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Development of a Roasted Groundnut Skin Peeling Machine

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Abstract

The research work was conducted to design, fabricate and carryout performance evaluation of a roasted groundnut skinning machine, capable of skinning roasted groundnut and separating the skin from the white groundnut. Fundamental design analysis and calculations were carried out in order to determine and select materials of appropriate strength and sizes for the machine component parts. The major machine parts include hopper, skinning shaft, auger, brushes and electric motors. The results of testing of the machine revealed that highest skinning efficiency of 99.91 % was obtained from combination of 6 number of brushes and inner drum clearance of 1.4 cm while the lower value of skinning efficiency of 7.9 % was obtained when the sample was processed with 2 brushes and inner drum clearance of 1.8 cm. The optimisation of the machine parameters using response surface methodology produced optimum skinning efficiency of 81.45 % with desirability of 94.3% from combination of 5-number of brushes and inner drum clearance of 1 cm. The number of brushes has positive significant effects on the skinning efficiency while inner drum clearance has negative insignificant effect. The skinning efficiency increases with increase in brush number from 2 to 5 and at the same time decrease with increase in inner drum clearance. The machine capacity was 460 kg per day.

Keyword: Development; Efficiency; Groundnut; Machine; Skinning

Introduction

Groundnut seed (*Arachis hypogea*), also known as peanut and earthnut, is the most common oil nut grown as an annual crop on about 19 million hectares of land in tropical, sub-tropical and warm temperature regions of the world. It is grown principally for its edible oil and protein rich seeds. The oil content of the seeds is between 45% and 55% depending on the variety [1]. As human food the kernels are eaten raw, lightly roasted or boiled, sometimes salted or made into paste, which is known as peanut butter. It is also widely used in making candy bars, cookies and peanut brittle as well as cosmetics, plastics, dyes and paints production [2]. According to FAO (2002) [3] in developing countries, most of the groundnuts are used for extraction of oil for domestic consumption and export. It provides high-quality cooking oil and is an important source of protein for both human and animal diet and also provides much needed foreign exchange by exporting the kernels and cake. For example, groundnuts are important component of Nigerian diet and about 5% of the estimated 58.9 g of crude protein available per head per day, is contributed by groundnut. The extraction of oil from groundnut involved series of unit operations. Lawan et al. (2015) [1], reported that groundnut oil extraction involves shelling the groundnut pods, roasting the shelled groundnut seeds, de-skinning and winnowing the roasted groundnut seeds, milling the cleaned groundnut seeds and kneading the paste produced.

It has been observed that de-skinning and winnowing of groundnut is being carried out by manual manipulation which is a tedious exercise, time consuming and labour intensive. The traditional skinning operation provides for manipulation of the kernels between opposing tenacious yielding surfaces with which the kernels are preliminarily aligned. This exerts a retarding effect upon the skins while the kernels and the tenacious surfaces are being subjected to relative movement. The skin is being ruptured and loosened. The loosened skins are withdrawn by free falling of the kernels across the air flow or by blowing air through the kernels with mouth. On the other hand, the industrial machine used for groundnut oil extraction are expensive and sophisticated to be operated and maintained by local processors. Hence, the constraint to skinning as a unit operation in the processing line of peanuts demands for design and fabrication of a machine capable of removing the outer coat of roasted peanut kernels effectively, rapidly and gently without abrasion of the kernels, with minimum breakage and splitting.

Methodology

Materials Selection

Mild steel of gauge 16 (1.59 mm in thickness) was used for the construction of the hopper and the fan enclosure. Galvanized steel was used for construction of skinning unit and the conveyor in order to guide against food contamination. Mild steel angular bar (40 mm x 40 mm) was used for the frame [4].

Machine Description

Machine Components

The machine is made up of the following components;

I. Hopper: The roasted groundnuts are fed to the machine through the hopper. It was made from mild sheet, and of conical shape as shown in Figure1.

II. Skinning Unit: this consists of both inner and outer drums. They are both of tapered cylindrical shapes. The cylindrical segment of the inner drum contains auger which conveys the peanuts to the frustum segment on which brushes are attached for peanut skinning in order to enhance the removal of the skins, while the outer drum is an enclosure for the inner drum which holds the peanuts (Figure 1).

III. Cleaning Unit: The cleaning unit comprises of the blower and its enclosure. The blower winnows the peanut skins off the free falling peanut kernels while the enclosure controls the direction of air flow.

IV. Drive Mechanism: the drive mechanism consists of the pulley and the belt. The pulley is a wheel around which a belt passes; it is used in power transmission from the electric motor and in speed reduction to the skinning shafts.

V. Main Frame: the frame is the rigid structure on which all other machine parts are installed. It bears the loads of the machine members. It is shown in Figures 1 and 2.

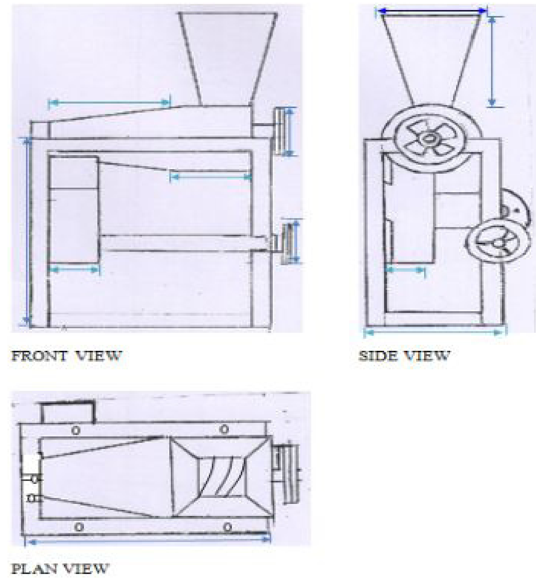

Figure 1: Orthographic View of the Machine.

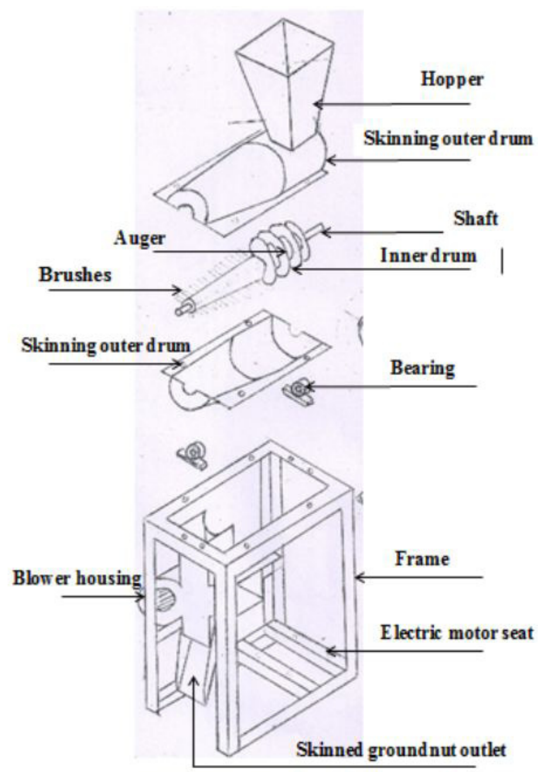

Figure 2: Part drawing of the machine.

Design Analysis of Machine Components

Fundamental design analysis and calculations were carried out in order to determine and select materials of appropriate strength and sizes for the machine component parts.

Determination of power requirement

The power requirement of the machine depends on the force on the skinning shaft and auger, mass of the ground nut, skinning brush, blower, and the machine pulley. This was computed from the equation given by Khurmi and Gupta (2005) [5].

$$P = 2 \times \pi \times N \times \tau / 60 \quad (1)$$

$$\tau = F \times r_d \tau = F \times r_d \quad (2)$$

$$F = M \times r_d \times \omega^2 \quad (3)$$

$$\omega = 2 \times \pi \times N / 60 \quad (4)$$

$$M = (M_{au} + M_{sh} + M_B + M_G + M_P + M_{BL}) \quad (5)$$

where, P is power required by the machine (watts), F is the total force (N), V is the velocity of skinning shaft (m/s), τ is the torque generated (Nm), M is total mass of skinning mechanism and the fed roasted groundnut (kg), M_{sh} is mass of the shaft (kg), ω is angular speed of the skinning mechanism(rpm), $M_{au}$is mass of auger (kg), M_G is mass of the roasted groundnut (kg), M_B is mass of the brushes(kg), M_{BL} is mass of the blower (kg), *g* is acceleration due to gravity =9.81m/s^2, π is constant, r_d is radius of the skinning auger (m), N is revolution per minute

Hopper Design

The hopper is intended to accommodate 8 kg of roasted groundnut and from preliminary study carried out the bulk density of the roasted groundnut was 590Kg/m^3.

Volume of the hopper

The volume of the hopper was obtained by considering safety and adding 20% of the calculated volume of groundnut to be fed at a time. This was obtained as reported by Gana et al. (2017) [4] and is given as

$$V_h = \left(\frac{m_g}{\rho_g} + 0.2\frac{m_g}{\rho_g}\right) \quad (6)$$

Where, V_h is volume of the hopper(m^3), m_g is mass of the groundnut fed (kg), ρ_g is the bulk density of the roasted groundnut was (Kg/m^3)

Height of the Hopper

The height of the hopper was obtained as

$$V_h = \left(\frac{1}{3}\right)\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)h \quad (7)$$

$$h = \frac{\left(\frac{1}{3}\right)\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)}{V_h} \quad (8)$$

Where, V_h is volume of the hopper (m^3), h is the altitude or perpendicular height of the hopper (m), A_1 and A_2 are the area of the two bases (m^2)

The Mass of the Hopper

The mass of the hopper was calculated as reported by Gana et al. (2017) [4] and is given as

$$M_h = \rho_h \, X \, V_h \quad (9)$$

Where, M_h is mass of the hopper (kg), ρ_h is the bulk density of the hopper material (kg/m^3) and V_h is volume of the hopper (m^3)

Capacity of the Machine

The capacity of the machine was obtained as reported by Gana et al. (2017) and is given as

$$C_{md} = M_{gb} \times \left(\frac{N_{md}}{N_{mb}}\right) \quad (10)$$

Where, C_{md} is capacity of the machine per day/8 hours operational time (hr/day), N_{md} is number of minutes in 8 hours per day (minutes), N_{mb} is number of minutes to complete one operation including loading and dislodging (minutes)

The Total Mass of the Brush

The total mass of the brush was computed as reported by Gana (2011) [6] and is given as

$$M_p = N_b(\rho_b \, X \, V_h) \quad (11)$$

Where, M_p is mass of the hopper (kg), $N_b$is the number of the brushes(kg), ρ_b is the bulk density of the hopper material (kg/m^3) and V_h is volume of the hopper (m^3).

Determination of The Total Length of Belt

The length of belt required to transmit power from the electric motor pulley to the machine speed pulley was computed as reported by Ballaney (2005) [7], and is given as

$$L = 2D + \left(\frac{\pi}{2}\right)(d_2 + d_1) + \frac{(d_2 - d_1)^2}{4D} \quad (12)$$

Where, L is the length of the belt (m), D is the center distance between the motor and the speed reduction shafts (m), d_2 is the diameter of the speed reduction pulley(m), $d_1$is the diameter of the motor pulley(m).

Determination of the Shaft Speed

The shaft linear velocity was obtained as reported by Khurmi and Gupta (2005) [5], and is given as

$$V = \frac{\pi N d}{60} \quad (13)$$

Where, $V$is the linear velocity of the machine (m/s), N is the speed of the motor pulley (rpm), d is the diameter of the motor pulley (m).

Shaft Design

The shaft is the machine element which carries the load of the inner drum, its components and the pulley. Power is transmitted by some tangential force and the resultant torque i.e. twisting moment set up within the shaft. The shaft is subjected to bending moment and torsional forces (Khurmi and Gupta 2005) [5].

Determination of the Bending Moment at Each Point of Loading

Figure 3 (a) depicts the distribution of load on the shaft and explains the reactions at the bearings due to vertical loading i.e. vertical forces acting on the shaft respectively.

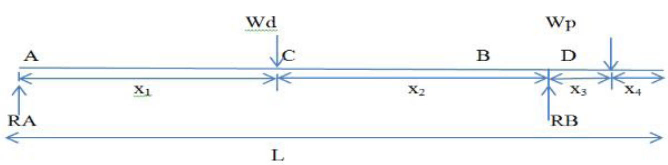

Figure 3 (a): Loads Distribution on the Shaft.

From Figure 1 (a), Wd is the weight of the inner drum (uniformly distributed) (N), Wp is the pulley's weight (N), RA is the reaction at the first bearing and RB is the reaction at the second bearing. To obtain the reaction at each bearing, bending moment about the two respective bearings is taken independently as reported by Khurmi and Gupta (2005) [5]. In other words, bending moment of loads (skinning drum and the shaft pulley) applied transversely to the longitudinal axis of the shaft was computed by taking moment about point A as reported by Khurmi and Gupta (2005) [5] and is given as:

$$BM = Rax - \frac{wx^2}{2} \quad (14)$$

Where, w is the weight acting on the shaft (uniformly distributed), x is distance in (m),

Maximum Bending moment occurs at the point where shear force is zero i.e. at 0.35m from point A.

$$Max\ BM = Rax - \frac{wx^2}{2}$$

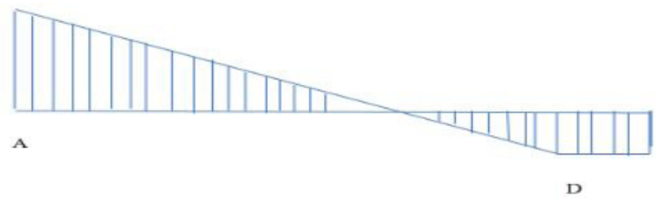

Figure 3 (b): Representation of the shear force on the shaft.

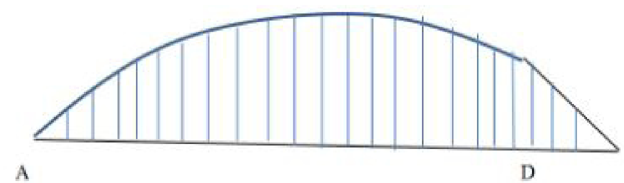

Figure 3 (c): R Bending moment diagram.

Torsional Moment or Torque on the Shaft

In order for the shaft not to fail, the value of the twisting or torsional moment on the shaft as a result of power transmission is expected to be within the permissible limit as reported by Khurmi and Gupta (2005) [5].

Therefore, equation (15) was given for determining the torsional moment.

$$T_m = \frac{P}{\omega} \quad (15)$$

Where, T_m is the torsional moment, P is the power transmitted (Watt), andω is the angular velocity in rad/sec.

Diameter of the Shaft

The diameter of the central shaft was computed using equation (16) reported by Khurmi and Gupta (2005) [5].

$$d^3 = 16/\pi S_s \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (16)$$

where, d is expected diameter of shaft (m), M_t is belt torque moment (Nm), M_b is bending moment (Nm), K_b is shock and fatigue factor applied to bending moment, $K_t K_t$ is shock and fatigue factor applied to torsional moment, S_S is permissible shear stress of the shaft, and 16 is a factor.

Second Polar Moment of Area of the Shaft

The second polar moment of area of the central shaft is essential in determination of the resistance of the shaft to bending and deflection and was computed as reported by Gbabo and Igbeka (2003) [8] as:

$$J = \pi ds^4/32 \quad (17)$$

where, J is second polar moment of area, d_S is the diameter of shaft (m).

Working Procedure of the Machine

The various parts of the machine were assembled, after which a 2 hp electric motor was mounted and connected through belts and pulleys to the speed reducer pulley. This pulley was then connected to skinning shaft pulley. The speed reducer pulley with a turning ratio of 1:5 was used to reduce the speed of the electric motor to the speed required by the skinning shaft to skin the roasted groundnut and also to separate the skin from the white groundnut. The machine was then test run without groundnut poured into the hopper. This was done to study the behavior of the machine. Roasted groundnut seeds were fed into the skinning unit via the hopper. The skinning process was made possible by the rotary action of the skinning shaft. The skinning shaft carries an auger which conveys the roasted peanut to the frustum where brushes are arranged for gentle rubbing of the ground nut against the drum. The machine was designed with a blower which aid in the separation process. The light skin is lifted and blown out of the machine through an outlet while the white groundnut which is heavier than the skin flows out through the lower outlet.

Testing of the Machine

The performance of the machine was evaluated in accordance with procedures reported by Gana et al. (2016) [9]. The groundnut variety (Rmp 12) was purchased from Bida central market and the samples were cleaned and sorted to remove unwanted materials (Gaffa et al., 2003) [10] before processing using the developed machine. The experiment was carried out to investigate effects of brush number and inner clearance on skinning efficiency. The experiment was carried out at the Agricultural and Bio -Environmental Engineering Department of Federal Polytechnic Bida, Nigeria.

Design of Experiments

The experimental design was designed as a function of machine functional parameter of number of brushes (A) and inner clearance (B) (independent variables) using Central Composite Rotatable Design (CCRD) of Response Surface Methodology (rsm). In order to obtain the required data, the range of values of each of the two variables (k) was determined as reported by Tran et al., (2010) [11] and Anuonye (2006) [12] and is presented in Table 1. For three variables (k=2) and the five levels (-α, -1, 0, 1 and + α) experiments, the total number of runs was determined by the expression; 2k (22= 4 factorial points) + 2k (2 × 2 = 4 axial points) + 5 (center points: six replications) as 13 (Cukor et al., 2011; Tran et al., 2010; Anuonye, 2006) [11-13] and the design is shown in Table 1. The objective function here was to minimize the effects of unexpected variability in the observed response. Skinning efficiency was considered as the response in this case.

Statistical Analysis

Design expert software package (version7.0.0) was used for the regression and graphical analysis. A quadratic polynomial equation was developed to predict the response as a function of independent variables and their interaction. In general, the response for the quadratic polynomials is described below as reported by [14]:

$$Y = \beta_0 + \sum_{g=1}^{N} \beta_g x_g + \sum_{g=1}^{N} \beta_{gg} x_g^2 + \sum_{g<f} \sum \beta_{gf} x_g x_f \quad (12)$$

where Y is the response (skinning efficiency), β_0 is the intercept coefficient, β_g is the linear terms, β_{gg} is the squared terms, β_{gf} is the interaction terms, x_g and x_f are the uncoded independent variables.

Analysis of Variance (ANOVA) was carried out to estimate the effects of main variables and their potential interaction effects on the paste expelling efficiency.

Determination of Machine Performance

Skinning Efficiency It is the ratio of the mass of skinned groundnut to the mass of groundnut fed into the hopper expressed in percentage and was given, as reported by Gana et al. (2016) [9], as follows:

$$E_S = \frac{M_S}{M_g} \times 100 \quad (13)$$

Where, E_S is the skinning efficiency (%), M_S is mass of skinned groundnut (kg), M_g is mass of the groundnut fed into the hopper (kg).

Results and Discussion

Results

The machine was designed, fabricated and the results of the performance testing are presented in Table 1. The highest skinning efficiency of 99.91 % was obtained when the machine was processed with 6 number of brushes and inner drum clearance of 1.4 cm while the lowest value of skinning efficiency of 7.9% was obtained when the sample was processed with 2numbers of brushes and inner clearance of 1.8 cm as shown in Table 1.

Std. ord.	Run Ord.	Number of brush	Inner clearance	Skinning efficiency
9	1	4	1.4	20.7
11	2	4	1.4	20.7
8	3	4	2	29.62
7	4	4	0.8	49.89
1	5	2	1	15.4
3	6	2	1.8	7.9
13	7	4	1.4	20.7
6	8	6	1.4	99.91
10	9	4	1.4	21.7
2	10	5	1	71.99
4	11	5	1.8	53.99
5	12	1	1.4	15.99
12	13	4	1.4	21.7

Table 1: Results of Interaction between Machine Parameters and the Skinning Efficiency.

Discussion

The result of statistical Analysis of Variance (ANOVA) of the experimental is presented in Table 2. The effects, contribution, model coefficient, test for Lack-of-fit and the significance of the variables and their respective interaction on the paste expelling efficiency were determined as reported by Anuonye (2006) and Aworanti et al (2013) [12,15]. A quadratic model was statistically significant for the responses. The significant model terms were identified at 95% significance level. The Quadratic regression model equation developed to predict skinning efficiency with respect to functional machine parameters (independent variables) is shown in Eq. (14). The model F - value of 6290.39 implies that the model is significant. There was only 0.01% chance that a Model F value this large could occur due to noise. The value of Probability > F less than 0.0500 indicated that model terms were significant. In this case both A and B is significant model terms with P-values of < 0.000 each. It can be clearly observed that A had more significant effect on de-skinning efficiency with coefficient of estimate of 25.39 [15].

	Coef. of	Standard	F	p-value	
Source	Estimate	Error	Value	Prob > F	
Model	10.7714	0.24995	6290.3	< 0.0001	significant
A-No. Brush	25.3696	0.16852	22663	< 0.0001	
B-Inner clearance	-6.3354	0.19007	1110.9	< 0.0001	
AB	-2.6118	0.25501	104.89	< 0.0001	
A^2	17.0182	0.16155	11097.1	< 0.0001	
B^2	9.38882	0.20186	2163.1	< 0.0001	
Lack of Fit	0.72212		0.8023	0.5541	not significant
R-Squared					0.9998

Table 2: Regression Analysis of Response of Skinning Efficiency.

Aworanti et al. (2013) [15] reported that the Lack of Fit F-value of 0.8 implies that the Lack of Fit is not significant relative to the pure error. Also there is 55.41 % chance that a Lack of Fit F-value this large could occur due to noise. In general, non-significant lack of fit was considered good indicative that the model equation can predict the response. The coefficient of correlation R-squared value of 0.9998 was high. Also the coefficient of determination R value of 0.999 indicated that the model was able to predict 99.97 % of the variance and only 0.001 % of the total variance was not explained by the model. Predicted R - Squared value of 0.9991 was in reasonable agreement with the Adjusted R - Squared of 0.9996which indicated that the experimental data fitted better [16].

Adequate Precision value of 259.1 is above the desirable minimum value of 4, and as was reported by Salam et al. (2014) [17], it indicated that the model can be used to navigate the design space.

The regressed d-skinning efficiency model equation is given by as:

$$Y_{SE} = 10.77 + 25.37A - 6.34B - 2.61AB + 17.02A^2 + 9.39B^2 \quad (15)$$

where, Y_{SE} = Skinning Efficiency (%),A is the number of brush and B is the inner drum clearance (cm).

It is important to add that the variables A in the model have positive co-efficient implying a direct proportionality. That is, independent increase in A increased the skinning efficiency while independent increase in B decreased the skinning efficiency. The model equation obtained was simulated and the skinning efficiency was observed to be within the experimental range. From Table 1, the actual values of skinning efficiency were observed to be in close agreement with the predicted values. This is an indication to close agreement between the two values validating the need for the model equation to use to determine the optimum skinning efficiency at various operating conditions. The response surface and contour plot for de-skinning are shown in Figures 4 and 5 respectively. The skinning efficiency increases from 17.42 to 75.25 % with increase in number of brushes from 2 to 5 numbers. This could be due to increase in impact force and robbing action of the brush on the groundnut with increase in brush number. This is in agreement with results of similar studies conducted by Gana (2011) [6] where increase in number of blending blades increased the rate of segregation of materials due to increase in contact. A significant effect was observed with increasing brush number from 2 to 5. On the other hand, the skinning efficiency decreased from 27 % to 7 % as the inner drum clearance increased from 1 cm to 1.8 cm. This could be due to increase in space that allows the material to pass through freely without getting in contact with the brush. An insignificant effect was observed with increasing the clearance from 1.6 to 1.8 cm. But significant effect was obtained from increasing the clearance from 1 to 1.2 cm.

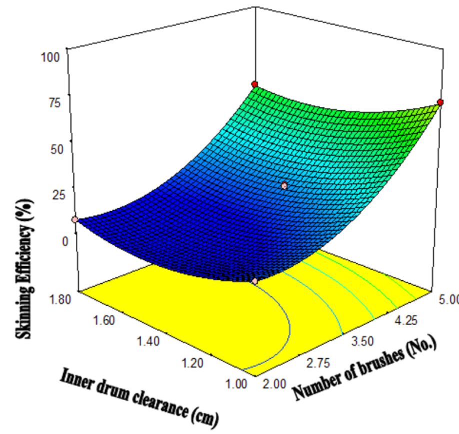

Figure 4: Response Surface for De-Skinning Efficiency (%).

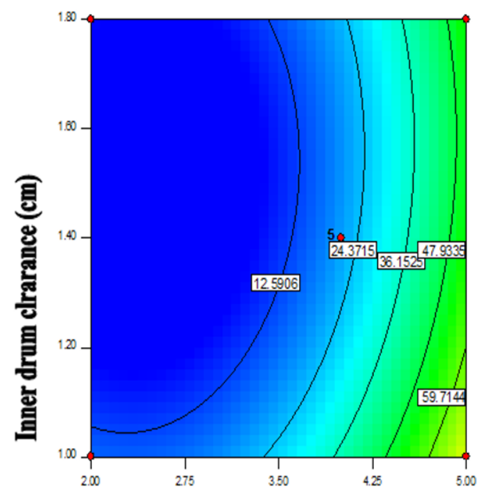

Figure 5: Contour Plot for De-Skinning Efficiency (%).

It was obvious that number of brushes had more significant effects ($p \leq 0.05$) on the de-skinning efficiency of the machine than the inner drum clearance. Also, from the analysis of variance (ANOVA) conducted, number of brushes was observed to have more significant effect (P ≤ 0.05) on the skinning efficiency. The optimization of the machine functional parameters; number of brush and inner drum clearance was carried out using numerical technique in rsm with the goal of maximizing the skinning efficiency. The ramp of the optimization process is shown in Figure 6 with optimum values of 5- number of brushes and inner drum clearance of 1 cm. On the other handde- skinning efficiency and desirability of 81.45 and 0.943 respectively were also obtained.

Figure 6: Ramp for Optimization Desirability.

Conclusion

A roasted groundnut skinning machine has been developed and tested. Test results of the machine revealed that the highest skinning efficiency of 99.91 % was obtained from combination of 6 number of brushes and inner clearance of 1.4 cm while the lowest value of skinning efficiency of 7.9 % was obtained when the sample was processed with 2 numbers of brushes and inner clearance of 1.8 cm. Also, number of brushes has significant effects on the performance of the machine. The developed mathematical models and individual coefficient were found to be significant while the Lack of fit was insignificant. The experimental values were found to be better with close agreement between predicted R-squared and adjusted R-squared values. The model equations can be used to navigate within the experimental ranges with high adequate precision values of 259.1. Optimization of the machine parameters carried out using numerical optimization technique by applying desirability function method in rsm produced optimal values 5-number of brushes, inner drum clearance of 1 cm.

References

1. Lawan I, Ali MA, Abubakar MS, Muhammad AI (2015) An Overview of Groundnut Oil Extraction Technologies. Proceedings of Second International Interdisciplinary Conference on Global Initiatives for Integrated Development (IICGIID 2015 Chukwuemeka Odumegwu University, Igbariam Campus Nigeria). Pg No: 2-5.
2. Nisha A (2015) Top Ten Peanut Producing Countries in the World, Perfect Insider.
3. Food and Agricultural Organisation (2002) Groundnut Post-Harvest Technology, INPHO- Post harvests Compendium.
4. Gana IM, Agidi G, Idah PA, Anuonye JC (2017) Development and testing of an automated grain drinks processing machine. Journal of Food and Bioproducts Processing 104: 19-31.
5. Khurmi RS, Gupta JK (2005) Machine Design. First Multicolour Edition. Enrasia Publishing House (PVT) Ltd. Ram Nagar, New Delhi-110 055.
6. Gana IM (2011) Development and Performance Evaluation of Grain Drinks Processing Machine, Unpublished M. Engineering Thesis, Federal University of Technology Minna, Nigeria.
7. Ballaney PL (2005) Theory of Machine and Mechanisms. (24th Edition). Romesh Chander Khana Publishers. 2-B, Nath Market, NaiSarak, Delhi. Pg No: 525.
8. Gbabo A, Igbeka JC (2003) Development and Performance of a Sugar Centrifuge. Journal of Sugar Tech 5: 131-136.
9. Gana IM, Shehu AA, Dauda SM, Ahmad D (2016) Design, fabrication and testing of shea nut shelling machine. International Food Research Journal 23: 71-79.
10. Gaffa TI, Jideani IA, Nkama I (2003) Traditional Production, Consumption and Storage of Kunu – a non-Alcoholic Cereal Beverage. Journal of Plant Food for Human Nutrition 57: 73-81.
11. Tran TAT, Ho TT, Le TVH, Bui H (2010) Using Central Composite Design-Response Surface Methodology to Optimize in Veratse Activity Condition for Fructose Production. Conference Proceedings of Biotechnology for Green Solutions and Sustainable Environment. Pg No: 82-87.
12. Anuonye JC (2006) Effect of Extrusion Process Variables on Physioco-Chemical, Sensory, Microbial and Storage Properties of Products from Acha (Digitariaexilis) and Soybean (Glycine max (L) Merill) Flour Blends. Unpublished Thesis on Degree of Doctor of Philosophy in Food Science and Technology, University of Agriculture, Makurdi Nigeria.
13. Cukor G, Jurkovic Z, Sekulic M (2011) Rotatable Central Composite Design of Experiments versus Taguchi Method in the Optimization of Turning. (METABK 5091) Pg No: 17-20.
14. Chih WT, Lee IT, Chung HW (2012) Optimization of Multiple Responses Using Data Envelopment Analysis and Response Surface Methodology. Tamkang Journal of Science and Engineering 13: 197-203.
15. Aworanti OA, Agarry AO, Ajani AO (2013) Statistical Optimization of Process Variables for Biodiesel Production from Waste Cooking Oil Using Heterogeneous Base Catalyst. British Biotechnology Journal 3: 116-132.
16. Xin L, Saka S, (2008) Optimization of Japanese Beech Hydrolysis Treated with Batch Hot Compressed Water By Response Surface Methodology. Int J Agric Biol Eng 1: 239–245.
17. Salam KK, Arinkoola AO, Oke EO, Adeleye JO (2014) Optimization of Operating Parameters Using Response Surface Methodology for Paraffin-Wax Deposition in Pipeline. Pet Coal.