Modeling and optimization of catalyst concentration and reaction temperature on yield and calorific value of biodiesel from CPO

Y Hendrawan1, Daisy2, R Utami1, D Y Nurseta1, R Yudho1, B D Argo1, and B Susilo1

1Department of Agricultural Engineering, Universitas Brawijaya, Jl. Veteran, Malang, ZIP 65145, Indonesia
2Department of Agricultural Product Technology, Universitas Brawijaya, Jl. Veteran, Malang, ZIP 65145, Indonesia
E-mail: yusuf_h@ub.ac.id

Abstract. In this research, response surface methodology (RSM) has been developed with a central composite design (CCD) model using two input variables i.e. KOH concentration and the reaction temperature, and two responses i.e. biodiesel yield as quantity parameter and calorific value as quality parameter. RSM optimization result showed a parabolic curve with a maximization function with a quadratic mathematical model. Mathematical model that had been given for yield response was \( Y_1 = -361.75066 + 298.06346X_1 + 15.36142X_2 + 0.5X_1X_2 - 159.4X_1^2 - 0.14463X_2^2 \), where \( Y_1 \) = Yield response, \( X_1 \) = KOH concentration (% w/v) , \( X_2 \) = reaction temperature (°C), meanwhile the mathematical model for calorific value response was \( Y_2 = 21534.81810 + 2163.76029 X_1 - 487.60022 X_2 + 69.11980 X_1X_2 - 2709.22080 X_1^2 + 3.84021X_2^2 \). The optimum solution obtained by RSM was a KOH concentration of 1.08% (w/v) and reaction temperature at 60.11 °C. Validation data indicated that the actual value (obtained by experimental result) was similar to that of the prediction value (obtained from RSM). Meanwhile, biodiesel characteristics that had been produced included: viscosity 7.356 cst, water content 5.6%, density 0.864 g/ml, a flashpoint at 135 °C, yield 210.90 ml, and calorific value is 9864.834 cal/g.

1. Introduction

Palm oil is obtained from the processing of palm fruit with a varying fatty acid content, both in length and in its carbon chain structure. The carbon chain length in palm oil ranges from C12-C20 carbon atoms. Various studies have proven the effectiveness of the use of crude palm oil (CPO) as biodiesel [1][2]. Biodiesel is a product of the chemical reaction of transesterification with raw materials of plant oils and/or animal fats, where the results of the transesterification are methyl esters, known as biodiesel. Thus, this chemical reaction called free fatty acids (FFA) has been neutralized and glycerin has been removed from esters [3]. FFA are fatty acids that are not bound to alcohol molecules such as glycerin in plant oils or methanol in biodiesel. In biodiesel production with transesterification, the FFA is changed
to soap. Whereas in acid esterification reaction, FFA is converted directly into biodiesel [4]. KOH and reaction temperature affects biodiesel production [5][6].

Modeling and optimization techniques provide optimal research results, so the results can be utilized in product development applications [7][8]. Response surface methodology (RSM) is a collection of statistical and mathematical techniques that are useful for the development, improvement, and optimization of processes where the desired response is influenced by several variables and then it can optimize the response [9]. The advantage of RSM over ordinary experiments is that RSM provided a lot of information from just a few experimental experiments. RSM also allows for the observation of the interaction of independent parameters on responses [10]. Many biodiesel studies use RSM optimization with excellent optimization results [11][12]. The objectives of this study are (1) to find a mathematical model and the optimum point of the biodiesel production; (2) characterizing the biodiesel produced from the optimization process.

2. Materials and Methods
This research was conducted at the Laboratory of Chemical Engineering, Politeknik Negeri Malang, Indonesia Research Center for Sweeteners and Fiber Plants, Malang, and the Motor Fuel Laboratory, Mechanical Engineering, Universitas Brawijaya, Indonesia. The tools that were used for this research include water bath, stirrer, beaker glass, thermo-controller, thermo-shaker, analytical scales, measuring cups, spatulas, Erlenmeyer, burette, pipette, stative, and hotplate magnetic stirrer. The materials that were used in this study include crude palm oil (CPO), KOH, Sulfuric Acid (H₂SO₄), methanol, distilled water, PP indicator, 0.5 N NaOH, and 0.25 N NaOH. This research was conducted using Design Expert 7.0.0 software with a central composite design (CCD) from RSM (RSM-CCD) [13][14]. The factors used in this study consisted of two i.e. KOH concentration (%) as factor 1 and reaction temperature (°C) as factor 2. While the response to be observed was the yield of biodiesel (methyl ester) and the calorific value.

Based on the preliminary research, the initial optimum point was a KOH concentration of 1% and the reaction temperature was 55 °C. Factors that influence the yield/output of biodiesel with two numeric factors were included KOH concentration with a lower limit of 0.75% (-1 Level) to an upper limit of 1.25% (+1 Level) and reaction temperature of 45 °C at the lower limit (-1 Level) to 65 °C as the upper limit (+1 level). At this stage, the biodiesel production is carried out after inputting data into the software. Then a simulation of 13 treatment combinations was carried out. The process biodiesel production [14] starts from: (1) CPO was given an esterification pre-treatment by adding acid and methanol at 60 °C for 1 hour; (2) purification of CPO from water by-products after the esterification process; (3) analysis of free fatty acid levels by KOH base titration; (4) mixing of materials to be used in the process biodiesel production, included: 50 ml of methanol, 250 ml of CPO material, and the concentration of KOH in accordance with the treatment; (5) KOH and methanol catalysts were reacted in a beaker glass; (6) the measured CPO was then put into the stirrer together with the KOH and methanol mixture, and stirred for 1 hour; (7) the reaction product was cooled and precipitated for 24 hours to form two layers (methyl ester and glycerol); (8) the formed methyl esters and glycerol were separated; (9) methyl esters which had been separated with glycerol were then given a washing treatment using water in a ratio of 1: 1 (methyl esters: water); (10) methyl esters were heated with water at 95 °C for 20 minutes; (11) the desired reaction product (biodiesel) was obtained.

3. Results and Discussion
RSM-CCD simulates 13 treatments with various combinations to obtain response data as shown in Table 1 and obtains mathematical equations for modeling and optimization. The results of selecting the first type of model with a sequential sum of summary analysis on the yield response gave results where the p-value was 0.9570 (95.70%), this value shows that the first model i.e. linear model type has an inaccuracy of 95.70% to the response. The second model was 2FI (interaction between two factors), which shows the p-value of 0.8902 (89.02%), so the 2FI model was not suitable for yield response modeling. The third model was quadratic where the p-value results was 0.0171 (1.71%). From the p-
value, it can be concluded that the quadratic model was suggested in the determination of the mathematical model of yield response because the inaccuracy of the model shown was below the 5% limit. The second model on the yield response was the lack of fit test or the model imprecision test. Based on the lack of fit test data, the quadratic modeling had a p-value of 0.1628 (16.28%). From these results, it can be concluded that the quadratic model was suggested because the p-value of the quadratic model exceeded the established level (α) of 0.05 or 5% so that this type of model had no significant effect on the response. The quadratic type was the right modeling for yield response. The third mathematical model was the model summary statistics. In testing the model summary statistics for the type of quadratic model, the R-Squared value was 0.6905 while the Adj value. R-Squared was 0.4695. It means 69.05% of the variation in the output variable was explained by the input variables, this value is generally considered a moderate effect size. The quadratic model was suggested in the selection of model types for yield responses. Testing this Summary Statistics Model also took into account the value of PRESS or Prediction Error of Sum of Squares. The PRESS value on the quadratic model type was stated as suggested or recommended with a PRESS value of 4692.33. It can be concluded that from the three types of mathematical model testing i.e. the sequential sum of summary, lack of fit test, and model summary statistics for the type of model used in the mathematical model for yield response was quadratic.

**Table 1. Research design and experimental results.**

| No | KOH concentration (% b/v) | Reaction Temperature (°C) | Yield (ml) | Calorific Value (cal/g) |
|----|--------------------------|---------------------------|------------|------------------------|
| 1  | 0.75                     | 45                        | 200        | 9776.48                |
| 2  | 1.25                     | 45                        | 188        | 10215.5                |
| 3  | 0.75                     | 65                        | 185        | 10276.06               |
| 4  | 1.25                     | 65                        | 178        | 10407.1                |
| 5  | 0.65                     | 55                        | 180        | 8701.24                |
| 6  | 1.35                     | 55                        | 203        | 9071.54                |
| 7  | 1                        | 40.86                     | 175        | 9772.68                |
| 8  | 1                        | 69.14                     | 190        | 10213.5                |
| 9  | 1                        | 55                        | 220        | 9898.36                |
| 10 | 1                        | 55                        | 200        | 9812.31                |
| 11 | 1                        | 55                        | 219        | 9583.56                |
| 12 | 1                        | 55                        | 208        | 9435.83                |
| 13 | 1                        | 55                        | 212        | 9217.83                |

The results of the analysis of the first model selection test of the response to the calorific value based on the sequential sum of summary were tested using 4 types of models. In the first model, which was linear, the p-value was 0.7664. For the second model i.e. 2FI model (the interaction between two factors) the p-value was 0.554. The third model i.e. a quadratic model in the analysis results obtained a value of 0.1012. The quadratic model was a model that has a significant or real influence on the equations of the mathematical model used in the calorific value response, so it can be said that the quadratic model was the suggested model for the calorific value response model. Meanwhile, the fourth model i.e. cubic mathematical model was not recommended because the p-value was too large (0.8262), so there was a possibility of 82.62% for the mathematical model not having a significant effect on the response to the calorific value. For the second model selection test on the response of the calorific value was the model inaccuracy test or lack of fit test [16]. The first model i.e. the linear model had a p-value that was greater than the 5% limit, with a value of 0.0557. As for the second model i.e. 2FI model it can be seen that it had a p-value below 5%, with a value of 0.0455, which means that the 2FI model had a significant effect on the inaccuracy of the calorific value response model. The third model i.e. quadratic model with the largest p-value of 0.0749 had a greater value than the value of 5% (0.05), so this made the quadratic model suggested because it has the largest p-value compared to other types of models. For the fourth
model i.e. cubic model, it had the smallest p-value with a value of 0.0204 so it was not recommended to be used as a mathematical modelling of the calorific value response. The third model selection test used was the model summary statistics [15]. The first model was linear with an R-Squared value of 0.0518 and an Adj.R-Squared value of -0.1378. The second model, 2FI, had an R-Squared and Adj.R-Squared values, respectively, 0.09 and -0.2133. In the third model i.e. quadratic model, the R-Squared value was better than the other models with the achievement value of 0.5271 while the Adj.R-Squared value was only 0.1893. It means 52.71% of the variation in the output variable was explained by the input variables, this value is generally considered a moderate effect size. Meanwhile, the fourth type of model, cubic, had an R-Squared and Adj.R-Squared values, respectively, 0.5619 and -0.0515. This cubic model was not recommended to be used as a mathematical model of calorific value. Although the R-Squared value of the cubic was slightly higher than the quadratic, the Adj.R-Squared cubic value was negative, while the quadratic itself was positive. This causes the quadratic model to be suggested to be used compared to the cubic model.

The results of the analysis of the variance on the yield response, the p-value of the yield response model, showed a value of 0.0848 or 8.48% which was above this level (α) 0.05 or 5%. Therefore, it can be concluded that the model had no significant effect. A p-value of less than 0.0500 indicated that the model is significant. Based on the results obtained, it was stated that source B² had a significant effect on yield response. This was indicated by the value of p-value which was below the level of 0.05 or 5% with a value of 0.0112. In addition, it can also be concluded that the lack of fit test on ANOVA response yield showed insignificant results because the p-value was above 0.05 or 5% with a value of 0.1628 or 16.28%. This showed the model was in accordance with the entire design.

From the results obtained it can be concluded that the mathematical modeling of the yield response was obtained by the type of quadratic model in the form of an actual variable (actual coded):

\[ Y_1 = -361.75066 + 298.06346X_1 + 15.36142X_2 + 0.5X_1X_2 - 159.4X_1^2 - 0.14463X_2^2 \]  \hspace{1cm} (1)

Where: \( Y_1 = \) yield response, \( X_1 = \) KOH concentration (% b/v), \( X_2 = \) reaction temperature (°C).

Equation 1 was a second-order polynomial equation that can later be used to determine the yield response value (\( Y_1 \)) based on the independent variable KOH concentration (\( X_1 \)) and reaction temperature (\( X_2 \)). Negative values on the variables \( X_1^2 \) and \( X_2^2 \) showed the maximum quadratic pattern and the parabolic chart that was opening down. While the mathematical model equation with coded variables was as follows:

\[ Y_1 = 211.8 + 1.69A - 0.47B + 1.25AB - 9.96A^2 - 14.46B^2 \]  \hspace{1cm} (2)

Where: \( Y_1 = \) yield response, \( A = \) KOH concentration factor, \( B = \) reaction temperature factor.

ANOVA analysis results for the response of the calorific value showed no significant results on the mathematical model used. Based on the previous fit summary calculations, quadratic modeling was used. The p-value of the model was 0.2856 (28.56%). A value of 0.2856 or 28.56% indicated a difference in results of 28.56% compared to the actual value. The level of significance in this study was 5% (0.05) so that a p-value greater than 0.05 was considered insignificant, where the calculation of the p-value on ANOVA response to the calorific value showed a result of 0.2856 so it was considered insignificant. However, from the results obtained, whether it has a significant or insignificant effect, it does not affect the resulting modelling, because the purpose of this study is not to look for the influence between variables but to model and optimize the input variable on the response variable.

For variable A or KOH concentration, the p-value 0.4279 showed that variable A or KOH concentration did not show a significant effect on the response of the calorific value because the p-value was above 0.05, as well as the variable B or reaction temperature which showed no significant effect on the response of the calorific value. Because the p-value obtained was 0.8152. For the p-value of AB (the
interaction between variables A and B) a value of 0.4766 was obtained. A<sup>2</sup> and B<sup>2</sup> values were 0.3636 and 0.0634, respectively. The lack of fit test on ANOVA showed the value of 0.0749 showed that the results were not significant to the response of the calorific value because it exceeded the significant level of 5% or 0.05.

After calculating the exact mathematical model used to describe the response of the calorific value with various methods in the fit summary of the design expert, the quadratic model was described as the coded factors equation in equation 3 and the actual factors equation in equation 4.

\[
Y_2 = 9589.58 + 136.73 A + 39.43 B + 172.80 AB - 169.33 A^2 + 384.02 B^2 \tag{3}
\]

Where \( Y_2 \) is as a response to the calorific value, while the variable represents the KOH concentration factor and the B variable represents the reaction temperature factor.

\[
Y_2 = 21534.8181 + 2163.7603 X_1 - 487.6002 X_2 + 69.1198 X_1X_2 - 2709.2208 X_1^2 + 3.8402X_2^2 \tag{4}
\]

Where \( Y_2 = \) calorific value, \( X_1 = \) KOH concentration (% w/v), \( X_2 = \) reaction temperature (°C).

The graph of the response surface graph of yield and contour plot can be seen in Figure 1. The response surface graph in Figure 1 shows the shape of the curve that opens downward, besides that the response graph of the yield increased with increasing reaction temperature. Likewise, the concentration of KOH showed an increase in yield response along with the increasing use of KOH base catalyst in the process of making biodiesel. However, the use of excess KOH catalyst as well as a continuous increase in reaction temperature results in a decrease in yield response.

The surface graph of the response to the calorific value to the KOH concentration and the calorific value and contour plot can be seen in Figure 2. From the surface graph, the response of the resulting calorific value was not obtained optimal point because the graph did not form a curve that had a peak point in the middle or commonly called strictly concave. The graph showed the highest calorific value found in the 13<sup>th</sup> experiment (based on run order) i.e. with a variable KOH concentration of 1.25% (w/v) and a reaction temperature of 65 °C, the resulting calorific value was 10407.1 cal/g. While the lowest calorific value was obtained in the 8<sup>th</sup> experiment (based on run order) i.e. with a variable KOH concentration of 0.65% (w/v) and a reaction temperature of 55 °C and the resulting calorific value was only 8701.24 cal/g. Experiments with a variable concentration of 1% (w/v) and a reaction temperature of 55 °C which was a set point for each factor used in the RSM design of this study, only obtained a calorific value that was only in the middle, which was 9217.83 cal/g, 9435.83 cal/g, 9583.56 cal/g, 9812.31 cal/g, 9898.36 cal/g so that the results shown cannot show the optimum point with the strictly concave curve.

\[\text{Figure 1.} \] (a) the surface of the yield response; (b) contour plot of the yield response to the interaction of the KOH concentration factor and the reaction temperature.
Figure 2. (a) the surface response of the calorific value; (b) the contour plot of the calorific value to the interaction of the KOH concentration factor and the reaction temperature.

The calorific value of biodiesel was influenced by several factors including the refining process, the time of manufacture, the source of supply of fuel, and the composition of the fuel. The calorific value of an oil is influenced by the length of the carbon chain of the oil itself. The longer the carbon chain owned by the oil, the greater the calorific value produced, and vice versa the shorter the carbon chain owned by the oil, the smaller the caloric value produced [17].

From the optimization results obtained an optimum point solution by taking into account the constraints that had been set. The KOH concentration variable had an optimum value of 1.08% (w/v) while the reaction temperature had the optimum temperature at the point of 60.11 °C. The yield response was 207.566 ml while the calorific value at the optimum point was 9762.88 cal/g. The desirability value obtained was 0.671 which is still acceptable for biodiesel modeling [18]. Figure 3 with a contour plot graph and response surface graph shows the desirability graph to the optimum point, where the best desirability was obtained at 0.671 with a response surface showing graph that shaped strictly concave facing down with maximum function response obtained one optimum point.

Data validation was the final stage in the RSM optimization process in which a data validation was needed to test the accuracy of the data from the RSM optimization results with data according to the results of experiments in the laboratory [19][20]. The optimum solution given by RSM was a concentration of 1.08% (w/v) and a reaction temperature of 60.11 °C. After conducting experimental testing in the laboratory, the comparison of actual results in the laboratory against the predicted results on the RSM can be compared. From the experimental results obtained the value of each response, for the yield itself the value obtained was 210.90 ml while the calorific value generated was 9864.834 cal/g. When it was compared with the predicted value of the results of RSM optimization, the actual value of the results of the experimental results generated was not significantly proportional. For the yield response, the predicted value was 207.566 ml while the actual value was 210.90 ml and for the response of the calorific value was obtained for the predicted value of 9762.88 cal/g and the actual value was 9864.834 cal/g. The value produced by the actual value against the predicted value cannot be completely the same. The desirability value in the optimum solution was 0.671 (67.1%). Table 2 shows the results of testing the characteristics of biodiesel produced. The test results show several characteristics of the biodiesel produced. The viscosity characteristics of biodiesel produced were 7.356 cst, water content was 5.6%, biodiesel density was 0.864 g/ml, the flashpoint was 135 °C, and the calorific value produced by biodiesel was 9864.834 cal/g. When compared to the biodiesel quality standard, it can be said that there are several characteristics of biodiesel that are in accordance with the standards that have been applied. The density of biodiesel was in accordance with the biodiesel quality standard which is in the range of 850-890 kg/m³, and the resulting flashpoint was also in accordance with the biodiesel quality standard which requires flash point characteristics at a minimum value of 100 °C. The resulting calorific value has exceeded the minimum requirements applied by the biodiesel quality standard, which was 9321 kcal/kg.
Figure 3. (a) contour plot desirability and (b) surface desirability of the optimum point of the KOH concentration variable and reaction temperature to yield and calorific value.

Table 2. Characteristics of biodiesel test results.

| No | Characteristic      | Unit | Results       |
|----|--------------------|------|---------------|
| 1  | Viscosity          | cst  | 7.356         |
| 2  | Water content      | %    | 5.6           |
| 3  | Density            | g/ml | 0.864         |
| 4  | Flash Point        | C    | 135           |
| 5  | Calorific value    | cal/g| 9864.834      |

4. Conclusions
The optimum point produced by RSM was at the KOH concentration of 1.08% (w/v) and the reaction temperature of 60.11 °C with a predicted biodiesel yield value of 207.566 and a calorific value of 9762.88 cal/g and desirability of 0.671 was obtained. The results showed the highest yield was found at 1% KOH concentration (w/v) and the reaction temperature was 55 °C with a yield of 220 ml while the highest calorific value was obtained in the treatment with a 1.25% (w/v) KOH concentration and reaction temperature 65 °C with a result of 10407.1 cal/g. The characteristics of biodiesel produced in the data validation were: 7356 cst viscosity, 5.6% moisture content, density 0.864 g/ml, flash point 135 °C, and calorific value 9864.834 cal/g. In future research, it can be developed to optimize the quality characteristics of biodiesel i.e. viscosity, water content, density, flash point, etc.

References
[1] Khalid A, Suardi M, Chin R Y S, Amirnordin S H 2017 Effect of biodiesel-water-air derived from biodiesel crude palm oil using premix injector and mixture formation in burner combustion Energy Procedia 111 877-884
[2] Maulidiyah, Nurdin M, Fatma F, Natsir M, Wibowo D 2017 Characterization of methyl ester compound of biodiesel from industrial liquid waste of crude palm oil processing Analytical Chemistry Research 12 1-9
[3] Martin P 2006 Biodiesel for the small producer 3rd edition (East Brunswick: Grown Fuel)
[4] Ahmad M, Khan M A, Zafar M, Sultana S 2012 Practical handbook on biodiesel production and properties(Boca Raton: CRC Press) pp 167
[5] Cantu M S, Tellez M M, Diaz L M P, Diaz R Z, Martinez J C H, Ramirez J S 2019 Biodiesel production under mild reaction conditions assisted by high shear mixing Renewable Energy 130 174-181
[6] Roschat W, Phewphing S, Thangthong A, Moonsin P, Yoosuk B, Kaewpuang T, Promarak V 2018 Catalytic performance enhancement of CaO by hydration-dehydration process for biodiesel production at room temperature Energy Conversion and Management 165 1-7
[7] Hendrawan Y, Maharani N S, Argo B D, Wibisono Y 2020 Modeling and optimization of palm oil moisture loss as biodiesel pretreatment. IOP Conf. Ser.: Earth Environ. Sci. 456 012035

[8] Sandra S, Hendrawan Y, Perdana T W, Lutfi M, Argo B D 2020 Modeling and optimization of electrocoagulation voltage and water immersion time on heavy metal reduction in fish International Journal on Advance Science Engineering Information Technology 10 2 2088-5334

[9] Bas D, Ismail H B 2007 Modeling and optimization i: usability of response surface methodology Journal of Food Engineering 78 3 836-845

[10] Hendrawan Y, Sumarlan S H, Argo B D, Kusuma F M 2017 Rancang bangun fungsional alat pervaporasi dan optimasi kadar etanol dengan variable suhu feed dan tekanan pada sisi permeat menggunakan response surface methodology (Functional design of pervaporation unit and ethanol concentration optimization with feed temperature and pressure on the permeate side as variables) Jurnal Keteknikan Pertanian Tropis dan Biosistem 5 2 129-137 [In Indonesian]

[11] Anwar M, Rasul M G, Ashwath N 2018 Production optimization and quality assessment of papaya (Carica papaya) biodiesel with response surface methodology Energy Conversion and Management 156 103-112

[12] Krishnamurthy K N, Sridhara S N, Kumar C S A 2018 Synthesis and optimization of Hydnocarpus wightiana and dairy waste scum as feed stock for biodiesel production by using response surface methodology Energy 153 1073-1086

[13] Caglar A, Sahat T, Cogenli M S, Yurtcan A B, Aktas N, Kivrak H 2018 A novel central composite design based response surface methodology optimization study for the synthesis of Pd/CNT direct formic acid fuel cell anode catalyst International Journal of Hydrogen Energy 43 24 11002-11011

[14] Mukherjee A, Banerjee S, Halder G 2018 Parametric optimization of delignification of rice straw through central composite design approach towards application in grafting Journal of Advance Research 14 11-23

[15] Cukalovic A, Monbaliu J C M, Eeckhout Y, Echim C, Verhe R, Heynderickx G, Stevens C V 2013 Development, optimization and scale-up of biodiesel production from crude palm oil and effective use in developing countries Biomass and Bioenergy 56 62-69

[16] Myers R H, Montgomery D C, Anderson-cook C 2002 Response surface methodology: process and product optimization using designed experiments (USA: Wiley-Interscience Publication)

[17] Oliveira L E, Da Silva M L C 2013 Comparative study of calorific value of rapeseed, soybean, jatropha curcas, and crambe biodiesel International Conference on Renewabele Energy and Power Quality Journal (RE & PQJ)Bilbao, Spain, March 22 11

[18] Bobadilla M C, Lorza R L, Garcia R E, Gomez F S, Gonzalez E P V 2017 An improvement in biodiesel production from waste cooking oil by applying thought multi-response surface methodology using desirability functions Energies 10 1 130

[19] Hendrawan Y, Fauziah T R, Putranto A W, Argo B D 2019 Modeling and optimization of tensile strength of arrowroot bioplastic using response surface method. Int. Conf. on Sustainable Agriculture and Biosystem Universitas Andalas, Padang, Indonesia 12-13 March

[20] Hendrawan Y, Dumayanti R, Khotimah R A H, Wibisono Y, Argo B D 2019 Modeling and optimization of total phenol of tamarillo seed extract using response surface method. Int. Conf. on Sustainable Agriculture and Biosystem Universitas Andalas, Padang, Indonesia 12-13 March