DYNAMICS OF THE FUNCTIONAL PARAMETERS OF AN AUTOMATED MACHINE ON SOYA MILK YIELD

Gana, I. M[1], Gbabo A[2], Peter Idah[2] and Anounye, J. C[3]

1. *Agricultural & Bio-Environmental Engineering Department, Federal Polytechnic Bida, Nigeria.*
2. *Agricultural & Bioresources Engineering Department, Federal University of Technology, Minna, Nigeria.*
3. *Food Technology Department, Federal University of Technology, Minna, Nigeria.*

Corresponding author: ganaibro74@yahoo.com

ABSTRACT

The dynamic of the functional parameters of an automated grain drinks processing machine on yield of soya milk was investigated in this study. Response Surface Methodology (RSM) was used to develop polynomial regression model and investigate the effect of changes in blending blade, basket orientation and speed of rotation on yield of the milk using central composite rotatable design (CCRD). The result reveals that blade type and speed of rotation have significant ($p \leq 0.05$) effect on yield of the milk while basket orientation has insignificant ($p \leq 0.05$) effect. It was observed that the experimental data fitted well. The value of adequate precision of 19.55 also showed that the model equation can be used to navigate within the experimental range. Numerical optimization carried out produced optimum values at basket orientation of 44.25°, 3-blade assembly, speed of 1400 revolution per minute with corresponding milk yield of 98.2 %.

Key Word: *Blade type, basket orientation, speed, optimization, yield, milk.*

INTRODUCTION

In order to develop alternative machine for production of hygienic grain drinks from different varieties of soaked grains, effects of blade configuration, basket orientation and speed on yield of the grain milk were studied. The production of grain drinks from grains can be accomplished using different equipment (Simolowo, 2011). According to Gbabo *et al.*, (2012) burr mill and small household blender are mostly used in Nigeria. For dimensioning the machine and their component, several factors should be taken into consideration, from hygiene of the product, time taken in the production process, to tediousness of the operation (Simolowo, 2011).

The introduction of new technology which enable the combination of the basic operations of blending of the soaked grains, mixing of the slurry, extraction of the milk and expelling of the paste out of the machine all in single unit, as well as the automation of these operation makes the process more attractive.

The automated grain drink processing machine makes the production process of grain beverages production more attractive, more efficient compared with the existing method which involves different equipment for different operation. The innovation is also relevant when the goal is to produce hygienic drink which is free from contamination and of high quality. This paper presents of optimization of functional parameters of the machine based on yield of grain milk

MATERIALS AND METHODS

Experimental Setup

For performing the experiment on optimization of functional machine parameters based on yield of soya milk, an automated grain drink processing machine was used as shown in Plate I. The machine functional parameters which include blade type, basket orientation and speed were studied. Each of these factors was design to have five different levels as shown in Table 1. The soya milk and paste obtained from processing soya beans using the developed automated grain drinks processing machine are shown in plate II and III.

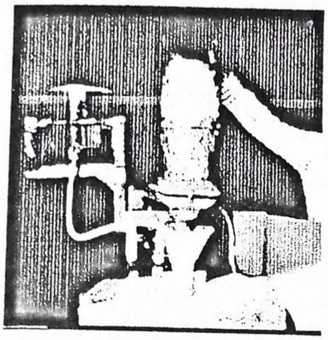
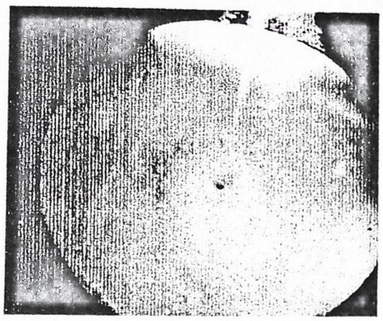
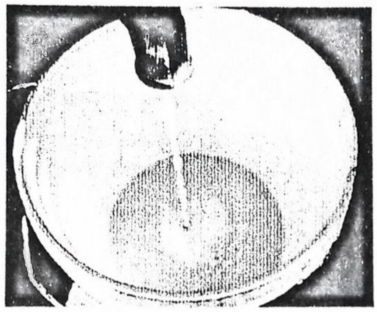


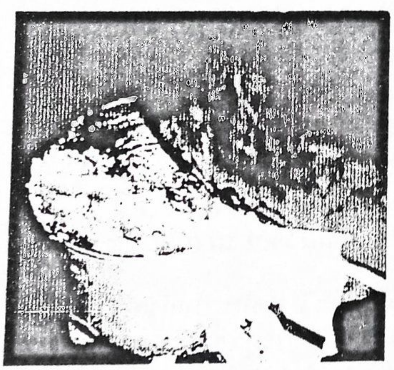
Plate I: Automated Grain Drinks Processing Machine

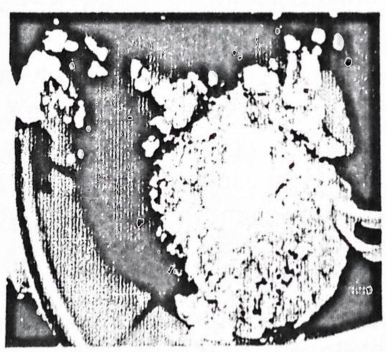




(A) **(B)**

Plate II: Soya Milk Flow from Blending Chamber to; (A) Temporary Milk Tank and (B) Out of the Machine





(A) **(B)**

Plate III: Soya Paste Expelled out; (A) Paste Collector (B) Packed Out of the Machine

Material preparation

The soya bean (TGX 1954-IFXTGX 1835-10E) was obtain from Kure Market in Minna, it was cleaned, sorted and soaked before processing using the developed machine as recommended by Gaffa *et al.*, (2003) and as shown in Plate II and II.

Experimental Design

In this investigation three factors and five levels were studied as shown in table 1. Based on preliminary investigation and review of literature the high and low values were selected as reported by Gbabo *et al.* (2012) and Hassan *et al.* (2011). The factors levels were utilized for conduction design of experiment as shown in Table 1.

Table 1: Matrix Transformation of Five Level- Three Factors Central Composite Rotatable Design of the Experiment

Run order	Coded X_1	Values X_2	X_3	Real Blade Configuration	Values Basket Orientation	Speed of Rotation
1	-	-	-	3	30	1000
2	+	-	-	5	30	1000
3	-	+	-	3	50	1000
4	+	+	-	5	50	1000
5	-	-	+	3	30	1400
6	+	-	+	5	30	1400
7	-	+	+	3	50	1400
8	+	+	+	5	50	1400
9	-1.682	0	0	2	40	1200
10	+1.682	0	0	6	40	1200
11	0	-1.682	0	4	23	1200
12	0	+1.682	0	4	57	1200
13	0	0	-1.682	4	40	864
14	0	0	+1.682	4	40	1536
15	0	0	0	4	40	1200
16	0	0	0	4	40	1200
17	0	0	0	4	40	1200
18	0	0	0	4	40	1200
19	0	0	0	4	40	1200
20	0	0	0	4	40	1200

Note: X_1= Blade Type, X_2= Conical Basket Orientation, X_3= Combine Speed of Blade and Basket, -1.682 and +1.682 = Axial Values of X_1, X_2 and X_3 (Anuonye, 2006).

Statistical and Optimization Analysis

Design Expert Software Version 7.0.0 was used for the regression and graphical analysis. Analysis of variance w also carried out at 5 % significant level (Myers *et al.*, (2004). Optimization is the process of finding the best soluti for a system or operation. The main purpose of optimization is to achieve optimum conditions for the operation of system or machine. In this study the optimization analysis were carried out as reported by Anounye (2006).

Optimization Technique

Design expert ® 7.0.0. software was employed using numerical technique for the optimization of independent va and the dependent variables in this study. By applying the desirability functions method in RSM, numbers of sc were obtained for the optimum covering criteria with desirability close to 1 and the first solution with desirability to 1 was selected.

Conducting the Experiments

The experiment was conducted following the design matrix, and the yield of milk was computed as follows;

Yield of the Milk

This is the quantity of the aqueous liquid produced by the machine and was determined as reported by Onuoral *al.*(2007). It is given as

$$Y_M = \frac{A}{MT} \times 100 \quad (1)$$

where, Y_M = the Yield of the Milk (%)

A = the amount of the material passed through the sieve (kg)

MT = the total weight of the material fed into the machine (kg)

RESULTS AND DISCUSSION

Yield of the Milk

The yield of the milk is percentage ratio of weight of the aqueous liquid produced by the machine to total wei material fed into the machine and it was evaluated using the formula reported by Onuorah *et al.* (2007) (equati milk was presented in Table 2. It was observed that the yield of the milk ranged from 91.47 % to 98.2 %. The highest value of 98.2 % was obtained from combination of 3 blades assembly, basket with half angle of 30° and speed of 1400 r.p.m, while the least yield of milk of 91.47 % was obtained from interaction between 4 blades assembly, basket with half angle of 40° and speed of 864 r.p.m.

Table 2: Matrix Transformation of Five Level- Three Factors Central Composite Rotatable Design of the Experiment

Run order	Real Blade Configuration	Values Basket Orientation	Speed of Rotation	Yield of Milk (%)
1	3	30	1000	94.72
2	5	30	1000	94.14
3	3	50	1000	95.3
4	5	50	1000	94.95
5	3	30	1400	95.53
6	5	30	1400	95.07
7	3	50	1400	97.85
8	5	50	1400	92.63
9	2	40	1200	95.41
10	6	40	1200	97.5
11	4	23	1200	98.2
12	4	57	1200	97.16
13	4	40	864	95.65
14	4	40	1536	95.88
15	4	40	1200	95.53
16	4	40	1200	92.17
17	4	40	1200	97.16
18	4	40	1200	91.93
19	4	40	1200	93.79
20	4	40	1200	91.47

Statistical Analysis

The result of statistical analysis of variance (ANOVA) of the experimental is shown in Table 3. The significant model terms were identified at 95% significance level.

Calibration of the Model

The model F – value of 31.94 implies that the model is significant. There was only 0.01% chance that a Model F value this large could occurred due to noise. The value of Probability > F less than 0.0500 indicated that model terms were also significant. In this case A, C, A^2, and C^2 were significant model terms. It is observed that C (speed) had more significant effect on yield of the aqueous milk with coefficient of estimate of 1.745 followed by blade configuration of -1.30546.

The "Lack of Fit F-value" of 0.05 implies that the Lack of Fit is not significant relative to the pure error. There was a 99.72% chance that a "Lack of Fit F-value" this large could occur due to noise. The non-significant lack of fit is good for model to be able to predict the response (Aworanti *et al.*, 2013). The coefficient of determination R value of 0.9831 indicated that the model was able to predict 98.31 % of the variance and only 1.69 % of the total variance was not explained by the model. The coefficient of correlation R- Squared value of 0.9664 was high though large value of R^2 does not always suggest that the regression model is a good one because it will increase when a variable is added regardless of whether the additional variable is statistically significant or not Xin and Saka (2008). Hence predicted and adjusted R^2 were suggested to be used to check the model adequacy. It was also observed that the Predicted R – Squared of 0.9415 was in reasonable agreement with the Adjusted R – Squared of 0.9361 which indicated that the experimental data fitted better. The value of adequate precision of 19.54661 obtained which was above the minimum value of 4 was reported by Salam *et al.* (2014). This indicated an adequate signal which showed that the model can be used to navigate the design space (Salam *et al.*, 2014).

Table 3: Regression Analysis of Response of Yield of the Milk

Source	Coefficient of	Standard	F – value	P- value Prob >F	R-	
Model	95.82549	0.2028	31.94282	< 0.0001	0.9664	Significant
A-Blade Confg. (No.)	-1.30546	0.134553	94.13304	< 0.0001		
B-Basket Orient.	-0.07349	0.134553	0.298301	0.5969		
C-Speed (r.p.m.)	1.745	0.134553	168.1914	< 0.0001		
AB	0.14625	0.175802	0.69206	0.4249		
AC	-0.31875	0.175802	3.2874	0.0999		
BC	-0.00125	0.175802	5.06E-05	0.9945		
A^2	-0.35258	0.130984	7.245867	0.0226		
B^2	-0.20939	0.130984	2.555626	0.1410		
C^2	-0.49754	0.130984	14.42855	0.0035		not
Lack of Fit			0.051826	0.9972		

Regressed Model Equation

$$Y_{M}) = 95.83 - 1.31A - 0.073B + 1.75C + 0.15AB - 0.32AC - 1.250 \times 10^{-3}BC - 0.35A^2 - 0.21B^2 - 0.50C^2 \quad (1)$$

Where, Y_M = Yield of Milk (%), A = is the blade type (Number), B = is the basket orientation (Degree) and C = is the speed of blending (r.p.m)

The model equation was improved by removing the insignificant model terms. Values greater than 0.1000 implies that the model terms are not significant (that is B, AB, AC, BC, B^2 were not significant) and since these terms are insignificant the models were reduced to equations 2 from 1, in order to improve the models (Aworanti *et al.*, 2013).

Fitted Model Equation

$$\text{Yield of Milk (\%)} = 95.83 - 1.31A + 1.75C - 0.35A^2 \quad (2)$$

It is important to add that the variable C in the model has positive co-efficient implying a direct proportionality while A has negative co-efficient implying an indirect proportionality. That is independent increase in A decreased the yield of the milk while increase in C increased the yield of the milk.

Simulation and Validation of the Model

The model equation obtained was simulated and the yield of the milk was observed to be within the experimental range as shown in Table 3. The actual value of yield of the milk was in close agreement with the predicted value. This indicated close agreement between the predicted value and observed value validating the need for the model equation to be used to determine the optimum yield of milk at various operating conditions.

Table 3: Relationship Between Actual and Predicted Values of Yield of Milk

Standard Order	Actual Value	Predicted Value
1	94.14	94.22617
2	91.93	91.96024
3	93.79	93.78919
4	92.17	92.10826
5	98.2	98.35617
6	94.72	94.81524

7	97.85	97.91419
8	94.95	94.95826
9	97.16	97.02375
10	92.63	92.63271
11	95.53	95.35682
12	95.07	95.10963
13	91.47	91.4835
14	97.5	97.35296
15	95.41	95.82549
16	95.88	95.82549
17	97.16	95.82549
18	95.3	95.82549
19	95.65	95.82549
20	95.53	95.82549

Response Surface and Contour Plot for Yield of the Milk

The response surface and contour plot for the yield of the milk are presented in Figures 1 and 2. The yield of the milk increased from 92.2 % to 98.3 % as the speed of blending increased from 1000 r.p.m to 1400 r.p.m. This could be due to increase in cutting and shearing actions of the blade with increased in rotational speed. Jayesh (2009) had reported that speed of blending had a significant effect on size reduction of solid materials. Where, higher speed of blending resulted to more yield of the material than lower speed of blending. But the yield of the milk was observed to decrease from 98.3 % to 94.4 % with increased in blade configuration from 3 blades to 5 blades assembly with speed of 1400 r.p.m. This could be as result of decreased in contact between the blade and the grains with increased in configuration. This result agreed with the result of earlier findings by Rachel *et al.* (2007) where blade design was found to affect blending of materials. There was significant ($P \leq 0.05$) difference of 6.1 % in yield of the milk between speed of 1000 r.p.m and 1400 r.p.m. Also significant ($P \leq 0.05$) difference of 3.8 % was observed in yield of the milk from 3 and 5 blades assembly. The maximum yield of the milk of 98.3 % was obtained from combination of speed of 1400 r.p.m and 3 blades assembly. This value was observed to decrease to 97.5 % when the speed was increased to 1536 r.p.m and also decrease to 97.16 % when the blade number was reduced to 2 blades assembly. This could be as result of clogging of the sieve holes by fine particles (increase in segregation) produced by increased in speed of blending and decreased in blade configuration. This agreed with the result of an earlier study by Douglas (1997) where high speed of blending was found to produced finer particles that clogged together and blocked the sieve holes, thus prevent materials from passing through the holes.

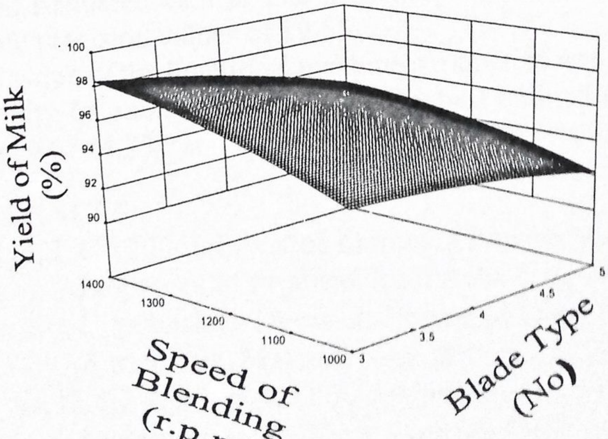


Figure 1: Response Surface of Yield of Milk

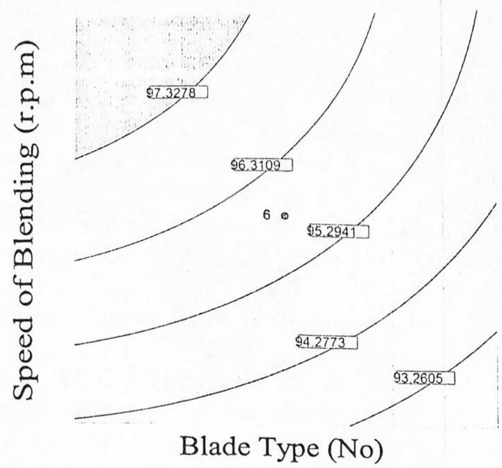


Figure 2: Contour Plot of Yield of Milk

3.2.4 Optimization of the Machine Functional Parameters

The ramp for the optimization is shown in Figure 3; it gives the optimum values of 3-blades assembly, basket of ha angle of 44.25 ° and speed of 1400 r.p.m., while for the responses; yield of milk was 98.2 %.

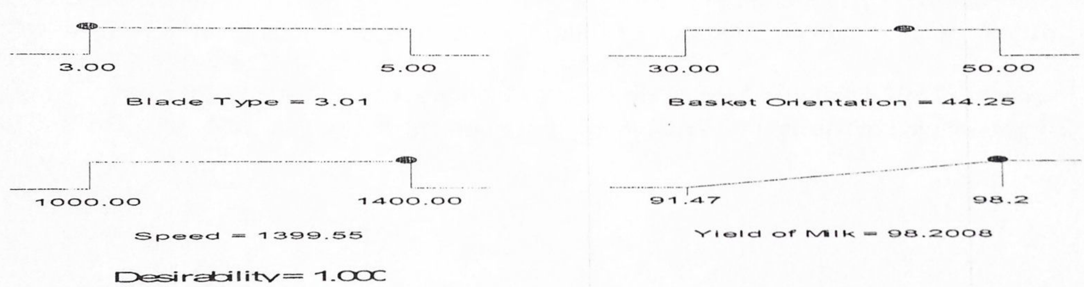


Figure 3: Ramp for Optimization of Machine Performance Parameters

CONCLUSIONS

The interaction effects between the machine parameters showed that yield of the milk increase with increased in spee of blending from 1000 r.p.m to 1400 r.p.m and also with decrease in blade type (number) from 5 blades assembly to blades assembly. The basket orientation was found to have no significant effect on blending efficiency.

The developed mathematical models and individual coefficient were found to be significant while the Lack of fit wa significant. The experimental values were found to fit better with close agreement between predicted r-squared ar adjusted r-squared values. The model equations can be used to navigate within the experimental ranges with hig adequate precision values of 19.55.

Optimization of the functional machine parameters was carried out using numerical optimization technique by applyin desirability function method in rsm. The best optimal machine functional parameters of 3-blades assembly, basket c half angle of 44.25 ° and speed of 1400 r.p.m., while for the yield of milk was 98.2 %,

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