



Utilization of Chia Seeds Powder in Wet Noodle Substituted with Modified Cassava Flour

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Abstract

The Indonesian food industry needs to utilize local food commodities as an alternative to wheat, supporting local farmers as part of sustainable agriculture. Modified cassava flour (MOCAF) has similar characteristics to wheat flour yet it lacks gluten and has low protein content. Chia seeds have the potential to improve the textural characteristics of gluten-free products due to their gel-forming ability and are a good source of plant-based protein. This study aims to utilize chia seed powder in the formulation of wet noodles substituted with MOCAF to possibly obtain wet noodles with equal textural characteristics and protein content to 100% wheat flour noodles. In this study, different ratios of wheat flour to MOCAF (100:0, 90:10, 80:20, 70:30, 60:40) and different amounts of chia seed powder (0%, 5%, 10%, 15%) are studied in terms of cooking quality (cooking loss and water absorption), textural properties (hardness, cohesiveness, and chewiness), color (brightness and hue angle). Higher MOCAF substitution resulted in higher water absorption and cooking loss, as well as undesirable (harder) textural properties. Incorporation of chia seeds powder successfully lowers the cooking loss and higher water absorption of the MOCAF-substituted noodles and noodles with 100% wheat flour without chia seeds powder. Chia seed powder can reduce the hardness while maintaining and increasing the chewiness of the MOCAF-substituted noodles. In the MOCAF-substituted noodles, comparable protein content to that of 100% wheat flour noodles can be achieved with the use of 10 to 15% chia seeds powder at a maximum 80:20 substitution ratio.

Keywords: cooking quality; local commodity; plant protein; textural properties; wheat substitution

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INTRODUCTION

According to the Foreign Agricultural Service USDA in 2022, wheat consumption for 2022/2023 was forecasted to increase to 9.4 from 9.1 million metric tons for 2021/2022. Indonesia depends on wheat imports to fulfill wheat flour-based food products. It is therefore important for the Indonesian food industry to begin utilizing local food commodities as an alternative to wheat flour for staple food products (Agustia et al., 2019), supporting local farmers as part of sustainable agriculture. Furthermore, wheat is

considered a resource-intensive crop. Therefore, substitution can help to reduce the environmental impact of wheat flour production. Local commodities such as cassava (*Manihot esculenta* Crantz) can be processed into cassava flour and modified cassava flour (MOCAF) as an alternative for wheat flour substitution. MOCAF has a similar chemical composition to cassava flour, but the former has an advantage as it contains little to no cyanogen compound and exhibits better taste and physicochemical

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properties, with a neutral aroma (Kardhinata et al., 2019). MOCAF is cheaper than rice flour and has a similar price as wheat flour (Anggraeni et al., 2017). In addition, MOCAF resembles wheat flour in terms of appearance, which is soft and white. MOCAF does not contain any gluten that will give elasticity to food products like noodles (Agustia et al., 2019). Significant reduction in terms of elasticity can be seen in noodles substituted with MOCAF as shown by Ramadhan and Sari (2015). Using a sensory test, the study also showed that more amount of MOCAF resulted in significantly less preferred chewiness. In the study done by Diniyah et al. (2018), different types of hydrocolloids, namely xanthan gum and konjac, were used to increase the chewiness of gluten-free noodles made using MOCAF and corn flour. The study found that the use of 0.75% konjac resulted in the most preferred texture as well as cooking loss and swelling power.

In recent years, a considerable number of studies have been directed towards health-promoting food ingredients. An example of a food ingredient of plant origin with interesting properties and used for many years for medicinal purposes is chia (*Salvia hispanica*) seeds. Chia seeds can be directly consumed as ingredients, but can also be incorporated into food products. Nowadays, chia seeds are also used as thickeners in soups and sauces (Kulczyński et al., 2019). Studies have shown that protein-rich fractions in chia seeds can form a gel, providing thickening and consistency to various foods (Grancieri et al., 2019). In the study done by Oliveira et al. (2015), chia seed flour was utilized in the production of pasta to substitute wheat flour. It was observed that 7.5% chia seed flour substitution produced better quality pasta by preventing the loss of solids. Another utilization of chia seeds in pasta was also proposed by Menga et al. (2017). In that study, chia seeds were used as a thickening agent as well as a nutrient enhancer in gluten-free pasta. It was found that when compared to commercial gluten-free pasta, comparable cooking characteristics (firmness) can be achieved by substitution of hydrocolloids using chia seeds. In addition, the use of chia seeds in the formulation improved the protein, dietary fiber and phenolic acids of the gluten-free pasta.

Substitution of wheat flour in wheat-based products remains a challenge. Despite its potential, the use of MOCAF to substitute wheat flour in noodle is not a popular choice

as it lacks of gluten, resulting in less acceptable textural characteristics. To improve the textural characteristic of wet noodles substituted with MOCAF, chia seeds can be incorporated as they can act as hydrocolloids due to their gel-forming ability that could improve the textural properties of the noodles. Therefore, this study aims to utilize chia seeds in the form of powder in the formulation of wet noodles substituted with MOCAF to possibly obtain wet noodles with equal textural characteristics to 100% wheat flour noodles. In this study, different ratios of wheat flour to MOCAF (100:0, 90:10, 80:20, 70:30, 60:40) and amount of chia seeds powder (0%, 5%, 10%, 15%) are studied in terms of cooking quality (cooking loss and water absorption) and textural properties (hardness, cohesiveness, and chewiness) of the noodle. In addition, the substitution of wheat flour using MOCAF in the wet noodles would lead to lower protein content due to lower protein content of local commercial MOCAF compared to typical commercial wheat flour (9 to 13%). Recently, the trend of plant-based food and protein is emerging as academia and the food sector is transitioning towards sustainable nutrition. Concerns regarding the environmental footprint of animal-based foods arise due to their high environmental and climate impact as a result of intensive livestock farming (Aschemann-Witzel et al., 2020). In this study, the relatively high protein content of chia seeds is expected to complement the nutritional value of MOCAF-substituted wet noodles.

MATERIALS AND METHOD

Materials and equipment

Materials used in the formulation of wet noodle were “SuperFood Indonesia” black chia seeds, “Cakra Kembar” wheat flour, “Prodes” MOCAF, “Cap Gajah” ash water (*kansui*), “Refina” table salt, and “Unilever Pureit Classic” distilled water. Equipment used for making noodles were “Philips” dry blender, “Mettler Toledo” balance, “Iwaki Pyrex” graduated cylinder, a 35-mesh sieve, “Fomac” noodle roller, and trays. In addition, equipment used for analyses were “OHAUS Pioneer” analytical balance, “DURAN” vacuum desiccator, “Iwaki Pyrex” beaker glass, “Iwaki Pyrex” volumetric flasks, evaporating dish, “Mommert UNE 200-800” universal oven, and “Stable Micro Systems TA-XT Plus” texture analyzer.

Methods

All experiments were conducted at Food Processing and Quality Control Laboratories, Universitas Pelita Harapan. This research was divided into preliminary study and main study. The preliminary study was conducted to prepare chia seed powder and analyze the powder on proximate analysis, while the main study involves the preparation of unsubstituted and MOCAF-substituted wet noodles to be analyzed on cooking quality, textural properties, protein content, and color properties.

Wet noodle preparation

Prior to the noodle-making process, the chia seeds were ground using a dry blender and sieved through a 35-mesh screen sieve to obtain chia seeds powder. To obtain the wet noodles, a total of 50 g of ingredients were weighed accordingly based on the formulation in Table 1. After weighing, the predetermined ratio of wheat flour to MOCAF and chia seeds powder were mixed, while salt and ash water (*kansui*) were dissolved together in water beforehand. The dry and wet ingredients were then mixed until a homogeneous dough was formed. The dough was then wrapped in plastic wrap and rested for 30 minutes. After resting, the dough was put into the noodle roller, starting with the widest gap and gradually narrowing it down until 1 to 2 mm thickness of the dough sheet was acquired. The noodle dough sheet was then slit into strands using the noodle roller. The noodle strands were boiled for 3 minutes, drained, and rinsed with cold water.

Cooking quality analysis

After the wet noodle was obtained, the cooking quality and textural properties of the noodle were analyzed to determine the preferred formulation. In this study, cooking quality of the wet noodle was represented by water absorption and cooking loss. Both water absorption and cooking loss analyses were done following the analysis method by Anggraeni and Saputra (2018) with

modifications. For cooking loss, 5 g of sample was taken and put into 60 ml boiling water for 10 minutes. Afterward, the sample was drained, and then the drained sample was used for subsequent water absorption analysis. The water used for cooking the sample was dried in the oven at 105 °C and weighed to constant weight. For water absorption, 5 g of sample was taken and put into 60 ml boiling water for 10 minutes. Afterward, the sample was drained for 5 minutes and weighed. The cooking loss and water absorption were calculated using Equation 1 and 2, respectively.

Textural profile analysis

Textural properties of the noodle that were observed in this study include hardness, cohesiveness, and chewiness. The textural profile of the noodle was studied using a texture analyzer (TA-XT) with a cylindrical probe 36 mm diameter 25 g of noodles cooked in 300 ml boiling water for 3 minutes. A strand of cooked noodles was placed on the flat metal and subjected to texture analysis. The textural profile analysis (TPA) settings were: pre-test speed 2.0 mm s⁻¹, test speed 1.0 mm s⁻¹, post-test speed 2.0 mm s⁻¹, and time 5 seconds (Afifah and Ratnawati, 2017).

Moisture content analysis

The moisture content analysis was carried out by using the oven method. Empty evaporating was placed in the oven and weighed periodically until constant weight was obtained. Five grams of sample was then put onto the evaporating dish. Afterward, the sample was placed in the oven at 110 °C for 24 hours and weighed until constant measurement. The constant weight was recorded and the moisture content was calculated using Equation 3.

Ash content analysis

The analysis of the ash content of the sample was done by using dry-ashing method. Initially, the ashing-crucible was placed in the oven and weighed until constant measurement was

Table 1. Formulation of wet noodles

Ingredients	N1 (%)	N2 (%)	N3 (%)	N4 (%)	N5 (%)
Wheat flour	100	90	80	70	60
MOCAF	0	10	20	30	40
Chia seeds powder	0/5/10/15	0/5/10/15	0/5/10/15	0/5/10/15	0/5/10/15
Water	40	40	40	40	40
Ash water (<i>kansui</i>)	1	1	1	1	1
Salt	1.5	1.5	1.5	1.5	1.5

Note: N1 = 100% wheat flour; N2 = 90:10 wheat flour:MOCAF; N3 = 80:20 wheat flour:MOCAF; N4 = 70:30 wheat flour:MOCAF; N5 = 60:40 wheat flour:MOCAF

acquired. Subsequently, 3.5 g of sample was weighed and placed inside the crucible. The crucible was then placed into a muffle furnace at 550 °C until the ash became white. After that, the ash sample was weighed to a constant weight. The ash content can be calculated using the Equation 4.

Fat content analysis

Soxhlet method was performed to determine the fat content of the sample. Firstly, approximately 3 g of dry sample was weighed and wrapped in a filter paper. The wrapped sample was placed inside the extraction thimble. Meanwhile, 150 ml of hexane solvent was prepared and put into the boiling flask which had been weighed until constant beforehand. The Soxhlet instrument was set up and the boiling flask containing the solvent was heated and extraction of fat from the sample occurred. The extraction process lasted for 6 hours or until the solvent appeared to be clear. The fat was then separated from the hexane solvent by distillation process using a rotary evaporator. Afterwards, the boiling flask was dried in the oven at 100 °C and into desiccator prior to weighing. The weighing was done periodically until constant

weight was achieved. The fat content was calculated using Equation 5.

Protein content analysis

The protein content of the sample was determined using the Kjeldahl method. Initially, 2 g of the sample was weighed and transferred into the Kjeldahl tube. Afterwards, 7 g of K₂SO₄, 5 mg of selenium, 10 ml of 96% H₂SO₄, and 10 ml of 30% H₂O₂ were placed inside the Kjeldahl tube. The sample was digested by heating the tube until a clear, transparent solution was obtained. By using a distillation apparatus, 50 ml of 35% NaOH was added to the sample. The distillate will be transferred into an erlenmeyer flask containing 25 ml of 4% boric acid solution and 1 to 2 drops of mix indicator. The solution imparted a green-bluish color and was titrated with 0.2 N HCl until the pale pink color was achieved. The protein content, in the form of Nitrogen, was calculated using Equation 6 and 7.

Carbohydrate content analysis

In determining the carbohydrate content of the chia seeds powder, available carbohydrate by difference method was used i.e., residual weight after subtracting amounts of water, protein, fat,

$$\% \text{ Cooking loss} = \frac{\text{Dried supernatant}}{\text{Initial weight of sample}} \times 100\% \quad (1)$$

$$\% \text{ Water absorption} = \frac{\text{Weight of cooked noodle} - \text{weight of raw noodle}}{\text{Weight of raw noodle}} \times 100\% \quad (2)$$

$$\text{Moisture content (\% wet basis)} = \frac{\text{Initial weight of sample} - \text{final weight of sample}}{\text{Initial weight of sample}} \times 100\% \quad (3)$$

$$\% \text{ Ash content} = \frac{\text{Weight of sample after ashing}}{\text{Initial weight of sample}} \times 100\% \quad (4)$$

$$\% \text{ Fat content} = \frac{\text{Weight of fat and boiling flask} - \text{weight of boiling flask}}{\text{Weight of sample}} \times 100\% \quad (5)$$

$$\% \text{ N} = \frac{(\text{ml of HCl sample} - \text{ml of HCl blank}) \times 0.2 \text{ N HCl} \times 14.007}{\text{Weight of sample (mg)}} \times 100\% \quad (6)$$

$$\% \text{ Protein content} = \% \text{ Nitrogen content} \times \text{protein conversion factor} \quad (7)$$

$$\text{Protein conversion factor} = 6.25$$

$$\% \text{ Carbohydrate content} = 100 - (\% \text{ moisture} + \% \text{ ash} + \% \text{ fat} + \% \text{ protein}) \quad (8)$$

$$\text{°Hue} = \text{Arctan} \left(\frac{b}{a} \right) \quad (9)$$

and ash. The calculation of carbohydrate content can be seen in Equation 8.

Color analysis

Color of the noodle was examined using Konica Minolta CR-400 chromameter to evaluates L^* , a^* , and b^* values. The L^* value represents darkness/brightness, which ranges from 0 to 100 (dark to bright). The a^* value denotes redness (+) and greenness (-) of the sample. While b^* value indicates the yellowness (+) and blueness (-) of the sample. To conclude the color description of the noodle, the hue angle ($^{\circ}$ Hue) can be determined by using the a^* and b^* values to acquire and interpret the description of the color. The hue angle can be calculated using Equation 9 and the result can be referred to the color wheel of $^{\circ}$ Hue values.

Statistical analysis

This research was carried out using a completely randomized two-factorial experimental design with three replications (duplo). The two factors include the ratio of wheat flour to MOCAF and the amount of chia seed powder. The results were statistically analyzed using the two-way ANOVA Duncan multiple range test (DMRT). The data were processed using IBM SPSS Statistics Version 25.

RESULTS AND DISCUSSION

Color properties and proximate composition of chia seed powder

The chia seed powder obtained in this research was analyzed based on color and proximate composition. The results of the analysis are presented in Table 2 and 3. The chia seed powder shows a brightness/darkness value of 37.65 ± 0.21 , which implies relatively dark in color with a $^{\circ}$ Hue value of 73.16 ± 1.01 , which falls into the category of "yellow-red" according to the hue angle color wheel. Proximate analysis was performed to obtain the composition of the chia seeds powder (Table 3). The results indicate that the chia seed powder was low in moisture content ($5.06 \pm 0.24\%$) and relatively high in fat ($39.13 \pm 0.69\%$), protein ($23.72 \pm 1.29\%$), and carbohydrate ($28.80 \pm 1.45\%$) contents.

Chia seeds stand out for their nutritional value due to its high fat content (Kulczyński et al., 2019). Fat content of chia seeds may vary depending on the country of origin. As reported by Ashura et al. (2021), the fat content of chia seeds varies between 30 to 33%, while Jin et al. (2012) reported a value of up to 40%. Chia is

known to be a rich source of polyunsaturated fatty acids (PUFAs), mainly linolenic and linoleic acids (Di Marco et al., 2020). In this study, however, the protein content was being emphasized since chia seeds is also considered as a good source of protein. The substitution of wheat flour with MOCAF in the wet noodles would lead to lower protein content. As can be seen in a study conducted by Ratnawati et al. (2021), the protein content of biscuits made from MOCAF was found to be $4.08 \pm 0.01\%$, significantly lower than that of commercial biscuits ($8.56 \pm 0.01\%$). Different studies reported different protein content of chia seeds, ranging from 16 to 25% (Dinçoğlu and Yeşildemir, 2019). The supplementation of chia seeds into food products will, therefore, increase the protein content. The addition of chia seeds in bakery products and gluten-free noodles was found to increase their protein content (Grancieri et al., 2019).

Cooking quality of wet noodles

Water absorption refers to the amount of water absorbed by noodles during boiling process. It can be seen in Figure 1 that there is an interaction and significant difference between the different ratios of wheat flour substitution and different concentrations of chia seed powder. Based on Figure 1, it can be inferred that the addition of chia seed powder increases the water absorption ability of the wet noodle. Overall, significantly higher water absorption was shown by 10% and 15% chia seed powder at 60:40 wheat flour to MOCAF substitution ratio. The control wet noodles (100:0 ratio of wheat flour to MOCAF and 0% chia seed powder) showed significantly lower water absorption compared to the other formulations.

Chia seeds can absorb water due to their hydrophilic properties. Gel or mucilage forms, surrounding the seeds upon contact with water.

Table 2. Color properties of chia seed powder

Component	Value
L^*	37.65 ± 0.21
$^{\circ}$ Hue	73.16 ± 1.01

Table 3. Proximate composition of chia seed powder

Component	Amount (%)
Moisture	5.06 ± 0.24
Ash	3.83 ± 0.05
Fat	39.13 ± 0.69
Protein	23.72 ± 1.29
Carbohydrate	28.80 ± 1.45

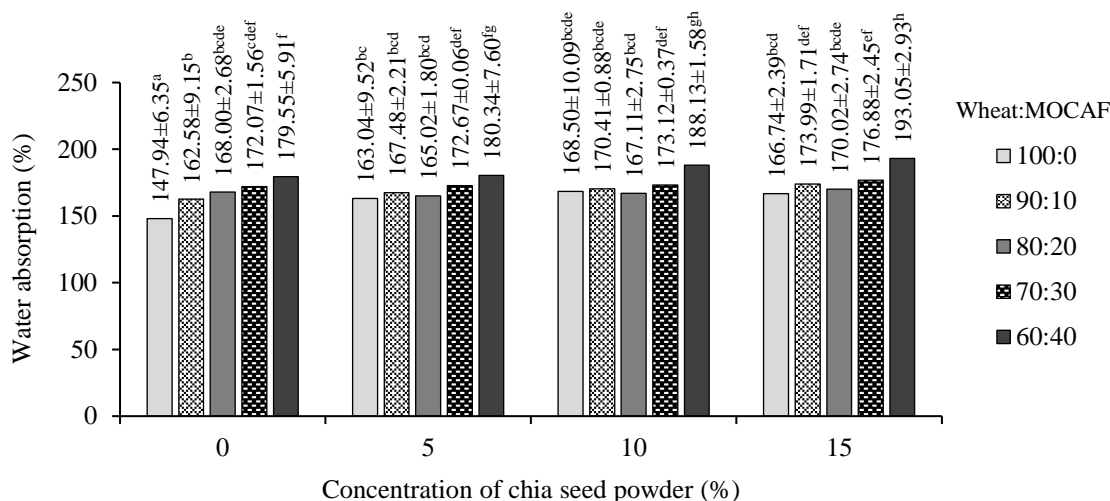


Figure 1. Effects of wheat flour to MOCAF ratio and chia seed powder towards water absorption
Note: Different superscripts indicate significant difference ($p < 0.05$)

This mucilaginous compound, which has similar properties to hydrocolloids, has high water absorption and retention capacity (Levent, 2017). In addition, the presence of hemicellulose and lignin in chia seeds contributed to greater water absorption mainly due to the soluble fiber structures which have high water-holding capacity (Gropper and Smith, 2013). This explains why the addition of chia seed powder in the wet noodles resulted in increased water absorption due to its water-binding capacity. An increase in water absorption due to the use of chia seeds in pasta formulation was seen by Oliveira et al. (2015). In that study, 50% higher water absorption at 7.5% chia seeds substitution was seen compared to the control pasta.

The fermentation process involved in the processing of MOCAF causes the degradation of starch granules, particularly decreasing the crystallinity and becoming more amorphous and porous (Diniyah et al., 2018). The water-binding capacity of the starch is enhanced as more water is trapped within the amorphous form. Other than that, the reduced proportion of wheat flour means reduced protein to form a gluten network, facilitating water penetration. Hence, higher substitution of MOCAF leads to higher water absorption. In the study done by Lala et al. (2013) regarding characteristics of instant noodles based on wheat flour and MOCAF, a higher proportion of MOCAF resulted in instant noodles with higher water absorption, ranging from 226.73 to 305.25% compared to the control wet noodle, which was 212.49%.

Cooking loss is an important attribute in determining quality of noodle. It is defined as the amount of solid substance lost into the cooking water (Sirichokworrakit et al., 2015). According to Pongpichaiudom and Songsermpong (2018), cooking loss of less than 10% is recommended because high loss of solids indicates poor quality of noodles. High cooking loss is undesirable as it suggests high starch solubility, indicated by turbid cooking water, low cooking tolerance, and sticky mouth feel. In this study, statistical analysis showed no interaction between the different wheat flour substitution ratios and concentrations of chia seed powder towards cooking loss of the wet noodles. Yet, there were significant differences ($p < 0.05$) in cooking loss due to the two factors independently. The effects of different wheat flour substitution ratios and concentrations of chia seed powder are displayed in Figure 2 and 3, respectively.

Figure 2 shows that 60:40 wheat flour to MOCAF ratio resulted in significantly higher cooking loss while 90:10 and 80:20 show comparable cooking loss compared to the control wet noodle (100:0). The loss of the components in the cooking water is due to the leaching of some soluble components, primarily amylose, from the dough network. The result found in this study is similar to the result reported by Odey and Lee (2020), in which pasta made from fermented cassava roots exhibited significantly higher cooking loss due to higher amylose content. The presence of the protein-gluten network can encapsulate and trap the starch granules, preventing the loss of starch. The substitution of

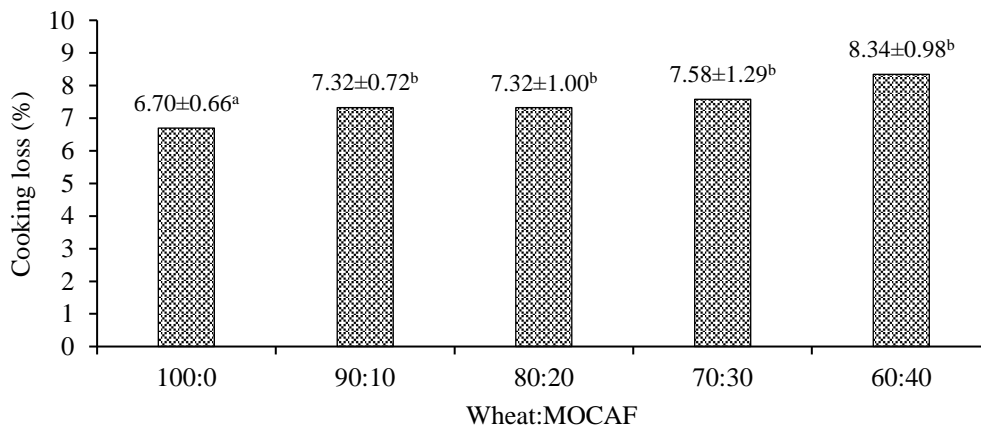


Figure 2. Effects of wheat flour to MOCAF ratio towards cooking loss of wet noodles
Note: Different superscripts indicate significant difference ($p < 0.05$)

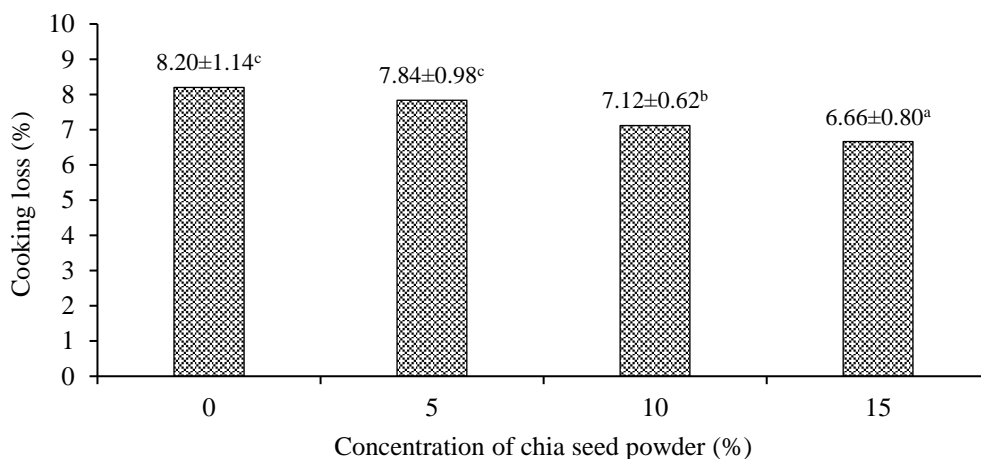


Figure 3. Effects of chia seed powder concentration towards cooking loss of wet noodles
Note: Different superscripts indicate significant difference ($p < 0.05$)

MOCAF in the wet noodle formulation reduced the protein-gluten network and weakened the gluten network of the dough, lowering the degree of structure of the noodles and hence resulted to inferior cooking quality.

In Figure 3, it can be seen that the addition of chia seed powder at 10% and 15% significantly decreased the cooking loss compared to the control sample (0% chia seeds powder). The cooking loss decreased from 8.20±1.09 to 6.66±0.68% by the addition of 15% chia seed powder. This may be due to the high protein content in chia seeds that are able to retain amylose from diffusing out from the noodle dough system by reducing swelling of starch granules (Oliveira et al., 2015; Levent, 2017). The unique characteristic of chia seeds also contributed to the reduced cooking loss as also seen in a study done by Huerta et al. (2018) where mucilage from chia seeds that were used in the formulation of gluten-free bread led to lower cooking loss. In this study, the addition of chia

seed powder at 10% and 15% into the wet noodle formulation was effective in reducing the cooking loss.

Textural properties of wet noodles

Texture profile analysis was performed to study whether the utilization of chia seed powder may improve the texture of the wet noodle. The parameters to be observed were hardness, cohesiveness, and chewiness. Hardness is the peak force obtained during the first compression. In other words, it can be referred to the noodle bite (Nouri et al., 2015). Based on the statistical analysis, there was an interaction between the wheat flour-to-MOCAF ratio and chia seed powder concentration in terms of the hardness of the wet noodles (Figure 4). The results also indicate that a higher level of MOCAF substitution would increase the hardness of the noodles. The particular pattern can be seen in noodles at a 60:40 ratio, in which a significant increase can be seen from 10% and 15% addition

of chia seed powder while at 5% addition, comparable hardness was seen in comparison to noodles without any chia seeds. The control noodle was not significantly different from the noodles with a 90:10 ratio using 5% chia seed powder and an 80:20 ratio using 5%, 10%, and 15% chia seed powder.

The addition of chia seed is thought to increase the hardness of noodles as the seeds would form a gel upon contact with water. However, the hardness did not increase upon increasing the concentration of the chia seed powder, except in the noodles with a 60:40 wheat flour to MOCFAF ratio. The addition of chia seed powder may interact and dilute the gluten network and also interfere with starch gelation, hence, impairing the textural properties of the noodles (Zhu and Li, 2019). A decline in hardness due to the use of chia seed powder was also found by Romankiewicz et al. (2017) in wheat bread. The chia seed addition would weaken the gluten matrix, which led to weak cell structure, thus decreasing the force required to compress the product (hardness).

One plausible explanation that could justify the result is that MOCFAF contains more than 25% of amylose content, slightly higher than wheat flour which ranges from 22.7 to 24.9% of amylose content (Raharja et al., 2017). Afifah and Ratnawati (2017) reported that the amylose content in MOCFAF was 27.83%. Fairly high amylose content can, therefore, increase the

hardness of the noodles. Wu et al. (2018) observed the same behavior when studying characteristics of brown rice noodles with different amylose content, in which they found that increase of amylose content generally increased the hardness, cohesiveness, and chewiness of the noodle. This is because higher amylose content in noodle would undergo higher degree of gelatinization during the boiling process and experience retrogradation during tempering. The retrogradation, which is most likely to occur in high amylose starches, would result in textural changes such as increased hardness due to starch being retrograded into a more crystalline structure during cooling (Vaclavik and Christian, 2014).

Noodle cohesiveness can be defined as the strength of internal bonds that form the structure of the noodles. High value of this character is desirable towards the quality of the noodles. Based on statistical analysis, significant effect towards cohesiveness of the noodles was only shown by the wheat flour to MOCFAF ratio (Figure 5). It can be seen that the 60:40 ratio resulted in significantly higher cohesiveness compared to wheat wet noodle with no substitution of MOCFAF, while ratios of 90:10, 80:20, and 70:30 showed no significant difference compared to the control wet noodles. Longer resting time, which leads to lower conditioning temperature may result in an increase in cohesiveness due to the process of starch

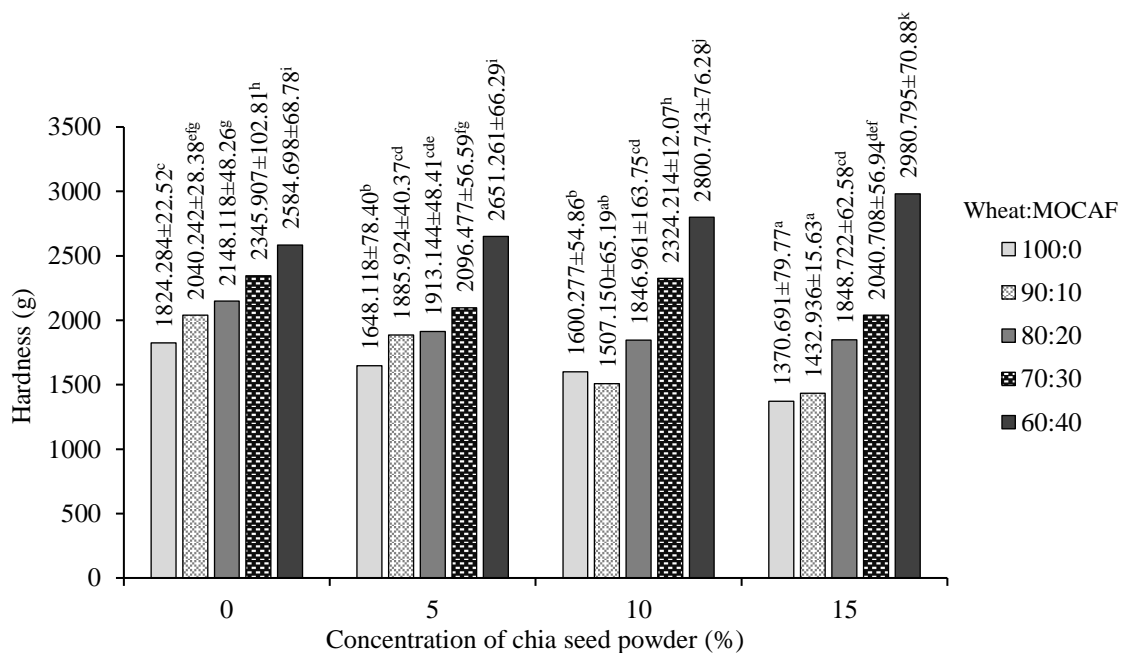


Figure 4. Effects of wheat flour to MOCFAF ratio and chia seed powder concentration towards hardness of the wet noodles

Note: Different superscripts indicate significant difference ($p < 0.05$)

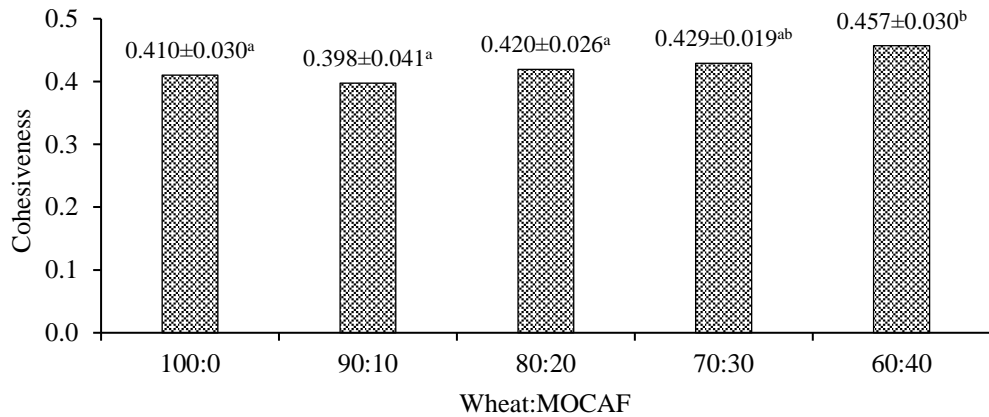


Figure 5. Effects of wheat flour to MOCAF ratio towards cohesiveness of wet noodles
Note: Different superscripts indicate significant difference ($p < 0.05$)

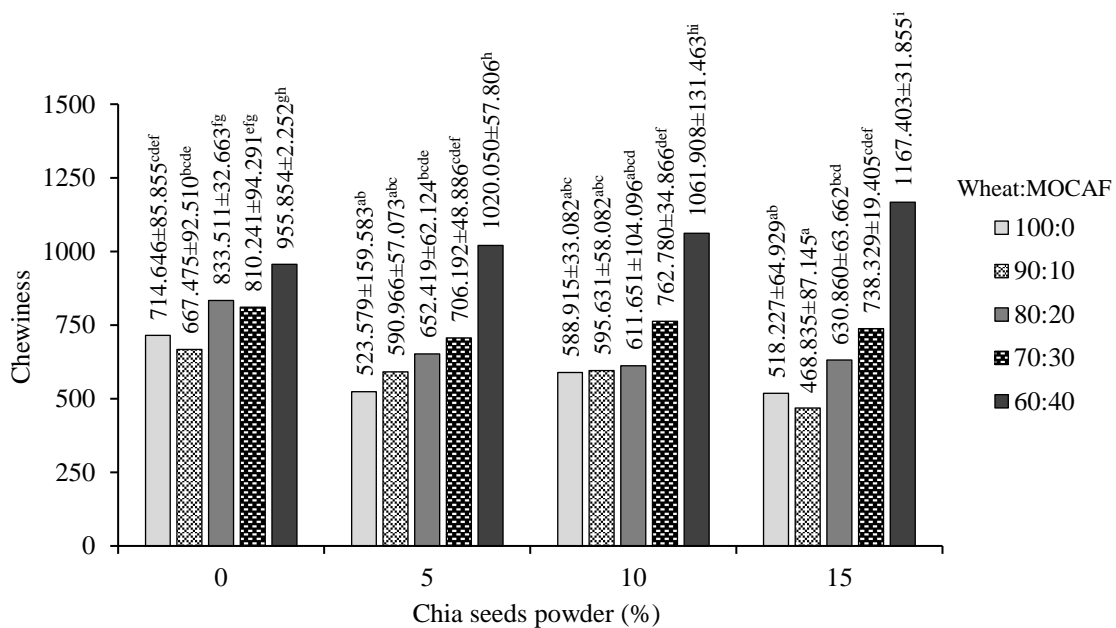


Figure 6. Effects of wheat flour to MOCAF ratio and chia seed powder towards chewiness of wet noodles

Note: Different superscripts indicate significant difference ($p < 0.05$)

retrogradation. In this case, the noodle formulation 60:40 had relatively higher amylose and amylopectin content, which would undergo starch retrogradation, leading to increased cohesiveness. Moreover, the result of cohesiveness in this research is similar to a study conducted by Wu et al. (2018), which reported that higher amylose content increased the cohesiveness of noodles.

Chewiness indicates the energy required to chew a food until it is adequate enough to be swallowed (Fernández-López et al., 2019). Like hardness, statistical analysis showed that there is an interaction between the flour ratio and the amount of chia seeds powder. According

to Figure 6, the addition of chia seeds powder caused a varying result to the chewiness of the noodle. Overall, an increase in chewiness can be observed in the 60:40 flours ratio with or without chia seed powder. However, it can also be seen that at a 60:40 flour ratio, increased amount of chia seed powder increased chewiness of the noodles. The higher chewiness value exhibited by the 60:40 flour ratio might be due to higher starch content that underwent a retrogradation process (Vaclavik and Christian, 2014). In a recent study (Odey and Lee, 2020), it was reported that higher amylose content of MOCAF in pasta resulted in higher chewiness value as well. The increase in chewiness of the noodles can also be attributed

to the increase in hardness (Figure 4) and cohesiveness (Figure 5), which in turn influence chewiness.

Protein content of wet noodles

Protein analysis was done to identify whether chia seed powder addition can complement the reduced protein content due to MOCAF substitution as chia seeds are known to be a good source of protein. Based on the statistical analysis, there was an interaction between the wheat flour to MOCAF ratio and chia seed powder concentration in terms of protein content of the wet noodles (Figure 7).

Based on Figure 7, higher MOCAF substitution ratio significantly reduced protein content of the noodles. This is because of the lower protein content in MOCAF compared to wheat flour. Commercial all-purpose wheat flour typically contains 9 to 12% protein, while Dewi et al. (2020) reported that MOCAF of various local varieties have protein content between 0.76 to 1.24%. Therefore, substituting wheat flour with MOCAF will decrease the protein content of the wet noodles.

On the contrary, it can be seen that the protein content increased with the addition of chia seed powder. Protein content of the control noodles (0% MOCAF substitution and 0% chia seed powder) was not significantly different to the noodles with a 90:10 wheat flour to MOCAF ratio at 10% and 15% chia seed powder, and an 80:20 flour ratio at 15% chia seed powder. Moreover,

for unsubstituted noodles (100:0 ratio), the incorporation of chia seed powder at 5%, 10%, and 15% significantly increased the protein content from 5.06 ± 0.02 to $5.70 \pm 0.01\%$. In this study, the protein content of the chia seed powder was $23.72 \pm 1.29\%$ (Table 3). These results confirm the benefit of increased protein content upon supplementation of chia seed powder in the product. The increase of protein content was also seen in gluten-free noodle as reported by Levent (2017), where addition of 10 to 30% chia seed flour resulted in 7 to 10% protein content, while the one without chia seed flour resulted in 6% protein content.

Color properties of wet noodles

As presented in Figure 8, it can be inferred that the addition of chia seed powder resulted in a lower L^* value, which means that the wet noodles containing more chia seed powder are darker in appearance, while the substitution of MOCAF gives a varying result. The wet noodles with no addition of chia seed powder is significantly brighter compared to the other formulations. The addition of 15% chia seed powder resulted in the darkest wet noodles. Since the chia seed used in this study was the black chia seed, color of the seeds is likely to influence color of the final product. Hence, higher chia seed powder concentration led to a reduction in brightness. Similar behavior was found by Levent (2017), indicating that higher chia seed proportion resulted in lower L^* value.

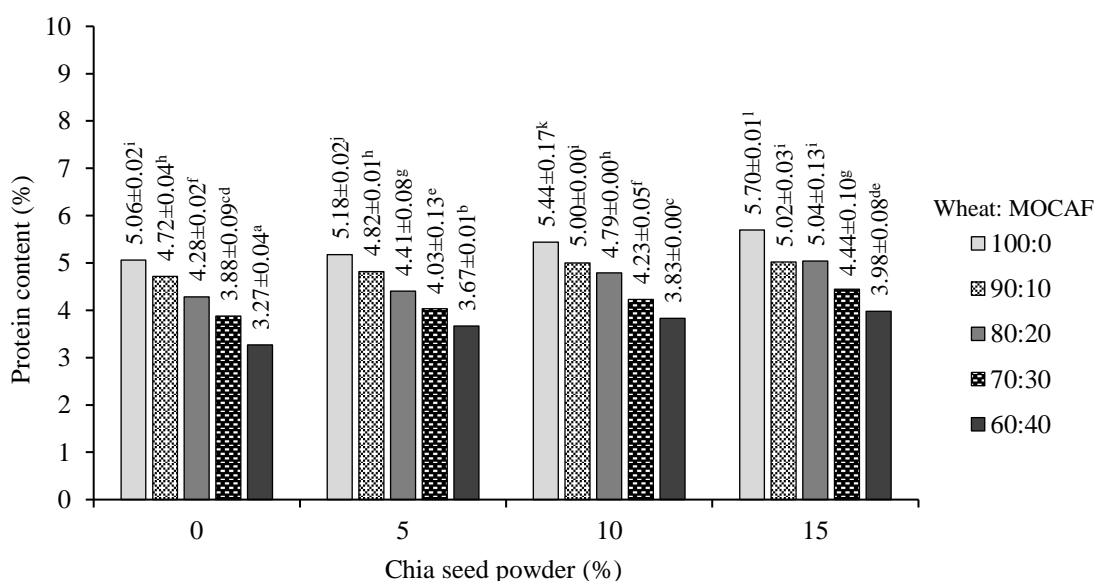


Figure 7. Effects of wheat flour to MOCAF ratio and chia seed powder concentration towards protein content of wet noodles

Note: Different superscripts indicate significant difference ($p < 0.05$)

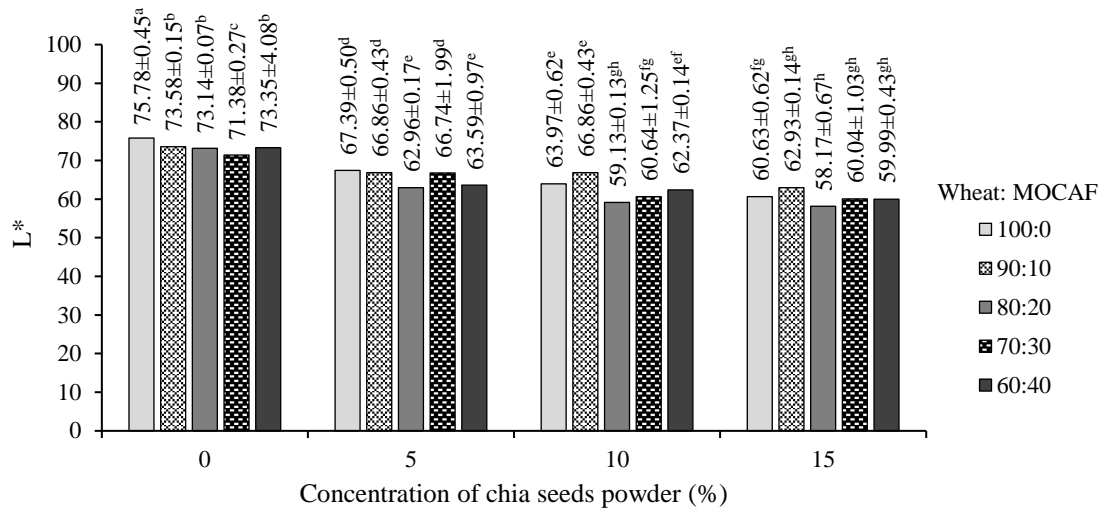


Figure 8. Effects of wheat flour to MOCAF ratio and chia seed powder towards brightness/darkness of wet noodle

Note: Different superscripts indicate there is significant difference ($p < 0.05$)

Table 4. Effects of wheat flour to MOCAF ratio and chia seed powder towards °Hue angle of wet noodles

Chia seed powder (%)	Wheat flour to MOCAF ratio	°Hue	Color description
0	100:0	72.75 ± 0.28 ^j	Yellow-red
	90:10	88.22 ± 0.30 ^p	
	80:20	84.00 ± 0.75 ^o	
	70:30	87.91 ± 0.62 ^p	
	60:40	74.67 ± 0.43 ⁿ	
5	100:0	82.71 ± 0.28 ^j	Yellow-red
	90:10	62.52 ± 0.84 ^c	
	80:20	67.05 ± 0.22 ⁱ	
	70:30	65.72 ± 1.34 ^{gh}	
	60:40	65.56 ± 0.16 ^{gh}	
10	100:0	80.77 ± 0.06 ^m	Yellow-red
	90:10	59.66 ± 0.09 ^b	
	80:20	65.36 ± 0.04 ^{fgh}	
	70:30	63.21 ± 1.25 ^{cd}	
	60:40	64.02 ± 1.48 ^{de}	
15	100:0	79.02 ± 0.11 ^l	Yellow-red
	90:10	57.30 ± 0.50 ^a	
	80:20	64.38 ± 1.32 ^{ef}	
	70:30	66.31 ± 0.41 ^{hi}	
	60:40	65.09 ± 0.06 ^{efg}	

°Hue of the wet noodles was also calculated based on the a^* and b^* values. Table 4 presents that the wet noodle without the addition of chia seed powder shows °Hue value ranging from 72° to 88°, indicating that the wet noodles were “yellow-red” in color according to the color wheel of °Hue value. The addition of chia seed powder resulted in a change of °Hue value from 57° to 67°, except for the wet noodles with a 100:0 ratio. Even though there was a significant decrease in the hue angle value due to the addition of

chia seed powder, the wet noodles still fall into the same category as “yellow-red”, but moving closer towards “red” based on the color wheel of °Hue value.

CONCLUSIONS

Chia seeds in the form of powder can be used for making wet noodles as hydrocolloid with its gel-forming ability. The substitution of wheat flour using MOCAF at different ratios affect the

cooking quality and textural properties. Higher MOCAF substitution resulted in higher water absorption and cooking loss, as well as undesirable (harder) textural properties. Incorporation of chia seed powder successfully lower the cooking loss and higher water absorption of the MOCAF-substituted noodles and noodle with 100% wheat flour without chia seed powder. In regards to the textural characteristics, it can be concluded that the chia seed powder is able to reduce the hardness while maintaining and increasing chewiness of the MOCAF-substituted noodles compared to the 100% wheat flour noodle without chia seed powder. Further study on the morphology of the noodles using scanning electron microscope (SEM), spectral analysis, and thermal analysis should be performed to strengthen the results. It is also found that the addition of chia seed powder significantly increases the protein content of the unsubstituted noodle, confirming the use of chia seeds as a plant-based source of protein in food products. Specifically, for the MOCAF-substituted noodles, comparable protein content to that of 100% wheat flour noodles, can be achieved with the use of 10 to 15% chia seed powder at a maximum 80:20 substitution ratio.

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