrap of an open belt
n_1	Speed of the driver pulley	μ	Coefficient of friction between the cassava and peeling
n_2	Speed of the driven pulley	$\sum$	Summation
N	Speed in revolution per minute	$\propto$	Angle of contact
P	Power to turn the shaft	**Abbreviations**	
P_E	Peeling efficiency	*FAO*	Food and Agriculture Organization

R	Radius of driven pulley	*IITA*	International Institute of TropicalAgriculture
R	Radius of driver pulley	*MTC*	Machine through put capacity

1.0 Introduction

Cassava, *manihot esculent crantz,*is a tuberous starchy root crop of the family euphorbiaceae [1]. It is a food crop, known worldwide for drought tolerance and for thriving well on marginal soils [2].Cassava is believed to grow well in areas with annual rainfall of 500 – 5000mmand full sunshine, but susceptible to cold weather and frost [3].Cassava is a cheap source of calorie intake in human diet and a source of carbohydrate in animal feed [4]. Cassava is believed to have originated from South America but is now grown in most of the tropical countries of the world like Brazil, Indonesia, Nigeria, Congo Kinshasha, Congo, Brazeville, Uganda, Ghana, Democratic Republic of Congo, and many other countries of the world [5].

Nigeria is currently the largest producer of cassava in the world with an annual output of over 34 million tonnes oftuberous roots [6]. Cassava is a major source of carbohydrate in most developing nations of the world. It is an important diet to more than eight hundred million (800,000,000) people around the world [7] and it is referred to as a food security crop [8].

Various cassava tuber peeling machine had been designed and tested by various researchers [9-15]. However, most of these machines have been widely acknowledged as being inefficient [16-18]. Most of them were batch peelers with straight edges abrasives and knives. They all suffer from the fact that:

i. Cassava tubers are irregular in shape

ii. Cassava tubers taper from head to tail

iii. Cassava tubers can be harvested at different stages of maturity by farmers.

However, it was realized that combining the insights shown in [19] and [20], the following were achieved:

i. Cassava tubers required peeling force of 500N

ii. The small laceration in the body of cassava tubers significantly reduce this peeling force

iii. That cassava tuber can be sorted into significant diametral sizes.

According to Ohwovoriole [19], cassava tubers require a cutting force of 500N. However, Owhovoriolepeeler could not control the depth of peel and is limited to batch production. It was consequently modified in [21]but the modified peeler suffered a similar fate hence, there is need for accurate study of the physical properties and characteristics of cassava tubers as a pre-requisite to the successful design of an efficient cassava tubers peeling machine for minimal useful flesh loss[20]. However the major constraint of the machine designed by the past researchers was the poor quality of finished products, large numbers of broken cassava tubers recorded, large quantity of useful flesh loss, coupled with poor efficiency obtained. In oder to curb these cited problems, there is a need to develop an improved cassava peeling machine, capable of peeling cassava conveniently with high efficiency and to achieve this, proper analysis that has to do with physics and mathematical equation were applied in this research work.

2.1 Design Consideration

Power required to peeled the cassava tubers is determined from equation (2.1) and equation (2.4) while the force and speed required are determined from equation (2.2) and equation (2.3);

$$P = FV = Frw = Tw \quad (2.1)$$

$$F = mg \quad (2.2)$$

$$V = \frac{\pi DN}{60} \quad (2.3)$$

$$P = \frac{ma\pi DN}{60} \quad (2.4)$$

Coefficient of friction (μ) is given by

$$2.3log\left(\frac{T_1}{T_2}\right) = \mu\alpha \quad (2.5)$$

For cross belt, angle of contact (α) is given by

$$sin\alpha = \frac{R+r}{x} \quad (2.6)$$

For open belt, angle of contact (α) is given by

$$sin\alpha = \frac{R-r}{x} \quad (2.7)$$

Therefore, angle of wrap(θ) can be expressed as

$$\theta = 180 \pm sin^{-1}\left(\frac{R-r}{x}\right) \quad (2.8)$$

The tension on the tight side (T_1) and slack sides (T_2) is given by

$$T_1 - T_2 = \frac{P}{V} \quad (2.9)$$

The speed of the driver pulley (n_1)and driven pulley (n_2) is given by

$$\frac{n_2}{n_1} = \frac{d_1}{d_2} \quad (2.10)$$

Length of the belt (L_1)that passes over the driver pulley in one minute is given by

$$L_1 = \pi d_1 n_1 \quad (2.11)$$

Similarly, length of the belt (L_2)that passes over the driven pulley in one minute is given by

$$L_2 = \pi d_2 n_2 \quad (2.12)$$

Since the same belt length passed over both the driver and driven pulley, and it took the same time (i.e.one minute)for the belt to passed over the driver and driven pulley, therefore

$$\pi d_1 n_1 = \pi d_2 n_2 \quad (2.13)$$

Thus;

$$\frac{n_2}{n_1} = \frac{d_1}{d_2} \quad (2.14)$$

The belt length is obtained as follows:

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{D_1 + D_2}{4C}$$

(2.15)The centre to centre distance (C) between driver and driven pulley is given as

$$C = 2D_1 + D_2 \quad (2.16)$$

3.1 Results and Discussion

Table 1 show the masses of manual and machine peeling carried out consecutively in three stages.

Table 1.Results obtained with manual and cassava peeling machine

S/N	Cassava tubers	S_1	S_2	S_3	S_4	Ave.
1.	Mass of cassava tubers fed into the machine(M)	10.00	10.00	10.00	10.00	10.00
2.	Mass of peel removed manually (M_1)	0.80	0.82	0.79	0.98	0.85
3.	Mass of cassava tuber peeled manually (M_2)	9.20	9.18	9.22	9.02	9.16
4.	Mass of peel removed by machine (M_3)	0.86	0.88	0.84	0.89	0.87
5.	Mass of peeled cassava tuber by machine (M_4)	9.14	9.12	9.16	9.11	9.13

The result of the peeling time and machine through put capacity is show in Table2

Table 2. Results of peeling time and machine through put capacity

n_t	T_{manual}	$T_{machine}$	MTC
1.	12.05	1.08	9.25
2.	11.05	2.01	4.98
3.	9.45	1.55	6.45
4.	11.65	2.35	4.26
5.	10.25	2.05	4.88
6.	10.05	1.55	6.45
7.	10.65	2.15	4.65
8.	11.05	1.09	9.17
9.	9.85	1.65	6.06
10.	11.05	1.95	5.13
11.	9.95	2.01	4.98
12.	10.50	1.05	9.52
13	12.12	1.98	5.05
14	13.41	2.34	4.33
15	11.09	1.12	8.93
16	11.87	1.85	5.41

17	12.23	2.01	4.98
18	13.45	2.19	4.57
19	10.23	1.00	10.00
20	12.11	1.23	8.13
21	11.87	1.09	9.17
22	12.12	1.89	5.29
23	10.39	0.85	11.76
24	10.58	0.99	10.10
25	12.01	1.59	6.29
	ΣT_{manual}=281.03	$\Sigma T_{machine}$=40.62	Σ_{MTC}=169.79
	$Ave._{manual}$=11.24	$Ave._{machine}$=1.62	$Ave._{MTC}$=6.79

The average peeling time by machine and manual peeling are determined from equation (3.1) and equation (3.2)

$$Ave. = \frac{\Sigma T_{machine}}{\Sigma n_t} \quad (3.1)$$

$$Ave. = \frac{40.62}{25} = 1.62 minutes$$

$$Ave. = \frac{\Sigma T_{manual}}{\Sigma nt} \quad (3.2)$$

$$Ave. = \frac{281.03}{25} = 11.24 minutes$$

The percentage of mass of peels removeby machine and manually are determined from equation (3.3) and equation (3.4) as:

$$M_3 P_{machine} = \frac{M_3}{M} \times 100 \quad (3.3)$$

$$M_3 P_{machine} = \frac{0.87}{10} \times 100 = 8.7\% \approx 9\%$$

$$M_1 P_{manual} = \frac{M_1}{M} \times 100 \quad (3.4)$$

$$M_1 P_{manual} = \frac{0.85}{10} \times 100 = 8.5\% \approx 9\%$$

The efficiency of the cassava continuous peeling machine and the machine through put capacity (MTC) aredetermined from equation (3.5) and equation (3.6) as

$$P_E = \frac{Output}{Input} \times 100 = \frac{M_4}{M} \times 100 \quad (3.5)$$

$$P_E = \frac{9.13}{10} \times \frac{100}{1} = 91.3\%$$

$MTC = \frac{M}{T_{machine}}$ (3.6)

$$MTC = \frac{10}{6.79 \times 60} = 0.147kg/sec$$

The percentage of useful flesh loss of cassava tubers (%Fl) is given by equation (3.7)

$\%Fl = \frac{M_2 - M_4}{M_2} \times 100$ (3.7)

$$\% = \frac{9.20 - 9.14}{9.14} \times 100 = 0.6565\%$$

Table 1shows the results obtained with manual and machine peeling carried out on three stages with the same mass of cassava tubers fed into the machine. Their average was taken into account to determine the percentage of flesh loss, peeling efficiency, the percentage of mass of peels removed manually and with the cassava peeling machine. The results obtained show that the percentage of mass of peels removed by machine and manually are approximately the same (9%) . Average peeling time of 11.24 minutes and 1.62 minutes were obtainedfor cassava tubers peeled manually and with machine respectively. The results show that peeling with machine was faster and the end product was as good as tubers peeled manually.Peeling efficiency of 91.3% was calculated and this shows that the machine is good and its performance was satisfactory. The graph of peeling time by machine and manual is show in Fig.1, as can see from the graph, at each stage of testing, peeling by machine is faster than peeling by manual(traditional method).

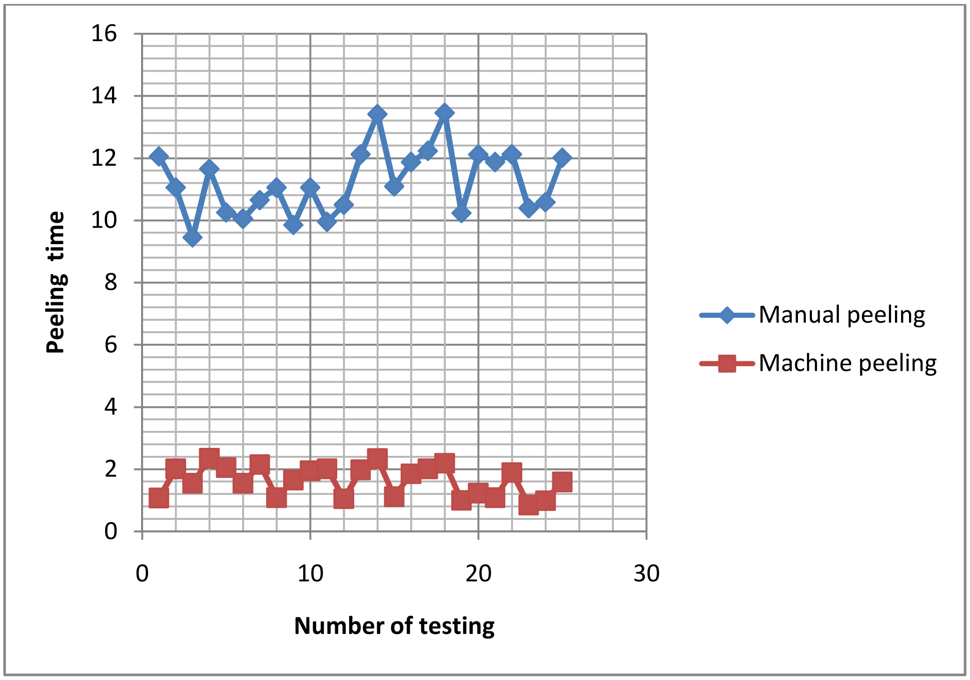

Fig.1. Graph of peeling time by machine and manual

To have a better idea of the quantity of useful cassava flesh that was lost in the peeling process, the mass of peel removed manually with knife without flesh loss was subtracted from the mass of peeled cassava tubers obtained by the peeling machine. The result indicated a 0.6565% of useful flesh was lost by the cassava peeling machine, which was minimal when compared to useful flesh loss in existing cassava peeling machine.The average peeling time by machine and total mass of cassava fed into the machine were used to calculate the machine through put capacity (0.147kg/sec). The graph of machine peeling time and machine through put capacity is show in Fig. 2. From the graph, it was observed that the peeling time is a function of machine through put capacity. The higher the peeling time, the lower the machine through put capacity. On the hand, the lower the peeling time, the higher the machine through put capacity.

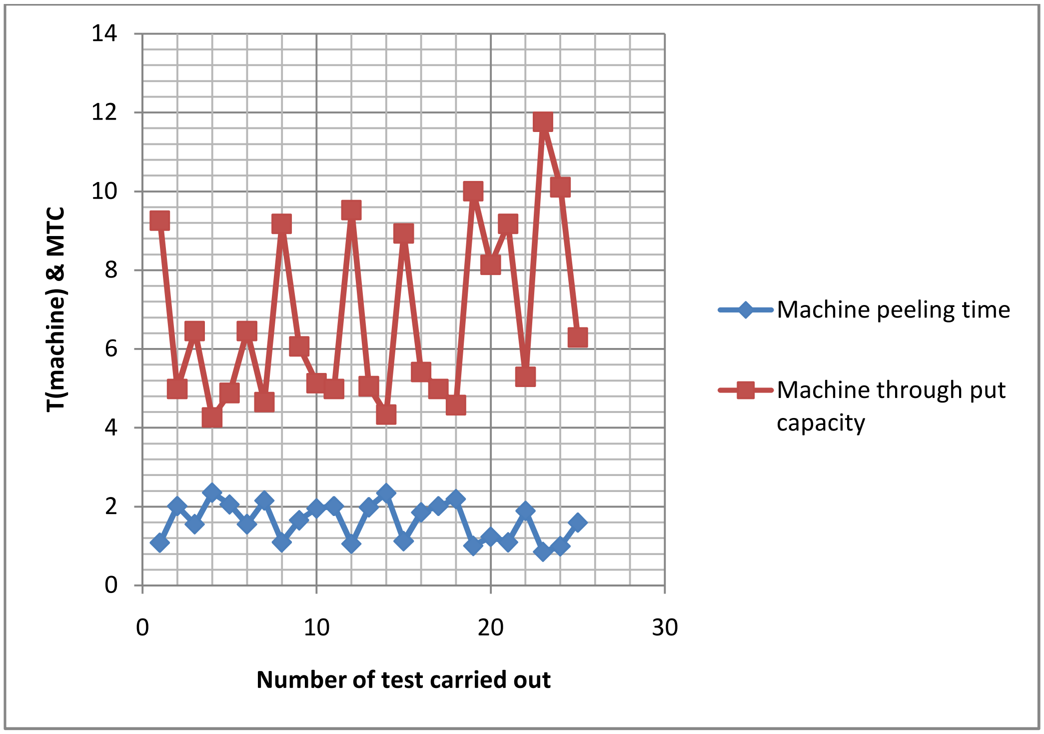

Fig.2 Graph of machine peeling time and Machine through put capacity

4.0. Conclusion

The continuous cassava peeling machine was successfully designed and fabricated and this was aimed at solving an aged long manual peeling of cassava tubers. Test performance was carried out on the fabricated continuous cassava peeling machine. Analysis was carried out on the efficiency and the results shown that low efficiency and poor quality of the mechanized products have been overcome. Force required to obtained efficient peeling was achieved and the machine was found to be most efficient in removing the cortex at a range of the cassava tubers. Minimizepercentage of useful flesh loss and average time of peeling were recorded. Good quality of finished products was obtained and minimize number of broken cassava tubers were recorded. For all cassava production, the peeler developed from this model will greatly enhance production speed, product integrity, quality and availability at minimum cost. This will also enhance large scale cassava cultivation and reduce unemployment. From the results obtained based on the quality of peeled cassava produced by the cassava peeling machine, the machine was efficient and can be used locally and industrially in small scale.

5.0. References

[1] Kochlar, S. L. (1981). Tropical crops: A Textbook of Economic Botany. Macmillan Publishers Ltd,pp 467

[2] IITA (International Institute of Tropical Agriculture) (1990):Cassava in tropical Africa.Reference Manual, IITA, Ibadan, Nigeria

[3] Agodzo S. K and Owusu, F. A. (2002): Crop coefficient determination of a six-month varietycassava. Journal of Agricultural Engineering and Technology. No.10, pp.1-6

[4] Kordylas, J.M. (2002): Processing and preservation of tropical and sub-tropical foods. Macmillan Education Ltd., UK, pp 414

[5] Odigboh, E. U. (1983): Cassava Production, Processing and Utilisation. In. Chan. Jnr.,H.T. (ed), Handbook of Tropical Foods.Mercel Decker Pub.Inc., 270, Madison Avenue, New York.pp.145-200

[6] FAO (Food and Agriculture Organization):Production Yearbook, Vol.60, Rome Italy (2006)

[7] FAO (Food and Agriculture Organization):Production Yearbook, Vol.61, Rome Italy (2007)

[8] Barrat N., Chitundu D., Elsinga J., Eriksson S., Guma L., Haggblade M., Haggblade S., Henn T.O., Locke F.R., O'Donnel C., Smith C. and Stevens T. (2006): Cassava as drought insurance: Food security implications of cassava trials in Central Zambia. Agrekon 45 (1): pp.593-620

[9] Ezekwe G. O. (1976):A feature for achieving a constant depth of peel in the mechanical peeling of cassava. Nigerian J. Engr. 1(3): pp.174 – 181

[10] Nwokedi, P. M (1984): Performance evaluation of cassava peeling machine. In: Tropical root crops: Production and uses in Africa, E.R Terry, E.U. Doku, O.B Arene and N.M Mahungu(eds) Int. Development Research Centre, pp. 108-110

[11] Ohwovoriole, E. N., Oboli, S. and Mgbeke, A.C. (1991):Studies and preliminary design for a cassava tuber peeling machine",a paper published by the power and machinery division of ASAE

[12] Odigboh, E. U. (1983): Cassava Production, Processing and Utilisation. In. Chan. Jnr.,H.T. (ed), Handbook of Tropical Foods.Mercel Decker Pub.Inc., 270, Madison Avenue, New York.pp.145-200

[13] Sheriff, J.T., Kurup, G.T. and Nanda, S.K. (1995): Performance evaluation of a cassava peeling machine", Journal of Root Crops, Vol.21, No., pp.30-35

[14] Itodo, I. N. (1999): Peeling rate of a manually-operated cassava (Manihot esculenta Crantz)peeling machine. African Journal of Root and Tuber Crops, 3(2): 3-7

[15] Olukunle, O.J. (2005): Development of a cassava peeling machine. Abstract Proceedings of the International Conference on Global Food and Product Chain. – Dynamics. Innovations, Conflicts and strategies ‘Tropentag (2005)’, University of Hohenheim Stuttgart, Germany, pp.54

[16] Adetan, D.A, Adekoya L. O and Aluko, O. L. (2006):Theory of a Mechanical method of peeling cassava tubers with knives. International Agrophysics, 20: pp.269-276

[17] Davies, R. M., Olatunji, M. O and Burubai, W. (2008): Mechanization of cassava processing in Iwo Local Government Area of Osun State, Nigeria. World Journal of Agricultural Sciences,4(3): 341-345

[18] Kolawole O.P., Agbetoye, L. A. S. and Ogunlowo, A. S. (2010): Sustaining world food security with improved cassava processing technologies: The Nigerian Experience. Sustainability, No.2, pp.3681- 3694

[19] Ohwovoriole, E. N., Oboli, S. and Mgbeke, A.C. (1988):Studies and preliminary design for a cassava tuber peeling machine, Transactions of the ASAE, Vol.31, No.2, pp.380-385

[20] Ebunilo P.O. and Ariavie (2008). A Technical Design and Evaluation of a Manually Operated Cassava Sizing, Cutting and Sorting Machine. Journal of Agriculture, Forest and Fisheries, Vol. 9.pp 21-26

[21] Aravie, G. O. and Ejovo, O. N. (2002), Improved Ohwovoriole’s rotary cassava tuber peeling machine. Nigerian Journal Engineering Research and Development, Vol. 1(2),pp.61-63