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Optimization of the manufacturing process of fried instant corn noodles using response surface methodology

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Instant corn noodles can be manufactured using the air drying and frying process. This study aimed to determine the optimum process parameters and emulsifier concentration to produce instant corn noodles from 100% corn flour with relatively good quality characteristics using a cooking-forming single screw extruder. This study consisted of two stages, namely the determination of corn noodles with the fastest cooking time using emulsifier concentrations of 0, 0.5, 1, and 1.5% from the weight of corn flour, as well as the optimization of the manufacturing process using Response Surface Methodology. Wet corn noodles were dried using dry air at room temperature and fried using deep fat frying. The results showed that the dry corn noodle with a 1% emulsifier has the fastest cooking time of 6.1 minutes to reach the optimum cooking level. The optimum process combination was a drying time of 0 minutes and a frying process at 115 °C for 10 minutes. The verification of this process showed that instant corn noodles' water content, cooking loss, and elongation percentage were 13.32%, 10.50%, and 127.48%, respectively, in a 95% confidence interval. In addition, the cooking time of these optimized instant corn noodles was 6.8 minutes.

1. Introduction

The development of non-wheat-based noodles such as rice (Charutigon et al., 2007), sago (Engelen et al., 2017), sorghum (Suhendro et al., 2000), and corn (Muhandri et al., 2011; Aminullah et al., 2019) noodles have been conducted by researchers. Muhandri et al. (2011) explained that corn noodle manufacturing to form sturdy structures relied on gelatinization, flour granule rupture, and retrogradation mechanisms. Corn noodles manufacturing, both in the form of wet and dry noodles, can be conducted using the extrusion method (Muhandri et al., 2011; Waniska et al., 1999; Subarna et al., 2012), as well as a combination method of calendering and extrusion (Subarna & Muhandri, 2013; Kusnandar et al., 2009). The dehydration process in noodles can be done using drying and frying processes that produce dried and fried instant noodles, respectively (Gatade & Sahoo, 2015). Dried instant corn noodles were developed using a fluidized bed dryer (Muhandri et al., 2019) and a tray dryer (Subarna and Muhandri (2013). Several materials were related to fried instant corn noodles, such as high-protein corn flour (Kalsum & Nirmagustina, 2009), local cornflour and sago starch (Ali et al., 2018), and resistant corn starch and green banana flour (Vernaza & Chang 2017). Olorunsogo et al. (2019) produced a noodle from a sweet potato, soybean, and corn flour mixture. These studies were done by mixing corn flour with other flour to improve the noodle textures. The texture improvement of instant corn noodles can also be conducted by mixing additional ingredients such as hydrocolloids or emulsifiers.

Some studies on emulsifiers for improving corn noodle textures, such as Subarna et al. (2012), which used Glyceryl Mono Stearate (GMS), and Taqi et al. (2018) used Propylene Glycol Alginate (PGA) to reduce cooking loss and hardness of corn noodles. Also, Ding & Ying (2013) reported that emulsifiers of polysorbate-60 (P60), and diacetyl tartaric esters of mono-glycerides (DATEM) improved springiness, firmness, and overall acceptability in fried instant noodles. Lipids can affect the texture and adhesiveness of the extrudates (Ilo et al., 2000). Emulsifiers are food additives in the form of surfactants closely related to the texture of food products. The interaction between emulsifiers, protein, and carbohydrates in starch-based food products can modify the products' rheological, textural, and shelf-life properties. Based on the previous studies, the optimization of 100% corn instant noodles by adding additives in emulsifiers has yet to be fully documented in the literature.

This research aimed to optimize the manufacturing process of fried instant corn noodles, which are added by DIMODAN® commercial emulsifier with an extrusion system using Response Surface Methodology.

2. Materials and Methods

The primary material for manufacturing corn noodles was 80 Mesh corn flour from PT FITS Bogor Life Science and Technology (Indonesia). Other ingredients were water, salt, and DIMODAN® commercial emulsifier. This research consisted of two main stages: determining the optimum emulsifier concentration to obtain the fastest cooking time for dry corn noodles and optimising the manufacturing process of fried instant corn noodles.

2.1. Determination of the optimum emulsifier concentration

The formula and process for manufacturing corn noodles were referred to by Muhandri et al. (2011). DIMODAN® emulsifiers (0%, 0.5%, 1%, and 1.5% by weight of corn flour) and corn flour were mixed. Then, the 2% NaCl salt (by weight of corn flour) was dissolved into water as much as 70% by weight of flour, and then this solution was added to the mixture using a hand mixer for 5 minutes.

The dough was put into a single-screw cooking-forming extruder type LE25-30/C (Labtech Engineering Co. Ltd.) with an extruder temperature of 90 °C and a screw speed of 130 rpm. Corn noodles were cut and shaped into a circle, then dried using a tray dryer for 24 hours at room temperature. After that, their optimum cooking time of them was tested. The selected emulsifier concentration was determined based on the fastest cooking time to reach the optimum cooking level of the noodle.

2.2. Optimization of the manufacturing process of fried instant corn noodles

Optimize the manufacturing process of fried instant corn noodles using Response Surface Methodology (RSM) with the Design Expert 7.0 (DX7) application with D-Optimal design. The objective of this stage was to determine three optimum parameters, namely drying time, frying temperature, and frying time, which were set in the range of 0 - 120 minutes, 105 - 125 °C, and 2 - 10 minutes, respectively. Hattunisa (2011) stated that a frying temperature of 130 °C would swell the noodle surface, so the research temperatures were set at less than 130 °C. Kim (1996) stated that generally, the industries use 90 - 120 seconds for the frying duration on the instant noodle, but due to low temperatures, the frying time was set in the range of 2-10 minutes. Responses used in this research were water content after frying, cooking loss, and elongation of instant noodles after the rehydration process. The research treatments were presented in Table 1, and the criteria listed in Table 2 determined the optimum conditions.

2.3. Product Analysis

2.3.1. The optimum cooking time

Measure the optimum cooking time using a hedonic test with a scalar test of 10 cm (Meilgaard et al., 2016)

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Table 1. The experimental design of the optimization process

No.	Drying time (minutes)	Frying Temperature (°C)	Frying time (minutes)
1	48	105	5
2	120	125	10
3	120	105	10
4	75	112	2
5	120	117	5
6	0	125	7
7	120	105	2
8	0	113	7
9	0	112	2
10	78	125	2
11	49	117	10
12	48	105	5
13	0	105	10
14	46	118	5
15	120	105	10
16	120	115	10
17	0	105	10
18	0	125	2
19	120	105	2
20	120	125	10

Table 2. Criteria for factors and responses and the importance level of the optimization stage

Component		Criteria	Importance level
Factor	Drying time	*In Range*	3 (+++)
	Frying Temperature	*In Range*	3 (+++)
	Frying time	*In Range*	3 (+++)
Response	Water content after frying	*Minimize*	5 (+++++)
	Cooking loss	*Minimize*	3 (+++)
	Elongation	*Maximize*	3 (+++)

on raw, precooked, cooked, overcooked, and porridge attributes, where the distance for each attribute was 2.5 cm. The number of panellists in this research was nine trained panellists selected from 30 random panellists. Determination of the panellists referred to SNI/ Indonesian National Standard 01-2346-2006 (Badan Standardisasi Nasional, 2006), which stated that the minimum number of standard/trained panellists in one test was six. The score was processed into a line relationship between the cooking level (y-axis) and cooking time (x-axis). The obtained line equation was used to find the optimum cooking time by entering a cooking level (y value) 5. The obtained cooking time was verified using the American Association of Cereal Chemist (2000) method, visually observing the noodles after cooking. The optimum cooking time was the time to cook the noodles until the white spot in the middle disappeared.

2.3.2. Analysis of elongation percentage using the TA-XT2i Texture Analyser

Corn noodles were wrapped around the stationary and moving probes at a distance of 2 cm and a speed of 0.3 cm/s. The elongation was calculated using Eq. 1.

$$Elongation = \frac{break\ time\ (s) x\ 0.3\ cm/s}{2\ cm}\ x\ 100\% \qquad (1)$$

2.3.3. Analysis of water content (Association of Official Analytical Chemistry, 2005)

The water content of corn noodles was used in the cooking loss calculation. 3-5 g samples were weighed on a dry cup and then dried in an oven at 105 °C for 4-6 hours until a constant weight was achieved. The sample and the dry cup were cooled in a desiccator and then weighed. Water content on a wet basis can be calculated by Eq. 2.

$$Water\ content\ \left(\frac{g}{100} g\ wet\ material\right) = \frac{W - (W1 - W2)}{W} \times 100\% \qquad (2)$$

where W = sample weight before drying (g),
W1 = sample weight + empty dry cup (g), and
W2 = empty cup weight (g).

2.3.4. Analysis of cooking loss (Oh et al., 1985)

Determination of cooking loss on corn noodles was conducted by boiling 3-5 grams of noodles in 100 mL of water during the optimum time then the noodles were drained. The noodles were dried at 105°C until the weight was constant, then weighed again. Cooking loss was stated by following Eq. 3.

$$Cooking\ loss\ (\%) = \frac{Dry\ weight\ before\ boiling - dry\ weight\ after\ boiling}{Dry\ sample\ weight\ before\ boiling} \times 100\% \qquad (3)$$

3. Results

3.1. The optimum emulsifier concentration based on the fastest cooking time on dry corn noodles

The desired optimum cooking level has a value of 5 as the median value of the line given where the test results are presented in Table 3. Dry corn noodles without an emulsifier and with a 0.5% emulsifier have a cooking time of 7 minutes with cooking levels of 5.1 and 5.3, respectively. Adding 1% and 1.5% emulsifiers can accelerate the cooking time of dry corn noodles with a cooking time of 6 minutes and cooking levels of 5.4 and 5.1, respectively.

3.2. Optimization of the manufacturing process of fried instant corn noodles

Analysis of variance (ANOVA) evaluation for responses of water content after frying and elongation of instant corn noodles and cooking loss response are presented in Tables 4 and 5, respectively.

3.2.1. The response of water content after frying

The water content of processed food products is one of the parameters determining product shelf life. Water content is also a parameter of the adequacy of the dehydration process to classify pasta products as standard or not. Based on SNI 3551-2012 (BSN, 2012), dried and fried instant noodles have maximum water contents of 14.5% and 8%, respectively (wet basis). Gulia et al. (2014) explained that frying and drying processes would decrease the water content of instant noodles to 2 – 5% and 8 – 12%, respectively. The suggested model on the water content response after frying is linear, as shown in Eq. 4.

$$Water\ content = 69.559 + 0.000A - 0.442B - 0.748C \qquad (4)$$

where A is the drying time (minutes), B is the frying temperature (°C), and C is the frying time (minutes). The relationship of water content after frying with these factors can be seen in Figure 1.

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Table 3. Emulsifier concentration on cooking level of dry corn noodles

Emulsifier concentration (%)	Cooking time (minute)	Cooking level	Linier equation	R^2
0	7	5.1	y=0.6627x	0.9408
0.5	7	5.3	y=0.7156x	0.9415
1	6	5.4	y=0.8196x	0.9005
1.5	6	5.1	y=0.7341x	0.8076

Table 4. Analysis of variance evaluation of a linear model for responses of water content and elongation after frying and elongation of instant corn noodle

Source	df	Water content after frying			df	Elongation		
		Coefficient	Sum of squares	P value		Coefficient	Sum of squares	P value
Model	3	69.559	363.51	< 0.0001‡	3	820.456	50017.42	< 0.0001‡
A-Drying time	1	< 0.0001	0.058	0.9225	1	– 0.219	2421.21	0.1666
B-Frying temperature	1	– 0.442	249.97	< 0.0001‡	1	– 6.092	47579.45	< 0.0001‡
C-Frying time	1	– 0.748	124.13	0.0004‡	1	– 1.871	776.39	0.4239
Residual	16		102.27		16		18445.99	
Lack of fit	11		101.54	0.0001	11		18416.18	< 0.0001
Pure error	5		0.73		5		29.82	
Total	19		465.78		19		68463.42	
R^2		0.7804				0.7306		
Adj-R^2		0.7393				0.6801		
Pre-R^2		0.6652				0.6227		
Adeq Precision		13.106				9.755		

‡Significant at 5% level; df, degree of freedom

Table 5. Analysis of variance evaluation of a mean model for cooking loss response

Source	df	Coefficient	Sum of squares	P value
Model	0	10.52	0.000	
Residual	19		280.87	
Lack of fit	14		279.73	< 0.0001
Pure error	5		1.14	
Total	19		280.87	
R^2		0.4370		
Adj-R^2		0.1772		
Pre-R^2		-1.1810		
Adeq Precision		4.589		

df, degree of freedom

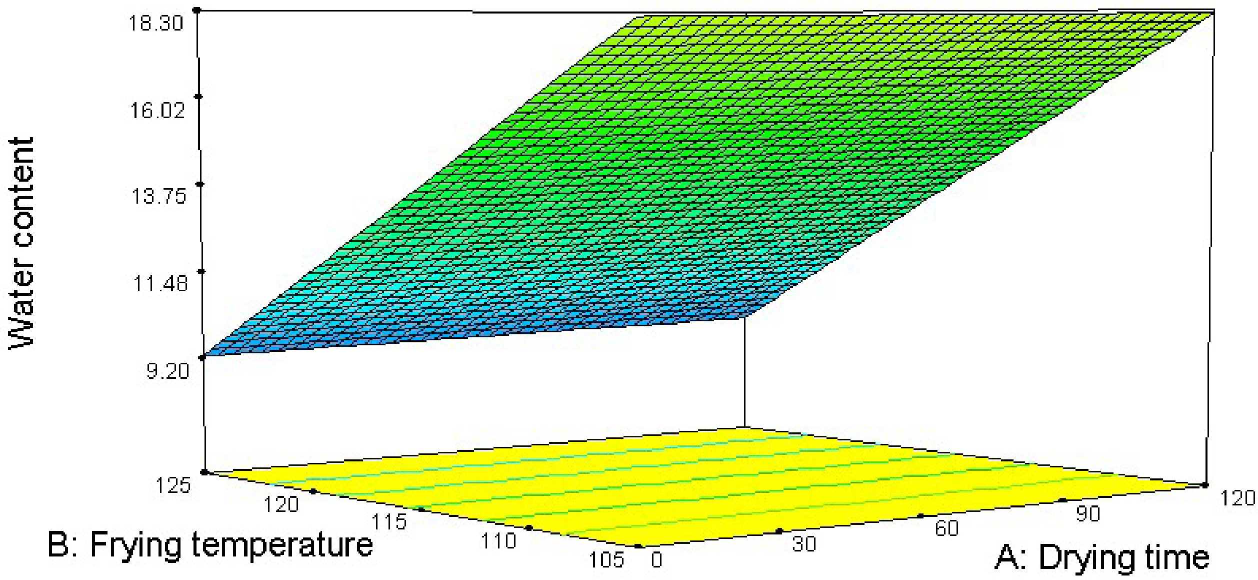

Figure 1. Three-dimensional graph of water content after frying response

3.2.2. The response of elongation

A high percentage of elongation shows the characteristics of noodles that are not easily broken. The gelatinization process's adequacy greatly determines the noodles' elongation percentage (Hattunisa, 2011). Analysis of Variance shows that the suggested model is linear (Eq. 5) and has a p-value smaller than 0.05, so the model has strong significance as an elongation response model.

Elongation = 820.456 – 0.219A – 6.092B – 1.871*C* (5)

where A is the drying time (minutes), B is the frying temperature (°C), and C is the frying time (minutes). The influence of these factors can be determined by the three-dimensional graph in Figure 2.

3.2.3. The response of cooking loss

Cooking loss is one of the cooking quality parameters of instant noodle products. Cooking loss can be interpreted as the number of solid noodles dissolved in the water during cooking. This parameter indicates the ability of the product to maintain its structural integrity during the cooking process in boiling water (Liu, 2009). A three-dimensional graph of the cooking loss response is presented in Figure 3.

3.3. Optimum Process

An optimum process combination, predicted by the Design Expert 7 program shown in Table 6 and Figure 4, is obtained after determining the criteria for factors and responses and their respective importance levels. The selected process combination is a process combination that has a maximum desirability value close to 1.0.

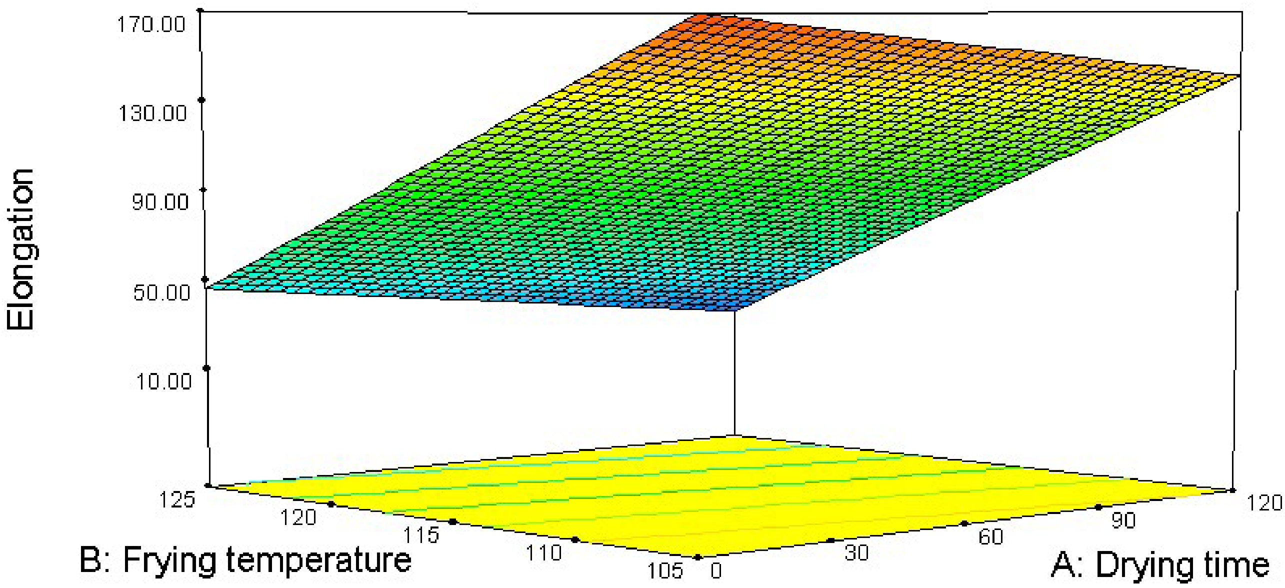

Figure 2. Three-dimensional graph of elongation response

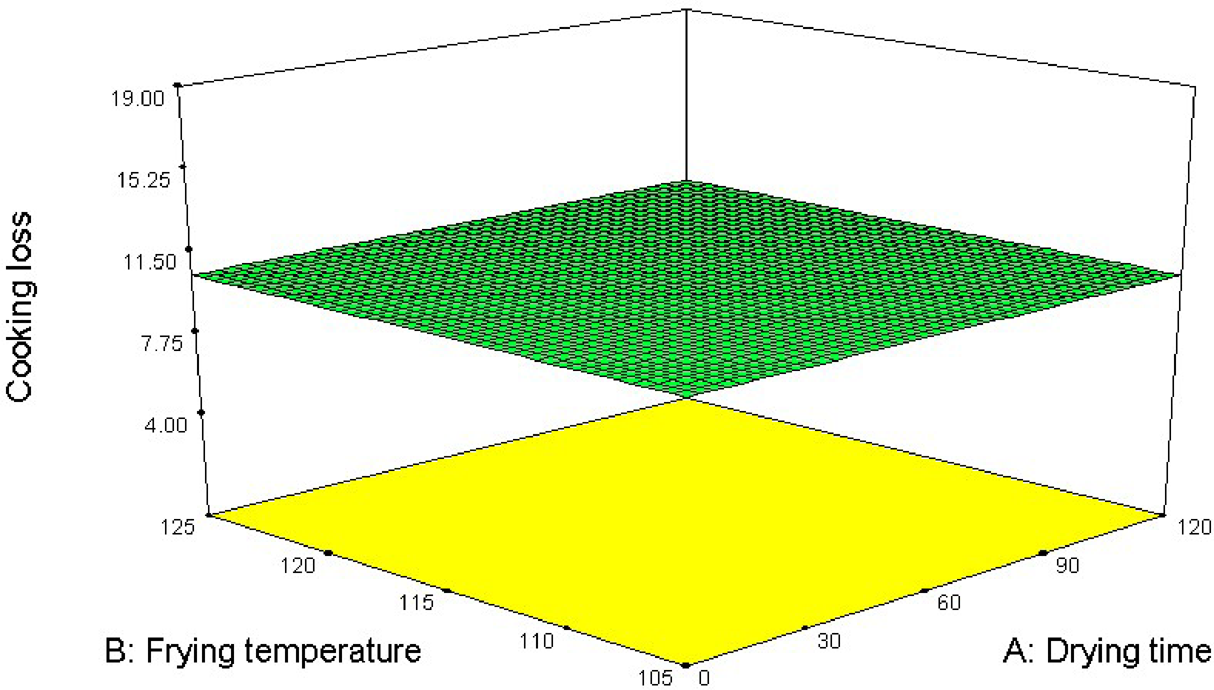

Figure 3. Three-dimensional graph of the cooking loss response

Table 6. Desirability values for various process combinations

No	Drying time (min)	Frying temperature (°C)	Frying time (min)	Water content after frying (%)	Cooking Loss (%)	Elongation (%)	Desirability
1	0	115	10	11.28	10.52	100.87	0.649‡
2	0	116	10	11.07	10.52	98.06	0.648
3	0	115	10	11.20	10.52	99.25	0.648
4	3	115	10	11.15	10.52	98.56	0.647
5	3	115	10	11.33	10.52	100.86	0.647
6	5	115	10	11.42	10.52	101.69	0.646
7	0	112	10	12.44	10.52	116.91	0.645
8	0	117	10	10.66	10.52	88.42	0.640
9	43	112	10	12.80	10.52	111.81	0.628
10	51	115	10	11.49	10.52	91.91	0.627

§selected process combination

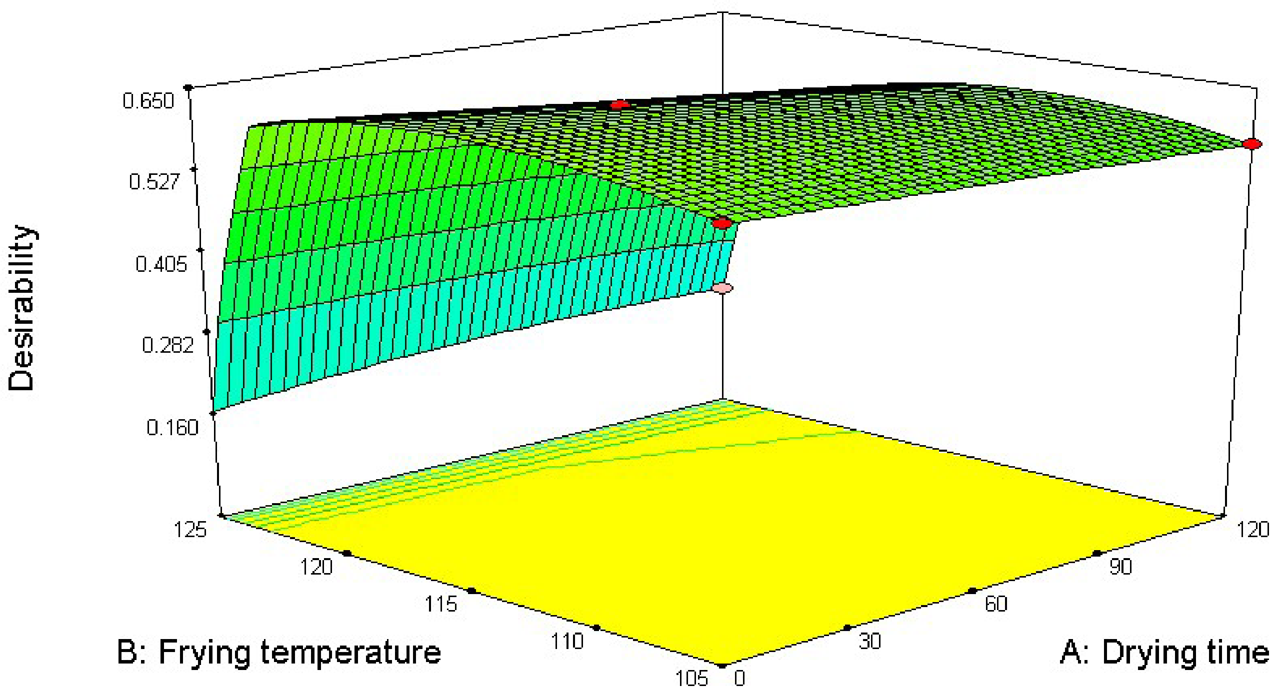

Figure 4. Three-dimensional graph of the optimum process combination

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3.3.1. Verification and characterization of the quality of the optimized instant corn noodles

The responses in the selected process combination are then verified by comparing them against the actual condition, presented in Table 7. The Design Expert 7.0 program will give CI (Confident Interval) and PI (Prediction Interval) values at a significance level of 5%. The CI value indicates that 95% of the population will be between the mean and standard deviation, and only 5% will be outside it (Navidi, 2006).

3.3.2. Verification of the optimum cooking time of the instant corn noodle

The actual cooking time for optimum instant corn noodles needs to be verified. This verification uses organoleptic methods and visual observations of the white spots in the middle of the noodle's string. Determination of organoleptic cooking time is conducted by testing the cooking level of the noodles at various cooking times. The results are then processed into a regression equation, and the optimum cooking time is determined when the noodles reach the optimum cooking level (value 5). A graph of the cooking level at various cooking times is presented in Figure 6, and visual observation of noodles after rehydration is shown in Figure 7.

4. Discussion

4.1. The optimum emulsifier concentration based on the fastest cooking time on dry corn noodles

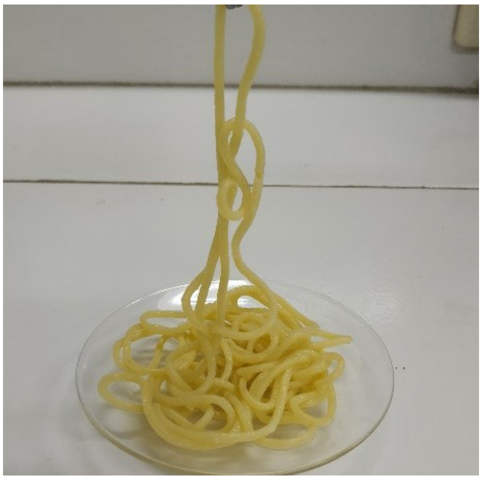
Table 3 shows that the emulsifier addition can accelerate the cooking time of dry corn noodles; however, this is only effective until the emulsifier addition of 1%. This result is in line with Subarna et al. (2012), which stated that adding more than 1% GMS to corn noodles no longer significantly improved the quality

Table 7. Response prediction and verification of the optimum process

Response	Prediction	Verification	95% CI Low	95% CI High	95% PI Low	95% PI High
Water content (%)	11.28	13.32	8.81	13.74	5.38	17.17
Cooking loss (%)	10.52	10.50	8.72	12.32	2.27	18.76
Elongation (%)	100.87	127.48	67.78	133.97	21.65	180.09

The appearance of the optimized instant corn noodles is presented in Figure 5.

(a)



(b)

Figure 5. The optimized instant corn noodles (a) before and (b) after rehydration process

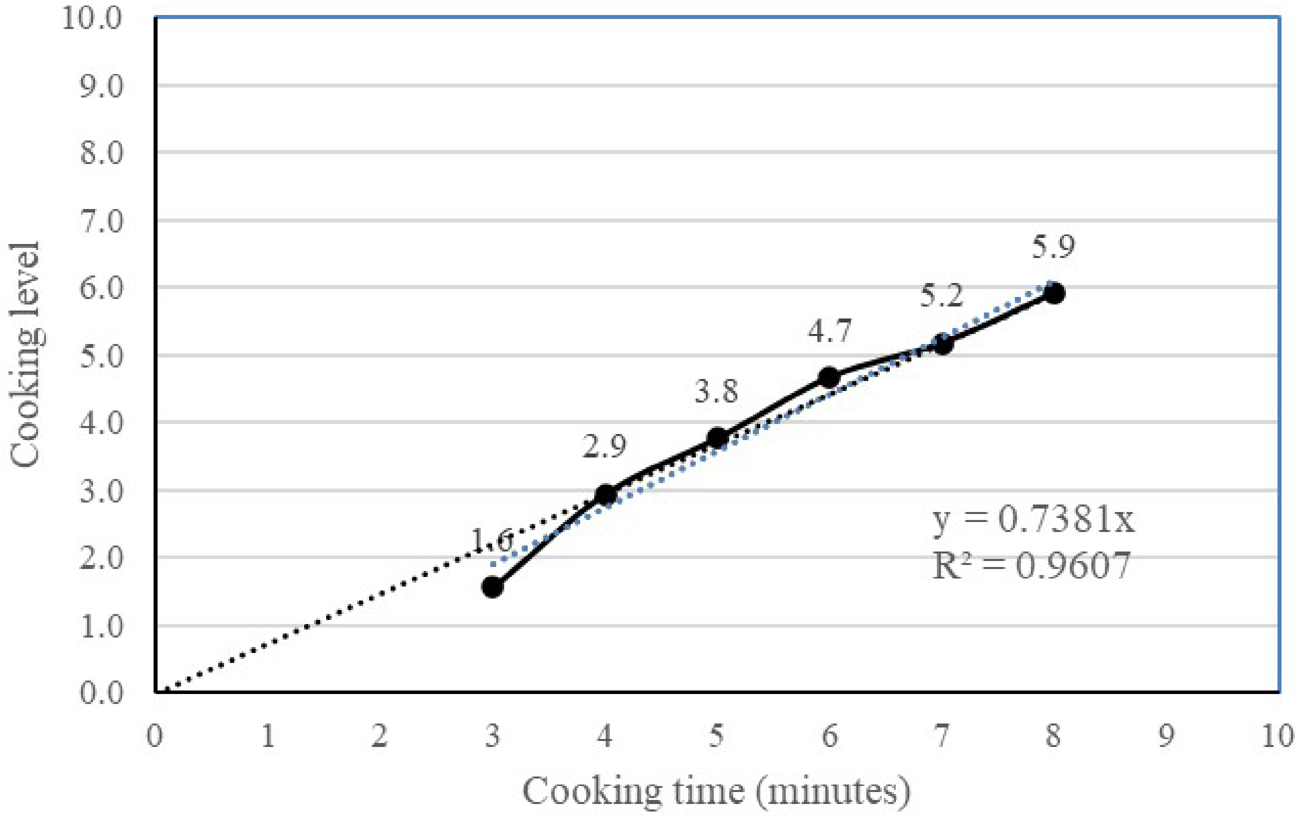


Figure 6. Cooking level of instant corn noodles at various cooking times

Figure 7. Visual observation of rehydrated instant corn noodles

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of corn noodles. The emulsifier addition can improve the quality of corn noodles; however, too much addition will have negative impacts, such as increased cooking loss and the noodles being too dry. Corn noodles, adding 1% emulsifier, reach an optimum cooking level with a cooking time of 6.1 minutes (6 minutes 6 seconds). Distilled monoglycerides form a mesomorphic layer between water and the emulsifier (Chen, 2015). This property implies that the water will be easily bound to the noodles during cooking, resulting in faster cooking times.

4.2. Optimization of the manufacturing process of fried instant corn noodles

4.2.1. The response of water content after frying

Table 4 shows that the model has a p-value of less than 0.05, so the model has strong significance as a response model for water content after frying. The R^2 value of the water content response model after frying is 0.7804. This value means the selected model can explain 78.04% of the available data. The model has an adeq precision more significant than 4. This model also has high Adj R^2 and Pred R^2 values of 0.7393 and 0.6652, respectively, which means that the selected model can represent 73.93% of the actual value and 66.52% of the predicted value.

Table 4 shows that drying time has no significant effect on the water content of instant corn noodles. The drying process, set in the range of 0 - 120 minutes, may not be enough to decrease the water content of corn noodles after frying. The drying process is conducted using a tray dryer at room temperature. Subarna and Muhandri (2013) suggested that 60 °C for 40 minutes of low-temperature drying can produce good physical quality dry corn noodles. The drying process in corn noodles is different from that in spaghetti. Baiano et al. (2006) explained that good quality spaghetti, in terms of cooking and sensory, was obtained by drying at a high temperature of 90 °C for 5 hours. Using high temperatures in the drying process of corn noodles can crack the noodle surface and produce lower elongation and rigidity of corn noodles. In addition, Frying time affects the water content of corn noodles, where the higher the frying temperature leads to the lower the water content of instant corn noodles at a certain point. It is found that the lowest water content that can be achieved is 6.8%, and the highest is 23.48%. The frying process is the evaporation process of replacing water mass in materials with oil (Dana & Saguy, 2006). The higher the frying temperature, the further away from the water's boiling point so that the water's mass will more quickly turn into a mass of water vapour and come out from the materials. The evaporation process of the mass of water will create shaft holes in the string of fried instant noodles, so water is easier to penetrate the strands of noodles during the rehydration process, which impacts the faster cooking time of corn noodles (Gulia & Khatkar, 2013).

4.2.2. The response of elongation

The R^2 value of the elongation response model is 0.7306, which means 73.06% of the available data can be explained by the selected model and the model, which has adeq precision more significant than 4. This model also has high Adj R^2 and Pred R^2 values of 0.6801 and 0.6227, respectively, which means that the selected model can represent 68.01% of the actual value and 62.27% of the predicted value.

Table 4 shows that frying temperature is a significant factor in the elongation response, while drying and frying times have no significant influences. Figure 2 shows that the higher the frying temperature, the lower the elongation of instant corn noodles. The frying process at a high temperature can release the water from the noodle strands and immediately make holes/pores in the shape of small and uniform sponges (McDonough et al., 2001). However, based on Table 4, drying and frying times have no significant effect on the noodle elongation, although Eq. 5 shows negative coefficients for them, which implies that the longer the drying and frying times, the lower the elongation of instant corn noodles. Subarna and Muhandri (2013) explained that drying at low temperatures can produce noodles with more minor structural changes. These changes can strengthen the structure of noodles and make the noodles have higher elongation after rehydration. The gelatinized starch has a strong matrix, so air does not easily escape from the strand because the formed crust layer on the noodle surface blocks it. The crust surface, pushed by the water vapour, can be identified as the swelling on the noodle surface. This condition indicates that the noodles will break when rehydration is applied (Hattunisa, 2011).

4.2.3. The response of cooking loss

Table 5 shows that the cooking loss response has a mean model because it does not produce a model with a significant p-value. An insignificant response indicates that combining the drying and frying processes does not influence the cooking loss of instant corn noodles. This condition is supported by a negative pred-R^2, which implies that the overall mean is a better predictor for the response.

Figure 3 provides further information that the three independent variables do not significantly affect the cooking loss of instant corn noodles. Similar results were confirmed by Subarna & Muhandri (2013) and Lee et al. (2005), which reported that the drying process had no significant effect on the cooking loss of dry corn noodles. Hattunisa (2011) stated that the frying process in corn noodles could increase the cooking loss. This increase can occur due to holes/pores in the noodle strand during the frying process, which results in the ease of starch particles on the noodle strand detached during cooking. The easier the starch particles detach, the higher the cooking loss of noodles after rehydration.

4.3. Optimum Process

4.3.1. Verification and characterization of the quality of the optimized instant corn noodles

Table 7 shows that the actual values of all responses are in the range of 95% CI, and the model can be used to predict the responses. Howell (2008) defined CI as a range of values containing the probability value of the tested parameter. Moreover, Heiberger & Holland (2004) explained that the narrower range of CIs shows better optimization values. The actual water content of the optimum instant corn noodles is 13.32%. This value is still in the program prediction range of 8.81 - 13.74%. This actual value is similar to Olorunsogo et al. (2019), who reported that instant noodle from a blend of sweet potato, soybean, and corn flour has a water content of 13.17%. Even so, the water content in this research is higher than that of instant noodles from a mixture of corn and tapioca flours by 6.22% (Pato et al., 2016). Water content that is still relatively high can occur due to using a relatively low frying temperature compared to the commercial frying temperature conducted in the industry. The frying process for the commercial instant noodle is usually conducted at 150-180 °C for 90-120 seconds (Kim, 1996). The lower the frying temperature, the lower the evaporation rate of the water mass so that it can cause the water content to remain high enough. Low temperatures with a long frying duration cause the appearance of instant corn noodles to look greasy.

The actual cooking loss of instant corn noodles is 10.50%, in 95% CI and 95% PI. Charutigon et al. (2007) explained that consumers could accept noodles with a cooking loss of less than 12.5%. This cooking loss is higher than that of dry corn noodles, which is 4.56% (Muhandri et al., 2011). The frying process can influence the high cooking loss of instant corn noodles. Using high temperatures in the frying process can immediately change the water into water vapour and push the starch component into the noodles. This push can form a sponge-like structure in the noodle strand, which releases the starch particles quickly during the frying process. In addition, the elongation percentage of instant corn noodles is 127.48%, which is good enough for pasta products. Instant corn noodle has a good structure, are compact, and are not easily broken when drained. High elongation means the high extensibility of noodles when pulled under a specific force.

4.3.2. Verification of the optimum cooking time of the instant corn noodle

Figure 6 shows a graph of the relationship between the cooking level of instant corn noodles and the cooking time to produce a linear equation of $y = 0.7381x$ with an R^2 of 0.9607. The y value is the cooking level of the noodles, while the x value represents the cooking time of the noodles. It can be seen by entering the y value of 5 in the equation (the desired optimum cooking level) that the actual cooking time to produce the optimum cooking level of instant corn noodles is 6.8 minutes, equivalent to 6 minutes and 48 seconds. The disappearance of the white spot in the middle of the noodles marks this optimum cooking time. In addition, This R^2 indicates a solid relationship between the cooking level and the cooking time of the noodles on the linear line.

This cooking time is longer than that of dry corn noodles in the previous stage, which is 6.1 minutes. It can be caused by the amount of absorbed oil by the noodles. Oil and water are two substances that cannot be mixed due to their different specific densities. Oil binding to the noodle structure inhibits water penetration during the rehydration process. The oil in instant noodles can reach 20% of the product's total weight. Cooking starch at temperatures more than 107 °C produces the amylose-lipid complex structure. This structure can inhibit the starch's swelling and solubility during the cooking process (Sittipod & Shi, 2016) and take the longer cooking time of instant corn noodles.

Data in Figure 6 are supported by visual observation of the white spots present after rehydration in Figure 7. The optimum cooking time is defined as the cooking time needed for the noodles until the disappearance of the white spot in the middle of the noodle strands when pressed between two glass plates (Marti et al., 2010).

5. Conclusion

Adding a DIMODAN® type emulsifier at a 1% level (by weight of flour) accelerated the cooking time of dry corn noodles to 6.1 minutes from corn noodles without adding an emulsifier (7 minutes). Optimization of the manufacturing process of fried instant corn noodles using the D-optimal RSM showed that the optimum process was a combination of a drying time of 0 minutes and a frying temperature of 115 °C for 10 minutes. This optimum process produced instant corn noodles with a water content of 13.32% (wet basis), cooking loss of 10.50%, and elongation percentage of 127.48%, while the optimum cooking time for this instant corn noodle was 6.8 minutes.

Conflict of interest

The authors declare no conflict of interest.

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