ISSN 2229-5518

# Optimization of the Grain Formed as the Output of Simulated Rice Grain Machine

Iyus Hendrawan, Sutrisno, Purwiyatno Hariyadi, Y.Aris Purwanto, Rokhani Hasbullah

**Abstract**—Efforts to diversify the main food product have good prospects of developing, bearing in mind that Indonesia has great potential in relation to the variety, amount, and spread of sources of non-rice carbohydrates. The formulation for creating a rice-like grain ingredient has always followed the direct presentation determination approach. The purpose of this research is to optimize the grain formed by a simulated rice grain (SRG) machine, using Response Surface Methodology (RSM). Using RSM, the research finds the optimization result for the grain produced by an SRG machine, allowing pressure treatment times of 2, 3.5, and 5 seconds, compression ratios of 1.9, 2.1, and 2.3, and the water content of the SRG ingredients in their dry state of 12%, 14%, and 16%. The optimized grain is obtained with a compression ratio of 1.9, a pressure time of 3.39 seconds, and a water content of 15.7%, and has a predicted hardness of 0.95 N, Bulk's density 706 kg/m$^3$, water uptake 2.83 g/g, L/B ratio of 3.97, and a brightness level of 78.31%

**Index Terms -**food diversification, optimization, physicochemical features of various carbohydrate sources, Simulated Rice Grain Simulated rice grain

## 1 Introduction

The average growth rate of the Indonesian population is 1.42% per year [1].This must be supported by an adequate amount of food. On the assumption that the population growth rate will decrease by 0.03% per year, the total Indonesian population for 2010, 2015, and 2020 will be 235, 249, and 263 million people. If rice consumption of 137 kg per head per year is assumed, the total rice consumption for 2010, 2015 and 2020 will reach 32.13 million tons, 34.12 million tons, and 35.97 million tons, respectively. The pressure of the need for rice will decrease if food diversification is successfully achieved[2].

Efforts to diversify the main food products in Indonesia have great potential, both in the amount and in the spread of various of carbohydrate sources, such as cassava, arrowroot, canna, breadfruit, sweet potato, corn, taro, lesser yam, elephant foot yam, yam, kimpul, black potato, and sago. The 52 million hectares of forest have the potential to produce 1,560 million tons of food per year [3]. Indonesia also has diversity, with 77 varieties of sources of carbohydrate and 26 varieties of bean [4]. From 1998 to 2010, the forestry sector produced food from 16 million hectares of agricultural land. Using the tumpang sari pattern among the trees, the forestry sector can produce 9.4 million tons of rice, corn, and soybeans each year [3].

Research has been conducted into the development of several types of grain that have similar physicochemical features to rice, using different materials, processes, and technology. Artificial rice has been produced from various starch sources, with nutrients and flavors that are not contained in the rice being added by granular roll-type[5]. A grain that looks like rice and is known as simulated rice grain has been developed using the addition of Ferrous Sulfate Heptahydrate (FSH) as a fortification substance, through an extrusion process[6]. Extrusion technology has been used for the development from rice starch of grain that looks like rice[7]. The purpose of this research is to discover the optimal physical features of grain produced by a simulated rice grain (SRG) machine from a mixture of various non-rice carbohydrate sources, using Response Surface Methodology.

- [1]*Departement of Mechanical Engineering ,Institut Teknologi Indonesia.E-mail : iyushendrawan15@gmail.com*
- [2]*Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University. E-mail :Kensutrisnio@yahoo.com*
- [3]*Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University. E-mail :phariyadi@ipb.ac.id*
- [4]*Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University. E-mail :arispurwantoo@ipb.ac.id*
- [5]*Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University. E-mail :rohashb@yahoo.com*

## 2 MATERIALS AND METHODS

### 2.1 SRG process

The SRG was made from a mixture of 30% canna starch (*Maranta arundinacea* Linn), 42% beneng taro flour (*Xantoshma undipes* K.Koch), and 28% sorghum flour (*Sorghum bicolor*) of the Numbu variety[8]. The tools used in this research were an SRG forming machine[9], a cabinet dryer tool, and a Chromameter CR300 Minolta. The SRG forming machine was tested with pressure treatment times of 2, 3.5, and 5 seconds, compression ratios of 1.9, 2.1, and 2.3, and SRG ingredients with a water content of 12%, 14%, and 16% background material (bk). The SRG produced was dried using the cabinet dryer until its water content reached 12% bk.

### 2.2 SRG grain analysis

The bulk density was measured by pouring the grain into a measuring glass until it filled a certain volume without compression, then weighing the grain. The bulk density was calculated by dividing the mass of the grain by the volume of the glass [10]. The water uptake ratio was measured by pouring 2 grams of the grain sample into a cylinder containing 20 ml of distilled water and then putting the cylinder into a pot of boiling water for 10 minutes. The sample was then drained by putting it onto filter paper, and then it was weighed. The water uptake ratio is the ratio between the weight of grain after cooking and its weight before cooking. The L/B ratio is the ratio between the length of a grain and its thickness [11]. The brightness level was measured using a Chromameter CR300 Minolta and the grain's hardness was measured using a Rheometer.

### 2.3 Experimental design and equation model test

The Box-Behnken method is used to analyze response variables that are influenced by several variables. The actual level of the variables for each experiment and the experimental design coding are shown in Table 1. The statistical analysis of the experimental results used the Minitab 17 software. This software was also used to conduct second order equation modeling to optimize the bounded variables (Equation 1). The response variables of the surface and contour plot for this model were plotted as functions of two variables while the other variables were held at the optimum level.

$$Y = b_o + \sum_{i=1}^{3} b_i X_i + \sum_{i=1}^{3} b_{ii} X_i^2 + \sum \sum_{i<j=2}^{3} b_{ij} X_i X_j \quad (1)$$

where b_o, b_i, b_ii, b_ij are the coefficients for the interaction intercept, linear, quadratic, and effect terms, and X_i and X_j are the coded variables.

### 2.4 Second order equation model validation

The validation of this model was conducted by comparing the behavior of the model with the real system through the Mean Absolute Percentage Error (MAPE) test. The MAPE test is a relative measurement involving the percentage error, and shows how well the predicted result matches the actual data (Equation 2). The criteria for the accuracy of the model with this test are: MAPE < 5% means that the model is very accurate, 5% < MAPE <10% means that it is accurate, and MAPE > 10% means that it is not accurate[12]

$$MAPE = \frac{1}{n} \sum_{n=1}^{n} \frac{|X_m - X_d|}{X_d} \times 100\,\% \quad (2)$$

where $X_m$ are the simulated data results, $X_d$ are the actual data, and $n$ is the period/amount of data.

## 3 Results and Discussions

### 3.1 Model analysis and validation

The bulk density is significant ($P < 0.1$) for the quadratic term at $B^2$. The 'lack of fit' analysis shows that this is less significant in the data representation, because of the deviation of the data at numbers 9 and 12 (Table 3). The test of the model's accuracy produces a MAPE value of 4.16%. This shows that Equation 3 can be used to predict the bulk density from the pressure time, the compression ratio, and the water content of the material.

Grain hardness is not significant for all the response variables, as can be seen from the very low correlation coefficient value despite the significant data representation ($P > 0.05$) (Table 3). However, the result of the MAPE test to validate the equation model produced to predict grain hardness shows that the model is not accurate because the MAPE value is above 10%.

Water uptake is significant at $P < 0.10$, and the regression value reaches 85%, which shows that the water uptake is influenced by the pressure time, the compression ratio, and the water content of the material; it is significant for the quadratic terms at $A^2$, $B^2$, or $C^2$, but is not significant for the AB, AC, or BC interaction terms (Table 3). The data representation shows that the model is significant, while the accuracy test of Equation 5 for the model shows that it is a very accurate model with a MAPE value of 2.59%

The L/B ratio is very significant for the model, with $P < 0.05$; the ratio is significant for the linear term only for B, and significant for the quadratic term only for $A^2$. The data representation is significant and the validation test result is 1.53% so this model comes within the very accurate category. The brightness level is not significant in the Equation 4 model, for the linear or quadratic terms, or for interaction among the response variables. The data representation of the model is significant, while the test for the validation of the model gives a very accurate value for MAPE (MAPE < 5%). Therefore, the brightness level of the grain can be predicted using Equation 2

### 3.2 Bulk density

Equation 3 (Table 3) shows that $Y_1$ is not significant to the response variables, with a negative coefficient for the linear (A, B, and C) and interaction (AB, AC, and BC) terms that causes a decrease in the value of $Y_1$. The quadratic terms ($A^2$, $B^2$, and $C^2$) have positive coefficients, causing an increase in the value of $Y_1$. The SRG's bulk density has its maximum value for low water content and a high compression ratio or for high water content and a low compression ratio (fig. 1). Moreover, it has its maximum value for high water content and the lowest pressure time (fig. 2).

The maximum bulk density is 684.4 kg/m$^3$ at a pressure time of 4 seconds, a compression ratio of 1.9, and a water content of 12%. The value of the SRG's bulk density for the various treatments ranges between 600 and 770 kg/m$^3$, with a maximum value of 684.4 kg/m$^3$. These values are close to the bulk density of the Ciherang variety of rice (780 kg/m$^3$) and higher than the bulk density of the analog rice that has ever been produced, which is 591 kg/m$^3$ [13]. Given the pressure time, the compression ratio, and the water content response variables, the SRG's bulk density can be predicted using Equation 3, and the validation test using Equation 2 shows that this is very accurate [12]. Knowing that Equation 3 gives the model, the bulk density can be controlled as the dependent variable.

**Table 1 Level code for 3 independent variables**

| Run | Code value | | | Actual value | | |
|---|---|---|---|---|---|---|
| | $X_1$[a] | $X_2$[b] | $X_3$[c] | *A*[a] | B[b] | C[c] |
| **1** | -1 | -1 | 0 | 2 | 1.9 | 14 |
| **2** | +1 | -1 | 0 | 5 | 1.9 | 14 |
| **3** | -1 | +1 | 0 | 2 | 2.3 | 14 |
| **4** | +1 | +1 | 0 | 5 | 2.3 | 14 |
| **5** | -1 | 0 | -1 | 2 | 2.1 | 12 |
| **6** | +1 | 0 | -1 | 5 | 2.1 | 12 |
| **7** | -1 | 0 | +1 | 2 | 2.1 | 16 |
| **8** | +1 | 0 | +1 | 5 | 2.1 | 16 |
| **9** | 0 | -1 | -1 | 3.5 | 1.9 | 12 |
| **10** | 0 | +1 | -1 | 3.5 | 2.3 | 12 |
| **11** | 0 | -1 | +1 | 3.5 | 1.9 | 16 |
| **12** | 0 | +1 | +1 | 3.5 | 2.3 | 16 |
| **13** | 0 | 0 | 0 | 3.5 | 2.1 | 14 |
| **14** | 0 | 0 | 0 | 3.5 | 2.1 | 14 |
| **15** | 0 | 0 | 0 | 3.5 | 2.1 | 14 |

Note :[a)] $X_1$ and A, press duration (s) [b)] $X_2$ ans B, compaction ratio [c)]$X_3$ and C, moisture content of materials (%, bk

.

**Table 1 The results of the analysis of physical properties SRG**

| Run | $X_1$[a] | $X_2$[b] | $X_3$[c] | Density ($kg/m^3$) | Grain hardness (N) | *Water uptake* (g/g) | Ratio of L/B | Brightness level (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1.9 | 14 | 770 | 1.1 | 2.50 | 3.78 | 76.7 |
| 2 | 5 | 1.9 | 14 | 750 | 0.9 | 2.33 | 3.65 | 77.6 |
| 3 | 2 | 2.3 | 14 | 685 | 0.2 | 2.40 | 3.15 | 80.5 |
| 4 | 5 | 2.3 | 14 | 640 | 0.6 | 2.45 | 3.25 | 77.1 |
| 5 | 2 | 2.1 | 12 | 685 | 0.5 | 2.35 | 3.50 | 78.0 |
| 6 | 5 | 2.1 | 12 | 680 | 0.2 | 2.60 | 3.46 | 79.5 |
| 7 | 2 | 2.1 | 16 | 670 | 0.5 | 2.50 | 3.59 | 77.6 |
| 8 | 5 | 2.1 | 16 | 620 | 0.8 | 2.38 | 3.55 | 77.3 |
| 9 | 3.5 | 1.9 | 12 | 620 | 0.2 | 2.85 | 3.88 | 80.7 |
| 10 | 3.5 | 2.3 | 12 | 680 | 0.8 | 2.73 | 3.58 | 78.0 |
| 11 | 3.5 | 1.9 | 16 | 700 | 0.7 | 2.90 | 3.97 | 79.1 |
| 12 | 3.5 | 2.3 | 16 | 725 | 1.0 | 2.53 | 3.46 | 77.3 |
| 13 | 3.5 | 2.1 | 14 | 615 | 0.8 | 2.55 | 3.32 | 79.8 |
| 14 | 3.5 | 2.1 | 14 | 620 | 0.6 | 2.60 | 3.52 | 79.6 |
| 15 | 3.5 | 2.1 | 14 | 600 | 0.8 | 2.75 | 3.44 | 80.7 |

[a] press duration (s), the compaction ratio b, and c of water content (%, bk)

**Table 2 Prediction model of equality and the value of MAPE**

| Response | Equation | | $R^2$(%) | F | MAPE (%) |
|---|---|---|---|---|---|
| $Y_1$(bulk density) | $6986-41A-5836B–15C+18.2A^2+1464 B^2 +2.76 C^2 -20.8AB-3.75AC -21.9BC$ | (3) | 59.70 | 0.82 | 4.16 |
| $Y_2$(grain hardness) | $1.5-1.41A-6.7B+1.2C-0.0463A^2 +1.77B^2-0.0323C^2+0.500AB+0.0500AC-0.188BC$ | (4) 3 | 48.64 | 0.48 | 42.61 |
| $Y_3$(water uptake) | $5.46+0.834A-2.92B-0.116C-0.1130A^2+0.99B^2 +0.0193C^2+0.187AB-0.0313AC-0.156BC$ | (5) | 85.51 | 3.28 | 2.37 |
| $Y_4$(ratio of L/B) | $24.17-0.164A-11.77B-0.994C-0.0361A^2+2.82B^2 +0.0458C^2+0.192AB+0.0003AC-0.134BC$ | (6) | 95.18 | 10.98 | 1.53 |
| $Y_5$ (brightness level) | $-42+13.67A+75.9B+3.14 C-0.600 A^2-17.1 B^2-0.146 C^2-3.59AB-0.146AC+0.55BC$ | (7) | 64.19 | 1.00 | 0.97 |

### 3.3 Hardness of the grain

Equation 4 (Table 3) shows that $Y_2$ is not significantly affected by the response variables. Negative coefficients occur for the linear (A and B), quadratic ($A^2$ and $C^2$) and interaction (AC) terms, which cause a decrease in the value of $Y_2$, while the linear (C), quadratic ($B^2$), and interaction (AB and AC) terms have positive coefficients that can increase the value of $Y_2$.

The hardness of the SRG grain will increase when the water content of the ingredients and the compression ratio are lower (fig. 3), and will increase with an increase in the pressure time (fig. 4). The maximum hardness of the SRG grain is 0.949 N with a pressure time of 3.36 seconds, a compression ratio of 1.9, and a water content of 15.8%. The hardness of the SRG grain is still far from the hardness of the Ciherang variety rice grain, which is valued at (68 ± 3.8) N and of analog rice (the output of grain formed by the twin-roll process), which is valued at 2.4 N[14].

Mixing in pre-gelatinized flour will strengthen the flour particles' interlocking bonds, while an increase in the water content will have an effect when the mixture of ingredients fills the chamber. Another step that can be taken to increase the grain's hardness is to increase the pressure. In this research, the maximum pressure was 5000 N/cm². A pressure of 12,500 N/cm² should be applied to increase the hardness of the grain. The validation test result for the actual data for various treatments against the predicted output data produced from Equation 3 shows the inaccurate result (MAPE > 5), although the data representation is significant for all treatments.

### 3.4 Water Uptake of the Grain

Equation 5 (Table 3) shows that the value of $Y_3$ depends on the three response variables (pressure time, compression ratio, and water content). Negative coefficients occur for the linear (B and C), quadratic ($B^2$), and interaction (AC and BC) terms, which will decrease the value of $Y_3$. Positive coefficients are for the linear (A), quadratic ($A^2$ and $C^2$), and interaction (AB) terms, which can increase the value of $Y_3$.

The maximum value of water uptake occurs for either high or low water content and a low compression ratio. Water uptake will also take its maximum value for low water content and a high compression ratio (fig. 5). Looking at the pressure time, water uptake will be at its maximum for a water content of 16%, a pressure time of 3.18 seconds, and a compression ratio of 1.9 (fig. 6). The maximum value of the water uptake was 3.84. The water uptake for the SRG is higher than it is for Ciherang variety rice (2.0 ± 0.21 g/g) and lower than the water uptake for System of Rice Intensification (SRI) rice, which is valued 3.75 g/g [11]

The validation test for the actual data for various treatments against the predicted output data produced from Equation 5 shows that the result is very accurate –the MAPE value is 2.37, with the data representation being significant for all treatments. An increase in water uptake is determined more by the value of the compression ratio. Water uptake will be higher, and the produced grain denser, because there will be more particles in the grain as a result of the compression of the material. High water uptakes mean that water content is expected to be held in the grain after it is cooked so the grain will be hydrated for longer.

### 3.5 L/B Ratio

Equation 6 (Table 3) shows that the value of $Y_4$ depends on the three response variables, pressure time, compression ratio, and water content. Negative coefficients occur for the linear (A, B, and C), quadratic ($A^2$) and interaction (BC) terms that will decrease the value of $Y_4$. Positive coefficients occur for the quadratic ($B^2$ and $C^2$) and interaction (AB and AC) terms that can increase the value of $Y_4$.

The L/B ratio will become higher with an increase in the water content of the ingredients and a low compression ratio (fig. 7). For a compression ratio of 2.1, the maximum L/B ratio will be produced for a high water content (fig. 8). The optimum value of the L/B ratio is 4.02, which occurs for a pressure time of 2.78 seconds, a compression ratio of 1.9, and a water content of 15.9%. The L/B ratio for the SRG of 4.02 is higher than that for Ciherang variety rice (3.2 ± 0.31) and for SRI rice (4.87) [11].

The validation test result, comparing the actual data for the various treatments and the predicted output data using Equation 6, shows that Equation 6 is very accurate, with a MAPE value of 1.53, and the data representation is significant for all treatments. The value of the L/B ratio is more strongly determined by the compression ratio. Because the grain's length is relatively constant, the L/B ratio is actually more strongly determined by the grain's thickness (B), and, therefore, the compression ratio has an impact on the thickness of the output grain. This conclusion shows that the compression ratio does not yet create solids that are more compact.

### 3.6 Brightness Level

Equation 7 (Table 3) shows that $Y_5$ does not have a significant relationship with the experiment response variables. Negative coefficients occur for the quadratic ($A^2$, $B^2$, and $C^2$) and interaction (AB and AC) terms, and these can decrease the value of $Y_5$. Positive coefficients occur for the linear (A, B, and C) and interaction (BC) terms, which can cause the value of $Y_5$ to decrease. The brightness level has its maximum value with a pressure time of 3.35, a low water content, and a compression ratio of 2.1 (fig. 9); likewise, the maximum brightness level will occur with a low water content, a compression ratio of 2.1, and a pressure time of 2.5 (fig. 10). The maximum value of the brightness level is 78.36%, which occurs with a pressure time of 3.39 seconds, a compression ratio of 1.9, and a water content of 15.7%. The brightness level of the SRG is close to that of the Ciherang variety of rice, which is (73.8) %.

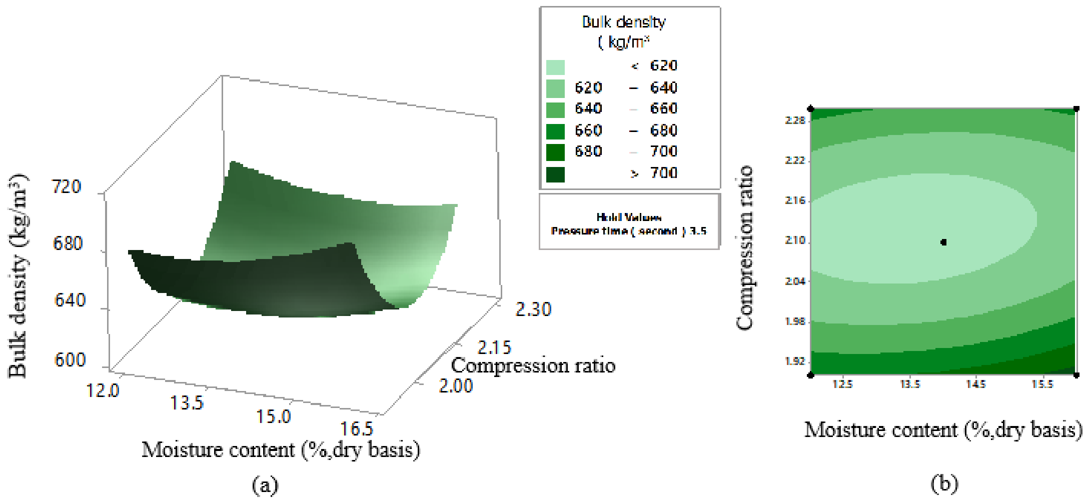


Figure 0 The 3D graphics optimization SRG grain density bulk against compaction and moisture content ratio of ingredients (a) Plot surface, (b) Plot contour.

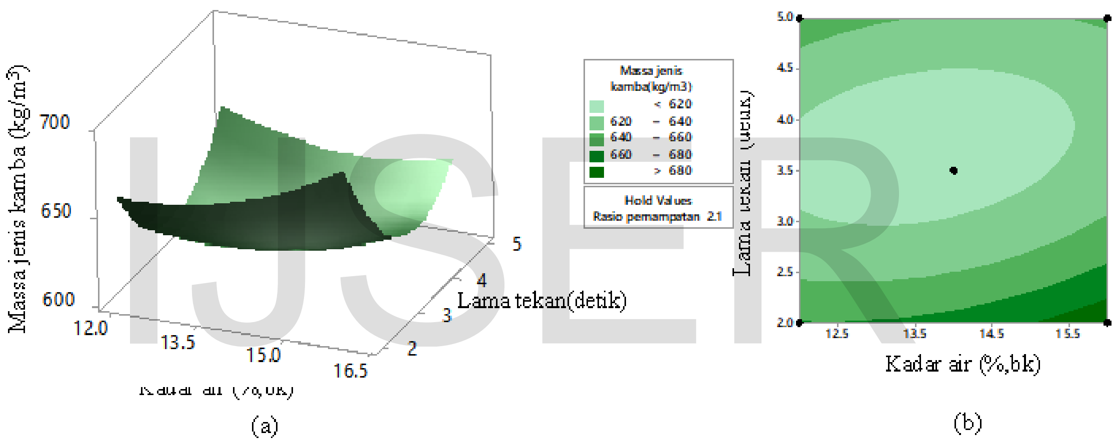




Figure 2 The 3D graphics optimization SRG grain density bulk against long tap and the water content of the ingredients (a) Plot surface, (b) Plot contour

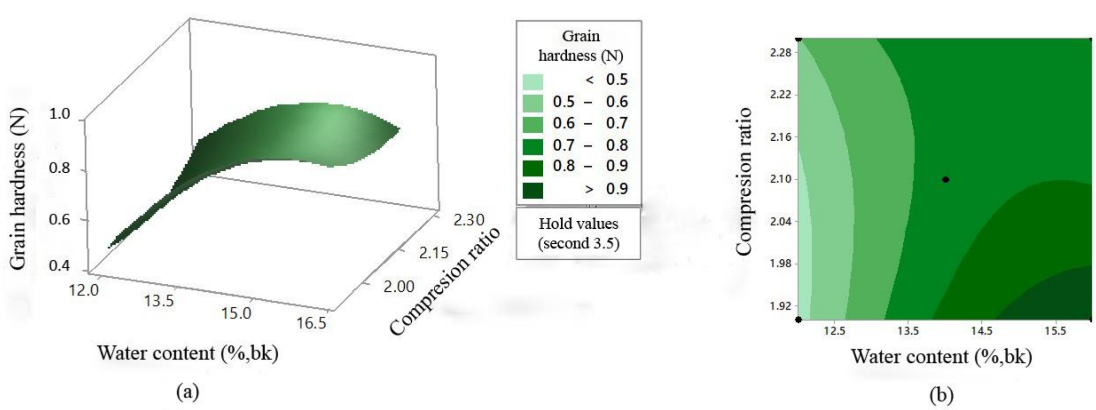


Figure 3 The 3D graphics optimization SRG grain hardness of the ratio of the density and moisture content of materials (a) Plot surface, (b) Plot contour

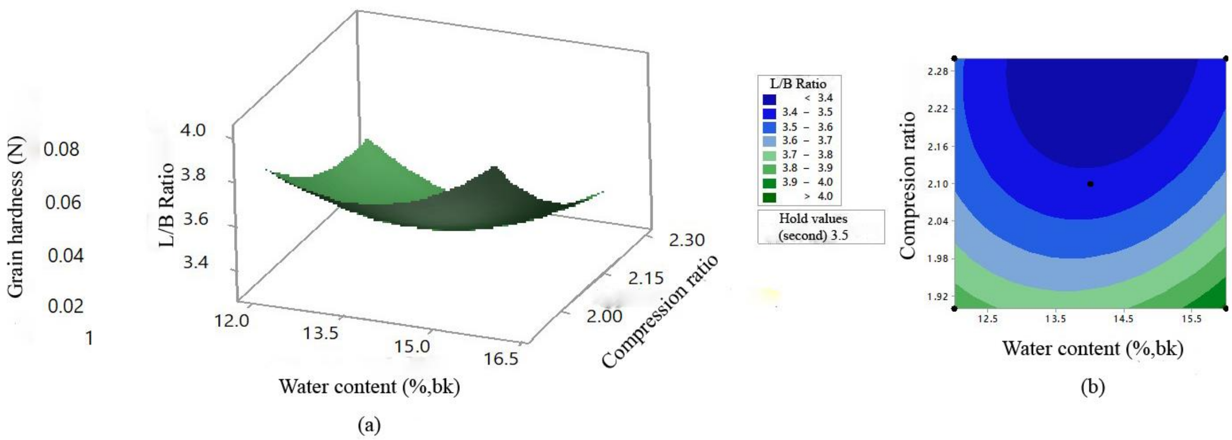


Figure 4 The 3D graphics optimization SRG grain hardness against long tap and the water content of the ingredients (a) Plot surface, (b) Plot contour

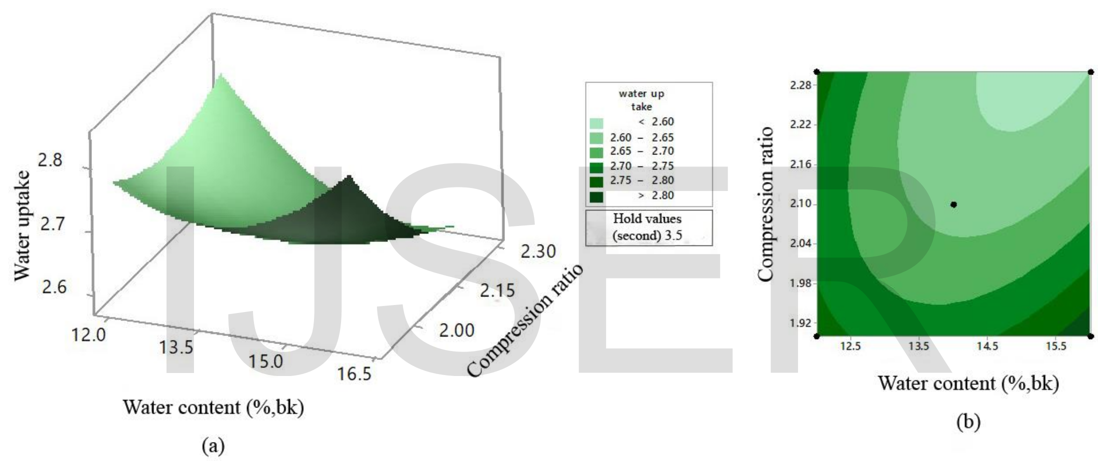




Figure 5 The 3D graphics optimization SRG towards water uptake ratio of compaction and moisture content of materials (a) Plot surface, (b) Plot contour

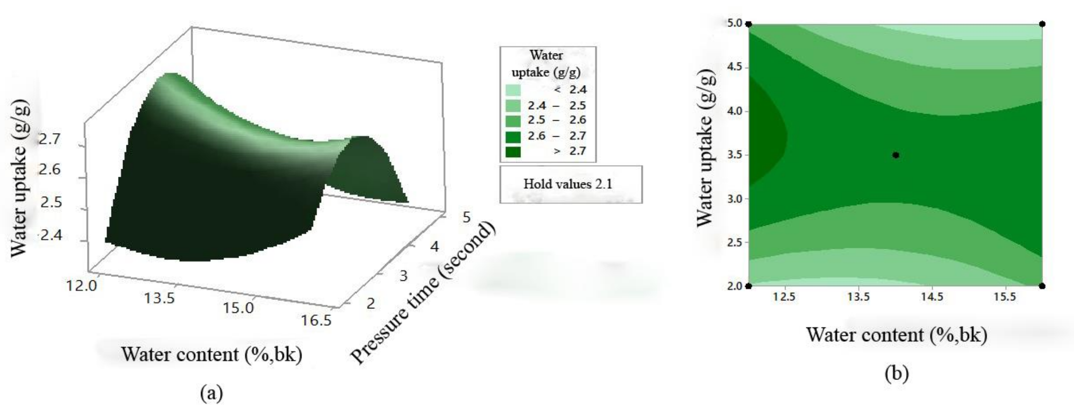


Figure 6 The 3D graphics optimization SRG water uptake of the old tap and the water content of the ingredients (a) Plot surface, (b) Plot contour.

Figure 7 The 3D graphics optimization of the ratio L / B ratio of SRG to the density and moisture content of materials (a) Plot surface, (b) Plot contour

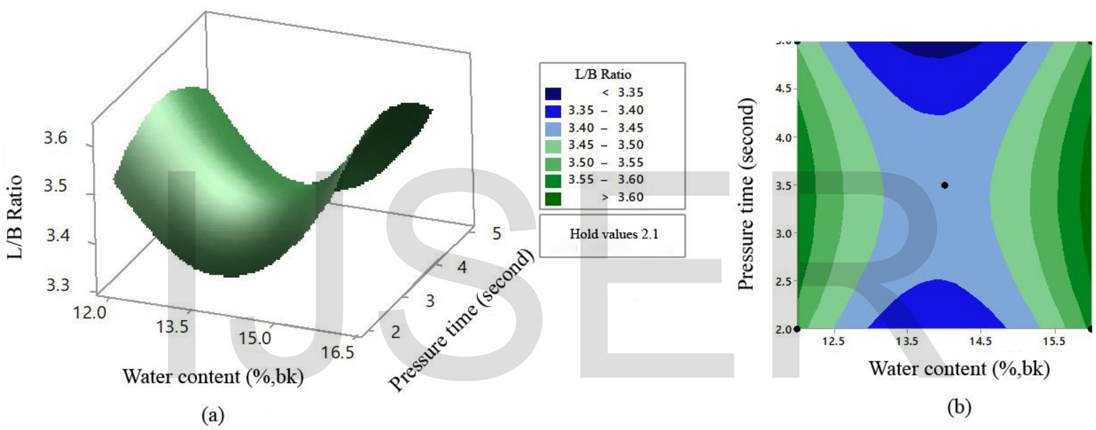


Figure 8

The 3D graphics optimization ratio L / B SRG towards the old tap and the water content of the ingredients (a) Plot surface, (b) Plot contour

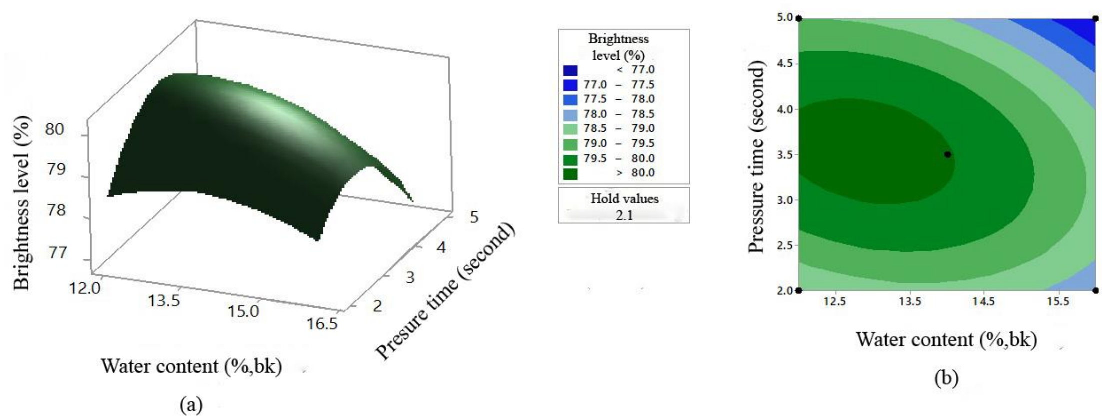


Figure 9 The 3D graphics optimization SRG degrees of brightness on the ratio of the density and moisture content of materials (a) Plot surface, (b) Plot contour

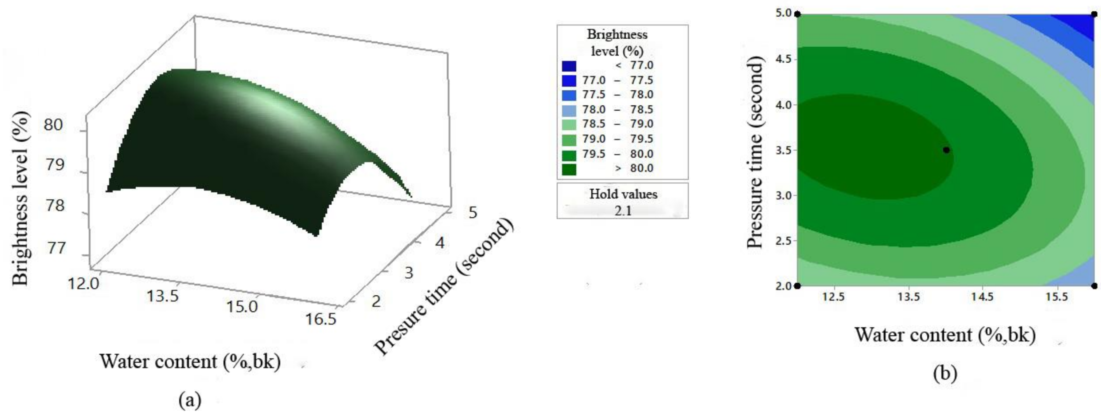


Figure 00 The 3D graphics optimization SRG degrees of brightness on the ratio of the density and moisture content of materials (a) Plot surface, (b) Plot contour.

The validation test result checking the actual data for the various treatments against the predicted output data produced using Equation 7 shows that the model is accurate, with a MAPE value of 0.97; the data representation is significant for all treatments. The insignificant effect of the response variables on the brightness level shows that there is no alteration to the color of the ingredients, or that the grain forming process using the SRG machine does not change the color of the material.

## 4 Conclusion

The optimization result for the grain produced by the SRG machine shows that the response variables have a very significant effect on the L/B ratio and the water uptake. However, they are insignificant for the bulk density, the hardness of the grain, and the brightness level.

## Acknowledgment

The authors would like to say thank to Doctoral Grant from Ministry of Education and Culture of Republic of Indonesia and also National Development and Research Partnership program from Center of Agricultural Research (KKP3N) – 2013.

## References

.
[1]Indonesian Bureau of Statistics Center (BPS). 2014. Statistik Indonesia 2014. Jakarta: Badan Pusat Statistik, Indonesia.
[2]Indonesian Department of Agriculture (DEPTAN). 2008. Peningkatan Produksi Padi Menuju 2020. Jakarta: Departemen Pertanian, Indonesia.
[3]Suhardi, S., S.A. Sabarnurdi, H.D. Soedjoko, Dwidjono, Minarningsih and A. Widodo. 1999. Hutan dan Kebun sebagai Sumber Pangan Nasional. Jakarta: Departemen Kehutanan.
[4]Kuswiyati, B., Djanuardi, and A. Syaefulah. 1999. Peningkatan Ketahanan Pangan Melalui Pemanfaatan Hutan dan Kebun untuk Pangan. Jakarta: Biro Perencanaan Dephutbun dan Menteri Negara Pangan dan Hortikultura.
[5]Kurachi, H. 1995. Process of making enriched artifical rice. US Patent No 5.403.606 (In US).
[6]Kapanidis, A. N. and T.C. Lee. 1996. Novel method for the production of color-compatible ferrous sulfate-fortified simulated rice through extrusion. *Journal of Agricultural and Food Chemistry*, 44(2): 522-525.
[7]Mishra, A., M.N. Mishra, and P.S. Rao. 2012. Preparation of rice analogues using extrusion technology. *International Journal of Food Science Technology*, 47: 1- 9.
[8]Hendrawan,I. Sutrisno, P. Hariyadi, Y.A. Purwanto & Hasbullah, R. 2015. Optimizing the formula of composite nonrice carbohydrate sources for simulated rice grain production. IJSER, 6(3), 7-13.
[9]Hendrawan,I. Sutrisno, P. Hariyadi, Y.A. Purwanto & Hasbullah, R. 2015. Rekayasa mesin pencetak butir beras simulasi dari materi tanaman hutan. Junal Penelitian Hasil Hutan. 33(3),235-246
[10]Hartoyo, A., and F.H. Sunandar. 2006. Pemanfaatan tepung komposit tepung ubi jalar putih (*Ipomoea batatas* L) kecambah kedelai (*Glicine max*, Merr) dan kecambah kacang hijau (*Virginia radiata* L.) sebagai subtituen parsial terigu dalam produk pangan alternatif biskuit kaya energi protein. *Jurnal Teknologi dan Industri Pangan*, 18(1): 50-57.
[11] Haqim, I. N., A. Aminah, and I. Anizan. 2013. Physicochemical, vitamin B and sensory properties of rice obatained by system of rice intensification (SRI). *Sain Malaysiana*, 42(11):1641-1646
[12]Soemantri, A. S., and R. Thahir. 2007. Analisis sistem dinamik ketersediaan beras di Merauke dalam rangka menuju lumbung padi bagi kawasan timur Indonesia. *Buletin Teknologi Pasca Panen Pertanian*, 3: 28-36.
[13]Budijanto, S., and Yuliyanti. 2012. Studi persiapan tepung sorghum (*Sorghum bicolor* L. Moench). *Jurnal Teknologi Pangan,* 13(3): 177-186.
[14]Gultom R, Sutrisno, and Budijanto, S. 2014. Optimasi proses gelatinisasi berdasarkan respon surface methodology pada pencetakan beras analog dengan mesin twin roll. *Jurnal Penelitian Pascapanen Pertanian,* 11(2):67-79.