

Drying kinetics of modification cassava-seaweed noodles using an oven

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ABSTRACT

Consumption of noodles in the world is always increasing. Noodles made from wheat flour are unhealthy because they cause diabetes, so alternative noodles are needed, such as modified cassava flour and seaweed. Modification cassava is used because it does not contain gluten and seaweed has nutritional value to make healthy, low-calorie noodles. The purpose of this study was to determine the temperature and time of the drying parameters of seaweed noodles. The drying method uses an oven with variable temperature (60, 70, 80, and 90 °C) and drying time (2, 4, 6, 8, and 10 hours). The results of the study obtained optimal water content at 60 °C with 6 hours of 11.75%. The drying kinetics evaluated by logarithmic equation, optimal drying constant value at 80 °C of 0.67 h⁻¹ with R² 0.9391. Effective moisture diffusivity (D_{eff}) maximum evaluated by second Fick law obtained 9.35×10⁷ m²/sec at temperature 90 °C with R²=0.9227. The proximate value of ash content is 12.11%, protein is 9.46%, lipid is 0.10%, and carbohydrates is 65.08%.

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1. INTRODUCTION

Noodles are one of the most widely consumed types of food by all people in the world. In this era of modernization, there have been many changes in human behavior in fulfilling their wants and needs. Increased activity from the bustle of society, causes people to need a product that is practical to consume when served. Community mobility has caused people to no longer use rice as the main source of carbohydrates, but instant noodles which are practically the main source of carbohydrates.

World Instant Noodles Association (WINA), instant noodle consumption in Indonesia is 13.27 billion servings in 2021. This number is the second largest after China/Hong Kong with an instant noodle consumption of 43.99 billion servings in 2021, Vietnam is in third place with an instant noodle consumption of 8.56 billion servings. Then, consumption of instant noodles in India amounted to 7.56 billion servings. Consumption of instant noodles in Japan was recorded at 5.85 billion servings. Meanwhile, consumption of instant noodles in the United States was reported at 4.98 billion servings. The Philippines is a country that consumes a lot of instant noodles, reaching 4.44 billion servings. Meanwhile, South Korea is in eighth position with instant noodle consumption of 3.79 billion servings [1], [2].

Wheat flour is the main raw material for making noodles. Wheat flour contains gluten which can increase blood sugar levels, causing various diseases if consumed in excess. Modified cassava flour can be

used as an alternative to wheat flour. Modified cassava flour is flour made from 100% cassava which is soaked using organic enzymes or through a fermentation process with enzymes without additives and produces gluten-free flour. The addition of seaweed will further add to the nutritional content of the resulting noodles. Seaweed is useful as an antioxidant, anti-inflammatory, anti-diabetic, and anti-cancer [3]. The advantage of seaweed in terms of processing is that it is very easy and simple to do on a household scale. The benefits of consuming seaweed are: a source of nutrition, diet, improving digestion, healing wounds, minimizing cancer cells, skin detox, and preventing premature aging, while the disadvantages of seaweed itself are: contact dermatitis, digestive tract disorders, goiter, cholera, and inflammation. The Indonesian National Standard (SNI) for seaweed 8169:2015 defines seaweed as dried seaweed that has been refined.

The process of making noodles includes making noodle dough and drying it. The process of drying noodles can be done using various methods [4], including traditional drying using the sun [5], [6], frying and roasting using an oven. Baking with an oven is considered healthier and more hygienic. Several studies on making noodles have been carried out, including making noodles using rice flour as raw material [7]. Noodle made from orange sweet potato [8], Bambara wheat protein [9]. Previous studies have discussed the characteristics, physicochemical properties [10], and nutritional content of noodles, there has been no discussion regarding the drying kinetic of modification cassava-seaweed noodles. The drying process of noodles is interesting to study because it determines the durability and quality parameters of noodles such as nutritional content.

2. RESEARCH METHOD

2.1. Noodle making

The making of dry noodles begins with making 100 grams of seaweed gel which has been made into a gel. The composition for each dough is modified cassava flour and flour by a ratio of 10:140 grams; 20:130 grams; 30:120 grams; 40:110 grams; and 50:100 grams. The addition of additional noodle ingredients, namely 2% salt and 1% carboxy methyl cellulose (CMC) from the weight of the noodles which have been mixed with the basic ingredients of 250 grams and divided into 4 parts as much as 50 grams of the flour weight which is put into the dough and stirred until smooth. The smooth dough was left for 10 minutes and then printed with a weight of 50 grams.

2.2. Drying

Noodles were dried with a long drying time using an oven consisting of four levels: 2 hours (L1); 4 hours (L2); 6 hours (L3); 8 hours (L4); and 10 hours (L5), for drying temperature (S) consisting of four levels: 60 °C (S); 70 °C (S2); 80 °C (S3); and 90 °C (S4). The dried noodles are then stored in a closed place.

3. ANALYSIS

3.1. Calculation of water content

Noodles are dried at 60 °C (S1); 70 °C (S2); 80 °C (S3); and 90 °C (S4), until constant noodle weight. 2 hours intervals (L1); 4 hours (L2); 6 hours (L3); 8 hours (L4); and 10 hours (L5) using the oven. The noodles were weighed to determine the weight loss of the ingredients. The decrease in water content is calculated by (1) [11]:

$$\text{Moisture content \%} = \frac{(\text{Initial weight} - \text{final weight})}{\text{initial weight}} \times 100\% \quad (1)$$

3.2. Noodle surface area calculation

Dry noodles that will be formed in the form of cubes and long blocks with the formula used are:

- Cube

$$L = s \times s \quad (2)$$

where L is the surface area of dry noodles (m²) and s is the square side of dry noodles (m).

- Blocks

$$L = 2 \times ((p \times l) \times (p \times t) \times (l \times t)) \quad (3)$$

where L is the surface area of dry noodles (m²), p is the length of the dry noodle surface (m), l is the width of the noodle surface (m), and t is the height of the noodle surface (m).

3.3. Calculation of drying kinetic constants

Several conventional drying models have been proposed to determine the moisture ratio as a function of time. In this study, the logarithmic model was used (4) [11]:

$$MR = A(e \times p - kt) + B \quad (4)$$

where M_R is moisture ratio, k is constant (1/h), t is time (h), and A and B are constants.

Moisture ratio (M_R) formula in (5):

$$M_R = \frac{M_t - M_e}{M_i - M_e} \quad (5)$$

According to Afifah *et al* [11], the equilibrium moisture content (M_E) is relatively small compared to the initial moisture content (M_I), especially for far infrared drying. So that the moisture ratio (M_R) can be simplified to M_T/M_I .

3.4. Calculation of the diffusivity coefficient of solids (D_{eff})

In drying, diffusivity is used to indicate the flow of the water content of the material. In the falling rate period, the reduction in water content is controlled mainly by molecular diffusion. The effective diffusivity coefficient is determined by adjusting the mathematical model for fluid diffusion according to the second Fick law (6) to (9) assuming the geometric shape is a slab, the water content only migrates by diffusion, ignoring volumetric shrinkage, constant temperature, and long drying time. For long drying times, (7) can be simplified into (8) where this equation can be rearranged into (9). From (9), plotting in a graph of value ($\ln M_R$) versus time will produce a straight line with slope [11].

$$\frac{\partial M}{\partial t} = M \cdot \nabla^2 \cdot D_{eff} \quad (6)$$

$$M_R = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)} \exp\left(-\frac{(2n+1)^2 \pi^2 D_{eff} t}{4L^2}\right) \quad (7)$$

$$M_R = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 D_{eff} t}{4L^2}\right) \quad (8)$$

$$\ln M_R = \ln \frac{8}{\pi^2} - \left(\frac{\pi^2 D_{eff}}{4L^2}\right) t \quad (9)$$

3.5. Proximate analysis

Proximate analysis classifies food ingredients according to chemical composition, namely total water content, total ash content, total crude protein content, and total crude fat content [12]. Proximate analysis, as a general method for determining the chemical composition of food ingredients, does not require sophisticated testing techniques, provides rough analysis results, and can calculate the total digestible nutrient (TDN) value. TDN has several advantages, such as providing a general rating for food. Proximate analysis also has several drawbacks, such as the inability to accurately produce the concentrations of chemical compositions and the inability to calculate the digestibility and texture of food components.

4. RESULTS AND DISCUSSION

4.1. Moisture content

Determination of water content in dry noodles by drying method using an oven within 2, 4, 6, 8, and 10 hours and temperatures 60, 70, 80, and 90 °C is presented in Table 1. Based on Table 1, the results of the analysis of the water content of dry noodles obtained an average moisture content ranging from 11.75-13.33% from a temperature of 60 °C at 4 and 6 hours, then at a temperature of 70 °C the results obtained a water content of 11.86-12.43% of the 4 and 6 hours. Then the temperature of 80 °C resulted in a moisture content of 12.94%-10.42% for 2 and 4 hours. For a temperature of 90 °C, the water content requirements at 6 °C (8.95%) are met according to SNI 8217:2015 concerning the moisture content of dry noodles, namely 8%-13%. So, it can be concluded that the water content at the drying temperature is 60 and 70 °C at 4 and 6 hours, the temperature is 80 °C at 2 and 4 hours, and the temperature is 90 °C at 6 hours which fulfills the water content requirements according to SNI 8217:2015, namely 8-13%. In general, the greater the difference between the drying medium and the food, the faster the heat transfer to the food and the faster the evaporation of water from the food, so high-temperature air takes water from food more quickly so that the drying process is faster [13].

In previous research, drying white noodles at a temperature of 50 °C using zeolite resulted in 13.7% moisture content within 90 minutes [4]. In this research, within 2 hours (120 minutes) without zeolite at a temperature of 60 °C can provide a moisture content average of 19%. Research by Engelen *et al.* [14] made dry noodles from modified cassava and starch, with a moisture content range of 7.35-9.81% at 4 hours and a temperature of 105 °C. This research at 4 hours and a temperature of 90 °C can obtain a moisture content of 6.11%. The higher temperature can break the nutrition in noodles. The factors that affect the decrease in the moisture content of dry noodles are temperature and humidity in the oven, temperature and air pressure in the oven chamber, the size and structure of the noodle particles, and the shape of the noodle container [15], [16].

Table 1. Moisture content in noodles drying using an oven

Time (h)	Temperature (°C)				Standard
	60	70	80	90	
2	24.61	24.08	12.94	17.25	
4	13.33	11.86	10.42	6.11	
6	11.75	12.43	5.73	8.95	8-13%
8	7.56	6.81	2.98	2.32	
10	6.04	4.58	0.75	0.78	

4.2. Drying kinetics

Moisture ratio (M_R) MR can be calculated by comparison of MI and MT. MI and MT data can be seen in Table 2. The drying constant (k) value using the moisture ratio (M_R) at 60 °C can be obtained graphically in Figure 1. Based on the graphical results of the drying kinetics and the constants in Figure 1, the effective diffusivity coefficient at 60 °C is obtained by the value of R^2 (coefficient of determination)=0.8858 while the equation of the line $y=-0.0704x+0.825$. From the linear equation, the value of k is -1.11 h^{-1} . Using the same calculation, Table 3 is obtained. Based on Table 3 constant values and logarithmic model parameters above, the results of constant values, M_R values, and R^2 (coefficient of determination) values and it can be seen that at each temperature the k value increases, this identifies the magnitude of the decrease in water content at the beginning of drying due to the high free water content in the material that moves to the surface and undergoes evaporation. However, the longer the time, the greater the effect on decreasing the drying rate. This is because what remains is bound water which is difficult to diffuse to the surface. The value of k will also affect the quality of the product that has been dried, because there are various accompanying phenomena, including heat transfer and reduced size due to reduced moisture content [11]. The optimum k value in this study using the logarithmic method was produced at a temperature of 80 °C of -0.69 h^{-1} with R^2 0.9391. In research conducted by Suprapti [16] drying noodles with corn and wheat flour at 70 °C has a k value of 0.1218, which is faster than other temperatures.

Table 2. Data moisture initial and final at various temperature

Time (h)	Temperature (°C)							
	60		70		80		90	
	MI	MT	MI	MT	MI	MT	MI	MT
2	0.32	0.25	0.33	0.24	0.22	0.13	0.27	0.17
4	0.31	0.13	0.31	0.12	0.32	0.10	0.35	0.06
6	0.30	0.12	0.32	0.12	0.27	0.06	0.43	0.09
8	0.34	0.08	0.34	0.07	0.31	0.03	0.37	0.02
10	0.34	0.06	0.35	0.05	0.35	0.01	0.40	0.01

Table 3. Constanta drying kinetic value by logarithmic equation

Temperature (°C)	Constanta (k) (h^{-1})	R^2	Logarithmic equation
60	-1.11	0.8858	$M_R=A \exp (1.11 t)+B$
70	-1.03	0.8837	$M_R=A \exp (1.03 t)+B$
80	-0.69	0.9391	$M_R=A \exp (0.69 t)+B$
90	#NUM	0.7531	-

4.3. Effective moisture diffusivity

Several conventional drying models have been proposed to determine the moisture ratio (M_R) relationship as a function of the characteristic drying time of the noodles, for each initial moisture content

(M_i) the initial weight is 50 grams. The calculation of effective moisture diffusivity (D_{eff}) describes the migration or diffusion of water in dry noodle products during drying operations which is a function of water content, temperature, and material structure. The effective moisture diffusivity value for a temperature of 60 °C can be obtained from Figure 2. Based on Figure 2, D_{eff} value at 60 °C was obtained by substituting (8) and (9) with the linear algebraic equations on the graph obtained, resulting in a D_{eff} value of 4.20 m²/second. The R^2 value generated in graph 2 is 0.9617.

Using the same calculation method, data obtained from the results of the D_{eff} value and the R^2 value for other temperatures is shown in Table 4. Based on Table 4, shows that the higher the D_{eff} value obtained, the greater the drying speed resulting from the drying process of dry modification cassava seaweed noodles. Factors that influence the results of the D_{eff} value at each temperature are temperature and humidity in the oven, temperature and air pressure in the oven chamber, the size and structure of the noodle particles, and the shape of the noodle container.

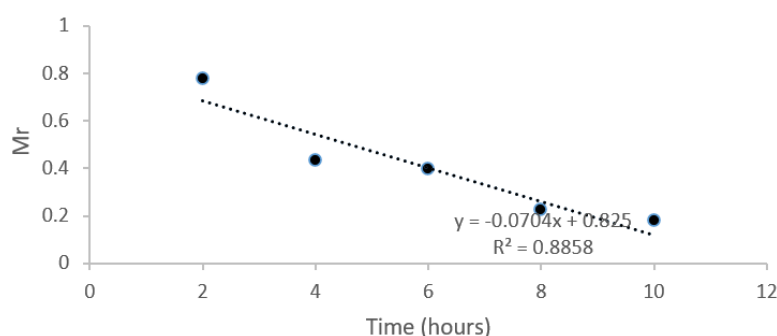


Figure 1. Moisture ratio experiment data and model logarithmic equipment

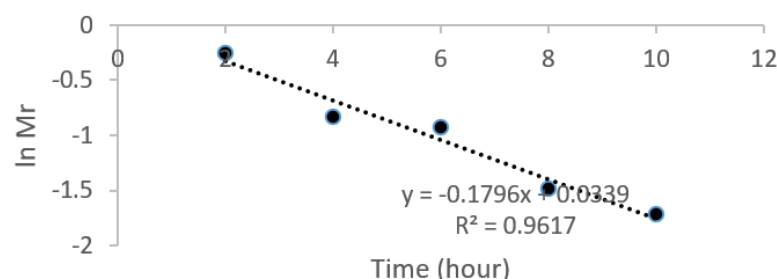


Figure 2. Effective moisture diffusivity

Table 4. Effective moisture diffusivity at various temperature

Temperature (°C)	$D_{eff} \times 10^7$ (m ² /sec)	R^2
60	4.20	0.9617
70	4.77	0.9507
80	9.17	0.9381
90	9.35	0.9227

4.3.1. Proximate analysis

Seaweed dry noodles are made from modified cassava flour with wheat flour which has been made into dry noodle products. Furthermore, it is analyzed based on analysis including the proximate test. The proximate test is a method of chemical analysis to identify the nutritional content such as protein, carbohydrates, fats, and fiber in a food substance from feed or food ingredients. Samples with optimum moisture content, namely at 60 °C, drying for 4 hours were used for the proximate test. This is because the temperature of 60 °C is still a safe range for drying food ingredients, and the water content obtained is by SNI standards. The results of the dry noodle proximate test can be seen in Table 5.

Based on the proximate test results of dried seaweed noodles made from modified cassava flour and wheat flour, for the analysis of dry noodles. Analysis of the ash content according to SNI for the maximum

quality of dry noodles is 3% in this study, the ash content of dried seaweed noodles made from modification cassava flour and wheat flour is 12.11%. According to Supraptiah *et al.* [16], the results of the ash content obtained were 1.78%. These results indicate that the results of the analysis of ash content in this study are greater than the SNI No. 01-2974-1996. Seaweed dry noodles made from modified cassava flour and wheat flour are noodles that do not meet the quality of the results of the analysis of ash content.

Furthermore, for analysis of total protein content according to SNI, the quality of dry noodles is at least 8% of the results obtained for seaweed noodles made from modification cassava flour and wheat flour of 9.46%. According to Supraptiah *et al.* [16], the results of the analysis of protein levels obtained were 10.7232%. Thus, the protein content produced in this study meets the value of SNI 8217: 2015. Therefore, it was found that noodles made from modified cassava flour and wheat flour were noodles with quality that met the analysis of total protein content.

For analysis of the fat content, the value produced for seaweed noodles made from modified cassava flour and wheat flour is 11.8%, while it is known that the fat content in dry noodles is 0.03%. Thus, the fat content produced in this study meets the nutritional value of 2022. Therefore, the noodles made from modified cassava flour and wheat flour are noodles with nutritional value quality that meets the fat content. Previous research from Ismail *et al.* [17] reported that treatment drying can decrease fat content. Furthermore, for the analysis of the carbohydrate content obtained in seaweed noodles made from modification cassava flour and wheat flour of 65.08%, while it is known that the carbohydrate value of the total energy consumption is 77.73-77.04% [18], [19]. Based on the nutritional value results for 2022, 50% is produced in carbohydrates for dry noodles.

Previous research reported that treatment or substitution noodles can affect protein, lipid/fat decrease, meanwhile ash content, and carbohydrate increase. The result can be attributed to the absorption of moisture during noodle drying, a phase in noodle processing that helped to trap water in the noodle structure. It is also interesting to note that there is an increase in ash content with an increase in the inclusion of the protein isolates. This may be a result of high mineral content especially the macro mineral present in modification cassava-seaweed isolate [4], [9], [20]–[26].

Table 5. Proximate test results on dry noodles

Parameter	Result	Standard
Ash content (%wb)	12.11	3% ^a
Total protein, Fk=6.25 (%wb)	9.46	8–10% ^a
Lipid (%wb)	0.10	11.8% ^b
Carbohydrates (%wb)	65.08	50% ^b

*Notes: a is the SNI standard (SNI 8217:2015) and b is the nutrition food standard (Ministry of Health Republic of Indonesia, 2014)

5. CONCLUSION

Based on research on dry seaweed noodles from modified cassava flour and wheat flour, it can be concluded that temperature and time affect a decrease in water content, drying speed, and drying constant. Optimal water content analysis results at 60 °C at 6 hours of 11.75%. The drying kinetics evaluated by logarithmic equation, optimal drying constant value at 80 °C was -0.69 h^{-1} with $R^2 0.9391$. Effective moisture diffusivity maximum evaluated by second fick law obtained $9.35 \times 10^7 \text{ m}^2/\text{sec}$ at temperature 80 °C with $R^2=0.9227$. The proximate value of ash content is 12.11%, protein is 9.46%, lipid is 0.10% and carbohydrates is 65.08%.

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