An Investigative Study on Effects of some Machine and Processing Parameters of a Mechanised Centrifugal Melon Shelling Machine

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Abstract: Egusi melon (*Citrullus lanatus*) is produced and consumed in Nigeria and in some West and East African countries. To address the shortcomings of breakage and cleaning of the shelled seed involved in melon shelling operation, which are among the major factors militating against the large-scale production, processing and the use of a melon seed, a mechanical centrifugal shelling and cleaning machine was developed. This study aims at the establishing the optimum machine parameters; speed and beatersand processing parameter; moisture content, capable of given the maximum recovery and cleaning efficiency of the machine. The result of the experiment revealed that the highest value of cleaning efficiency of 96.7% was obtained from a combination of speed of 2300 rpm, moisture content of 15% (w.b) and 16 beaters, while the least efficiency of 15% was obtained from an interaction between speed of 959 rpm, moisture content of 20% (w.b) and 18 beaters. The highest value of recovery efficiency of 99.9% was obtained from a combination of speed of 959 rpm, moisture content of 20% (w.b) and 18 beaters, while the least efficiency of 92.24% was obtained from an interaction between speed of 1800 rpm, moisture content of 12% (w.b) and 18 beaters. Optimum values of speed of 1842 rpm, moisture content of 11.6% (w.b) and 15 beaters for cleaning efficiency of 90.21%, recovery efficiency of 99.60 with desirability of 0.941 were obtained with the goal of maximising the cleaning and the recovery efficiency. The establishment of these parameters would encourage large scale production, processing and the use of this important oil crop.

Keywords: Melon, seed, cleaning, recovery, speed, moisture content, beaters

1. INTRODUCTION

Melon (*Citrullus lanatus*) also called *Egusi* in Nigeria and some of the African countries is a leguminous cropsgrown mostly in tropical parts of Africa (Ojiel *et al.,* 2007). Melon is a good source of amino acids, vitamins, minerals, oil and protein (Brande et al. 2012). Oluwabamiwoet al., (2015), reported that melon is rich in oil and protein, comprising about 50% oil and 35% protein,among major foods only peanut has such high oil content. The worldwide production ofmelon seed was estimated to be 586,605 metric tons; while Africa's production is approximately 548,600 metric tons, and Nigeria produces approximately 346,000 metric tons, representing 56% of global melon seed volume (Solomon et al., 2010). The major step in processing of *egusi*melon seeds are the fermentation, washing to remove the fermented pod husks (depodding), drying of the seeds using open air drying system, shelling and cleaning of the seed, coring, and extraction of oil (Giwa and Akanbi2020). The mechanization of melon processing method become necessary due to increase in consumer's awareness of its socioeconomic and health benefits that led to the expansion on its cultivation and also, the constraints associated with the manual processing method (Olaoye and Aturu (2018). The mechanical processing of melon seed becomes necessary to maintain the tempo of melon production and guarantee some conservation of energy for the women processors. The mechanical processing (shelling) of melon is fast and can produce very large amount of melon seeds for the market. (Muhammadet al. 2013). According to Shittu and Ndrika (2012) one of the major shortcomings of most of the machines developed for shelling melon are efficient but give high rate of seed damage. Based on these observations, women farmers are withdrawing gradually from the production of melon on commercial basis because of the low income received and the high resource input in terms of human and mechanical efforts. To address this problem Olaoye and Aturu (2018), developed mechanize centrifugal melon shelling and cleaning machine. The objective of this study is to investigate the effects of shelling speed, melon seed moisture content and number of beaters on the cleaning and recovery efficiency of the mechanised centrifugal melon shelling and cleaning machine.

2. Materials and methods

2.1 Melon seed samples preparation

Sample of Serewe varietyof melon seed was purchased from Minna central Market Niger State Nigeria.Twenty kilogrammes of the seed was measured, cleaned to remove impurities and divided into twenty samples based on the experimental design. Each sample was soaked in water for ten minutes at room temperature of 28ºC and then, subjected to natural air drying in order to obtain the required moisture content of 11.6%, 155, 20%, 25% and 28.4% (w.b) based on the design matrix. Instant moisture meter was used to determine their moisture content levels. The samples were processed using themechanizeedcentrifugal melon shelling and cleaning machine (Olaoye and Aturu, 2018) based on the design matrix shown in Table 1.

2.2 Equipment

A centrifugal melon shelling and cleaning machine (Figure 1) developed by Olaoyeand Aturu (2018) was used in this study. The machine shelled wet melon and then cleaned it, separating the white seed from the shelled and other impurities. The major components of the machine are as follows; hopper, shelling unit, cleaning unit and power transmission unit. The wetted melon was fed into the machine through the hopper. The electric motor was then switched on to provide the power required to rotates the shelling mechanism. The rubber beaters on the shelling discs beats the fed melon against the metallic encasement in order for the shells to be cracked open. The rotating shelling disc assembly generates a high air velocity in a whirly pattern at the base of the encasement so that any seed (shelled, unshelled and broken) that falls down on the base of the encasement after been beaten was easily blown by the circular motion of the wind through a tangential path into the cleaning chamber. The cleaning chamber serves as a conveying channel which helps to carry the shelled seeds through a piping chamber of varying diameters. At the first large diametric section, the shelled seeds falls freely under gravity and was collected while the broken and immature grain falls through the second chamber opening. Finally the chaff was blown out through the final chaff outlet.

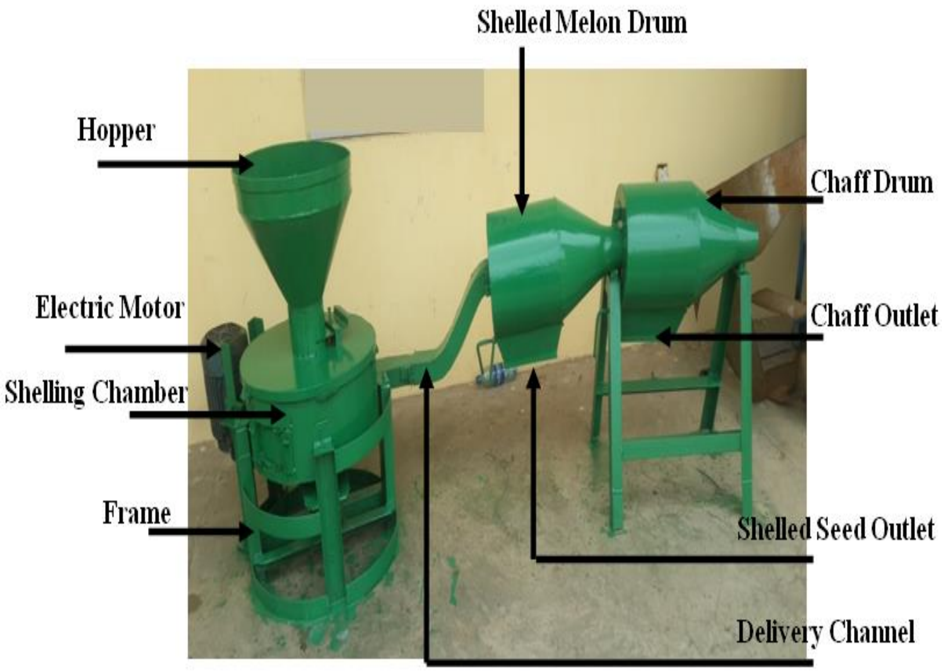

Figure 1: The Developed Melon Shelling and Cleaning Machine

2.3 Experimental setup and plan

A Response Surface Methodology was employed in this study using central composite rotatable design (CCRD). It consists of three factors which were varied at five levels (Gana et al. 2017). The CCRD consists of 20 experimental runs (2k + 2k + m, where k is the number of factors and m the number of replicated centre points), comprises of eight factorial point (2k), six axial points (2k), and six replicated centre point (m = 6). The three factors are speed, melon seed moisture content and number of beaters. The beater hits the melon seeds and thereby separated the seed from the shell. It was varied at configurations of 15, 16, 18, 20 and 21 numbers. The seed moisture content level was varied as 11.6%, 155, 20%, 25% and 28.4% (w.b). The speed of machine was varied as 960 rpm, 1300 rpm, 1800 rpm, 2300 rpm and 2640 rpm. The experiment was conducted base on the design matrix shown in Table 1.

2.4 Performance Evaluation

2.4.1 Cleaning efficiency

The ratio of the mass of separated shelled white seed to the total mass of unseparated shelled white seed expressed in percentage as reported as reported by Olaoye and Aturu (2018), and is given as

:$$C_{Ef} = \frac{M_{ws}}{M_{ws}+M_s} \times 100 \qquad (1)$$

Where, C_{Ef} is the cleaning efficiency (%),M_{ws} is mass of the white seed (g), M_s is the mass of the shell (g),

2.4.2 Recovery efficiency

The ratio of the mass of unbroken white seed to the total number of the white seed and was determined as reported by Gana et al. (2016), and is given as

$$R_{Ef} = \frac{M_{uw}}{M_{uw}+M_{bw}} \times 100 \qquad (4)$$

Where, R_{Ef} is the recovery efficiency (%),M_{uw} is mass of the un-broken white seed (g), M_{bw} is the mass of the broken white seed (g)

2.6 Statistical Analysis

Minitapsoftware package was used for the regression and graphical analysis. A quadratic polynomial equation was developed to predict the cleaning and recovery efficiency as a function of independent variables and their interaction.

3. Results and Discussion

The effects of independent variables; speed, moisture content and number of beaters on cleaning and recovery efficiencies are presented in Table 1. The cleaning efficiency ranged from 15% to 96.7%. The highest value of 96.7% was obtained from a combination of speed of 2300 rpm, moisture content of 15% (w.b) and 16 beaters, while the least efficiency of 15% was obtained from an interaction between speed of 959 rpm, moisture content of 20% (w.b) and 18 beaters.

The result of the statistical analysis of variance (ANOVA) of the experiment presented in Table 2 showed that the model terms were significant. The significant model terms were identified at 95% significance level. The Quadratic regression model equation developed to predict the cleaning efficiency and recovery efficiencywith respect to independent variables are shown in equation 3 and 4 respectively. The model F–value of 453.8implies that the model is significant. The value of Probability >F less than 0.0500 indicated that model terms were significant. In this case, A, B, C, AB, AC, A^2, and C^2 were significant model terms. The "Lack of Fit F-value" of 3.23 implies that the Lack of Fit is not significant relative to the pure error. Non-significant lack of fit is good (Gana et al., 2017).

Table 1. Matrix transformation of five level- three factors central composite rotatable design of the experiment

StdOrder	RunOrder	Speed	Moisture content	No. of Beaters	Cleaning Efficiency	Recovery Efficiency
4	1	2300	25	16	85.7	96.12
10	2	2641	20	18	75.3	95.06
16	3	1800	20	18	96.31	98.01
14	4	1800	20	21	89.11	97.79
13	5	1800	20	15	90.32	99.47
15	6	1800	20	18	95.45	98.01
11	7	1800	12	18	94	92.24
8	8	2300	25	20	89.11	94.21
20	9	1800	20	18	93	98.01
17	10	1800	20	18	95.32	98.01
9	11	959	20	18	15	99.9
5	12	1300	15	20	50.9	98.11
3	13	1300	25	16	55.45	99.50
1	14	1300	15	16	56.21	98.21
12	15	1800	28	18	92.65	93.82
18	16	1800	20	18	95	98.01
2	17	2300	15	16	96.7	94.57
7	18	1300	25	20	57.31	98.45
19	19	1800	20	18	94.2	98.01
6	20	2300	15	20	93	93.62

Table 2: Regresional Analysis of Response of Cleaning Efficiency

Source	**Coefficient of estimate**	**SE Coefficient**	**F – value**	**P- value Prob >F**	**R-Squared**	
Model	-350.7	0.574	516.24	< 0.0001	0.9979	Significant
A-Speed (rpm)	0.3083	0.381	2239.62	< 0.0001		
B-Moisture content (%)	- 0.02	0.381	4.90	0.051		
C-No of beater	15.50	0.381	1.23	0.293		
AB	-0.001027	0.497	26.64	< 0.0001		
AC	0.000395	0.497	0.63	0.446		
BC	0.1785	0.497	12.88	0.005		
A^2	-0.000072	0.371	2353.12	< 0.0001		
B^2	0.0378	0.371	6.51	0.029		
C^2	0.1785	0.371	35.94	< 0.0001		
Lack of Fit			2.01	0.231		Not Significant

The coefficient of determination R value of 0.9993 indicated that the model was able to predict 99.93% of the variance and only 0.07% of the total variance was not explained by the model. The coefficient of correlation R-Squared value of 0.9979 was high very close to 1 as recommended by Xin and Saka (2008). Predicted R – Squared of98.81%was in reasonable agreement with the Adjusted R – Squared of 99.59% which indicated that the experimental data fitted better (Salam et al., 2014). This indicated that the model can be used to navigate the design space.

The regressed shelling efficiency

$$C_{eff} = -350.7 + 0.3083A - 0.02B + 15.50C - 0.001027AB + 0.00359AC + 0.1785BC - 0.000072A^2 - 0.0378B^2 - 0.5554C^2 \quad (3)$$

Where, C_{eff} is the cleaning efficiency (%), A is the speed (rpm), B is the melon seed moisture content (%),C is the number of beaters

The model equation was improved by removing insignificant model terms. P - Values greater than 0.1000 implies that the model terms (B,C, AC, BCand B^2) were not significant. Consequently, the model was reduced to Equation 4 (Aworanti et al., 2017).

The fitted shelling efficiency model equation is givenas:

$$C_{eff} = -350.7 + 0.3083A - 0.001027AB - 0.000072A^2 - 0.5554C^2 \quad (4)$$

It is obvious that A and C have positive co-efficient implying a direct proportionality. That is an independent increase in any of the two variables.

3.1 Response Surface and Contour Plot for Cleaning Efficiency

The response surface and contour plot for clearing efficiencypresented in Figures 2 -5.From Figure 2 and 3 the cleaning efficiency was observed to increase from 10% to 98% with increased in speed of shelling from 1000 rpm to 1500 rpm and then remain constant with further increased in speed to 2500 rpm.This could be as the speed increased the air velocity also increased and more of the shelled are lifted and throw out. This agreed with the results of an earlier study by Hollatz and Quick (2003), where cleaning efficiency was observed to increase with increase in speed. On the other hand the cleaning efficiency was observed to be constant with change in the melon seed moisture content.

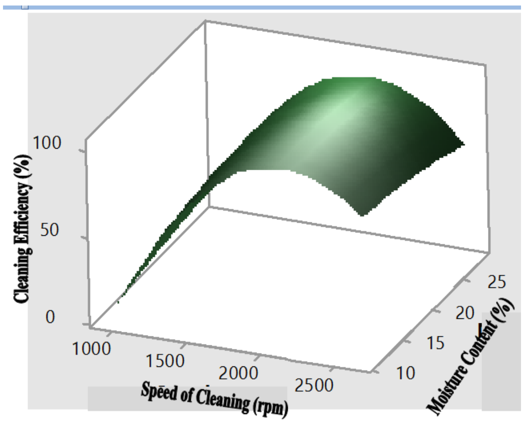

Figure 2. Response Surface for effects of Speed of Cleaning and Moisture Content on Cleaning Efficiency

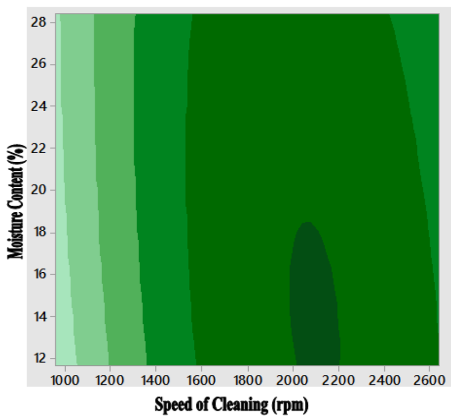

Figure 3. Contour Plot effects of Speed of Cleaning and Moisture Content on Cleaning Efficiency

From Figures 4 and5 the cleaning efficiency was observed to remain constant with change in number of beaters.This implies that the number of beaters have insignificant effects on the cleaning efficiency. Also, the result of the statistical analysis the beaters had values of 1.23 and 0.293 for F aand P-values. This is another indicative of insignificant effects of the beaters on cleaning efficiency.

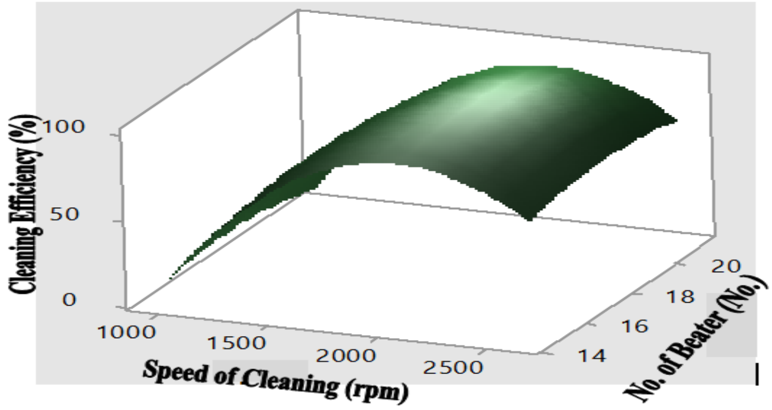

Figure 4. Response Surface for effects of Speed of Cleaning and Moisture Content on Cleaning Efficiency

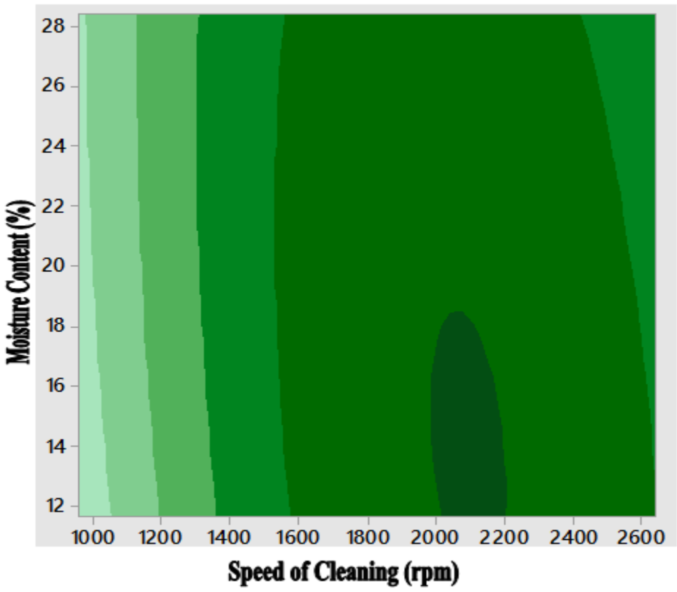

Figure 5. Contour Plot effects of Speed of Cleaning and Moisture Content on Cleaning Efficiency

3.2 Response Surface and Contour Plot for Recovery Efficiency

The response surface and contour plot for recovery efficiency presented in Figures 6 to 9. From Figures6 and 7 the recovery efficiency was observed to increase from 88% to 97% with increased in moisture content from 10% to 20% and then decreased to 94% with further increased in moisture to 25%. This could at low moisture content the seed are too dry and are easily break and also at higher moisture level the seed are easily grounded. The recovery efficiency also decreased from 97% to 88% as the speed increase from 1000 rpm to 2500 rpm. This could as result of more impact associated with the high speed and this resulted to grounding of the seed. This agreed with report of Shitu and Ndrika (2012), where melon seed damage increase with the increase in machine speed.

From Figures 8 and 9 the recovery efficiency was observed to increase from 94% to 99% with increased in moisture content from 10% to 20% and then decreased to 94% with further increased in moisture to 25%. This could at low moisture content the seed are too dry and are easily break and also at higher moisture level the seed are easily grounded. This is lined with the report of Shitu and Ndrika (2012) where the percentage seed damage decreased with the increase in seed moisture content. The recovery efficiency also decreased from 97% to 94% as the beaters increase from 14 to 18 and then remains constant with further increase in beaters to 20. This could be as result of more breakage of the seed as result more impact.

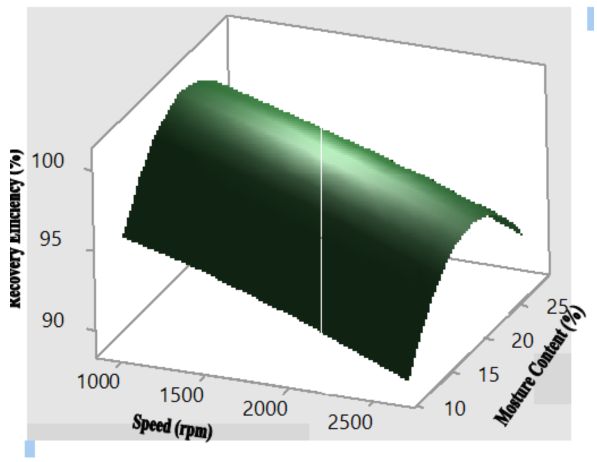

Figure 6. Response Surface for effects of Speed and Moisture Content on Recovery Efficiency

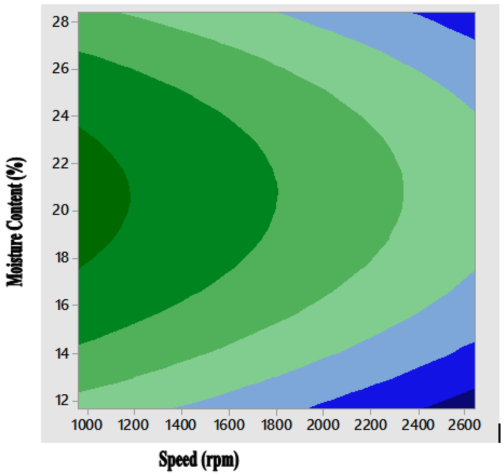

Figure 7. Contour Plot effects of Speed and Moisture Content on Recovery Efficiency

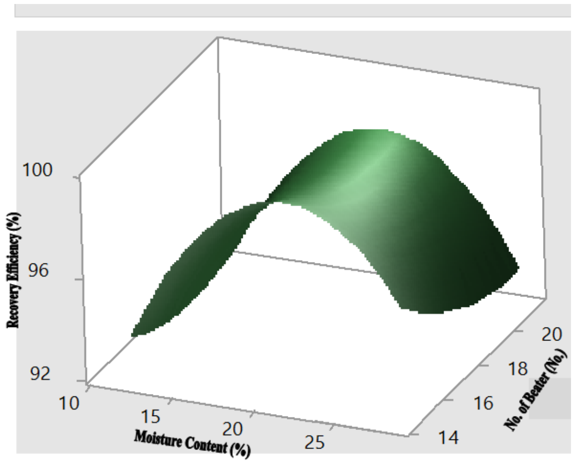

Figure 2. Response Surface for effects of Moisture Content and Number of Beaters on Recovery Efficiency

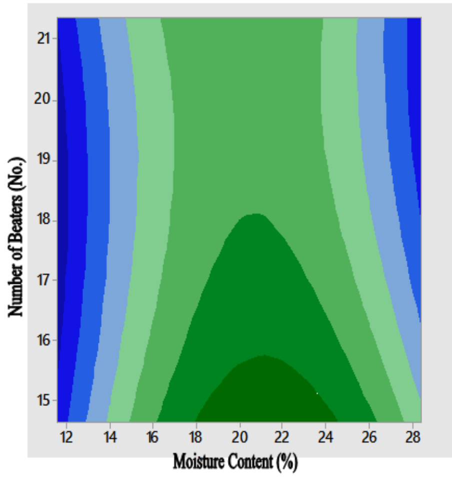

Figure 7. Contour Plot effects of Moisture Content and Number of Beaters on Recovery Efficiency

3.3 Optimisation of the Mechanical and Processing Parameters

The ramp for the optimization is shown in Figure 6. Optimizing the parameters with the goal of maximise the cleaning and recovery efficiency gave the optimum values of speed of 1842 rpm, moisture content of 11.6% (w.b) and 15 beaters forcleaning efficiency of 90.21%, recovery efficiency of 99.60 with desirability of 0.941as shown Figure10.

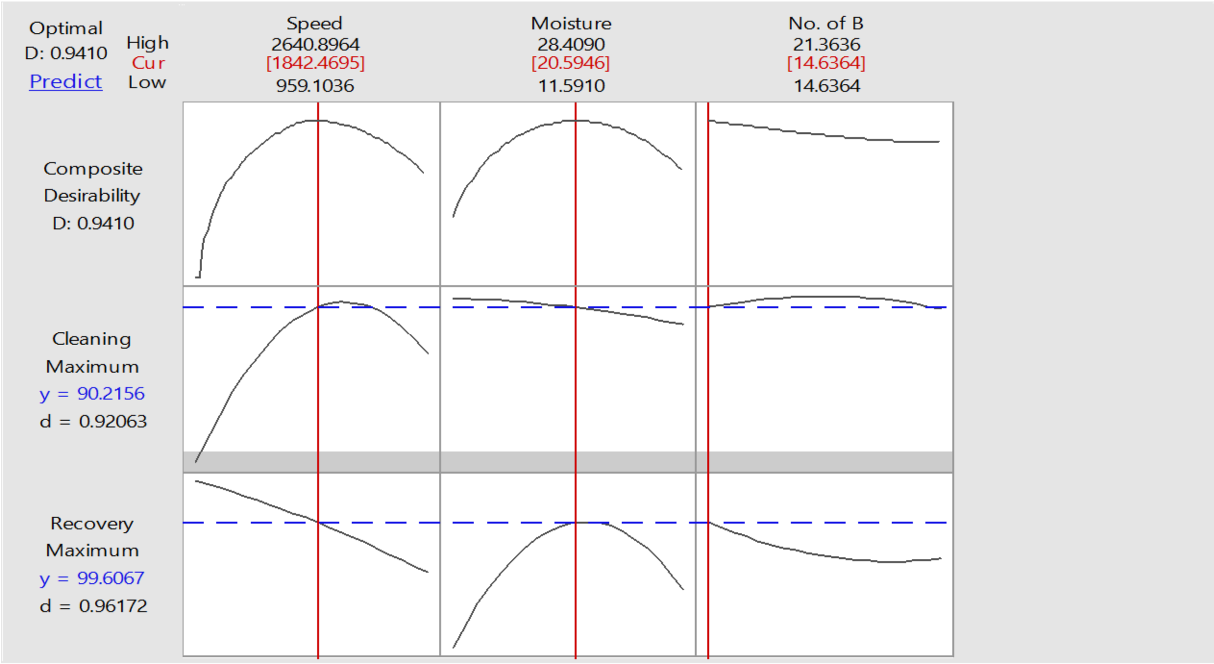

Figure 10. Ramp for Optimisation of Cleaning and Recovery Efficiency

4. Conclusion

The effects of parameters of a centrifugal melon shelling and cleaning machine are studied and major conclusions were as follows: the cleaning efficiency increase significantly withincrease in speed but remain constant with increase in both moisture content and number of beaters. Also, the speed and moisture content have significant effects on the recovery efficiency, while the number of beaters had insignificant effects on the recovery efficiency. Optimum values of speed of 1842 rpm, moisture content of 11.6% (w.b) and 15 beaters for cleaning efficiency of 90.21%, recovery efficiency of 99.60 with desirability of 0.941 were obtained with the goal of maximising the cleaning and the recovery efficiency.

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