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Variability Effect of Some Mechanical Parameters of an Automated Machine on Grain Drink Production Output

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***Abstract-* A single response optimization model based on Response Surface Methodology was employed to determine the best combination of the functional machine parameters such blade type, basket orientation and speed of a developed automated grain drinks processing machine to attain the maximum drink output. The automated grain drinks processing machine blend soaked grains, mixed the slurry, extract the aqueous liquid and expel the paste from the machine all in single unit. The experiment was based on central composite rotatable design (CCRD). The experimental result showed that the developed regression model could describe the performance indicators within the experimental range of the factors been investigated. Blade type and speed of rotation were found to be significant ($p \leq 0.05$), while basket orientation was insignificant. Numerical optimization carried out produced optimum values of 3-blade assembly, basket orientation of 33.44^{o} and speed of 1385 r.p.m and the blending efficiency was 8.47 lires from 400g of soya beans.**

***Index Terms-* automated, grain, drinks, output.**

I. Introduction

In the present investigation, a single response optimization model based on Response Surface Methodology was employed to determine the best combination of the functional parameters such blade type, basket orientation and speed of a developed automated grain drinks processing machine to attain the maximum drink output. In Nigeria the available equipment used for production of grain beverages are made from mild steel materials which can easily become rusted due to its frequent contact with water and this can lead to contamination of the product [1]. According to [2] the production process involves different stages using different equipment. In order to address the tedious of this operation and to produce hygienic drink with high quality, an automated grain drink processing machine was developed. Hence, there is a need to optimize the functional parameters of the machine based on the drink output in a systematic way to achieve the optimum parameters and maximum response by using experimental methods and statically models.

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II. EXPERIMENTAL PROCEDURE

The experiment was conducted as per design matrix shown in Table 2. The soya beans samples were obtained sorted and cleaned to remove foreign materials before soaking for 12 hours [2] : [3] : [4]. Water was drain from the soaked soya beans before feeding into the machine. The machine was switched on, data (blending and sieving time) were inputted and saved. The auto run switch was pressed which launched the system into automatic operation of the machine. The water valve was open in order to allow inflow of water into the system. The water to grain ratio of 10:1 was used for the washing of the milk from the paste in order to have proper washing of milk from the slurry. The blending blades blends the grains, mixed the slurry with water. The aqueous liquid with the paste were spins to the wall of the conical basket due to the centrifugal force generated, the liquid was filtered out of the machine through the perforated holes on the basket while the paste which are bigger in size than the perforated holes migrated up along the wall of the basket. The paste was discharged out at the top of the basket. The liquid were collected at the bottom of the basket and flow out to the temporary milk tank

III. EXPERIMENTAL SET-UP

A. EXPERIMENTAL APPARATUS

For performing the experiments, an automated grain drink processing machine developed at Agricultural and Bioresources Department of Federal University of Technology Minna, Nigeria was used. From preliminary studies and review of literature, blade type, basket orientation and speed were found to be the most critical factors that affect the process of grain beverages production from grains [2] ; [5]. Therefore these factors were selected as the machine functional parameters and there levels are presented in Table 1.

Table 1: Machine Functional Parameters with Their Values at Five Levels.

S/N	Parameter	Extreme Low	Low	Centre	High	Extreme High
1	Blade Type (No)	2.	3	4	5	6
2	Basket Orientation (Degree)	23	30	40	50	57
3	Speed of Rotation (r.p.m)	864	1000	1200	1400	1536

B. EXPERIMENTAL PLAN

In this investigation three factors have been studied and their levels are shown in the Table 2. These values of functional machine parameters were utilized for conducting design of experiments in an automated grain drink processing machine, based on design of experimental process. The response variable investigated was drink output

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

Run order	Coded Values X_1	X_2	X_3	Real Values Blade Configuration	Basket Orientation	Speed of Rotation (r.p.m)	Experimental Output (Litres)	Predicted Output (Litres)
1	-	-	-	3	30	1000	8.11	8.11746
2	+	-	-	5	30	1000	7.92	7.92253
3	-	+	-	3	50	1000	8.08	8.07968
4	+	+	-	5	50	1000	7.94	7.93475
5	-	-	+	3	30	1400	8.46	8.47334
6	+	-	+	5	30	1400	8.16	8.16841
7	-	+	+	3	50	1400	8.43	8.43556
8	+	+	+	5	50	1400	8.18	8.18063
9	-1.682	0	0	2	40	1200	8.37	8.35841
10	+1.682	0	0	6	40	1200	7.98	7.98013
11	0	-1.682	0	4	23	1200	8.23	8.21501
12	0	+1.682	0	4	57	1200	8.19	8.19352
13	0	0	-1.682	4	40	864	7.88	7.88126
14	0	0	+1.682	4	40	1536	8.4	8.38727
15	0	0	0	4	40	1200	8.21	8.25532
16	0	0	0	4	40	1200	8.37	8.25532
17	0	0	0	4	40	1200	8.23	8.25532
18	0	0	0	4	40	1200	8.26	8.25532
19	0	0	0	4	40	1200	8.24	8.25532
20	0	0	0	4	40	1200	8.22	8.25532

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).

C. EXPERIMENTAL TECHNIQUE

As shown in Table 2, the performance tests involved 20 trials (runs). The experiment was conducted as per the design matrix and the machine output was computed as follows;

D. MACHINE OUTPUT

This is the quantity of aqueous liquid obtained after processing the grains; it was measured in litres per second (Ls^{-1}) as reported by [2].

IV. RESULT AND DISCUSSION

A. MACHINE OUTPUT

The output of the machine was measured as the quantity of the aqueous liquid produced it was measured in litres as reported by [2]. The effects of independent variables; blade configuration, basket orientation and speed on the machine output was presented in Table 2. The output ranged between 7.88 litres to 8.46 litres. The highest value of 8.46 litres was obtained from combination of 3 blades assembly, basket with half angle of 30^o and speed of 1400 r.p.m, while the least machine output of 7.88 litres was obtained from interaction between 4 blades assembly, basket with half angle of 40^o (angle of 50^o from the horizontal) and speed of 864 r.p.m.

B. STATISTICAL ANALYSIS

The result of the statistical analysis of variance (ANOVA) of the experimental was shown Table 3. The significant model terms were identified at 95% significance level. The Quadratic regression model equation developed to predict machine output with respect to functional machine parameters (independent variables) were given as shown in equations 1 and 2.The model F – value of 32.13 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 significant. In this case A, C, A^2, and C^2 were significant model terms with P-values of estimate of < 0.000, < 0.0001, 0.0222 and 0.0035 respectively. Vividly C (speed) had more significant effect on machine output with coefficient of estimate of 0.15044.

The "Lack of Fit F-value" of 0.05 implies that the Lack of Fit is not significant relative to the pure error. There is a 99.72% chance that a "Lack of Fit F-value" this large value could occur due to noise. Non-significant lack of fit is good [6]. From Table in appendix E the coefficient of variation (C.V) of 0.522 % obtained was low which indicated that the deviation between experimental and predicted value was low as reported by [7]. The coefficient of determination R value of 0.9832 indicated that the model was able to predict 98.32 % of the variance and only 1.68 % of the total variance was not explained by the model. The coefficient of correlation R- Squared value of 0.9666 was high very close to 1 [8]. Predicted R –Squared of 0.9417was in reasonable agreement with the Adjusted R – Squared of 0.9365which indicated that the experimental data fitted better [8]. Adequate Precision of 19.60 is above the desirable minimum value of 4 was reported by [9].

Table 4: Regresional Analysis of Response of Machine Output

Source	Coefficient of Estimate	Standard Error	F – value	P- value Prob >F	R-Squared	
Model	8.255328	0.017426	32.13469	< 0.0001	0.9666	Significant
A-Blade Confg. (No.)	-0.11246	0.011562	94.62077	< 0.0001		
B-Basket Orient. (Degree)	-0.00639	0.011562	0.305498	0.5926		
C-Speed (r.p.m.)	0.15044	0.011562	169.3117	< 0.0001		
AB	0.0125	0.015106	0.684734	0.4273		
AC	-0.0275	0.015106	3.314111	0.0987		
BC	0	0.015106	0	1.0000		
A^2	-0.03043	0.011255	7.307891	0.0222		
B^2	-0.01805	0.011255	2.572331	0.1398		
C^2	-0.0428	0.011255	14.46109	0.0035		
Lack of Fit			0.052177	0.9972		not significant

This indicated that the model can be used to navigate the design space.

The regressed machine output model equation is given as

$$Y_0 = 8.26 - 0.11A - 6.390 \times 10^{-3}B + 0.15C + 0.012AB - 0.028AC + 0.000BC - 0.030A^2 - 0.018B^2 - 0.043C^2 \quad (1)$$

where, Y_0 = Output (Litres)

A = Blade Type (No)

B = Basket Orientation (Degree)

C = Speed of Blending (r.p.m.)

The model equation was improved by removing insignificant model terms. Values greater than 0.1000 implies that the model terms are not significant (that is B, AB, AC, BC, ABC, A^2B, A^2C, AB^2, AC^2, B^2C, BC^2, A^3, B^3 and C^3 are not significant) and since these terms were insignificant the fitted model was reduced to equation 2

The fitted machine output model equation is given as

$$Y_0 = 8.26 - 0.11A + 0.15C - 0.030A^2 \quad (2)$$

It is obvious that variable C in the model has positive co-efficient implying a direct proportionality while A has negative co-efficient implying a indirect proportionality. That is independent increase in C increased the machine output while increase in A decreased the machine output.

C. SIMULATION AND VALIDATION OF THE MODEL

The model equation obtained was simulated and the machine output was observed to be within the experimental range. From Table 2 the actual value of machine output was observed to be in close agreement with the predicted value.

D. RESPONSE SURFACE AND CONTOUR PLOT FOR MACHINE OUTPUT

The response surface and contour plot for machine output are shown in Figures 1 and 2. The machine output increased from 8.2 litres to 8.48 litres with increased in speed of blending from 1000 r.p.m to 1400 r.p.m. This could be as result of increase in input energy that generated more impact force. This is in line with the result of an earlier report by [10] where high speed of blending was found to be associated with high impact energy that reduced size of particles.

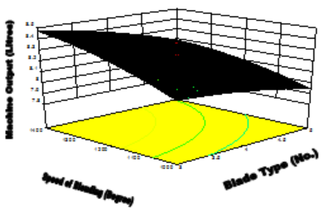

Figure 1: Response Surface for machine Output

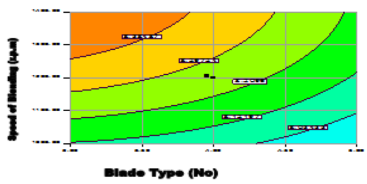

Figure 2: Contour Plot for Response Surface of Machine Output

The optimum machine output of 8.46 litres was obtained from combination of speed of 1400 r.p.m and 3 blades assembly. This value was observed to decrease to 8.4 litres when the speed was increased to 1536 r.p.m and also decrease to 8.37 litres when the blade was decreased to 2 blades assembly. This could be as result of clumping together of finer particles of the slurry to formed larger particles that blocked the sieve holes. Similar findings was reported by [11] where finer particles of slurry where found to clump together and formed larger particles that blocked the sieve holes.

E. EFFECT OF BASKET ORIENTATION ON BLENDING EFFICIENCY

From the analysis of variance (ANOVA) conducted basket orientation was observed to have no any significant ($P \leq 0.05$) effect on the output. Also from Figure 3 there was no any significant ($P \leq 0.05$) difference between basket orientation with half angle of 30° and that with 50°.

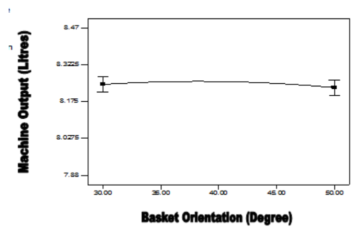

Figure 3: Effect of Basket Orientation on Machine Output

F. OPTIMIZATION OF THE MACHINE FUNCTIONAL PARAMETERS

The ramp for the optimization is shown in Figure 4; it gave the optimum values of 3-blades assembly, basket of half angle of 33.44° and speed of 1335 r.p.m., while for the responses; machine output was 8.46 %,

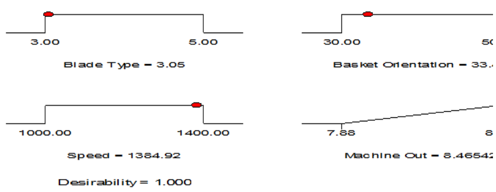

Figure 4: Ramp for Optimization of Machine Performance Parameters

CONCLUSIONS

The interaction effects between the machine parameters showed that machine output increase with increased in speed 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 3 blades assembly. The basket orientation was found to have no any significant effects on blending efficiency.

The developed mathematical models and individual coefficient were found to be significant while the Lack of fit was significant. The experimental values were found to fit 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 19.6.

Optimization of the functional machine parameters was carried out using numerical optimization technique by applying desirability function method in rsm. The best optimal machine functional parameters of 3-blades assembly, basket of half angle of 33.44° and speed of 1335 r.p.m., while for the responses; machine output was 8.46 %.

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