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OPTIMIZATION OF TEMPERATURE AND HEATING TIME IN THE PRODUCTION OF FEED WAFER CONTAINING PRILL FAT

OPTIMASI SUHU DAN LAMA PEMANASAN PADA PEMBUATAN WAFER PAKAN MENGANDUNG PRILL FAT

Qorry Nurul Hasanah, Indah Wijayanti*), and Y Retnani

Nutrition and Feed Science, Undergraduate School, IPB University
IPB Dramaga, Bogor 16680, West Java, Indonesia
*Email: wijayanti@apps.ipb.ac.id

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ABSTRAK

Prill fat merupakan hasil samping pembuatan minyak goreng yang dapat dimanfaatkan sebagai pakan sumber lemak. Karakteristik prill fat yang berbentuk granula halus dan susah homogen dengan bahan lain menjadi kendala dalam pemanfaatanya. Pengolahan prill fat menjadi wafer supplemen dapat dijadikan alternatif dalam pemanfaatanya dengan tetap memperhatikan titik leleh prill fat. Penelitian ini bertujuan mengoptimalkan proses produksi wafer supplemen mengandung prill fat dengan response surface methodology (RSM) dan perubahan kualitas selama masa penyimpanan. Tahapan penelotian yang dilakukan yaitu optimasi proses produksi dengan faktor suhu dan lama pemanasan dan respon yang diuji yaitu efisiensi produksi, kadar air (KA) serta wafer durability index (WDI). Suhu dan lama pemanasan optimal yang didapat yaitu suhu 50˚C dengan lama pemanasan 1 menit dengan respon efisiensi 95,2%, kadar air 5,6% dan WDI 95% dan hasil validasi memiliki tingkat kepercayaan 95 %. Dapat disimpulkan bahwa suhu 50 ˚C dengan lama pemanasan 1 menit dapat diterapkan pada produksi wafer supplemen mengandung prill fat.

Kata kunci : optimasi produksi, prill fat, response surface methodology, wafer supplemen

ABSTRACT

Prill fat is a by-product of cooking oil production that can be utilized as a fat source in animal feed. The prill fat’s fine granular form and difficulty in achieving homogeneity with other materials pose challenges in its utilization. Processing prill fat into supplement wafers can be an alternative for its use, with careful consideration of its melting point. This study aims to optimize the production process of supplement wafers containing prill fat using response surface methodology (RSM) and to evaluate the changes in quality during storage. The research stages include optimizing the production process with temperature and heating time as factors, and the responses tested are production efficiency, moisture content (MC), and wafer durability index (WDI). The optimal temperature and heating time identified were 50°C for 1 minute, yielding a production efficiency of 95.2%, a moisture content of 5.6%, and a WDI of 95%, with the validation results showing a confidence level of 95%. It can be concluded that a temperature of 50°C with a heating time of 1 minute can be applied to produce supplement wafers containing prill fat.

Keywords: production optimizing, prill fat, response surface methodology, wafer supplements

INTRODUCTION

Environmental conditions are one of the determining factors in the success of livestock farming, including dairy cattle farming. The ecologycal conditions in Indonesia, with air temperatures ranging from 28-34ºC and daily humidity levels of 60-90%, cause dairy cattle to easily experience heat stress. Animals that experience heat stress will show decreased appetite, increased thirst, elevated respiration rates, and increased salivation and sweating. Additionally, cows suffering from heat stress are at a high risk of developing acidosis and reduced dry matter intake, which can lead to decreased milk production, stunted growth, and health and reproductive issues (Mariana *et al.*, 2021). When heat stress occurs, cows will increase energy expenditure to maintain body temperature, leaving little energy available for milk production. Addressing the decline in milk production due to heat stress can be achieved through high-energy feed supplementation to meet energy needs during lactation. The provision of fat supplements can serve as an alternative for fulfilling the energy requirements of livestock. One potential fat source that can be used is prill fat.

Prill fat is a by-product of the production of cooking oil. Prill fat has a high fatty acid content, particularly palmitic acid, which makes up about 85%. It is in the form of fine solid granules with a melting point of 59˚C (Riestanti, 2019). This fine granular form of prill fat is very susceptible to spillage during storage and transportation;

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*Coressponding Author

additionally, the physical characteristics of the material make it difficult to homogenize with other feed ingredients, especially those that are powdery or granular. To address this issue, prill fat can be further processed into feed wafers. Wafers are one form of modifying livestock feed through mixing, compaction, and heating (Pratama *et al.*, 2015). The production of wafers is influenced by several factors, including machine temperature, pressure, heating duration, and the type of raw materials used. Currently, there are no standards or references for the temperature and heating duration in the production of wafer supplements containing prill fat. Therefore, it is necessary to optimize the production process to determine the optimum temperature and heating duration.

Production optimization is an approach to processes aimed at improving efficiency, productivity, and the quality of industrial or manufacturing products (Sasongko, 2023). The goal of optimization is to achieve the best results by efficiently utilizing available resources. Additionally, production optimization can reduce waste during production, lower production costs, increase output, optimize quality, and enhance overall performance (Hendrawan *et al.*, 2016). Production optimization can be analyzed using Response Surface Methodology (RSM). The principle of using RSM is to examine the relationships that occur based on several factors affecting a variable in an experiment. Thus, the use of this method can yield optimal values for a process and formulations from the experiments (Kusuma *et al.*, 2019; Maulinda *et al.*, 2019; Ngizudin and Harmoko, 2022). The production of wafer supplements containing prill fat has not yet been widely utilized, presenting opportunities for further development. This research aims to optimize the temperature and heating duration in the production of feed wafers using the application of response surface methodology (RSM).

MATERIALS AND METHODS

Materials

The materials and equipment used include prill fat, corn gluten feed, pollard, coffee grounds, molasses, vitamins and minerals, salt, lime, bags, plastic, wafer machine, mixer, basin, Grain Moisture Tester PM650, digital scale, hygrometer HTC-1, Aw meter, wafer durability index machine, Design Expert 12 software, and writing instruments. Prill fat was obtained from PT. Asianagro Agung Jaya, North Jakarta.

Research Method

Based on Figure 1. the formulation of the produced supplement wafers consists of 60% prill fat and 40% other raw materials, including vitamins and minerals, with a crude protein content of 7.12% and a crude fat content of 60.73%. The experimental design used is based on Response Surface Methodology (RSM), with analysis conducted using Design Expert 12 software. This experimental design aims to obtain a combination of several factors with optimal responses. The mixture design used is Central Composite Design (CCD). The optimization is performed using two factors: machine temperature and heating duration, while the responses tested are moisture content, wafer durability index, and production efficiency. Production efficiency is calculated as the ratio of actual output to the capacity of the machine used. Moisture content is tested using a rapid test with the Grain Moisture Tester PM650, and the WDI is tested using a durability machine at a speed of 50 rpm for 3 minutes. The treatment design is based on the results from the Central Composite Design (CCD) as follows Table 1.

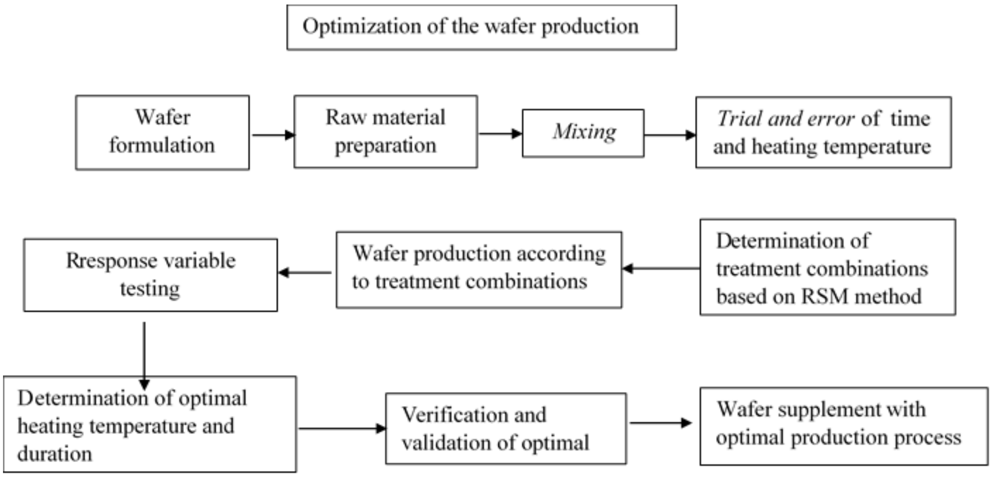


Figure 1. Research Flowchart

Table 1. Treatment design based on central composite design (CCD) for temperature and heating duration variables

Run	**Factor 1: temperature (ºC)**	**Factor 2: heating time (minutes)**
1	55	0,5
2	45	0,5
3	57	1
4	50	1
5	55	1,5
6	50	1
7	50	1
8	50	1
9	45	1,5
10	43	1
11	50	0,3
12	50	1,7
13	50	1

Table 2. Measurement results based on central composite design (CCD)

Run	**Production efficiency**	**Moisture content**	***Wafer durability index***
1	90,5	5,6	81
2	95,2	6,4	42,9
3	77,5	5,5	71,4
4	97	5,8	95,2
5	87,5	5,2	73,7
6	97,5	5,8	95,2
7	97,4	5,6	95
8	96,4	5,8	95,2
9	96,6	5,9	70
10	93,6	6,2	40
11	74,6	6,9	33,3
12	93	5,2	99,4
13	96,3	5,8	95

After obtaining the optimal values based on the responses of efficiency, moisture content, and WDI, verification and validation of the results are conducted to ensure that the obtained values are accurate. Validation of the results is performed by testing water activity (Aw), specific gravity, and calculating the production cost.

Moisture Content (MC)

The moisture content of the wafers is measured using the Grain Moisture Tester PM-650. The device is turned on by pressing the power button, then selecting the test code that corresponds to the sample, press the MEA button, and wait for the prompt to insert the sample. The sample is added until it covers the detector, after which the moisture content will be displayed in percentage (%).

Wafer Durability Index (WDI)

WDI is measured using a modified version of the Pellet Durability Index (PDI) method. WDI is measured using a durability machine that rotates for 3 minutes at a speed of 50 rpm (Sandra *et al.*, 2019). The WDI value can be calculated using the formula:

$$\text{WDI (\%)} = \frac{\text{Weight of the Wafer before rotation}}{\text{Weight of the intact wafer}} \text{x100\%}$$

Production Efficiency

Production efficiency in this study is calculated using the formula:

$$\text{Production efficiency} = \frac{\text{Actual output}}{\text{Efective capacity}} \text{x100\%}$$

RESULT AND DISSCUSION

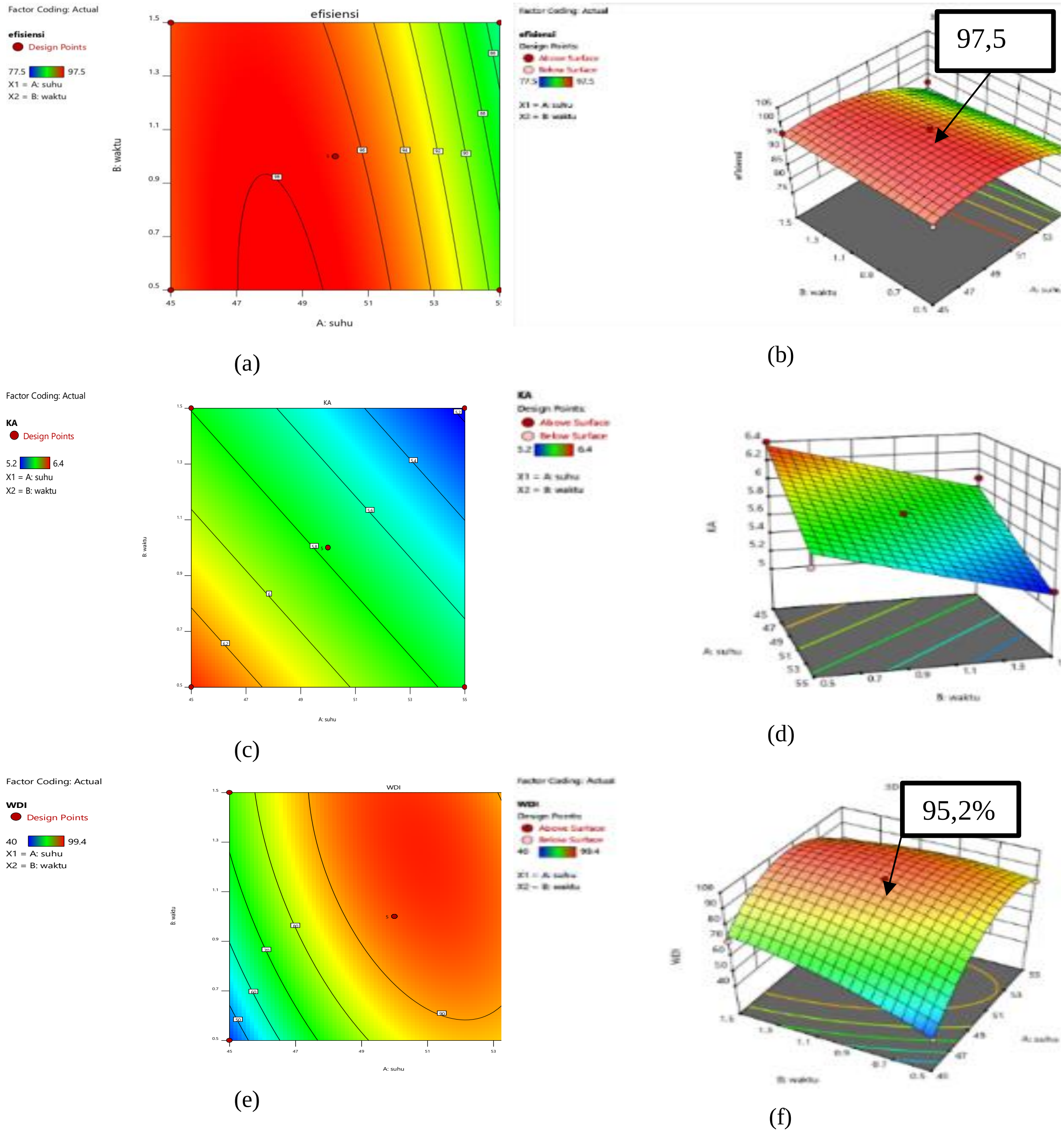
Analysis of Production Optimization Responses for Supplement Wafers

The optimization of the production process for supplement wafers containing prill fat was evaluated based on the responses of production efficiency, moisture content, and wafer durability index (WDI). The measurement results based on the Central Composite Design (CCD) are presented in Table 2. The results of the obtained responses were analyzed using software and are presented in Table 3.

Table 3. Response analysis results

Analysis	Value		
	Production efficiency	**Moisture content**	**Wafer durability index**
Mathematic model	*Quadratic*	*Linear*	*Quadratic*
Significance model	0,0013	< 0,0001	< 0,0001
Standard deviation	1,93	0,1167	3,39
Average (%)	93,21	5,73	79,50
CV (%)	2,07	2,04	4,27
R^2	0,9398	0,9103	0,9853
Adjusted R^2	0,8896	0,8904	0,9731
Predicted R^2	0,1703	0,8051	0,8673
Adeq precision	12,3381	20,3887	23,7786

Note: The model significance value is significant if $P < 0.05$



97,5

95,2%

(a)

(b)

(c)

(d)

(e)

(f)

Figure 2. (a) Contour Plot of Production Efficiency Response, (b) 3-D Surface of Production Efficiency Response, (c) Contour Plot of Moisture Content Response, (d) 3-D Surface of Moisture Content Response, (e) Contour Plot of WDI Response, (f) 3-D Surface of WDI Response.

Based on Table 3, the tested responses resulted in a significant model significance value ($P < 0.05$) with a quadratic model for production efficiency and WDI, and a linear model for moisture content response. This indicates that different settings of machine temperature and heating duration significantly affect production efficiency, moisture content, and WDI. The R^2 value (0.9398) for production efficiency shows that 93.98% of the wafer production efficiency is influenced by temperature and heating duration factors, while 6.02% is influenced by other factors not included in the model. For the moisture content response, the R^2 value (0.9103) indicates that 91.03% of the moisture content response is influenced by the model used, with the remaining 8.97% affected by other factors. The R^2 value (0.9853) suggests that the data obtained can influence the model by 98.53%, while the remainder is affected by other factors not included in the model. The positive predicted R^2 value for all responses indicates that the model used has good predictive capability. Adequate precision is greater than 4, suggesting that noise in the proposed model is minimal and can be used to navigate the design space. Furthermore, the adjusted R^2 value, which approaches 1, indicates that the model used is appropriate, and the difference between adjusted R^2 and predicted R^2 is less than 0.2. Based on several test criteria, the response data used is valid and can be utilized in the optimization stage.

The results of the analysis obtained from Table 3 are presented in the form of 3D images and contour plots shown in Figure 2. Figures 2c and 2d represent the moisture content response, where the results of the moisture content tests for 13 treatment combinations show wafer moisture values ranging from 5.2% to 6.4%. The lowest moisture content response was found in run 5 with a temperature of 55 °C and a time of 1.5 minutes, as well as in run 12 with a temperature of 50 °C and a time of 1.7 minutes. The moisture content in a feed can be influenced by the production process used. The feed production process utilizing heat can reduce the moisture content in the feed, as during the heating process, the moisture in the materials will evaporate due to the applied heat. The moisture content in the feed can affect the overall nutrient content and percentage in the feed, as well as the treatments applied during the production process (Ahadi and Effendi, 2019). The heating process in the production of supplement wafers can cause the evaporation of moisture in the materials, resulting in reduced moisture content in the final product (Nurhayati *et al.,* 2021). Additionally, the heating process can also stop enzymatic reactions, which can prevent changes in material quality (Syafrida *et al.*, 2018). Using different temperatures and heating durations in the feed production process will yield feed with varying moisture contents. The higher the temperature or the longer the heating time, the lower the resulting moisture content, and conversely.

Figures 2e and 2f show the WDI response from the treatments. The results of the WDI response tests for 13 treatment combinations yielded WDI values ranging from 40% to 99.4%, with an optimal value of 95.2% in run 6 at a temperature of 50˚C and a heating duration of 1 minute. The Wafer Durability Index (WDI) is one of the variables that can be used to represent the resilience of wafers to impacts and vibrations that occur during storage and transportation. A higher WDI indicates that the wafer has better physical quality and serves as an indicator of the success of wafer production (Kurniawan, 2020).

Determination of Optimal Production Process

The determination of optimal values is conducted by inputting the percentage values and the objectives of the desired optimization. This optimal process is determined based on the best experimental model (Kartika *et al.*, 2022). The importance value and optimization objectives used in Table 4 yielded a single solution from the Design Expert 12 application, which was utilized in analyzing the optimization as presented in Table 5.

Desirability refers to the level of success or suitability between the results obtained from experiments or mathematical models based on the established objectives. A desirability value approaching 1 indicates that the experimental conditions align with the optimization objectives set, and the model used can achieve the desired solution (Nurika *et al.*, 2021).

Table 4. Importance values and optimization goals for supplement wafer production process

Response	**Objective**	**Lower limit**	**Upper limit**	**Importance value**
Efficiency	*Maximize*	77,5	97,5	5 (+++++)
Moisture content	*In range*	5,2	6,4	3 (+++)
WDI	*Maximize*	85	99,4	5 (+++++)

Table 5. Recommendations and estimated optimization based on design Expert 12 Application

Temperature (˚C)	**Time (minutes)**	**Efficiency**	**Moisture content**	**WDI**	***Desirability***
50	1	96,8	5,7	94,6	0,663

Table 6. Verification of optimization results

Response	Prediction value	Actual value	95 % PI	
			Low	High
Efficiency	96.8	95.2	93.4	100
Moisture content	5.7	5.6	5.6	5.9
WDI	94.6	95	88.6	100

In Table 6, the verification values of the three tested responses meet 95% Prediction Index (PI), indicating that the production process is considered good as an optimal production process based on the obtained responses (Syafi'i *et al.*, 2016).

Table 7. Validation of optimization results

Variable	Value
Production efficiency (%)	95.1 ± 0.6
Moisture content	5.65 ± 0.05
WDI (%)	95.2 ± 0.2
Water activity	0.591 ± 0.002
Specific gravity	0.85 ± 0.04
Production cost (Rp/kg)	11.282.62

The production efficiency value based on the optimization results validation in Table 7 shows a result of 95.1%, which still falls within the range of production efficiency based on verification, between 93.4% and 100%. For the moisture content, the obtained values also remain within the verified range of moisture content, which is between 5.6% and 5.9%, and still below the maximum moisture content value for feed based on the Indonesian National Standard (SNI), which is a maximum of 14%. The WDI value (95%) obtained also remains within the WDI range based on the verification results, which is between 88.6% and 100%. Additionally, for the other variable tested, which is water activity, the wafer's water activity value is 0.591 ± 0.002, which is still below the maximum water activity value for feed. The maximum Aw value for a feed or feed ingredient is 0.7. Materials with Aw above 0.7 can experience faster deterioration, as microorganisms like bacteria and fungi thrive at Aw levels between 0.75 and 1. The heating process during wafer production can reduce the Aw value of the wafer because heat spreads more easily through water-containing materials, and the microorganisms present will also be killed (Azara and Saidi, 2020). Specific gravity is the ratio of the wafer's weight to its volume. The specific gravity of a feed is influenced by its constituent materials. The use of materials with significant differences in specific gravity can lead to unstable mixtures that are easily separated (Islami *et al.*, 2019). The specific gravity of the produced wafer is 0.85 ± 0.04 g/mL. A high or low specific gravity value indicates the strength of the attraction between the wafer's constituent particles. Wafer samples with higher specific gravity exhibit stronger particle attraction and reduced volume due to smaller distances and voids between particles. The production cost of supplement wafers containing prill fat in the most optimal production process is Rp. 11,282.62, with a formulation cost of Rp. 10,296.34 and Rp. 986.28 for electricity and labor costs. This additional feed cost can be compared with the quality and quantity of milk produced by the livestock.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The optimization of the supplement wafer production process containing prill fat resulted in an optimal production process with a temperature of 50˚C and a heating duration of 1 minute. The use of a wafer machine with higher precision in temperature and time is recommended to facilitate the adjustment of the temperature and time used.

Recommendations

The use of feed wafer machines with higher precision in temperature and time will facilitate the adjustment of production temperature and time. The temperature and heating duration obtained from this study can be used for the production of wafers with similar content.

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