



International Journal of Engineering, Business and Enterprise Applications (IJEBA)

(Open Access, Double Blind Peer-reviewed, Refereed and Indexed Journal)

www.iasir.net

Optimization of Head Rice Milled Using Conventional Rice Huller in Mubi, Adamawa state, Nigeria

E.K. Bwade¹, Y. Abubakar², S.M. Kaltiya² & M.S. Hussaini²

^{1,2} Department of Agriculture & Bio-Environmental Engineering Technology,
Federal Polytechnic, Mubi; Adamawa State, NIGERIA.

Abstract: : Rice (*Oryza sativa*) is a popular source of nutrition in most Nigerian homes. The differences in cost between the locally processed and the imported product and the shift in government policy almost recently have enhanced local participation in rice processing. However, local rice processing is associated with considerable kernel breakage amongst other challenges. The study evaluated the relative importance of the effects of roller speed, soaking temperature and the final moisture content of rough rice on head rice recovery rate (HRY) at 5% level of significance. It further optimized the head rice yield using Response Surface Methodology (RSM) based on Central Composite Design (CCD). Findings revealed that whereas roller speed and final moisture content were statistically relevant on the HRY ($P < 0.05$), the effect of soaking temperature was not. It was further revealed that optimum HRY could be achieved by setting the roller speed and final moisture content of rough rice at 6.27 m/s and 11.88% respectively. However, further studies on the relative influence of the engineering properties of rice would go a long way in providing supplementary insight into the minimization of kernel breakage during the milling operation and is hereby recommended.

Keywords: Head rice yield, steaming temperature, parboiling conditions, milling quality

I. INTRODUCTION

Rice is an annual grass in the Gramineae family, which originated from Asia (*Oryza sativa*) and Africa (*Oryzaglaberrima*) [1]. It plays an outstanding role in nutritional applications globally; it feeds more than half of the world's population (cooked rice, rice flour and brewer grain) [2], while rice husk (inedible) has been used both as fuel and in improving soil structure, seedbed mulch, and in brick making. Rice bran contains comparably higher levels of vitamins than the inner portion of rice kernel [3]; the bran is used as both raw material in oil extraction for human nutrition and an important component in the formulation of concentrated feeds for cattle, sheep, goat, poultry [4]. Its global production increased by 16 per cent in 14 years (i.e. from 520 million tons in 1990 to 605 tons in 2004). In Nigeria, growth in the demand and utilization of rice is evidenced by the increased importation as documented by Reference [5], who noted that Nigeria is the highest importer of rice in Africa and second highest in the world.

In Africa and Asia, both raw and parboiled rice has been processed locally for human nutrition, however, parboiling paddy is associated with a wide range of benefits such as enhancing milling yield, storability and nutritional value of rice kernels. The processing of parboiled rice involves the following steps – (i) soaking of paddy (ii) steaming to achieve partial gelatinization (iii) drying of steamed paddy; since up to 35% moisture is obtainable in paddy after parboiling [6] (iv) husking and (v) milling to remove bran from kernels [7].

Various quality and process parameters have been employed for evaluating the milling quality of rice (husked/milled rice), the most commonly employed are the head rice yield (HRY), total rice yield (TRY), colour index, kernel hardness, husking index (HI) ([8],[9]). Despite the aforementioned indices, however, the most important concern of rice processors is the minimization of kernel breakage during milling operation [10]. Head rice recovery rate or head rice yield, measures the proportion of milled rice kernels with length equal to or greater two-thirds the length of the original kernel in a given mass of milled sample [11]. Head rice attracts customers and generates more income than broken rice [12]. Correspondingly, a wide range of studies have been conducted with the essence of understanding the process of breakage in rice kernels, causative factors and the optimal settings for minimization of rice kernel breakage ([13], [8], [14]). Earlier researchers centred on investigating the effects of final moisture content, shade cooling time and paddy variety on the HRY [15], the effects of soaking temperature (45 - 80°C), soaking time (1.5 - 5 hours). Others were steaming methods (Atmospheric/ pressurized) on the percentage of broken rice kernels during de-shelling and milling [13]; effects of harvest moisture content on HRY of long and medium-sized rice grains [9].

Reference [16] evaluated the influence of tempering period and vacuum drying (0.4 to 1 atmosphere) on the crack formation of *Nemat* and *Pajouhesh* rice at varying temperature levels (40 - 70°C). They revealed that

the tendency for cracks to occur increases with an increase in drying time and temperature. Moreover, lower atmospheric pressure during the tempering phase of the drying process reduced grain breakage significantly, attributed the effects to the slow rate of heat transfer in rice kernels during tempering, which results in minimized thermal and moisture stress. Reference [15] investigated the effects of final moisture content, shade-cooling time and variety factors on the milling quality and HRY. Similarly, the effects of sun drying and hot air-drying at air temperature between 40 and 55°C on the shelling/milling qualities of parboiled paddy rice have also been studied ([17], [18]) but not without conflicting findings. While Reference [18] found comparably higher head rice recovery rate from hot-air drying (40 to 45°C) than from sun drying, Reference [17] documented similar HRY between heated air drying (45 to 50°C) and sun-drying.

Reference [19] acknowledged that artificial drying of rough rice immediately after harvest as the major cause of kernel breakage but quickly acknowledged that higher temperature drying does not affect HRY unless dried with an air of higher evaporative capacity. Reference [20] studied the effects of output flow rate between 400 and 600 kg/hr on the quality of *sorkheh* variety of rice at rotor speed of 600 rpm, it was found that rice breakage was significant ($P < 0.05$). In addition, highest kernel breakage and the least degree of milling (DOM) were revealed at an output rate of 600 kg/hr; below which the HRY was comparably higher. Similarly, Reference [21] observed a strong negative correlation between HRY and DOM; however, it was shown by their study that the change in HRY per unit change in DOM was significantly higher at higher moisture content.

Reference [15] modelled the quality attributes of parboiled rice (i.e. HRY, kernel hardness and cooking time) and optimized the HRY using response surface methodology (RSM). Similarly, Reference [11] studied the effects of soaking temperature (50, 60, and 70°C), steaming time (30, 40 and 50 minutes) and drying time (10, 15 and 20 hours) at the temperature of 32°C, and optimized the HRY using RSM method. While Reference [22] optimized the parboiling conditions of *Japonica* rice using the Taguchi orthogonal array (3^4). Reference [23] studied the effects roller clearance (0.4, 0.6 and 0.8 mm) of rubber rolls on the milling qualities of *Tarom Hashemi* and *Daillman Mazandarani* varieties of rice. Nonetheless, Reference [8] found a very significant effect of whitener type on HRY ($P < 0.01$) with the least and the highest percentage of broken kernels for abrasive whiteners and frictional type bladeless whiteners at moisture contents of 8 – 9 and 12 – 13% respectively. While, Reference [24] acknowledged the suitability of both abrasive polishers and friction type whiteners for polishing long – grained, non-parboiled rice.

Literature documents higher HRY at lower moisture contents (below 14%) ([25], [15]); hitherto, Reference [8] found that the amount of broken rice significantly increased at final moisture content between 12 and 13% (w.b) than at lower moisture content (8 - 9% w.b). In addition, the percentage of broken brown rice significantly decreased from 18.83 to 9.97% as the differential speed increased from 1.5 to 5 m/s. While other researchers demonstrated that kernel breakage may be minimized by the conditioning of parboiled paddy at moisture contents between 15 and 19% using hot air at 80°C. Reference [26] investigated the effects of milling duration and conditioning by adding 0, 1, 2, and 3% moisture to paddy of 13.6% moisture content. His findings revealed a positive correlation between milling duration (0 - 60 sec.) and kernel breakage and increase in conditioning moisture levels (0 – 3%). While Reference [6] suggests that soaking temperature should not exceed 75°C in order to avoid over-cooking paddy during the parboiling process, Reference [12] recommends that soaking temperature be 5% less than gelatinization temperature of rice, which ranges between 73 and 78 °C depending on the variety.

Despite the wealth of findings documented on the milling processes of rice, scanty studies were conducted on the effect of roller speed of steel rollers even though a considerable number of rice milling machines use steel rollers.

II. MATERIALS AND METHODS

2.1 Sample preparation

The study to optimize the HRY did not intend to evaluate the influence of variety factor, so a single variety was purchased from Mubi market. The dimensions of the purchased rough rice based on 50 observations are seed length (8.36 ± 0.41 mm), width (2.05 ± 0.13) and thickness (1.72 ± 0.09). The samples were manually cleaned of stones, debris and immature seeds, and the cleaned samples were packaged in perforated polyethylene sacs.

2.2 Soaking and steaming of samples

Samples were soaked with water at three temperatures of 29.0, 75.0 and 52°C corresponding to low, high and centre-point levels respectively for the screening experiment and at two additional water temperatures of 19.47 and 84.53°C corresponding to axial points of $\pm \alpha$ (Table, 1). The sacs containing samples with diverse soaking temperatures were labeled differently and steamed in a pot under atmospheric pressure for two hours and shade dried until a final moisture content of 9.0, 12.0 or 15.0% d.b (screening experiment) or/and 7.76 and 16.24 (axial points) (Table, 1) as determined with a digital moisture meter ($\pm 0.5\%$).

2.3 Rice milling

Rice samples were de-husked and milled with conventional hulling (steel-roller type) milling machine powered by a diesel prime mover of four horsepower (4 hp) capacity. The levels of roller speed used in the experiment were obtained by sampling the range of speeds used by 20 huller operators in Mubi town using digital photo/contact tachometer (model Lutron, DT- 2236). They were found to be 671 ± 12 and 943 ± 26 rpm corresponding to linear speeds of 5.27 and 7.41 m/s respectively ($v = 2\pi rN/60$). Prior milling each sample, the roller speed was adjusted until the required value was achieved as confirmed with the tachometer (Lutron DT-2236). A 50 g of each milled sample was manually sorted based on the length dimension and the HRY was calculated in accordance with Reference [6] (equation, 1).

$$\text{Head rice yield} = \frac{\text{Weight of whole rice (g)}}{\text{Weight of milled rice sampled (g)}} \quad (1)$$

2.4 Experimental Design and Statistical Analysis

The head rice yield was optimized using a two-step approach; (i) the screening design/experiment and (ii) the Response Surface Method based on Central Composite Design (CCD). The screening design to identify the significant factors consisted of a 2^k full - factorial based on a regression model (equation, 1).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon \quad (2)$$

Where $\beta_0, \beta_1, \beta_2, \beta_3$ are beta coefficients, X_1, X_2, X_3 are the studied factors (X_1 = roller linear speed or roller speed, X_2 = soaking temperature, X_3 = final moisture content) and ε is the error term. The natural units, X_i (i.e. X_1, X_2, X_3) are related to coded units, x_i by the following expression ([27], [11])

$$x_i = \frac{x_i - (x_{\text{high}} + x_{\text{low}})/2}{(x_{\text{high}} - x_{\text{low}})/2} \quad (3)$$

Where; x_i = coded unit of a factor, X_i = original unit of a factor, X_{high} and X_{low} are in natural/measurement units

Table 1, Experimental Settings in Coded and Natural units

Independent Variables (Natural units)	Coded units				
	- α				+ α
		Low	Center point	High	
	- 1.4142	-1	0	+1	+1.4142
Roller linear speed (X_1 , m/s)	4.83	5.27	6.34	7.41	7.85
Soaking temperature (X_2 , °C)	19.47	29.00	52.00	75.00	84.53
Final moisture content (X_3 , % db)	7.76	9.00	12.00	15.00	16.24

The design consists of five centre points (0), and to enhance the precision of the experiment ($dF_{\text{error}} \geq 12$), the three factors (roller speed, soaking temperature and final moisture content) were studied at three replications and the results were analyzed at 5% significance level. Based on experimental data, it was evident that both roller speed and final moisture content were statistically important ($P < 0.05$) (Table, 2). Moreover, there was significant curvature ($p < 0.05$); which was graphically shown in figure (1).

Table 2, ANOVA Statistics for the Screening Experiment

Source	DF	Adj SS	Adj MS	P-Value
Model	10	651.770	65.177	0.000
Blocks	2	0.761	0.380	0.894
Linear	3	531.505	177.168	0.000
X_1	1	49.020	49.020	0.002
X_2	1	15.200	15.200	0.050
X_3	1	467.284	467.284	0.000
2-Way	3	63.421	21.140	0.005
Interactions				
$X_1 * X_2$	1	20.720	20.720	0.025
$X_1 * X_3$	1	4.950	4.950	0.243
$X_2 * X_3$	1	37.750	37.750	0.004
3-Way	1	1.984	1.984	0.454
Interactions				
$X_1 * X_2 * X_3$	1	1.984	1.984	0.454
Curvature	1	54.100	54.100	0.001

Error	16	53.793	3.362
Total	26	705.563	

$\alpha = 0.05$; X_1 = Roller speed, X_2 = Soaking temperature, X_3 = Final moisture content

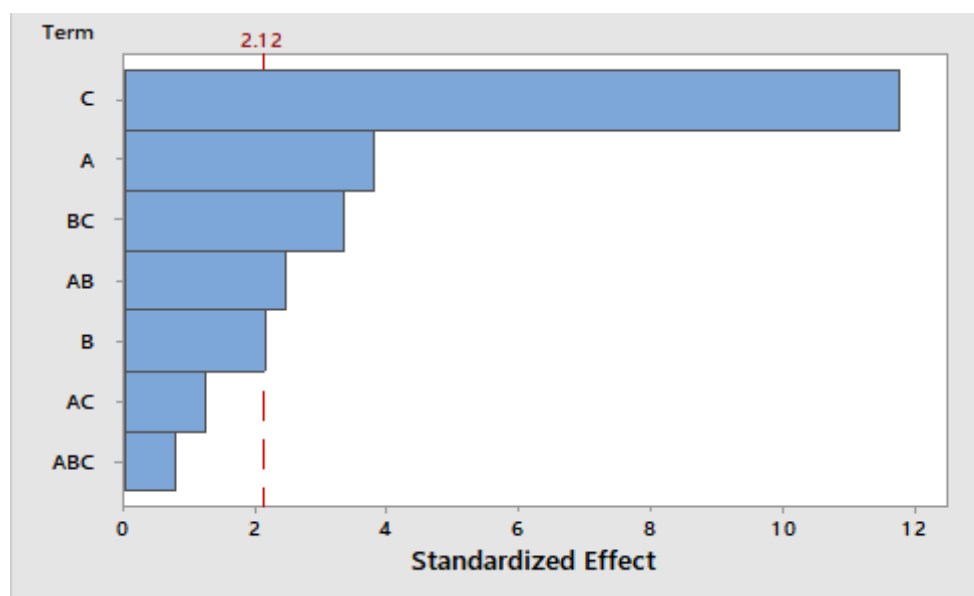


Figure 1, Pareto plot of the effect of roller speed, soaking temperature and final MC on HRY

According to the literature on statistical modelling, the presence of a significant curvature ($p < 0.05$) in a screening experiment limits the application of steepest ascent/descent method or any region-seeking approach optimization process [27], and suggested that a second order model may be fitted. Response surface methodology based on Central Composite Design (CCD) was used for model fitting, and a typical of which was presented in equation (4).

$$Y = \beta_0 + \sum_i^k \beta_i X_i + \sum_i^k \beta_{ii} X_{ii}^2 + \sum_{i < j}^k \sum_{j=1}^k \beta_{ij} X_i X_j \quad (4)$$

Where;

Y = response variable (HRY), X_i , X_j = independent variables, β_0 = regression constant, β_i , β_{ii} , and β_{ij} are the regression coefficients for the linear, quadratic and the interaction terms respectively in the regression model.

The CCD consisted of four cube points and four axial points ($\alpha = 2^{k/4}$), and to estimate pure error the center point was replicated five times (Table, 3).

Table 3, Central Composite Design Matrix for the Optimization of HRY

Standard Order	Run Order	Coded units		Natural units	
		Roller speed	Moisture Content	Roller speed (m/s)	Moisture Content (% d.b)
1	10	-1	-1	5.27	9.00
2	3	1	-1	7.41	9.00
3	7	-1	1	5.27	15.00
4	1	1	1	7.41	15.00
5	5	-1.4142	0	4.83	12.00
6	13	1.4142	0	7.85	12.00
7	8	0	-1.4142	6.34	7.76
8	12	0	1.4142	6.34	16.24
9	11	0	0	6.34	12.00
10	4	0	0	6.34	12.00
11	6	0	0	6.34	12.00
12	9	0	0	6.36	12.00
13	2	0	0	6.34	12.00

$\alpha = 2^{k/4} = 1.4142$; Each HRY reported is a mean of two measurement

The developed model was examined for lack-of-fit, and the region of maximum response was visualized using the contour and response surface plots. While the coordinates of the stationary point were calculated using the matrix approach, based on which the second – order model generally may be represented in matrix form by equation (5).

$$Y = b_0 + b^1x + x^1Bx \quad (5)$$

Where,

b^1 = vector of the first order parameter estimates ($b_1, b_2, \dots, b_k$) or the transpose of matrix b , B = second – order (quadratic) parameter estimate i.e.

$$B = \begin{pmatrix} b_{11} & b_{12}/2 \dots & b_{1k}/2 \\ \vdots & b_{22} \ddots & \vdots \\ \text{symmetric} & \dots & b_{kk} \end{pmatrix}$$

The stationary point of a second-order model can be obtained by setting the partial derivatives of the response variable (Y) with respect to the independent variables (X) in equation (5) to zero (0), $\frac{\partial y}{\partial x} = 0$ [27] the solution for which are the coordinates of the optimum (stationary point), and was estimated using the relationship $x^* = \frac{1}{2} B^{-1} b^1$

Where, B^{-1} is the inverse of matrix B (second - order parameter estimate).

III RESULTS AND ANALYSIS

The ANOVA statistics of the second –order model of HRY is presented in table (4). It indicates that both the linear and the quadratic terms were significant ($P < 0.05$), whereas the two-way interaction was not ($P > 0.05$). It is clear from the ANOVA statistics that at least one term in the model did not contribute meaningfully in describing the variations in the response variable ($P > 0.05$); thus indicating a mild presence of an over-fitted model (Predicted $R^2 > \text{Adjusted } R^2$).

Table 4, ANOVA Statistics of the Second- Order Model for HRY

Source	DF	Adj SS	Adj MS	P-Value
Model	5	448.623	89.725	0.000
Linear	2	6.867	3.433	0.022
X_1	1	4.465	4.465	0.020
X_3	1	2.401	2.401	0.064
Square	2	441.034	220.517	0.000
$X_1 * X_1$	1	215.729	215.729	0.000
$X_3 * X_3$	1	282.163	282.163	0.000
2-Way Interaction	1	0.722	0.722	0.267
$X_1 * X_3$	1	0.722	0.722	0.267
Error	7	3.470	0.496	
Lack-of-Fit	3	2.090	0.697	0.254
Pure Error	4	1.380	0.345	
Total	12	452.092		

X_1 = Roller speed, X_2 = Soaking temperature, X_3 = Final moisture content

However, despite the aforementioned evidence, the model exhibited statistical lack-of-fit ($P = 0.254$); this confirms the statistical validity of the developed model and its suitability for describing/predicting the

variations in the response variable. The coefficients of determination, which were all greater than 90% (R^2 , Adjusted R^2 and the predicted R^2); this further confirmed the aforementioned status of the developed model. In addition, analysis of the probability plot revealed that the residuals generated from the conducted experiment were normally distributed (figure, 2).

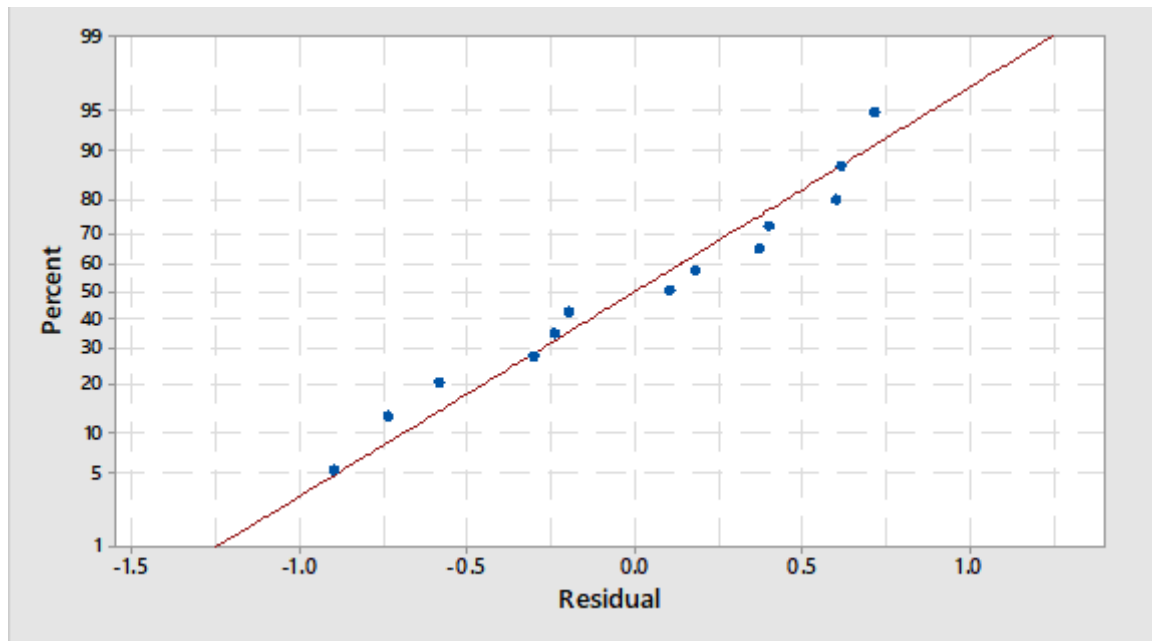


Figure 2, Normal Probability of Residuals in Head Rice Yield

A close examination of beta coefficients (β_i , β_{ii} , and β_{ij}) revealed that the model constant, roller speed and the quadratic terms are statistically important ($P < 0.05$), while, the interaction term (X_1X_3) and the final moisture content were not. Yet, their negative beta- coefficients indicate that lower levels of each term in the model are necessary for achieving the optimum yield (Table, 5).

Table 5, Regression Coefficients of HRY Versus Roller speed and Final MC

Term	Coefficient	Standard Error of Coefficient	T-Value	P-Value
Constant	63.900	0.315	202.95	0.000
X_1	-0.747	0.249	-3.00	0.020
X_3	-0.548	0.249	-2.20	0.064
$X_1 * X_1$	-5.569	0.267	-20.86	0.000
$X_3 * X_3$	-6.369	0.267	-23.86	0.000
$X_1 * X_3$	-0.425	0.352	-1.21	0.267

X_1 = Roller speed, X_2 = Soaking temperature, X_3 = Final moisture content

The developed model describing the optimized settings of roller speed and final moisture content on the head rice recovery rate (Adjusted $R^2 = 0.98$) is presented in equation (5), this was similarly presented using contour and surface plots (figures 3 & 4).

$$Y = 63.9 - 0.747X_1 - 0.548X_3 - 5.569X_1^2 - 6.369X_3^2 - 0.425X_1X_3 \quad (6)$$

Both plots indicate the absence of saddle point with a parabolic optimum region, and that the region lies around the centre points of the experimental space. The coordinates of the stationary were -0.0655 and -0.041 (coded units) for the roller speed and the final moisture content respectively. The findings in this study were similar to those by Reference [15], who documented the significant parabolic relationship between HRY and moisture content with optimum HRY ranging between 62.5 and 67.5% within moisture content range between 9.0 and

14.5%, and beyond which it declined. It compares favourably higher to HRY of 12.74 to 47.96% documented by Reference [28], and lower in comparison to the HRY of 70% and above documented by some authors ([22], [11], [23]). Reference [10] (2013) found optimum HRY of 73.9% for CO43 rice variety at soaking time of four hours, at a temperature of 60°C and steaming time of 3.0 minutes. The comparably lower HRY in this study may be attributed to varietal effects as documented by some researchers ([15], [11], [23]), who revealed that significant differences in HRY could result from varietal effects.

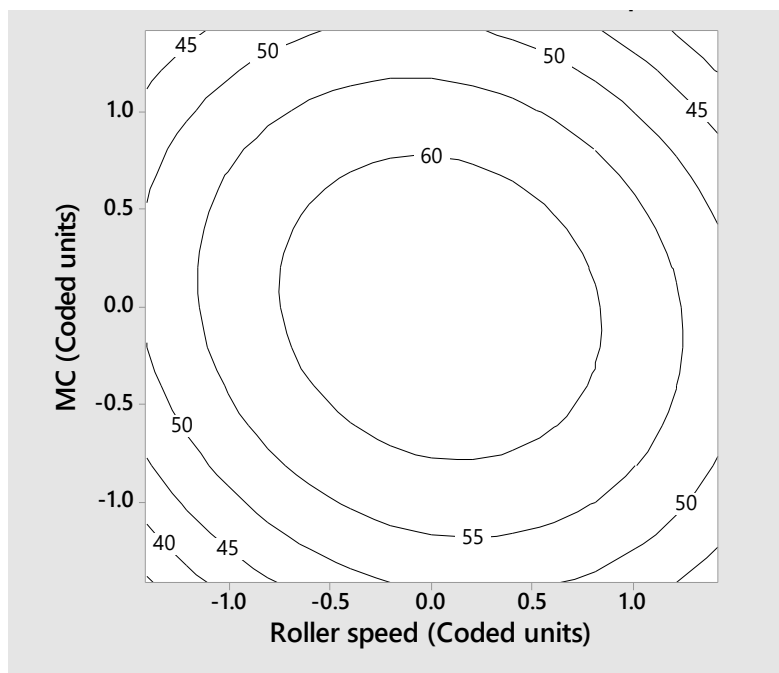


Figure 3, Contour plot of Head Rice Yield versus Moisture content and Roller Speed

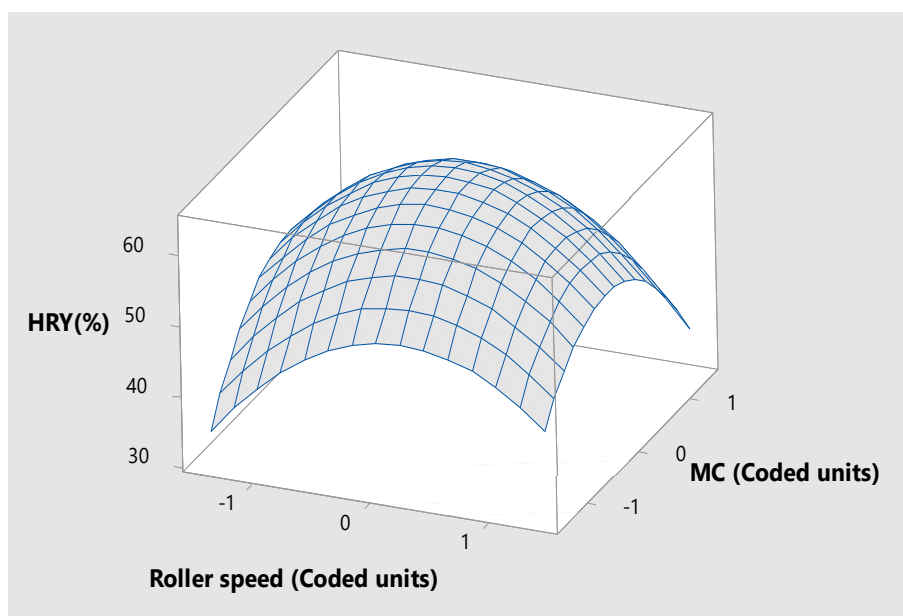


Figure 4, Surface Plot of HRY versus Roller speed and Moisture content

REFERENCES

- [1] Jouki M., and N. Khazaei (2012). Some Physical Properties of Rice Seed (*Oryza Sativa*). Research Journal of Applied Sciences, Engineering and Technology 4(13)1846 – 1849
- [2] Alfred *et al.* (1985). Integrated food Science and Technology for Tropics. Macmillan Publishers, UK
- [3] Euro Consult (1989). Agricultural Compendium for Rural Development in the Tropics and Subtropics, FAO Rome.
- [4] Oludare A. O., R. Akinoso, M. Olu (2012). Some Physical Properties and Yield of Ofada Rice. Journal and Applied Scientific Research 2(4):4098 – 4108.
- [5] Ojha, T. and Michael, A. (2003). Principles of Agricultural Engineering. Vol. I John Brothers Publishers. New Delhi, India

- [6] Itoh, K. and Kawamura, S. (1985). Processing conditions of parboiled rice and its qualities (Studies on parboiled rice, part I). *Nippon Shokuhin Kogyo Gakkaishi*, 32, 471–479
- [7] Firouzi, S., & Alizadeh, M. R. (2011). Effect of whitener type and paddy moisture content on rice grain damage during milling process. *American-Eurasian J. Agric. & Environ. Sci*, 10(3), 470-474.
- [8] Dong, R., Lu, Z., Liu, Z., Koide, S., & Cao, W. (2010). Effect of drying and tempering on rice fissuring analysed by integrating intra-kernel moisture distribution. *Journal of Food Engineering*, 97(2), 161-167.
- [9] Venkatachalapathy, N., & Udhayakumar, R. (2013). Effects of continuous steaming on milling characteristics of two indica rice varieties. *Rice Science*, 20(4), 309-312.
- [10] Danbaba, N., Nkama, I., Badau, M. H., Ukwungwu, M. N., Maji, A. T., Abo, M. E., & Oko, A. O. (2014). Optimization of rice parboiling process for optimum head rice yield: a response surface methodology (RSM) approach. *International Journal of Agriculture and Forestry*, 4(3), 154-165.
- [11] Rehal, J., Kaur, G. J., & Singh, A. K. (2017). Influence of Milling Parameters on Head Rice Recovery: A Review. *Int. J. Curr. Microbiol. App. Sci*, 6(10), 1278-1295.
- [12] Cherati, F. E., Babatabar, R., & Nikzad, F. (2012). Analysis and study of parboiling method, and the following impact on waste reduction and yield increase of Iranian rice in paddy conversion phase. *World Academy of Science, Engineering and Technology*, 63, 772-776.
- [13] Yousaf, K., Kunjie, C., Cairong, C., Abbas, A., Huang, Y., Arslan, C., & Xuejin, Z. (2017). The Optimization and Mathematical Modeling of Quality Attributes of Parboiled Rice Using a Response Surface Method. *Journal of Food Quality*, 2017.
- [14] Furahisa, K., L.M. Chove, & D. Chaula (2016). Effects of Final Moisture Content, Cooling Time and Paddy Variety on the Milling Quality of Rice (*Oryza Sativa* L.). *Journal of Agricultural Science and Food Technology* Vol. 2 (11), pp. 169-179. Available online at <http://pearlresearchjournals.org/journals/jasft/index.html>
- [15] Kalantari, D., & Eshtavad, R. (2013). Influence of different tempering period and vacuum conditions on the rice grain breakage in a thin layer dryer. *Cercetari Agronomice in Moldova*, 46(4), 5-12.
- [16] Akowuah, J. O., Addo, A., & Bart-Plange, A. (2012). Influence of drying temperature and storage duration on fissuring and milling quality of Jasmine 85 rice variety. *Journal of Science and Technology (Ghana)*, 32(2), 26-33.
- [17] Tabassum, M. A., & Jindal, V. K. (1992). Effect of drying conditions on moisture removal rate and head yield of Basmati-370. *Pakistan Journal of Agricultural Research*, 13(4), 312-319.
- [18] Abud-Archila, M., Courtois, F., Bonazzi, C., & Bimbenet, J. J. (2000). Processing quality of rough rice during drying—modelling of head rice yield versus moisture gradients and kernel temperature. *Journal of Food Engineering*, 45(3), 161-169.
- [29] Varnamkhasti, M. G., Mobli, H., Jafari, A., Keyhani, A., & Soltanabadi, M. H. (2007). Performance assessment of a modified blade-type whitener (frictional milling machine) considering rice output flow rate. *J. Agric. Technol*, 3(2), 183-190.
- [20] Reid, J. D., Siebenmorgen, T. J., & Mauromoustakos, A. (1998). Factors affecting the slope of head rice yield vs. degree of milling. *Cereal chemistry*, 75(5), 738-741.
- [21] Dooyum, U. D., Woo, S. M., Hong, D. H., & Ha, Y. S. (2016). Optimization of parboiling conditions for enhanced Japonica rice milling. *Emirates Journal of Food and Agriculture*, 764-771.
- [22] Alsharif, S. K. A., Arabhosseini, A., Kianmehr, M. H., & Kermani, A. M. (2017). Effect of Clearance on Mechanical Damage of Processed Rice. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 65(5), 1469-1476.
- [24] Roomi, M. S. M., Senanayake, D. P., & Palipana, K. B. (2004). *Evaluation of milling performance with different types of rice polishing machines available in Sri Lanka*. IESL.
- [25] Sadeghi, M., Hoseinian, S. H., & Hemmat, A. (2012). Influence of moisture content and whitening method on degree of milling and head rice yield of three Iranian rice varieties. *Australian Journal of Crop Science*, 6(11), 1481.
- [26] Hassoon, W.H. (undated). Effects of whitening Machine Duration on Rice Temperature and Breakage Percentage. Available online @ http://businessdocbox.com/Biotech_and_Biomedical/76799055-Effect-of-whitening-machine-duration-on-rice-temperature-and-breakage-percentage.html. Accessed: 03/02/2018
- [27] Montgomery, D. C., Runger, G. C., & Hubele, N. F. (2009). *Engineering statistics*. John Wiley & Sons.
- [28] Sanusi, M. S., Akinoso, R., & Danbaba, N. (2017). Evaluation of physical, milling and cooking properties of four new rice (*Oryza sativa* L.) varieties in Nigeria. *International Journal of Food Studies*, 6(2).