Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 47 No. 03
March 2026

Modelling of Gyroscopic Motion Approach to Peeling of Cassava Tubers on the Basis of Energy Consumption.

[1]T. K. Jinyemiema, [2]Ibezim Okachi and [3]G. O. Ariavie

[1,2]Department of Mechanical Engineering, Rivers State University, Port Harcourt.

[3]Department of Mechanical Engineering, University of Benin, Benin City. Edo State

Corresponding Author: Tamuno K. Jinyemiema

Abstract

Introduction: This paper is on modelling of the abrasive peeling of cassava tubers with some form of gyroscopic motion into the operation. The machine action required three motions of rotation, rocking and revolution of the abrasive peeling drum and balls. As such two or three electric motors are needed to provide the required motions, hence energy consumption was a major concern

Objectives: the objective is to develop a predictive model of the energy consumption rate of the peeling machine which can be used as a basis for design.

Methods: the involves developing A predictive mathematical modelling of the energy consumption rate during peeling was carried out, which revealed the angular velocity of the shaft, drum and the abrasive balls (ω_d), unevenness of the product surface (Φ), abrasive teeth shape and protrusion (λ) and angular velocity of the revolving assembly (ω_g) as the basic factors affecting peeling rate

Results: The results show that the motion of cassava in the chamber remains random for the different speeds of rotation modelled in this research. The limit set for each rotation was 100mm in diameter, and they are modelled for two cycles of 360^0 or 2π radians. In all the different speeds of rotation from 20rpm to 160rpm in steps of 20rpm, no appreciable difference in the motion was observed. Energy consumed during cutting shows remarkable difference with 20rpm recording the highest value of 6.0×10^8J and 120rpm producing the minimum value of 1.0×10^8J. It was also observed that, at 80rpm,100rpm, 140rpm and 160rpm the energy consumption rate is the same at 1.5×10^8J.

Conclusions: The predicted values shows that the energy consumption rate of the machine is quite reasonable for the commercialization of the machine.

Keywords: abrasive mechanical processing speed scratching predictive.

1. Introduction

Cassava is one of the commonly grown root crops in sub-Sahara Africa. It has gained so much popularity in all the geo-political regions of Nigeria. Traditionally, it is grown for food in Sub-Sahara Africa,[1]. In the tropical part of Africa, it has become the most important crop in terms of both the total land area devoted to its production and the proportion it contributes to the human diet,[2]. Cassava requires series processing into edible form, and one major aspect of its processing is peeling,[3]. Peeling is considered as the most important aspect of processing because it takes about 65% of the processing time and effort,[4]. Several methods of peeling have been investigated by researchers, such as chemical, thermal, and mechanical. Of all these methods, mechanical peeling appears to wider acceptability, because, the integrity of the final product is preserved and is devoid of side effects associate with other methods. Even in mechanical several methods such abrasive, knives, drums, and rollers have been reported by different researcher, some with marginal success, others with improved efficiency have to pre-shape tubers. An understanding of the processing of peeling is necessary for the optimal design and performance of mechanical peelers,[5].

One vital and persistent goal in engineering is to develop a performance relationship between all the variables and parameters in a system, in a mathematical form. Meng and Ludema (1995). A mathematical model of a peeling process could be an efficient tool for that purpose. Emardi *et al.* (2006). Few attempts have been made in modelling cassava peeling, Emadi *et al.* (2007), modelled the mechanical peeling of two pumpkin varieties, others are Somsen *et al*. (2004), Ferraz *et al*. (2007). Also, theoretical modelling of peeling cassava tubers with knives was developed by Adetan *et al.* (2006) and modelling of cassava tuber as a mean of theoretical peeling Olukunle and Akinnuli (2013). This paper discusses the modelling of cassava peeling using a gyroscopic motion approach based on an abrasive method of peeling.

2. Objectives

Nomenclature:

P_1 & P_2 ≡ Power required for fracturing & scratching skin Nmm/s,

η_ϵ = Peeling efficiency

E_p & E_d ≡ Penetration and deflection energy per point

ω_d = Drum angular velocity.

n_2 = No. of points on drum.

n_1 = Total number of points on balls.

K_1 ≡ shearing resistance/unit length N/mm

v_1 & v_2 = Penetration velocities of ball and drum protrusions, mm/s

$v_1 = v_2 = v$

δ_1 = Deflection of products (mm)

δ_2 & δ_3 = Average penetration depth of abrasive teeth (balls and drum)

$\delta_2 = \delta_3$

E ≡ Modulus of elasticity of abrasive material (balls and drum)

I_T ≡ Second moment of area of abrasive teeth of balls and drum

δ_4 ≡ Average deflection of abrasive teeth of balls and drum

Θ_1 ≡ Angle of teeth protrusion of balls and drum

d_2 ≡ diameter of protrusion hole of balls and drum

l_2 ≡ Length of tooth protrusion of balls and drum

l_1 ≡ Effective length covered by abrasive teeth of balls and drum

γ ≡ Ratio of product toughness of teeth and drum

β ≡ Density of abrasive protrusion (Number/mm^2)

F_c ≡ Cutting force

v_s ≡ Linear velocity of scratching teeth

F_f ≡ Frictional force

F_e ≡ Force of elastic and plastic deformation.

F_d ≡ Disintegration force of exerted by abrasive points.

K_2 ≡ Coefficient of friction based on product's properties and abrasive points parameters.

h ≡ Length of removed peel.

ϕ = degree of unevenness of product surface

β = density of protrusion of abrasive teeth(mm/s)

μ_d = coefficient of dynamic friction

F_R = normal reaction force

W_1 = weight of abrasive teeth (gm)

Θ_2 = normal angle between centroidal axis direction and abrasive teeth line of action

K_3 = coefficient that depends on teeth parameters

τ = shear strength of product (tuber)

K_4 = disintegration force coefficient of product

E_c = Energy required for peeling at the second stage

K_5 = scratching coefficient of the second stage

N = number of scratches in Number/min

n = $n_1 + n_2$ = number of abrasive teeth per ball and drum

ω_g = angular velocity of revolving system (entire assembly)

3. Methods

3.1: Mathematical Model Development

The essence of the mathematical model is to predict the actual performance of the various components of the machine before fabrication and identify areas of improvement where necessary. This model is generated to predict energy consumed at different speeds of machine operation and identify an optimum speed for energy consumption and peeling process. For economic reasons, the energy consumed was of great concern at the design stage because, three electric motors were initially considered to produce the three motions of the machine. It is expected that the model will be used to optimize the machine operation and give an insight of an optimum speed for machine. It is pertinent to note that; the mathematical model was able to predict the optimum speeds for the energy consumption at different stages of the peeling operation.

Assumptions

1. Peel removal rate is assumed to occur in layers and in the form of chips.
2. Peeling removal rate is directly proportional to applied force.
3. Angular velocity of the product is the same as the drum and abrasive balls.
4. Size and weight of product are assumed to be in common regular ratio.
5. The number of abrasive points on each ball is the same.

The total energy consumed (P_T) during the peeling process by abrasive drum and balls is the sum total of the power required for cutting and scratching of the skin. This is given as;

$$P_T = \frac{1}{\eta}(P_1 + P_2) \quad (1)$$

Emadi (2005)

3.2: Fracture stage

Energy consumed at the cutting stage is spent on penetrating the abrasive balls and the drum teeth, and the skin.

$$P_1 = (n_1 + n_2)\omega_d\left(E_p + E_d\right)\text{Ed)} \quad (2)$$

But n_1 and n_2 are in a common ratio, thus;

$$\frac{n_2}{n_1} = \alpha$$

Therefore equation (2) becomes

$$P_1 = (\alpha_1 n_1 + n_2)\omega_d(E_p + E_d)$$

$$= n_1(1 + \alpha_1)\omega_d(E_P + E_p)$$

$$= (1 + \alpha_1)n_1\omega_d(E_P + E_p) \quad (3)$$

The energy required to penetrate the abrasive points is given as;

$$E_p = K_1[(v_1 + v_2)t - \delta_1] \times (\delta_2 + \delta_3) \quad (4)$$

Therefore; equation (4.82) becomes

$$E_p = k[(2V_2)t - \delta_1] \times 2\delta_2$$

$$= 2k_1[\, V_d t - \delta_1]\, \delta_2 \quad (5)$$

The average energy spent on deflection is considered as a cantilever beam deflection,

$$E_d = \frac{3E L_T \delta_4^2}{(L^3 \times \delta_4)} \quad (6)$$

where;

$$\text{ShearStress}, \tau = \frac{F}{A} \quad (7)$$

$$F = 2\tau\pi d_1 l_1 sin\theta_1 \quad (8)$$

But; $V_T = L_1$

$$F = 2\tau\pi d_1 l_1 sin\theta_1 \cdot \beta\gamma \quad (9)$$

$$\tau = \frac{T_p}{T_t} \quad (10)$$

Considering number of abrasive points

$$F = 2\pi d_1 l_1 \sin\theta_1 \cdot \beta\times\gamma\times l_2\times 2 \quad (11)$$

$$K_1 = \frac{4\pi d_1 l_1 sin\theta_1 \beta\gamma l_2}{\delta_2} \quad (12)$$

Abrasive point protrusion surface is on both sides of l_2 as shown in figure 1.

Substituting Eqn. (12) into Eqn. (8) yields;

$$E_p = \frac{2\cdot 4\pi d_1 l_1 sin\theta_1\, \beta\gamma(v_{t-\delta_1})\times\delta_2}{\delta_2}$$

$$= 8\, \beta\gamma\pi d_1 d_2 l_1 l_2 \sin\theta_1 \quad (13)$$

Combining equations (6) and (13) yields

$$P_1 = (1+\alpha_1)\, n_1\omega_d\, [8\, \beta\gamma\pi d_1 d_2\, l_1 l_2\, \tau\, \delta_2 \sin\theta_1 + \frac{3EI_T\delta_4 2}{L^3}] \quad (14)$$

The second stage of energy is spent after fracture of the peel. This energy is required to remove the peel. The total energy rate is given as;

$$E_C = F_c \times V_s \quad (15)$$

But, the cutting force according to Dowgiallo (2005) is;

$$F_c = F_f + F_e + F_d \quad (16)$$

Using the law of friction, the energy spent due to friction is;

$$E_f = K_2 F_f \text{h} \quad (17)$$

But;

$$K_2 = \frac{\phi \pi l_1 d_1 \beta \delta_2}{d_2} \quad (18)$$

The force required to overcome friction can be estimated from the relationship below;

$$F_f = \mu_d F_R \quad (19)$$

F_R can be computed from two main forces, namely; (a) the normal force due to weight of abrasive teeth and (b) deflection force of the abrasive points.

$$F_R = F_N + F_{de} \quad (20)$$

But; $F_N = W_1 \cos\theta_2$ (21)

Substituting equation (18) and (21) into equation (19) yields;

$$F_f = \mu_d (W_1 \cos\theta_2 + \frac{3EI_T \delta_4 2}{L^3}) \quad (22)$$

Therefore, the total energy due to friction is given as;

$$E_f = K_2 h \mu_d \, (W_1 cos\theta_2 + \frac{3EI_T \delta_5}{L^3}) \quad (23)$$

The force required for elastic and plastic deformation is also very important at the second stage of cutting. This force can be determined from the relationship below;

$$F_e = K_3 \tau h l_3 \quad (24)$$

$$l_3 = 2 l_2 cos\theta_1 \quad (25)$$

hence;

$$K_3 = \pi l_1 d_1 \beta$$

Therefore, the total elastic and plastic deformation energy is;

$$E_e = 2\tau l_1 d_1 \beta h^2 cos\theta_1 \quad (27)$$

Summing equations (23) and (27) yields;

$$E_c = K_4 h \pi l_1 \beta [\frac{\delta_2 \phi h \mu_d}{d_2} (W_1 cos\theta_2 + \frac{3EI\delta_5}{L^3}) + 2\tau h l_2 cos\theta_1] \quad (28)$$

But power required for scratching is given as;

$$P_2 = K_5 E_c \quad (29)$$

$$K_5 = \frac{\omega_g}{\omega_d}(nN) \quad (30)$$

Putting n = n_1(1 + ɑ) yields;

$$K_5 = \frac{\omega_g}{\omega_d} N n_1 (1+\alpha) \quad (31)$$

Putting equation (29) into (31) yields;

$$P_2 = \frac{\omega_g}{\omega_d} N n_1 (1\alpha) K_4 h \pi l_1 d_1 \beta [\frac{\delta_2 \emptyset h \mu_d}{d_2} (W_1 cos\theta_2 + \frac{3EI\delta_5}{L^3}) + 2\tau h l_2 cos\theta_1] \quad (32)$$

Recall that the initial energy equation for abrasive cutting of the surface is;

$$P_T = \frac{1}{\eta_E}(P_1 + P_2) \quad (33a)$$

$$= (1+\alpha)\frac{n_1 \omega_d}{\eta_E}\left[8\beta\gamma\pi d_1 d_2 l_1 l_2 \tau \delta_2 sin\theta_1 + \frac{3I_T \delta_4^2}{L^3}\right] + \frac{\omega_g N n_1}{\omega_d \eta_E}(1 + \alpha) K_4 h \pi l_1 d_1 \beta \left[\frac{\delta_2 \phi h \mu_d}{d_2}\left(W_1 cos\theta_2 + \frac{3EI\delta_5^2}{L^3}\right) + 2\tau h l_2 cos\theta_1\right]$$

Equation (33a) can further be simplified to obtain Equation (33b) below;

$$P_T = \frac{(1+\alpha_1)n_1}{\eta_E}\{\left[\omega_d\left(8\beta\gamma\pi d_1 d_2 l_1 l_2 \tau\delta_2 sin\theta_1 + \frac{3EI_T\delta_4^2}{L^3}\right) + \frac{\omega_g Nn_1(1+\alpha)}{\omega_d}K_4 h\pi l_1 d_1 \beta\left(\frac{\delta_2\phi h\mu_d}{d_2}\left(W_1 cos\theta_2 + \frac{3EI\delta_5^2}{L^3}\right) + 2\tau h l_2 cos\theta_1)\right]\right\}$$

If we assume that, the peeling rate is directly related to the power consumed during the peeling process, then;

Peeling rate, $P_r = K_6 P_T$ (34)

$$P_r = K_6(1+\alpha_1)n_1\{\left[\frac{\omega_d}{\eta_E}\left(8\beta\gamma\pi d_1 d_2 l_1 l_2 \tau\delta_2 sin\theta_1 + \frac{3EI_T\delta_4^2}{L^3}\right)\right] + \frac{\omega_g}{\omega_d}Nn_1(1+\alpha)K_4 h\pi l_1 d_1 \beta\left[\delta_2\phi h\frac{\mu_d}{d_2}\left(W_1 cos\theta_2 + \frac{3EI\delta_5^2}{L^3}\right) + 2\tau h l_2 cos\theta_1\right]\}$$

Considering the equations obtained in this model, determination of individual parameters describing the equation will be very difficult. Therefore, the approach is to rewrite Equation (35) and rearrange it on the basis of input variables. A review of the effective parameters regarding the equation showcase four basic factors, which may serve as independent variables, these are;

(a) The angular velocity of the shaft, drum and the abrasive balls (ω_d)

(b) Unevenness of the product surface (ϕ)

(c) Abrasive teeth shape and protrusion (λ)

(d) Angular velocity of the revolving assembly (ω_g)

Hence, Equation (35) can be rewritten as;

$P_\tau = C_0 + C_1\omega_d + C_2\omega_g + C_3\phi + C_4\lambda$ (36)

Where; C_0, C_1, C_2, C_3 and C_4 are model coefficients and are represented as;

$C_0 = \frac{K_4K_6}{\eta_E}(1+\alpha)n_1 h\pi l_1 d_1 \beta N\frac{\omega_g}{\omega_d}\frac{3EI\delta_5^2}{L^3}$ (37)

$C_1 = \frac{K_6}{\eta_E}\left[8(1-\alpha)n_1\beta\gamma\pi d_1 d_2 l_1 l_2\tau\delta_2 sin\theta_1 + \frac{3EI\delta_4^2}{L^3}\right]$ (38)

$C_2 = \frac{K_4K_6}{\eta_E}\frac{\omega_g}{\omega_d}Nn_1(1+\alpha)h\pi\beta l_1 d_1\frac{\delta_2\mu_d}{d_2}(W_1 cos\theta_2 + \frac{3EI\delta_5^2}{L^3})$ (39)

$C_3 = \frac{2K_6K_4}{\eta_E}(1+\alpha_1)n_1\tau\pi\beta N l_1 d_1 h^2\frac{\omega_g}{\omega_d}$ (40)

$C_4 = \frac{K_{4N}}{\eta_E}h\pi l_1 d_1\beta[\frac{\mu_d}{d_2}(2\tau l_2 cos\theta_1)$ (41)

2.2: Input Variables

ω_g/ω_d = 0.5, and ω_d values starts from 20, 30, 40, 50, 60, 80, 100, 120, and 160rpm

n_1 = No. of teeth per ball = 15, total number of balls projected = 30 - 40

n_2 / n_1 = 40, Θ_2 = 45^0, W_1 = 240gm

Θ_1 = 63^0, γ = 0.005, β = 0.20, N = 4, δ_5 = 0.0001mm

l_1 = 10mm, l_2 = average length of protrusion, = 1.50mm

τ = 3.445KPa, d_2 = average value = 2.00mm, h = 12mm

Material for peeling is galvanised iron. Modulus of elasticity E = 110 x 10^3 KN/mm^2

$\delta_2 = \delta_3$ = 1.50mm, I = 0.7854mm^4

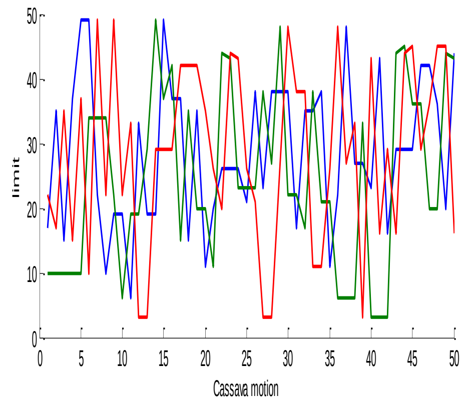
μ_d = 0.174

Results

Based on the mathematical modelling results obtained from Figures 3 to 20, it is obvious that the motion of cassava in the chamber remains random for the different speeds of rotation modelled in this research. The limit set for each rotation was 100mm in diameter, and they are modelled for two cycles of 360^0 or 2π radians. In all the different speeds of rotation from 20rpm to 160rpm in steps of 20rpm, no appreciable difference in the motion was observed.

However, the energy consumed during cutting shows appreciable difference with 20rpm resulting in highest consumption rate at 6.0 x 10^8J. Thereafter, the energy consumed continue to decrease reaching its minimum value of 1.0 x 10^8J at 120rpm. It was also observed that, at 80rpm,100rpm, 140rpm and 160rpm the energy consumption rate is the same at 1.5 x 10^8J . The theoretical results predict better cutting approach 80rpm and 160rpm, but best at 120rpm in terms of energy consumption. Rate of energy consumption is a key factor in this design because, it affects the commercial value of the machine, especially for industrial mass production processes. The predicted values shows that the energy consumption rate of the machine is quite reasonable for the commercialization of the machine

Cassava motion at 120 rpm



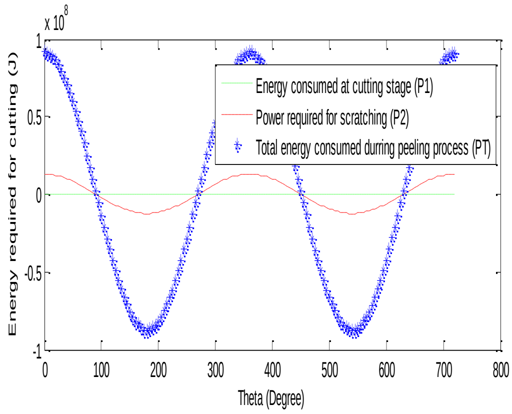
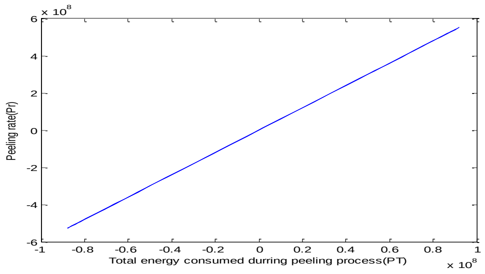


Figure 3. Cassava motion at 120rpm Figure 4: Energy consumption rate during cutting rotation at 120rpm



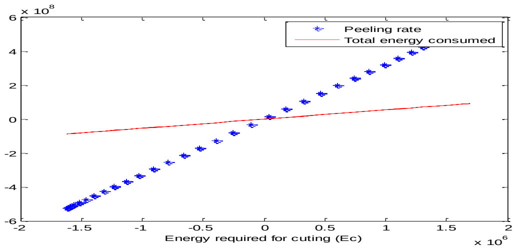


Fig 5: Peeling rate Vs Energy Consumed at 120rpm
Fig 6: Peeling rate Vs Energy required for cutting

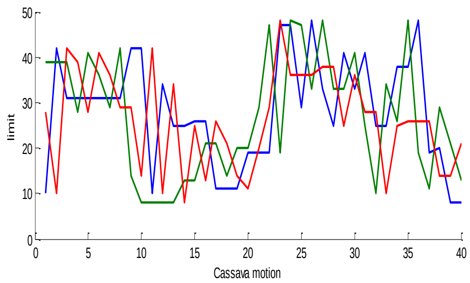
Initial size 126 132 138 144 150 156 162 168 174 180

final size162 156 150 144 138 132 126 120 114 108

Cutting force = 16.5000

The values above are machine estimated figures of cassava sizes, as output values. The program automatically develop such values based on the input variables shown in chapter four.

Result for speed at 20rpm



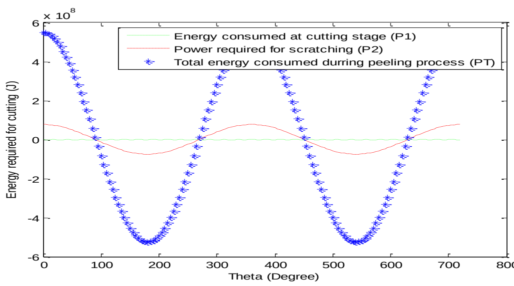


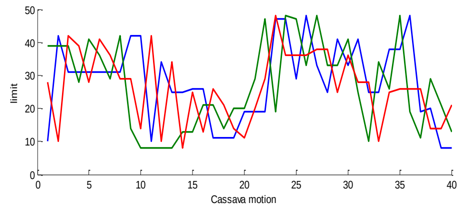
Figure 7: Random motion of cassava at 20rpm
Fig 8: Energy Consumption Rate of Machine at 20 rpm

Initial size 126 132 138 144 150 156 162 168 174 180

final size162 156 150 144 138 132 126 120 114 108

Cutting force = 16.5000

Cassava motion at 40 rpm



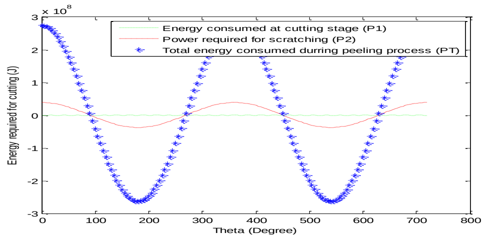


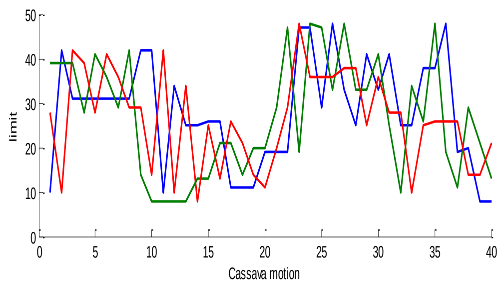
Figure 9: Cassava Motion at 40rpm Figure 10: Energy consumed During Cutting at 40rpm

Initial size 126 132 138 144 150 156 162 168 174 180

final size162 156 150 144 138 132 126 120 114 108

Cutting force = 16.5000

Cassava motion at 60 rpm



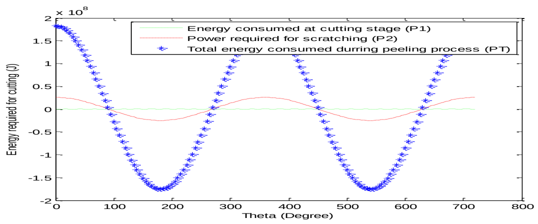


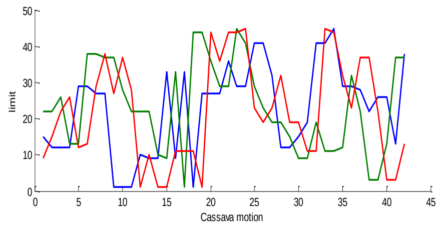
Figure 11: Cassava Motion at 60rpm Figure 12: Energy Consumed during Cutting at 60rpm

Initial size 126 132 138 144 150 156 162 168 174 180

final size162 156 150 144 138 132 126 120 114 108

Cutting force = 16.5000

Cassava motion at 80 rpm



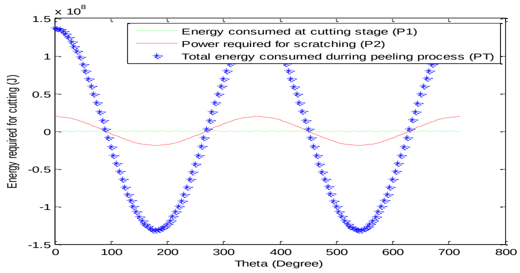


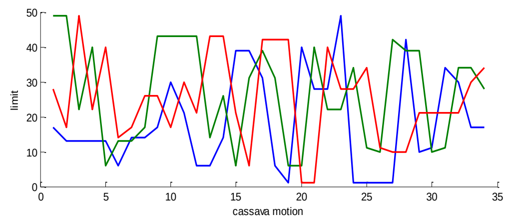
Figure 13: Cassava motion at 80rpm Figure 14: Energy Consumed during Cutting at 80rpm

Initial size 126 132 138 144 150 156 162 168 174 180

final size162 156 150 144 138 132 126 120 114 108

Cutting force = 16.5000

Cassava motion at 100 rpm



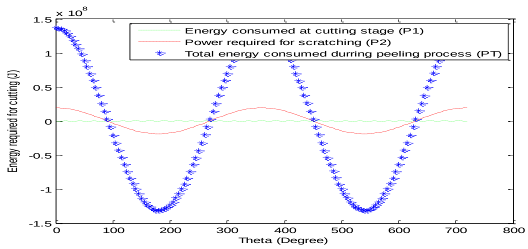


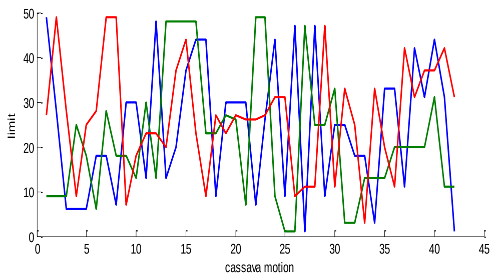
Figure 15: Cassava Motion at 100rpm Figure 16: Energy Consumed during Cutting at 100rpm

Initial size 126 132 138 144 150 156 162 168 174 180

final size162 156 150 144 138 132 126 120 114 108

Cutting force = 16.5000

Cassava motion at 140 rpm



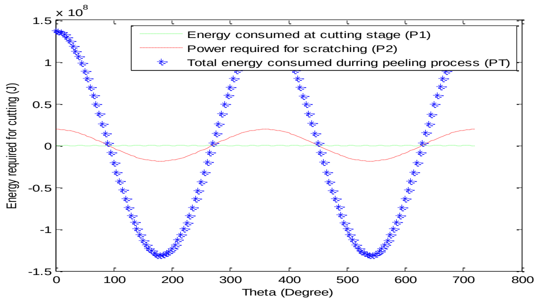
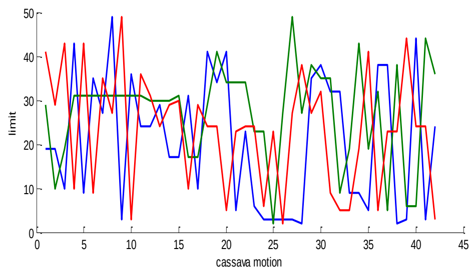


Figure 17: Cassava Motion at 140 rpm Figure 18: Energy Consumed during Cutting at 140rpm

Cassava motion at 160 rpm



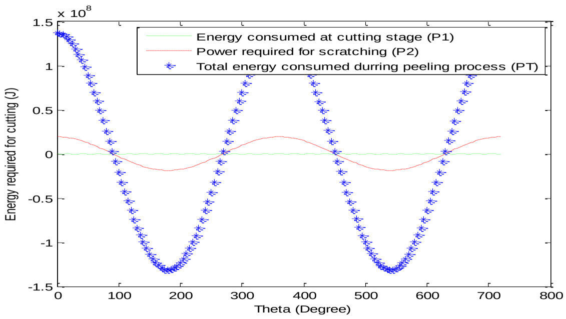


Figure. 19. Cassava motion at 160 rpm Figure 20: Energy Consumed during Cutting at 160rpm

Initial size 126 132 138 144 150 156 162 168 174 180

final size162 156 150 144 138 132 126 120 114 108

Cutting force = 16.5000

Discussion

The essence of predicting the energy consumption is to ensure that the consumption of energy in the actual machine is at the minimum considering the fact that between 2-3 electric motors are required to drive the machine. However, this result has enables us to modify the construction to save energy, but still maintaining the three motions of rotation, revolution and rocking of the peeler drum. The effort in the mathematical modelling has also predicted values of cutting force and range of energy to operate the machine for maximum results. When these values were inputted into the actual construction, reasonable level of certainty was achieved. Results from the MATLAB code modelling of the energy consumed during cutting and scratching of the cassava surface indicates that the optimal values ranges from 80 – 160rpm as shown in Figure 21 The lowest energy consumption as predicted by the codes coincides with 120rpm.

The cutting force which is between 6.50N to 15.00N, varies considerably as predicted by the code. This agrees with observations during experimentation, as initial peeling rate is low while the machine tries to pick up momentum for effective peeling of cassava tubers. Once the rotation becomes steady lesser time is used in peeling the cassava. Off course energy is require at the initial stage to overcome friction and dead load resistance. Energy consumption is highest at lower speeds as predicted by the modelling results. From Figure 20, the highest energy value was obtained 20rpm which is the lowest speed tested with the mathematical modelling. A value of $6.0 x 10^8$ J was predicted for 20rpm, but at 40rpm the value is halved that predicted for 20rpm and the value continues to decrease to 1.0×10^8J at 120rpm,and then begin to rise again. The prediction has clearly demonstrated that operating the machine at values below 80rpm and above 160rpm are not economical and are counterproductive as regard energy consumption.

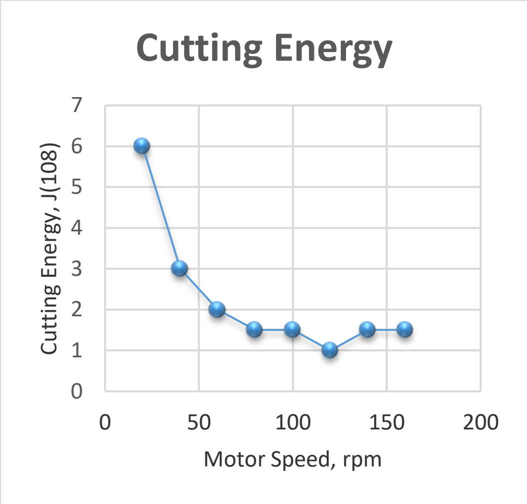


Figure 21: Energy Consumption during Cutting against the Cutting Speed.

From the mathematical modelling result as shown in figure 3 to 20 and the summary of energy consumption against speed plot in Figure 21, it can be deduced that, the energy consumption is lowest at 100rpm with optional values between 80rpm to 120rpm but, the cassava tuber motions as shown from Figures 4, 12, 14, 16 and 18 indicate a more uniform rotation as against lower speeds of 20, 40 and 60rpm as shown in Figures 7, 9 and 11. Figures from the lower speed show rising and falling pattern of tuber motion in addiction to rotation as against the higher speeds which indicate rotation without rising and falling.

The evaluation values show that, lower speeds recorded higher peeling efficiency than the higher values, this result agrees with experimentation on friction test, which recorded high peeling rate as the tuber slides along the inclined planes. It can be deduced that the more sliding action takes place at lower speeds which increase frictional contact within the peeling drum and the tubers to effect peeling

CONCLUSION

Mechanical peeling of cassava tubers using abrasive drum and balls with some gyroscopic motion effect was modelled and simulated for different speeds of drum rotation and revolution. The results show remarkable difference in the curves at various speeds, optimal energy consumption rate is 1.0 x 10^8J at 120rpm of drum speed. The relationship show a near Fourier model motion at all stages of peeling. Initial peeling rate consumed more energy than higher speeds of rotation, with more uniform tuber motion as shown in the curves above. Experimental values give better peeling rate at lower speeds, which are more of random motion in the curves are above.

Refrences

1. Odoemelam, S. A. (2005). Studies on residual hydrocyanic acid (HCN) in garri flour made from cassava. Pakistan Journal of Nutrition, 4(6); 376-378.
2. Jeon, Y.W., Halos, L.S. (1992). An Unpublished Training Manual: Design, Operation and Maintenance of IITA-developed Postharvest Technologies.
3. Jimoh, M.O. and Olukunle, O.J.(2012). An automated cassava peeling system for the enhancement of food security in Nigeria, Nigerian Food Journal, 30(2), 2012, 73-79
4. Adetan, D.A., Adekoya, L.O., Aluko, O.B. and Makanjuola, G.A. (2005). An experimental mechanical cassava tuber peeling machine, Journal of Agricultural Engineering and Technology (JAET), Vol. 13, pp. 27-34.
5. Emadi, B., Kosse, V., Yarlagadda, P. (2007). Abrasive peeling of pumpkin, Journal of Food Engineering Vol.79, pp.647-656.
6. Abdullah, K. H A (2007). Mathematical modeling of laser-based potato cutting and peeling. Bio-Systems, doi:10.1016/J.biosystems.2007.01.004.
7. Adetan, D.A., Adekoya, L.O. and Aluko, O.B. (2006). Theory of a mechanical methods of peeling of cassava tubers with knives. International Journal of Agrophysics, 20; 269-276.
8. Dowgiallo, A. (2005). Cutting force of fibrous materials, Journal of Food Engineering, 66; 27-36
9. Dushyant S. Saha, K. P., Mondal, D. P. (2011). Development of Mathematical Model for Prediction of Abrasive Wear Behaviour in Agric Grade Medium Carbon Steel. *Indian Journal of Engineering and Material Science.* 18: 125-136.

10. Emadi, B. (2006).Experimental studies and modelling of innovative peeling processes for tough-skinned vegetables.
11. Emadi, B., Abbaspour-Fard, M.H., Yarlagadda, H.P.K.V.(2009). Mechanical properties of melon measured by compression, solar and cutting modes, International Journal of Food Properties Vol.12 pp. 780-790.
12. Ferraz, A. C. O., Mittal, G. S., Bilanski, W. K., Abdullah, H. A. (2007). Mathematical modelling of laser based potato cutting and peeling. doi: 10.1016/ Journal of Biosystems, 1(4).
13. Jimoh, M. O., Olukunle, O. J., Manuwa, S. I., Amumeji, O. T. (2014). Theoretical analysis of tuber movement during mechanical peeling of cassava. IORS, Journal of Mechanical and Civil Engineering, 11(6); 57-61
14. Somsen, D., Capelle, A.,Trampe, J. (2004). Manufacturing of par-fried French fries, Part 2: Modelling yield efficiency of peeling. Journal of food Engineering, 61; 199-207.
15. Zhenfang, Z., Liangchi, Z., Yiu-Wing, M. (1994). Modelling friction and wear of scratching ceramic particle reinforced metal composites. Journal of food Engineering, Elsevier Food Science Journal. 176: 231-237