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by Syaharuddin Rasyid

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Application of Central Composite Design in Optimizing the Number and Angle of Pressure Plates in The Manufacture of Pelleted Chicken Feed

Syaharuddin Rasyid[a)], Muas Muchtar[b)]

Department of Mechanical Engineering, Politeknik Negeri Ujung Pandang Makassar 90245 Indonesia

syaharuddinrasyid@poliupg.ac.id[a], muasmuchtar@poliupg.ac.id[b]

Abstract. This paper applies the response surface methodology (RSM) approach using Central Composite Design (CCD) to develop a mathematical model and optimize process parameters in manufacturing chicken feed pellets using a rotating press plate pellet system. The individual and combined effects of two process parameters, namely the number of pressure plates and the angle of the pressure plates, were studied. Analysis of variance (ANOVA) shows the relative significance of the process parameters in making pelleted chicken feed. Press plate angle is more significant in increasing production capacity, pellet durability, and machine efficiency than the number of press plates. Design-Expert software was used in developing a second-order regression model to predict optimization of engine parameters. Optimal conditions for producing production capacity, pellet durability, and engine efficiency are found in the number of three press plates and the angle of the pressure plate 60°.

1. Introduction

The growth and development of chickens while on the farm are influenced by the amount and type of chicken feed. Therefore, the productivity of chickens is highly dependent on the type of feed eaten. Several types of feed can be given to chickens. Pelleted feed is one of the most preferred types of feed by chickens. This type of pellet feed is more efficient and efficient given to chickens because it has high nutrition, and the growth rate of chickens is faster [1,2].

Pelletizing can be described as a phase change in the raw material by increasing the temperature to have a final phase in solid and capsule form. This final phase is formed after the raw material passes through the mold according to the desired shape. This final phase combines heat treatment during extrusion, moistening, and gelatinization of several components of the feed ingredients that function as binders. This binding effect prevents nutrient loss and slows down the disintegration of pellets in water [3, 4, 5].

Pelleting is a method of heat processing of feed raw materials. Pelleting aims to agglomerate smaller particles of feed raw materials using mechanical pressure, humidity, and heat. The initial step in pelleting is conditioning the mash through the addition of steam [4,5,6].

Pellets are a type of mechanical compaction assisted by elements such as pressure, heat, and humidity. The amount of moisture in the raw material, the size of the particles, and the processing temperature all have an impact on the stability of the pellets. Additionally, these two elements have an impact on the stability, physical quality, and durability of pellets.

Pellets of feed are considered a kind of preservation since they increase the security of feed supply and procurement [2]. Making pellets involves compressing feed components into cylindrical forms or tiny bits with a range of lengths, diameters, and levels of hardness. Some of the components that determine the quality of pellets are starch, fiber, and fat [2]. When starch is cooked along with water, the starch goes through a gelatinization process that affects the pellet's strength. Fat serves as a lubricant and fiber serves as a mold for the creation of pellets.

In order to construct a mathematical model and optimize process parameters for producing chicken feed pellets utilizing a revolving press plate pellet system at 60 revolutions per minute, this research employs the response surface methodology (RSM) approach employing Central Composite Design (CCD). Earlier scholars have published numerous publications about machining parameters. [7-16].

2. Experimental Method

2.1. Machine Specifications

Figure 1 is a chicken feed pellet machine using a rotating press plate. This pellet machine is used to measure the effect of the number and angle of the pressing plate on production capacity, machine efficiency, and pellet durability. The specifications of this machine are: machine dimensions (930 x 440 x 1130 mm), number of pressure plates (2, 3, and 4 pieces), pressure plate angle (30º, 45º, and 60º), dies plate (∅254x10 mm), diameter mold hole (5 mm), dynamo motor (1HP, 3 Phase, 1450 rpm), engine speed (50-70 rpm). Figure 2 shows the shape and number of pressure plates.

The machine's working principle is that the pressure plate rotates on the surface of the dies disk. The feed mixture enters through the hopper and cylindrical tube. Furthermore, the feed mixture is leveled and pressed into the mold hole. Pelleted chicken feed is formed after passing through the mold hole.

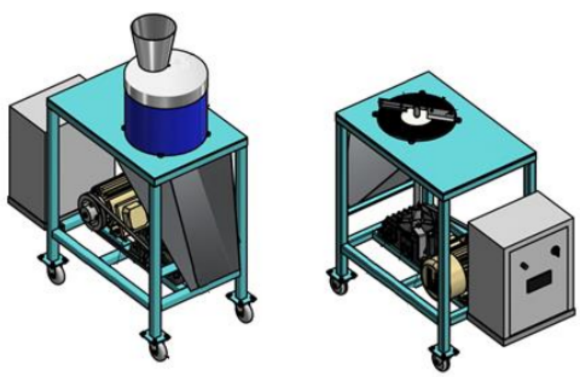

Figure 1. The chicken feed pellet machine uses a pressing plate.

(a) (b) (c)

Figure 2. Pressure plate models: two pressure plates (a), three pressure plates (b), and four pressure plates (c).

2.2. Stage of Testing Method

The feed mixture is formed on a press plate system pellet machine. The test aims to obtain the optimal number, and angle of pressure plate parameters at 60 rpm engine speed, 500 grams of feed ingredients, 25 grams of adhesive, and 400 water are prepared. The test parameters are the number of pressure plates 2, 3, and 4 pieces with pressure plate angles of 30°, 45°, and 60°. Equations (1), (2), and (3) are used to calculate pellet production capacity and durability, and machine efficiency.

$$\text{Production Capacity} = \frac{weight\ of\ pellet\ (Kg)}{Times\ (Hour)} \tag{1}$$

$$\text{Pellet Durability} = \frac{Weight\ of\ durablitiy\ pellet\ (Kg)}{Weight\ of\ broken\ pellet\ (Kg)} \text{ x } 100\% \tag{2}$$

$$Machine\ efficiency = \frac{Weight\ of\ feedmix\ (Kg)}{Weight\ of\ pellet\ (Kg)} \text{ x } 100\% \tag{3}$$

2.3. Experimental design and statistical analysis.

To examine the impact of operational parameters on response in the study region, the Central Composite Design approach on Software Design of Expert (DOE) is utilized. The number of pressure plates (pcs, A) and the angle of the pressure plates were chosen as independent variables (degree, B). Table 1 lists the factor codes' levels and value ranges. Based on the independent components and their interactions, the response was predicted using the polynomial equation (Equation 4) [11]. Due to the existence of two independent components in this paper, the result for a quadratic polynomial is:

Table 1. Independent variables and their effects on the DOE of the production of chicken feed pellets.

Independent Factors	Unit	Level		
		-1	0	1
Number of pressure plates (A)	(pcs)	2	3	4
Pressing plate angle (B)	(Degree)	30	45	60

$$Y = \beta_0 + \sum \beta_i x_i + \sum \beta_i x_i^2 + \sum\sum \beta_{ii} x_i x_j \tag{4}$$

Where b0, bi, bii, bij are the constant, linear, square, and interaction regression coefficient terms, respectively, and xi and xj are the independent factors (A and B).

For multiple regression analysis, analysis of variance (ANOVA), and analysis of the ridge maximum of data in the response surface regression (RSREG) technique, Design of Expert 6 software was utilized. The model's suitability was assessed by the coefficient of determination R2, and its statistical significance was examined using the F-test. For multiple regression analysis, analysis of variance (ANOVA), and analysis of the ridge maximum of data in the response surface regression (RSREG) technique, Design of Expert 6 software was utilized. The model's suitability was assessed by the coefficient of determination R2, and its statistical significance was examined using the F-test.

3. Result and Discussion

This study analyzed the effect of the number and angle of the pressure plate on the optimization of pelleted chicken feed production and engine efficiency. The design was used to obtain 11 design points across the two-factor range for the experiment. After the experiment, the response surfaces were analyzed by Central Composite Design. Table 2 shows the design, and the responses are given.

Table 2. Design layout and experimental results.

Run	Number of pressure plate (pcs)	Pressing plate angle (^{O})	Coded A	Coded B	Production Capacity ($Kghr^{-1}$)	Pellet Durability (%)	Machine Efficiency (%)
1	2	30	-1	-1	5.1	87.0	57.1
2	4	60	1	1	7.0	87.1	57.2
3	3	60	-1	1	7.7	87.6	57.7
4	3	30	0	-1	6.1	86.9	57.0
5	3	45	0	0	6.8	87.3	57.5
6	3	45	0	0	6.7	87.1	57.1
7	2	60	-1	1	7.0	87.4	57.5
8	4	30	1	-1	5.5	86.9	56.7
9	2	45	-1	0	6.2	87.1	57.0
10	3	45	0	0	6.9	87.5	57.5
11	4	45	1	0	6.4	87.1	57.1

3.1. Production Capacity

The quadratic model fits the production capacity results at the pressure plate and pressure plate angle. Table 3 provides the ANOVA for the production capacity data. The quadratic model is viable because its Prob>F value is substantially lower than 0.01. The number of the pressure plate and the angle of the pressure plate were regarded as important factors in terms of the coefficients.

Table 3. ANOVA for the model and factors affecting production capacity with a 95% confidence interval.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	5.39	5	1.08	85.76	<0.0001	significant

A	0.060	1	0.060	4.78	0.0805
B	4.17	1	4.17	331.70	<0.0001
A^2	1.01	1	1.01	80.45	0.0003
B^2	2.526E-003	1	2.526E-003	0.2	0.6726
AB	0.040	1	0.040	3.18	0.1344
Residual	0.063	5	0.013		
Cor Total	5.45	10			

Equation represents the empirical equation for the production capacity that was obtained as an actual factor (5),

$$\text{Production capacity} = 6.85 + 0.1 * A + 0.83 * B - 0.63 * A^2 - 0.032 * B^2 - 0.10 * A * B \quad (5)$$

Where A is the number of the pressure plate (pcs.), and B is the angle of the pressure plate (degree). Based on quadratic equation (5), the pressure plate angle is the most influential parameter in increasing production capacity. As demonstrated in Figure 3, the equation can be conveniently shown as a response surface contour and three-dimensional surfaces..

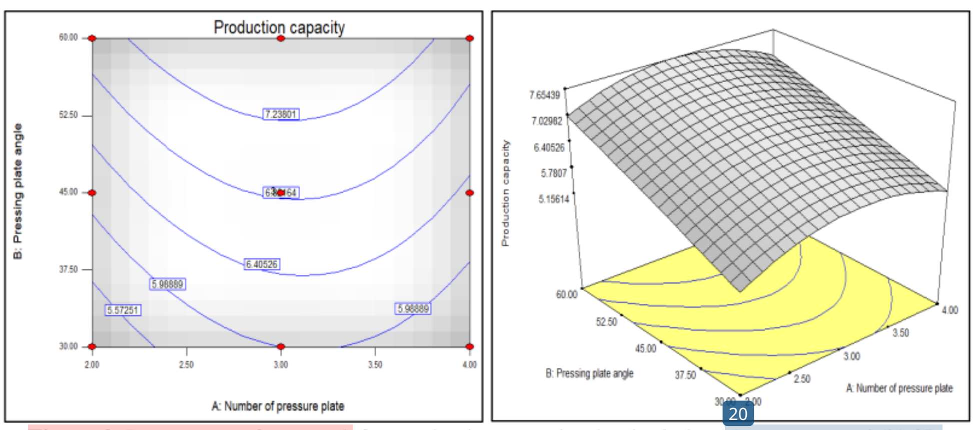

Figure 3. Response surface graph for production capacity that includes (a) contours and (b) 3D surfaces.

In Figure 3, it is known that the number of pressure plates affects the production capacity. Production capacity increased from 2 pressure plates to 3 pressure plates. However, there is a decrease in production capacity at four pressure plates. Suppose analyzed by linear regression, the more pressure plates, the greater the production capacity.

In Figure 3 it can also be analyzed the effect of the pressure plate angle on the production capacity. The greater the angle of the pressure plate, the higher the production capacity. Based on the analysis results of the effect of the number and angle of the pressure plate, the highest production capacity (7.7 Kg/hour) occurred in parameter 3 of the pressure plate, and the angle of the pressure plate was 60°. The pellet production capacity in this machine is lower than the previous test results [2, 6, 11]. However, the engine speed used in this test (60 rpm) is lower.

3.2. *Pellet Durability*

The linear model fits the data for durability pellet at pressure plate and pressure plate angle. Table 5 contains the results of the ANOVA for the data on pellet durability. The linear model is viable since it has a probability >F of much less than 0.01. Both the pressure plate and the angle of the pressure plate were thought to be important coefficients. The pressure plate's angle and change in pressure were insensitive to the durability of the pellets.

Table 5. ANOVA for the pellet durability model and components with a 95% confidence interval.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	0.31	2	0.15	4.97	0.0395	significant
A	0.027	1	0.027	0.86	0.3808	
B	0.28	1	0.28	9.08	0.0167	
Residual	0.25	8	0.031			
Cor Total	1.56	10				

The obtained empirical equation of pellet durability in the form of an actual factor is as stated in equation (6),

$$\text{Pellet durability} = 87.18 - 0.067 * A + 0.22 * B \qquad (6)$$

$$\text{Pellet durability} = 87.18 - 0.067 * A + 0.22 * B \qquad (6)$$

Where A is the number of the pressure plate (pcs.), and B is the angle of the pressure plate (degree). Based on the linear regression equation (6), the most influential parameter in increasing pellet durability is the angle of the pressure plate. For convenience, the equation can be displayed as response surface contour and three-dimensional surfaces, as shown in Figure 4.

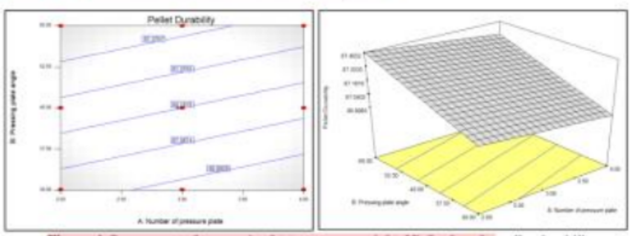

Figure 4. Response surface graph of (a) contours and (b) 3D Surface for pellet durability

Figure 4 shows the effect of the number and angle of the pressing plate on Pellet Durability. Pellet durability decreases with the increasing number of pressing plates, and pellet durability increase with increasing pressure plate angle. The best pellet durability (87.6%) occurred at three pressure plates, and the angle of the pressure plate was 60°.

3.3. Machine Efficiency

Results for machine efficiency at the various number of the pressure plate and angle of pressure plate show that it fits the linear model. The ANOVA for the machine efficiency data is given in Table 4. Having its probability>F of much less than 0.01, the linear model is valid. As for the coefficients, both the number of the pressure plate and the angle of the pressure plate was considered as a significant factor. Machine efficiency was insensitive to the change in the number of pressure plates and angle of the pressure plate.

Table 4. ANOVA with CI = 95% for model and factors of the machine efficiency.

Where A is the number of the pressure plate (pcs.), and B is the angle of the pressure plate (degree). Based on the linear regression equation (6), the most influential parameter in increasing pellet durability is the angle of the pressure plate. As demonstrated in Figure 4, the equation can be conveniently shown as a response surface contour and three-dimensional surfaces..

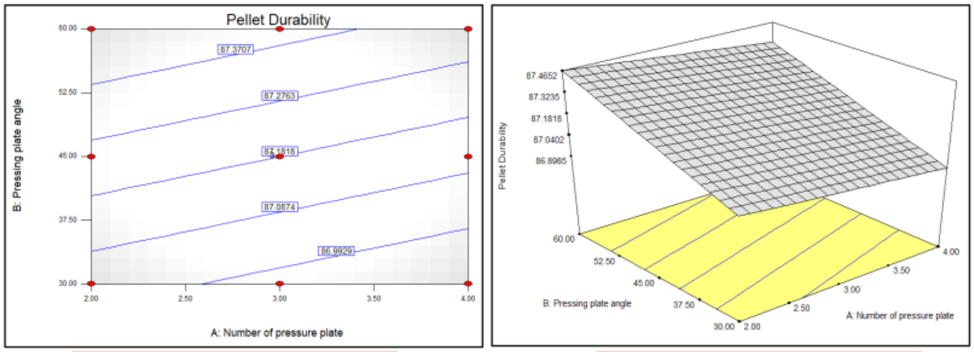

Figure 4. Response surface graph for pellet durability of (a) contours and (b) 3D surface

Figure 4 shows the effect of the number and angle of the pressing plate on Pellet Durability. Pellet durability decreases with the increasing number of pressing plates, and pellet durability increase with increasing pressure plate angle. The best pellet durability (87.6%) occurred at three pressure plates, and the angle of the pressure plate was 60^{o}.

3. *Machine Efficiency*

The linear model fits the results for machine efficiency at different pressure plate numbers and pressure plate angles. Table 4 contains the results of the ANOVA for the machine efficiency data. Given that the probability>F of the linear model is substantially less than 0.01, it is reliable. Both the number of the pressure plate and the angle of the pressure plate were thought to be important coefficients. The number of pressure plates and pressure plate angle had no effect on the machine's efficiency.

Table 4. ANOVA for the machine efficiency model and components with a 95% confidence interval.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	0.49	2	0.24	5.00	0.0391	significant
A	0.082	1	0.082	3.20	0.2993	
B	0.082	1	0.082	3.20	0.0182	
Residual	0.39	8	0.049			
Cor Total	0.88	10				

Equation is the machine efficiency empirical equation that was obtained as an actual factor (7),

$$Machine\ Efficiency = 57.22 - 0.100 * A + 0.27 * B \quad (7)$$

Where A is the number of the pressure plate (pcs.), and B is the angle of the pressure plate (degree). Based on linear equation (7), the most influential parameter in increasing engine efficiency is the angle of pressure plates. As demonstrated in Figure 4, the equation can be conveniently shown as a response surface contour and three-dimensional surfaces. As demonstrated in Figure 4, the equation can be conveniently shown as a response surface contour and three-dimensional surfaces..

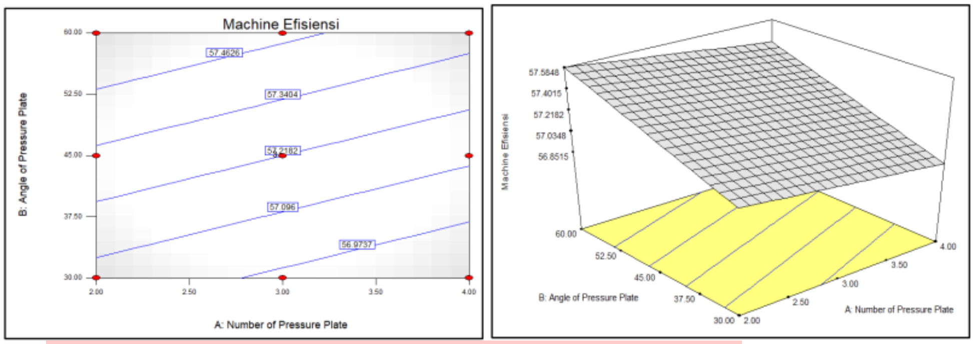

Figure 5. Response surface graph of (a) contours and (b) 3D Surface for machine efficiency.

Figure 5 shows the effect of the number and angle of the pressure plate on the machine efficiency. The highest engine efficiency (57.7%) occurs at three pressure plates, and the angle of the pressure plate is 60°.

3.4. Optimization

Empirical models have been obtained for all chicken feed pellet manufacturing process responses due to the number and angle of pressure plates. Selection of the optimal number and angle of pressure plate parameters can be made. The expected range can be adjusted from each chicken feed pellet manufacturing process response. The range of the number and angles of the press plates as expected for all pellet manufacturing process responses can be determined. For example, to get production capacity, pellet durability, and machine efficiency, the number and angle of pressure parameters must be selected in the range of the number of pressure plates 2, 3, or 4 pieces and pressure plate angles of 30°, 45°, and 60°. The range of pressure plate number and angle must fall within the yellow plot of the overlay (Fig. 6) of all the reactions to producing chicken feed pellets in order to meet this criterion.

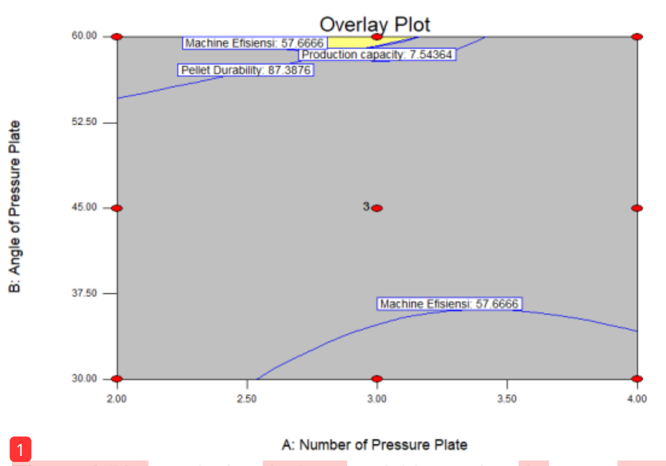

Figure 6. Plot overlaying the input variables against the preset response criteria for machine productivity and efficiency.

The Overlay plot of the input components for the specified response criterion is shown in Figure 6. The response criteria that have been determined are the production capacity of 7.54364 Kg/hour, pellet durability 87,3876%, and engine efficiency 57.6666%. Based on the optimal response criteria, the best parameters obtained are the number of pressure plates 3, and the angle of the pressure plate is 60^o.

4. Conclusion

The optimization of the number and angle of pressure plate parameters in the manufacture of chicken feed pellets has been investigated using a rotating press plate pellet system machine. The conclusions of this study are the highest pellet production capacity (7.7 Kg/hour), the highest pellet durability (87.6%), and the highest machine efficiency (57.6%). Analysis of variance (ANOVA) shows the relative significance of the process parameters in making pelleted chicken feed. Press plate angle is more significant in increasing production capacity, pellet durability, and machine efficiency than the number of press plates. Design-Expert software was used in developing a second-order regression model to predict optimization of engine parameters. Optimal production capacity, pellet durability, and engine efficiency are found in the number of 3 pressing angles and 60^o pressure plate angles.

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