Industria: Jurnal Teknologi dan Manajemen Agroindustri
Volume 9 No 2: 32-40 (2020)

Industria: Jurnal Teknologi dan Manajemen Agroindustri
http://www.industria.ub.ac.id
ISSN 2252-7877 (Print) ISSN 2548-3582 (Online)
https://doi.org/10.21776/ub.industria.2020.009.02.2

The Encapsulation of Noni Fruit using Foam Mat Drying Method

Enkapsulasi Buah Mengkudu dengan Metode Foam Mat Drying

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Received: 17th May, 2019; 1st Revision: 23rd February, 2020; 2nd Revision: 18th June, 2020; Accepted: 18th July, 2020

Abstract

Indonesia is an agrarian country with its extensive production sectors. One of them is of biopharma commodities called noni (Morinda sp.). The production number of noni fruit in 2013 is 8,432,119 kg and 8,577,347 kg in 2014. The research aims to obtain an optimum temperature and concentration of maltodextrin of noni powder making, the optimum total of yield and antioxidant. The powdering process was carried out using Foam Mat Drying. The research employed the Response Surface Method (RSM) with central composite design factorial 22 for optimization. The factors studied were maltodextrin (10%, 15%, and 20%) and temperatures (80, 85, and 90 °C). The results showed that the optimum formula composition specifically is at a temperature of 84.447 °C, and 20% w/w of maltodextrin. Based on the optimum formula, it was predicted that the value of the antioxidant activity was 60.473 mg/ml per 100 mg, and the yield was 22.417%. Hence, it can be concluded that the optimum formula obtained can be used as a model for the making of noni fruit powder.
Keywords: Foam Mat Drying, response surface method, noni powder

Abstrak

Indonesia adalah sebuah negara agraris dan hasil sektor produksi terbesar. Salah satunya dari komoditas Biofarmaka yaitu mengkudu (Morinda sp.). Tanaman mengkudu yang dihasilkan nilai produksinya pada tahun 2013 sebanyak 8.432.119 kg, tahun 2014 sebanyak 8.577.347 kg. Tujuan penelitian ini didapatkan suhu dan konsentrasi maltodekstrin yang tepat pada pembuatan serbuk mengkudu serta didapatkan total rendemen dan antioksidan yang optimal. Metode yang digunakan pada proses pembubukan adalah Foam Mat Drying. *Metode yang digunakan untuk optimasi adalah Metode Permukaan Tanggap (RSM) dengan rancangan komposit terpusat faktorial* 2^2*. faktor yang digunakan adalah maltodekstrin yaitu 10%, 15% dan 20% serta suhu yaitu 80 °C, 85 °C dan 90 °C. Hasil penelitian menunjukkan komposisi formula yang terbaik suhu sebesar 84,447 °C, dan maltodekstrin sebesar 20% b/b. Dapat diprediksikan dari formula optimal tersebut mendapatkan nilai aktivitas antioksidan sebesar 60,473 mg/ml per 100 mg dan rendemen sebesar 22,417%. Disimpulkan bahwa formula optimal yang telah didapatkan dapat digunakan sebagai model untuk pembuatan serbuk dari buah mengkudu.*
Kata kunci: *Foam Mat Drying, Metode Permukaan Tanggap, serbuk mengkudu*

INTRODUCTION

Indonesia is an agrarian country with its extension production sectors; one is of biopharma commodities called noni (*Morinda sp.*). Noni is one of the fruits that provide generous benefits. It is a fruit-bearing tree in *family Rubiaceae*, the varieties have been developed and utilized in Indonesia are *M. citrifolia* and *M. bracteata. M. citrifolia* is extensively known as *mengkudu Bogor* and is widely used as medicine (Winarti, 2005). It is additionally, improves body endurance and metabolism that are beneficial for the health (Bijanti, 2008). The plant's production can be processed into various products and used for sustaining the community economy (Kementerian Perdagangan Republik Indonesia, 2014). The production value of noni in 2013 is 8,432,119 kg and 8,577,347 kg in 2014, increasing by 1.72 % w/w (Badan Pusat Statistik, 2014). The plant plays a stimulus on farmers' economic level due to its easy cultivation and all-year-round fruit character.

The bioactive compounds of noni fruit are vitamin C, B1, B2, B3, B12, alkaloids, anthraquinones, antioxidants, flavonoids, saponins, scopoletin and sugar (Nandhasri et al., 2005). Moreover, secondary metabolites of *Morinda citrifolia* L. extract are ethanol and methanol. They provide steroids, cardiac glycosides, phenols, tannins, terpenoids, alkaloids, carbohydrates, flavonoids, reducing sugars, lipids, and fats of all extract varieties and acidic compounds in liquid extracts as well (Nagalingam, Sasikumar, & Cherian, 2012). Phenolic compounds are also dominant in noni fruit, including damnacanthal, scopoletin, morindone, alizarin, aucubin, rubiadin, and anthraquinone glycosides (Mahanthesh et al., 2013). The fruit, additionally, is used as high blood pressure medicine because it has active ingredients, called scopoletin, which is able to decrease peripheral resistance and the xeronine, that is helpful to increase urine volume, and it is safe to consume because it is categorized as a non-toxic substance (Sari, 2015). It also provides xeronine and proxeronine, various kinds of substances that beneficial for the human body, particularly as medicine for several diseases inter alia, hypertension, diabetes, jaundice, asthma, stomach ache, migraine, fever, cough, and flu or influenza (Fajjriyah, 2017). The substances have been known, but there are several leaving another problem−other component of extract result− and it indeed must be found first its more influential substances.

Nowadays, biopharma plants are popular and attractive for the society because of its herbal medicinal benefits. Its considerable potential is as functional food with various variants or products that positively impact health (Winarti, 2005). The plants can be processed as healthy drinks such as extract, juice, and coffee, which provide benefits for the body. noni based agro-industry opportunities are still wide open in Indonesia. Furthermore, it can be produced through follow-ing sequential steps; the fruits are sorted according to its level of maturity, the ripe ones are chosen, and then stored in an appropriate environment. The final products are then produced. The products can act as a stimulant for farmers' economic sustainability and can be developed to contribute to the national incomes. Recently, awareness of herbal consumption is embedded in society, as the higher growth of the human population, the higher their need for medicines. However, limited knowledge of local plants and fruit processing technologies lead to Indonesia's inability to compete in national or international markets. Besides, in 2018, noni fruit production reached 5,741,585 kg (Badan Pusat Statistik, 2018). That fact, substantively, should encourage society to create innovation regarding noni fruit processing to be further developed.

Foam Mat Drying is a drying method for liquid material and is sensitive to heat through foaming techniques with the addition of foam agents (Asiah, Sembodo, & Prasetyaningum, 2012). As the method applied, the innovation of noni fruit powder can be produced. In the modern era, people tend to choose instant products. Processed fast food in question is food in powder, and it is easily dissolved in water, more practical in presentation, and having a longer shelf life (Mulyani, Yulistiani, & Nopriyanti, 2014). The fruit was diluted in the research, thus becoming liquid and subsequently processed into the most optimum powder and formed into capsules. One of the methods used in determining the optimum value of formula was Response Surface Methodology (RSM), and it was further processed by *Design Expert 10.0.3.0.*

RESEARCH METHODS

Materials and Equipment

The material used in the research was fresh four-month noni fruits. The filling agent was maltodextrin and Tween 80 as a foaming agent. Chemical materials used to analyze are distilled water, methanol p.a. (Merck), DPPH p.a. (Merck), and ethanol 96%.

Types of equipment used for noni powder making are analytical scales (Sartorius), analog scales, fruit racks, fan, dryer blower, fermentation reservoir, spoons, basins, plastic containers, mixer, baking sheets, and cabinet dryer. Further, the types of equipment used for analysis are oven, vaporizer cup, cup clamp, desiccator, spatula spoon, tissue paper, pH meter, beaker glass, drop-per pipette, funnel glass, filter paper, 100 ml pumpkin, Erlenmeyer, measuring cup and blender.

Extraction Process

In the first phase, fruit extraction was con-ducted using the extraction type of maceration. The flow chart of noni extraction can be seen in Figure 1.

Encapsulation Process

The result of the dilution process in the re-search phase I was continued into research phase II, namely the encapsulation process using the Foam Mat Drying method. The research used 0.7% v/w concentration of Tween 80, maltodextrin with 10%; 15%; 20% w/w concentration and drying time for 10 hours, 12 hours, and 14 hours. Figure 2 presented the flow chart of the powder making.

Optimization Process

Laboratory. Furthermore, Response Surface Methodology with central composite design factorial 22 (CCD) was used to optimize noni powder. Two factors provided in the research, temperature (X1) of 80°C, 85°C, 90°C, and maltodextrin concentration (X2) of 10%, 15%, 20% w/w. On those factors, it was formed codes (-1.414, -1, 0, +1, +1.414) where -1 as a minimum value, 0 as middle value and +1 as maximum value of the factor. The values of -1.414 and +1.414 are a result of a comparison between those factors. Factors have been studied, and each level is presented in Table 1. The tests performed were yield analysis and antioxidant.

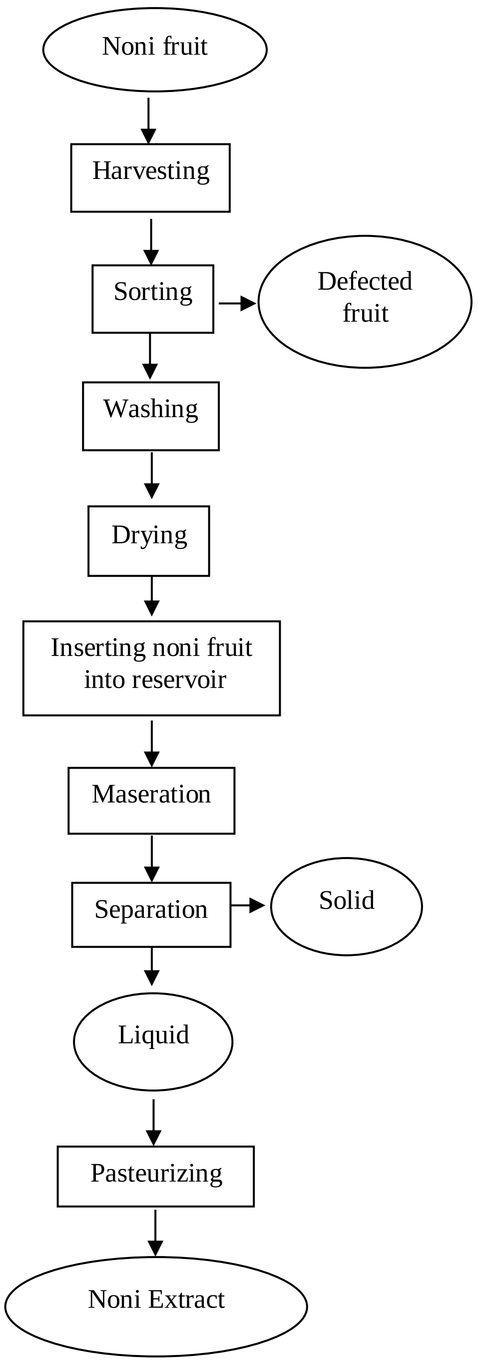

Figure 1. Flow Chart of Noni Liquid Making

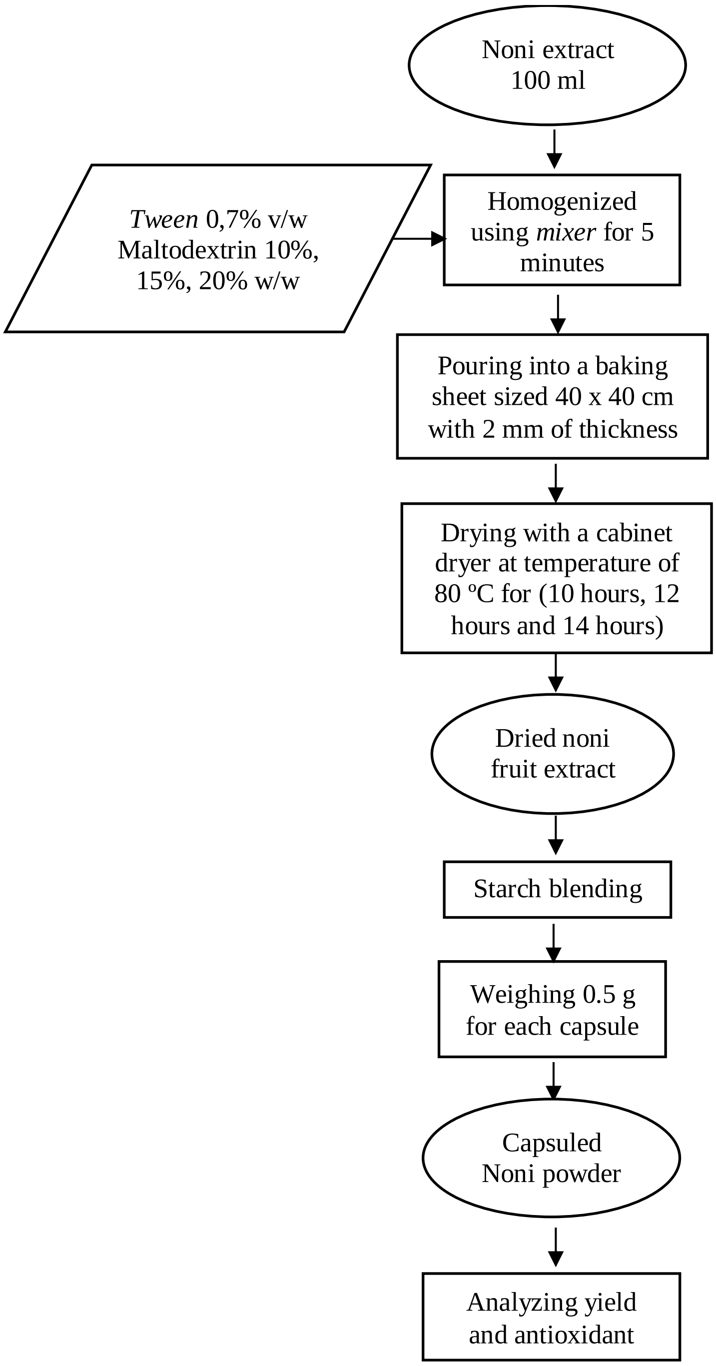

Figure 2. Flow Chart of Noni Powder Making

Table 1. Factors and levels studied in research

Factor	Unit	Lower limit (-1)	Upper limit (1)
Temperature	°C	80	90
Maltodextrin	% w/w	10	20

Table 2. Matrix of central composite design in experimental design

Code				Actual	
Std	Run	X_1	X_2	Temperature	Maltodextrin
9	1	1	-1	85.00	15.00
6	2	0	0	92.07	15.00
10	3	-1	-1	85.00	15.00
3	4	1	1	80.00	20.00
11	5	-1.41	0	85.00	15.00
7	6	0	1.41	85.00	7.93
4	7	0	0	90.00	20.00
8	8	0	0	85.00	22.07
1	9	0	0	80.00	10.00
2	10	0	0	90.00	10.00
12	11	-1	1	85.00	15.00
13	12	1.41	0	85.00	15.00
5	13	0	-1	77.93	15.00

There are 13 treatments in the research; each treatment was based on CCD's experimental design shown in Table 2. Once the optimum formula of the best noni powder was generated, the verification was conducted to determine whether the model suggested by the *Design Expert 10.0.3.0* program can predict response value accurately. The verification, moreover, seeks to assess the accuracy of the model in the real application.

RESULTS AND DISCUSSION

Analysis of RSM (*Response Surface Methodology*) Results

Analysis of Antioxidant Activity Response

The antioxidant is an important compound to maintain a healthy body due to its function as a free-radical catcher. It furthermore is a compound to slow down the oxidation process (Hanani, Mun'im, & Sekarini, 2005). The value of noni powder's antioxidant activity is greatly influenced by the phenolic component and vitamin C contained in the powder. The phenolic component is a simple phenol, including flavonoids, anthocyanins, and tannins that act as major antioxidants in complex phytochemicals that protect against the attack of dangerous reactive oxygen species (Antolovich et al., 2002; Sarikurkcu et al., 2009). The range value of noni powder's antioxidant activity is about 55.31-63.56 mg/ml per 100 mg of powder. The mathematical equation for the response of antioxidant activity is as follows:

Antioxidant Activity (mg/ml) = 61.09 – 0.68*A – 0.88*B + 0.79*A*B - 3.29*(A^2) + 0.32*(B^2)

Information:

A * Temperature B * Maltodextrin

The R^2 value of the response model of antioxidant activity is 0.8619. It means that the effect of temperature and maltodextrin concentration factors on noni powder's antioxidant activity response is 86.19% w/v, and the rest 13.81% w/v was influenced by other factors namely drying time. The value of predicted R-squared resulted is 0.2542, and the value of the adjusted R-squared is 0.7632. It shows the predicted data and actual data were encompassed into a model of 25.42% w/v and 76.32% w/v. Predicted R-squared value supported adjusted R-squared value because the difference between those values is 0.2. Adequate precision of antioxidant activity response is 9.569, which showed the magnitude of the signal to noise ratio. An adequate precision value, which is higher than 4, indicates adequate signal, so this model can use as design space guidelines and fulfilled the requirements as a fine model to make a prediction (Kurnia, Yasni, & Nurtama, 2013).

The value of low antioxidant activity was shown in the blue area of 55.31, while high

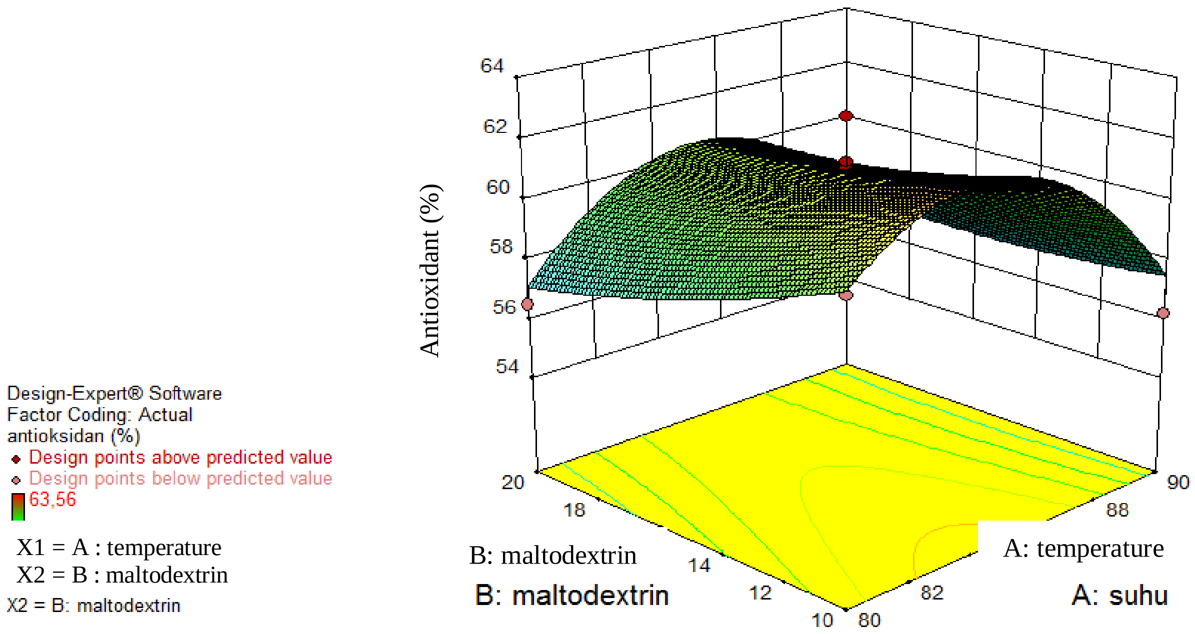

Figure 3. The Response of Noni Powder Antioxidant Activity Based on Temperature and Maltodextrin Concentration

antioxidant activity was shown in the red area of 63.56. There are several different colors on the graphs model, such as the red color that showed the highest value, yellow showed the middle value, and blue showed the lowest value. Figure 3 regard-ing the design expert dimension formed a parabola shape. The initial (low) point of re-sponse showed low antioxidant activity. It then curved upward to the optimum point of response. It curved downward means response of antioxidant activity was decreased, so as the temperature increases, the response will be decreased again. The proportion of temperature and concentration of maltodextrin both significantly influence the antioxidant value of noni powder. The higher the temperature and the concentration of maltodextrin applied in the manufacturing of noni fruit powder, the lower the antioxidant value gained. It is because antioxidants can be released when proteins are digested by enzymes, while proteins are damaged due to high temperatures. Thus, the third fraction increased as the increase of temperature so that some antioxidant groups were deteriorated (Hao et al., 2019).

Analysis of Yield Response

The economic value of a product can be affected by yield obtained through powder making. The more yield obtained, the better it is. Yield is a comparison between product weight and raw material used (Rahman, 2018). Yield, furthermore, can be acquired by dividing powder weight after blending and liquid before drying. The range value of the yield obtained was 17-23%. The mathemat-ical equation of response of antioxidant activity is as follows.

Yield (%) = 21.20 – 1.21* A + 1.38*B + 0*A*B – 1.04*(A^2) - 0.29*(B^2)
Information:
A * Temperature
B * Maltodextrin

Different colors in the graph (Figure 4) showed different response values of each combination between factor components. The low value of yield is shown in the blue area of 7% w/v. On the contrary, the red area showed a high value of 23% w/v. In the graph model, several colors such as red color showed the highest value; yellow showed the middle value, and blue showed the lowest value. Figure 3 regarding the design expert dimension formed parabola shape. It means that the initial (low) point of response showed low antioxidant activity, then it curved upward it is the optimum point of response, and it curved downward means response of antioxidant activity was decreased so as it formed parabola. The temperature and concentration of maltodextrin both have a significant influence on the antioxidant value of noni powder. Based on further analysis, the factor tended towards the change of yield value the most was maltodextrin. The higher the proportion of maltodextrin concentration added in noni fruit powder production, the more considerable increase of yield. It is because of the increase of monosaccharide as the substrate in mixing maltodextrin and liquid. In maltodextrin spectrum oligosaccharides, moreover, the proportion of monosaccharides is increased when DE value increased as well (Pycia et al., 2016).

Verification of the Optimum Condition of Model Prediction Result

The solution to the optimum formula of noni powder based on data processing is provided in Table 3. The result showed that two responses have the same desirability value of 0.752. The formula has been obtained through the *Design Expert 10.0.3.0* application, hence, a solution. Compositions of the formula, namely temperature of 84.447 and 20% of maltodextrin composition, showed a desirability value of 0.752. The optimum formula mentioned was predicted to possess the value of the antioxidant activity of 60.473 mg/ml per 100 mg and yield of 22.417%.

Desirability value is immensely influenced by component complexity regarding; its range, number, response, and target to be achieved in acquiring optimum formula. The complexity of components was described by raw material number requirement, which is considered essential and influences the product. The different ranges used in each component affected the desirability value. Thus, the wider the ranges used, the more challenging to get an optimum formula with a high value of desirability. Desirability is furthermore a function that can apply for the most optimum experimental condition (Leardi, 2009; Caldas et al., 2011). The optimum formula of selected noni powder further was verified to find out whether the suggested model by Design Expert 10.0.3.0 program can predict response value accurately. Based on the results of verification, it was obtained that the selected formula generated a value of the antioxidant activity of 63.477 mg/ml per 100 mg, and a yield of 22.828%. The actual values of the calculation and prediction results are presented in Table 4.

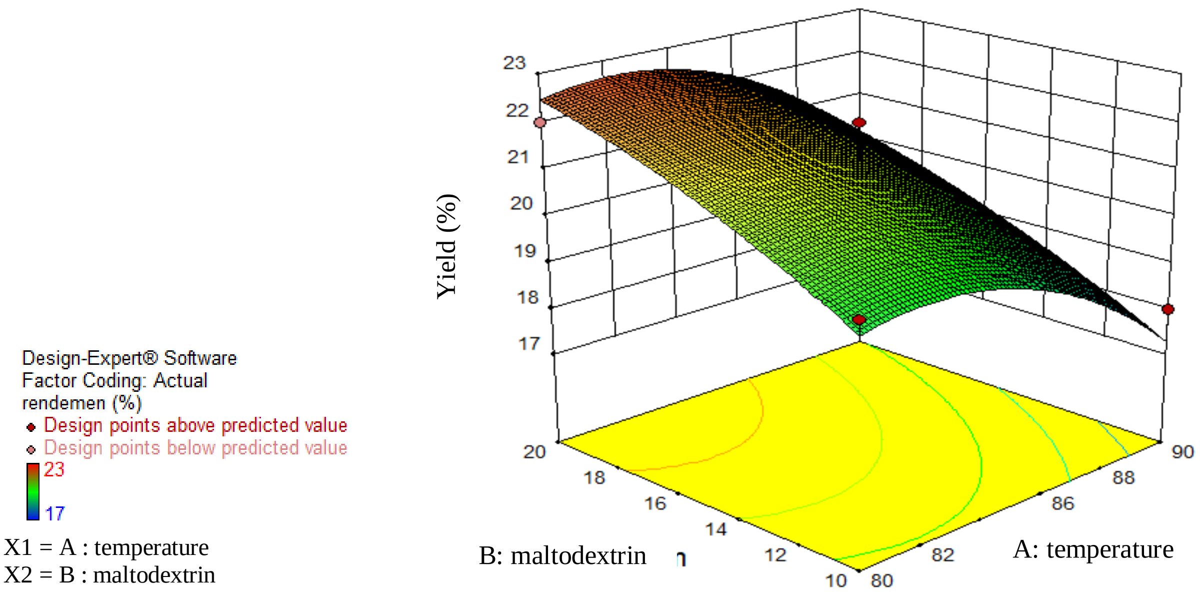

Figure 4. Yield response of noni powder based on temperature and maltodextrin concentration

Table 3. Solution on the optimum formula obtained through optimization results

No	Temperature	Maltodextrin	Antioxidant Activity	Yield	Desirability	
1	84.447	20% w/w	60.473 mg/ml	22.417%	0.752	Selected

Table 4. The comparison between actual response measurement and prediction value of selected noni powder

Response	Prediction	Verification	95% CI		95% PI	
			Low	High	low	High
Antioxidant activity	60.4639	63.477	58.6789	62.2489	52.3317	68.5961
Yield	22.4267	22.828	21.6977	23.1556	19.1056	25.7478

The verification results showed that the response value of antioxidant activity had met the value of *Confident Interval (CI). T*he total phenol response and the yield have met the value of *Prediction Interval (PI)* that has been predicted by *Design Expert 10.10. Confident Interval* (CI), moreover, is a range that shows the average expectations of the measurement results at a certain significance level of 5%. *Prediction Interval* (PI), on the other hand, is a range that shows an expectation of future or further response measurement result with the same condition at a significance level of 5% (Lins et al., 2015). Accordingly, the optimization of the use of temperature and maltodextrin in the noni powder-making has been verified with an antioxidant activity value of 63.477 mg/ml and a yield of 22.4267% w/v.

Production Capacity

In this research, the Foam Mat Drying method was used in the drying process. It is a process where liquid compound or half solid formed into stable foam by adding plenty of air volume or other gases of a foaming agent as a foam inducer or stabilizer. Further, Cabinet Dryer is a drying tool used in the method (for fruit drying). It has advantages due to its simple structure, low installation cost, and usable in all environmental conditions. In a conventional cabinet dryer, hot air is usually inserted under the first tray (lower tray) then normally is continued to other trays.

Dryers used in the research are available in the Entrepreneurship Laboratory of Faculty of Agricultural Technology. The maximum temperature can be used for cabinet dryer is 1000 C. Inside this equipment, there are ten levels of baking tray placement. The calculation of the production capacity of noni powder using the tool is as follows.

Initial weight of liquid = 120.84 g
Final weight = 20 g
Yield = 22.417%
Cabinet Dryer
1 Tre (3 baking sheets) = 3 x 20 g
= 60 g
10 racks = 10 x 60 g
= 600 g
If encapsulated = 600 g : 0.5 g
= 1,200 capsules (1x Production)
1 day (2x production) = 2 x 1,200
= 2,400 capsules (1 day)

Based on the above calculation, it is known that the initial weight before drying 120.84 g then became 20 g after drying and yield value of 22.417%. These results were obtained from a baking sheet sized 40 x 40 cm. Cabinet dryer used in the powder-making process contained several racks (baking sheet placement). The capacity of 1 rack is for three baking sheets so that the powder weight gained 60 g for one rack. Moreover, the cabinet dryer consists of 10 racks, so the total powder obtained of the tool was 600 g. If a capsule is filled ± 0.5 g, thus it will produce 1.200 capsules. The calculation above is for one production, and if the production process is twice a day, then, 2.400 capsules will be produced.

CONCLUSION

The study suggested the optimum drying temperature of 85 ^{o}C and maltodextrin concentration of 15% w/w with a desirability value of 0.752. According to the formula mentioned, it is predicted to acquire the value of the antioxidant activity of 60.4639% mg/ml and the yield of 22.4267% w/v. hence it is optimum for noni capsule materials, based on the best formula verification. The best formula obtained 63.477% mg/ml of antioxidant activity and as well of 22.828% w/v yield. In mass balance, the initial weight of noni fruit liquid was 200 g. After the drying process, its final weight became 20 g, so that the yield of the powder was 22.417% w/v. Moreover, in a drying process, the drying rate initially of 682.162% bk/hour, then it is reduced successively of 51.81022% bk/hour until the final rate of 1.390404% bk/hour. The total powder gained from the cabinet dryer was 600 g, and if the noni powder of 0.5 g is filled into a capsule, it will obtain 1,200 capsules. Hence, the calculation mentioned is for one production process, and if it is conducted twice a day, it will produce 2,400 capsules.

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