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Effect of Spirulina (*Arthrospira platensis*) Powder on The Physico-chemical and Sensory Characterization of Dry Noodle

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Abstract

Dry noodles are a staple food item among the Asian population. Generally, it contains a low-fat and a high-carbohydrate level, however, it lacks other nutrients, such as protein and dietary fiber. The addition of spirulina into dry noodles may increase both protein and dietary fiber. This study aimed to determine the effect of spirulina fortified in the dry noodle on physicochemical and sensory properties. The method used in this study was experimental with a completely randomized design (CRD) using 4 replications. The spirulina powders added into dry noodles were 0%, 4%, 4.5%, 5%, 5.5%, 6% and 6.5%. The results showed the addition of spirulina in dry noodles had a significant effect ($p<0.05$) on nutritional values, such as protein, fat, ash, carbohydrate, and dietary fiber. In addition, the physical properties of fortified noodles, including cooking loss, elongation, and tensile strength were also significant differences. For sensory attributes, noodles fortified with different concentrations of spirulina showed significant effects in appearance, aroma, color, taste, and texture. A selected dry noodle fortified with 6% spirulina based on the physicochemical and sensory characterization. The fortified dry noodle can contribute to improving the nutritional profile that may be beneficial to health.

INTRODUCTION

Noodles are a popular staple food item in the Asian community. Lü *et al.* (2014) proved that noodle products originated from China. Noodles are recently well-known around the world with a large variety of tastes and names in each country. By processing, noodles are classified into several categories among the most consumed, such as dry noodles, wet noodles, and instant noodles. Wet noodles are also called fresh noodles with a short shelf life when wet noodles are dried and are classified as dry noodles. Nowadays, dry noodles are much preferred by many people due to their low-fat content (Hou, 2010). However, commercial dry noodles are mainly produced with wheat flour. Rossel *et al.* (2014) revealed dry noodles formulated with wheat flour have high amounts of gluten, resulting in undesirable acceptance from some consumers with gluten sensitivity due to health issues. Moreover, dry noodles are considered food products with low nutritional values, including protein and dietary fiber. To deal with these issues, dry noodles can be substituted and formulated with other food ingredients (Astawan, 2008).

In recent years, there has been considerable attention in formulating food products with functional ingredients to solve the low nutritional aspect, as well as improve health benefits, particularly the noodle product (Zhu and Li, 2019). Previous studies reported dry noodles could be formulated with other food ingredients, such as seaweed and fish meat. Sozer *et al.* (2007) reported the effect of seaweed flour formulated with noodle samples increased its nutritional traits and decreased the amount of gluten. Another report showed that the dry noodles fortified with fish powder improved the nutritional contents, especially in protein (Debbarma *et al*., 2017; Jaziri *et al*., 2019). *Eucheuma spinosum* is an important seaweed used for fortification or substitution targets due to its nutrient composition, including protein, dietary fiber, and minerals. Meanwhile, *Pangasius pangasius*, a fresh-water fish, has the potential to be processed into raw material for fish flour as a source of protein (Murtidjo, 2001; De Oliveira *et al*., 2015).

Fish flour can be supplemented into dry noodles. However, a preliminary study showed that the dry noodles added with seaweed (*E. spinosum*) and fish meat (*P. pangasius*) still need to enrich the nutritional straits with another functional ingredient, particularly in protein and dietary fiber. Spirulina (*Arthrospira platensis*), a type of blue-green microalgae, is rich in protein around 60-70% (Christwardana *et al*., 2013) and high in dietary fiber (Enkantari *et al*., 2017). In addition, spirulina is highly known and generally regarded as safe (GRAS) and officially accepted by the Food and Drug Administration (FDA) (Chacón-Lee and González-Mariño, 2010). In food application, spirulina is widely consumed and fortified with a wide range of food products. Raja *et al*. (2018) reported the addition of spirulina powder into food samples increased the nutritional level up to 3-5%. This study hypothesized that fortifying dry noodles with spirulina powder may give favorable nutritional features.

Spirulina powder was added to up to 6.5% of whole flour used in the formulation of dry noodles. The physical traits of fortified dry noodles were analyzed. Also, the nutritional compositions, including protein, fat, ash, carbohydrate, moisture, and total dietary fiber were evaluated. Moreover, sensory attributes of the fortified noodles were also studied to give a basis for food product development. This study may stimulate further investigation into developing high-quality and healthy dry noodles.

METHODOLOGY

Place and Time

This research was conducted in Science and Technology of Fisheries Product, Universitas Brawijaya between January and March 2019.

Research Materials

Materials used in the research included a dry powder of spirulina (*A. platensis*) (Green Gold, Surabaya, Indonesia), wheat flour (Cakra Kembar, Indonesia), *P. pangasius* was purchased from a local market (Malang, Indonesia) and *E. spinosum* was obtained from a local market (Akar Mas, Malang, Indonesia). For chemicals, hexane, H_2SO_4, NaOH, 0.1% methyl red, ethanol and Na_2CO_3 are all supplied from Merck (Germany). All other chemicals used were of analytical grades.

Research Design

The research method used in this study was experimental with a completely randomized design (CRD) using 4 replications. The independent variables were the concentration of spirulina added to dry noodles, among others: 0%; 4%; 4.5%; 5%; 5.5%; 6%; and 6.5%. The physical parameters were cooking loss, elongation, and tensile strength. Chemical parameters were moisture, protein, fat, ash, carbohydrates, and dietary fiber. The sensory qualities were appearance, texture, aroma, taste, and color. The research stages were making Patin flour, *E. spinosum* flour, and dry noodles fortified with spirulina.

Work Procedure

Preparation of Patin (*P. pangasius)* Flour

Patin flour was made according to the research by De Oliveira *et al*. (2015). First, the fish was weeded and filed. Then, the fish meat was washed manually three times in ice water (7°C) for 5 minutes. Patin meat was mashed using a blender. After that, the meat was filtered using a calico cloth until the water content was reduced. The smooth meat was put in the oven at 60°C until dry (± 90 minutes). Dried meat was mashed using a dry mill (Cosmos CB802). The result was then sieved using a 100-mesh sieve.

Preparation of *E. spinosum* Flour

The preparation of *E. spinosum* flour used the method of Agusman *et al*. (2014) with several modifications. *E. spinosum* was washed in running water and then chopped into small pieces (± 0.5 cm). *E. spinosum* was put in an oven at 65°C for 12. The dried *E. spinosum* was ground using a disk mill and then passed through a 100-mesh sieve.

Preparation of Dry Noodle Fortified with Spirulina

The dry noodles were made based on the Vatsala and Sudesh (2017) method with slight modifications. The formulations can be seen in Table 1. Patin flour and E. spinosum flour were mixed with wheat flour, then added with spirulina powder. Warm water (45°C), eggs, and salt were added and then gently kneaded to form a doughy dough. Then the dough was allowed to rest at room temperature for 30 minutes. The dough was sheeted using a grinding tool (Ossel ZZ-150, Indonesia) with the thickest size for the first mill, then changed size to 3 mm which was repeated twice. The sheets were then molded into noodle strands. The noodles were folded in half and steamed for 2 minutes. The steamed noodles were then baked for 3 hours at 70°C. Dry noodles were put into polyethylene plastic and stored at room temperature before physical, chemical, and sensory analyses were carried out.

Table 1. The dry noodles formulation.

	Spirulina (%)						
	A	B	C	D	E	F	G
	0	4	4.5	5	5.5	6	6.5
Ingredient	Formula (%)						
Wheat flour	50	50	50	50	50	50	50
Patin flour	5	5	5	5	5	5	5
E. spinosum flour	5	5	5	5	5	5	5
Water	30	30	30	30	30	30	30
Egg	8	8	8	8	8	8	8
Salt	2	2	2	2	2	2	2

Analysis Dry Noodle Fortified with Spirulina

Cooking Loss (Kamble *et al.*, 2018)

Approximately 2 g of noodle was cooked in 100 ml of boiling water in a beaker glass. After boiling, the sample was removed and the boiling water was heated in the oven until its weight was constant. Cooking losses were calculated as follows:

$$CL = \frac{W_0 - W_1}{W_0} \times 100\%$$

Where:
CL = cooking loss (%)
W_0 = initial sample weight (g)
W_1 = final sample weight (g)

Elongation (Puspitaningrum *et al.*, 2018)

Elongation was analyzed by Texture Profile Analyzer (CT-3 Texture Analyzer, USA) with the following test procedure. The dry noodles were initially cooked and selected straight with a length of ± 4 cm. The noodle was clamped to the hook. The machine was run through the computer so that the noodles were pulled off. The elongation value could be read directly on the computer.

Tensile Strength (Puspitaningrum *et al.*, 2018)

Tensile strength was analyzed by Texture Profile Analyzer (CT-3 Texture Analyzer, USA). The principle of testing is that the sample is placed under the towing accessory. The computer will automatically record the pulling force (N) against the sample.

Proximate Composition Analysis (AOAC, 2005)

Proximate composition analysis included moisture, protein, fat, and ash content. Moisture and ash content were analyzed using the gravimetric method. Protein content was analyzed using the Kjeldahl method. Fat content was analyzed using the Soxhlet method.

Carbohydrate Content (Winarno, 2004)

The carbohydrate content was determined by a different method. This method is 100% reduced by protein, moisture, fat content, and ash content of dry noodles.

Dietary Fiber Content (Aalto *et al.*, 1988)

Dietary fiber including total dietary fiber, dissolved dietary fiber, and insoluble dietary fiber was analyzed using a multi-enzyme method.

Sensory Evaluation (SNI, 2006)

Sensory evaluation was analyzed using the hedonic scale test. A 40 untrained panel evaluated samples. The noodles were cooked in boiling water, drained, and tested. Panel fills out the assessment sheet. The attributes or parameters assessed by the panel include appearance, texture, aroma, taste, and color. The scales used are 1 (extremely dislike), 2 (dislike), 3 (like), and 4 (extremely like).

Data Analysis

Statistical analysis was performed with the SPSS 16.0 (IBM Corporation, New York, USA). Statistical significance was tested using one-way ANOVA and continued with the Duncan test with a significance level of 0.05 (5%). Data of sensory evaluation were analyzed using Kruskal-Wallis. The selected product was determined using the effective index method (De Garmo *et al.*, 1984).

RESULTS AND DISCUSSION

Physical Properties of Dry Noodles

Results of physical properties from each treatment can be seen in Table 2.

Table 2. Physical properties of the dry noodles fortified with Spirulina.

Dry Noodle	Cooking Loss	Elongation	Tensile Strength
A	13.65 ± 0.10^{g}	9.00 ± 0.01^{a}	0.06 ± 0.01^{a}
B	10.90 ± 0.12^{f}	13.33 ± 0.01^{b}	0.24 ± 0.01^{b}
C	9.70 ± 0.12^{e}	17.03 ± 0.01^{c}	0.27 ± 0.01^{c}
D	8.45 ± 0.10^{d}	21.00 ± 0.01^{d}	0.32 ± 0.01^{d}
E	7.45 ± 0.10^{c}	23.69 ± 0.01^{e}	0.35 ± 0.01^{e}
F	6.25 ± 0.10^{b}	27.31 ± 0.01^{f}	0.38 ± 0.01^{f}
G	5.65 ± 0.10^{a}	31.68 ± 0.01^{g}	0.42 ± 0.01^{g}

Note: The average in the same column with different superscript means are significantly different ($p<0.05$).

Cooking loss is the mass lost during heating or cooking (Soeparno, 1992). The percentage value of dry noodle cooking loss between treatments is presented in Table 2. Analysis of variance showed that the cooking loss value of noodles was significantly different ($p<0.05$). The lowest cooking loss value was 5.65% for dry noodles fortified with 6.5% spirulina and the highest shrinkage value was 13.56% for dry noodles without spirulina (control). The higher the spirulina added, the lower the cooking loss value of the noodles. This is due to the good homogeneity of the dough structure (Swinkels, 1985). The decrease in cooking losses along with the increase in the concentration of spirulina in dry noodles was due to the interaction between protein and starch. This study is in line with Duda *et al*. (2019) where the addition of cricket flour protein to wheat pasta can reduce cooking losses.

Debbarma *et al*. (2017) reported the value of cooking loss with the addition of 10% seaweed (*Ulva reticulata*) and 10% catfish (*Pangasianodon hypophthalmus*) by 8.20%. All of these studies were in accordance with the maximum cooking loss (10%) standard value of dry noodles reported by Murdiati *et al*. (2015). It is suggested that the addition of 6.5% spirulina in the manufacture of dry noodles can reduce the cooking losses of the resulting dry noodle products.

Elongation is the maximum extension of noodles which is given a tensile force until the noodles break (Fitriani, 2016). Analysis of variance in the elongation value of dry noodles was significantly different between treatments ($p<0.05$). The highest elongation value was 31.68% for dry noodles fortified with 6.5% spirulina. The dry noodles with the substitution of koro flour by Murdiati *et al.* (2015) were 7.9%. The elongation value of noodles in Herawati *et al*. (2017) study reached 41.61% with the addition of amylose-rich canna flour and Arenga starch. The increase in the value of elongation occurred with the increase in the concentration of spirulina in dry noodles. Agustini *et al*. (2017) stated that elongation is also influenced by protein content. Water bound by protein produces elastic dough (Husniati *et al*., 2015).

The force exerted on a material with the intention of knowing the strength of the material is called tensile strength (Salindeho *et al.,* 2013). Analysis of variance showed a significant difference in the tensile strength of dry noodles due to the addition of spirulina ($p<0.05$). The highest tensile strength value was 0.42 N in dry noodles fortified with 6.5% spirulina. The increase in the value of tensile strength is in line with the research of Herawati *et al.* (2017) with a tensile strength value of 0.03 N to 0.18 N. The quality of noodles that consumers want is one that has high tensile strength. Tensile strength and elongation have a correlation which is directly proportional. The tighter the structure on the noodle, the tensile strength and elongation will increase and the more difficult it is to break.

Proximate Analysis

Results of proximate analysis from each treatment can be seen in Table 3.

Table 3. Chemical properties of the dry noodles fortified with Spirulina.

Dry Noodle	Moisture	Protein	Fat	Ash	Carbohydrate	Total Dietary Fiber
A	7.40 ± 0.28[a]	8.78 ± 0.65[a]	3.75 ± 0.64[a]	1.17 ± 0.20[a]	78.90 ± 0.71[g]	1.39 ± 0.01[a]
B	8.30 ± 0.12[b]	14.77 ± 0.46[b]	5.13 ± 0.95[b]	1.92 ± 0.17[b]	69.89 ± 0.84[f]	3.41± 0.01[b]
C	8.60 ± 0.28[c]	16.57 ± 0.76[c]	5.75 ± 0.89[bc]	2.08 ± 0.17[b]	67.00 ± 1.18[e]	4.01± 0.01[c]
D	9.45 ± 0.25[d]	17.97 ± 0.46[d]	5.87 ± 0.48[bc]	2.58 ± 0.17[c]	64.13 ± 0.65[d]	4.26 ± 0.01[d]
E	10.15 ± 0.10[e]	19.16 ± 0.65[e]	6,13 ± 0.25[c]	2.75 ± 0.32[c]	61.81 ± 0.52[c]	4.82 ± 0.01[e]
F	10.85 ± 0.10[f]	21.36 ± 0.76[f]	6,37 ± 0.25[cd]	2.92 ± 0.32[cd]	58.50 ± 0.64[b]	5.16 ± 0.01[f]
G	12.25 ± 0.10[g]	22.56 ± 0.76[g]	7,13 ± 0.25[d]	3.17 ± 0.19[d]	54.90 ± 1.01[a]	5.94 ± 0.01[g]

Water is an important part of food because it can affect its appearance, texture, taste and durability. The moisture content depends on the water content which is chemically bound to the material. The energy that binds this type of water is relatively large, so a higher temperature is needed to evaporate it (Widiatmoko and Estiasih, 2015). Analysis of the variance of the addition of spirulina to the moisture content of dry noodles showed a significant effect ($p<0.05$). The moisture content of dry noodles ranged from 7.4% to 12.25% in dry noodles that were not fortified with spirulina. In contrast to the research of Aliya *et al.* (2016) which showed no significant effect of adding mocaf flour and catfish flour to the moisture content of dry noodles, which ranged from 11.15 ± 0.29% to 11.59 ± 0.31%. There was an increase in moisture content along with an increase in the concentration of spirulina in dry noodles. This increase in moisture content is due to the nature of spirulina which tends to be hygroscopic. Li *et al.* (2018) state that the presence of non-solution materials such as gluten, protein, starch, and other macromolecular compounds are known as water binders or deep binding water.

Proteins are macromolecular compounds that function for cell formation. Protein can also be used as a reserve to meet energy needs (Winarno, 2004). Analysis of variance showed a significant difference in protein content values between treatments ($p<0.05$). The highest protein content was 22.56% in dry noodles fortified with 6.5% spirulina. There was an increase in the value of protein levels with the addition of spirulina. In line with Amira *et al.* (2017) who obtained dry noodle protein content of 10.69% to 19.93%. The increase in protein levels is due to the influence of high levels of spirulina protein. The protein content in dry noodles fortified with spirulina based on SNI (2015) includes type I dry noodles because the protein content is above 11%.

Fat is the material that is the most effective source of energy (Winarno, 2004). Analysis of variance in the value of dry noodle fat content showed a significant difference ($p<0.05$). The highest fat content was 7.13% in dry noodles fortified with 6.5% spirulina. There was an increase in fat levels along with an increase in the concentration of spirulina in dry noodles. In line with the research of Agustini *et al.* (2017), the fat content of dry noodles is 1.76% in dry noodles that are not added with spirulina and 2.46% with the addition of 9% spirulina. Spirulina dry powder contains fat which can increase the fat content of dry noodles.

Ash content indicates the number of minerals in food. Henrikson (2009) states that spirulina contains calcium, iron, magnesium, sodium, potassium, phosphorus, zinc, manganese, copper, and chromium. Analysis of the variance of the ash content showed a significant difference between treatments ($p<0.05$). The highest ash content was 3.17% in dry noodles fortified with 6.5% spirulina. In contrast to the noodles with substitution of 5% to 20% fish flour which had a significant effect on the ash content of the noodles, the ash content ranged from 1.61% to 1.75%.

Carbohydrates are known as the main source of calories, especially for people in developing countries. Carbohydrates have a role in determining food properties such as texture, taste, appearance, etc. (Winarno, 2004). Analysis of the variance of the carbohydrate content of dry noodles between sublevels showed a significant difference ($p<0.05$). The highest carbohydrate content was 78.9% in dry noodles that were not fortified with spirulina. The lowest carbohydrate content was 54.9% in dry noodles fortified with 6.5% spirulina. In line with the research of Debbarma *et al.* (2017) which states that the substitution of patin and seaweed has a significant effect on the carbohydrate content of noodles, which ranges from 57.20% to 61.29%. Wulandari *et al.* (2016) stated that the higher the levels of other nutrients, the lower the carbohydrate content and vice versa.

Dietary fiber is a part of food that cannot be hydrolyzed by digestive enzymes (Bangun, 2003). Dietary fiber includes insoluble dietary fiber (IDF) and soluble dietary fiber (SDF). The effect of the addition of spirulina on the total dietary fiber of dry noodles showed a significant difference ($p<0.05$). The dry noodles with the highest dietary fiber were those with added 6.5% spirulina with a total dietary fiber of 5.44%. According to Belay (2008), 43% of the carbohydrate components in spirulina are dietary fiber. Spirulina contains hemicellulose and pectin. The addition of 7% spirulina in biscuits can increase food and food by up to 2.3% (Singh *et al.*, 2015).

Sensory Evaluation

Dry noodles in this study can be seen in Figure 1. The average value of the hedonic level of dried spirulina noodles is shown in Table 4. The *sensory quality evaluated* included appearance, texture, aroma, taste, and color.

Table 4. A sensory quality of the dry noodles fortified with Spirulina.

Sensory Properties	Average Value of The Hedonic Level						
	A	B	C	D	E	F	G
Appearance	2.70^{a}	2.98^{a}	3.00^{a}	3.05^{a}	3.08^{a}	3.18^{a}	3.10^{a}
Texture	2.65^{a}	2.83^{a}	2.98^{a}	3.00^{a}	3.10^{ab}	3.18^{ab}	3.28^{ab}
Aroma	3.15^{a}	3.03^{a}	2.75^{ab}	2.73^{ab}	2.63^{b}	2.63^{b}	2.60^{b}
Taste	2.60^{a}	3.00^{b}	3.08^{b}	3.10^{b}	3.18^{bc}	3.28^{bc}	2.98^{bc}
Color	2.93^{a}	3.03^{a}	3.08^{a}	3.20^{a}	3.03^{a}	2.95^{a}	2.78^{a}

Note: The average in the same column with different superscript means are significantly different ($p<0.05$).

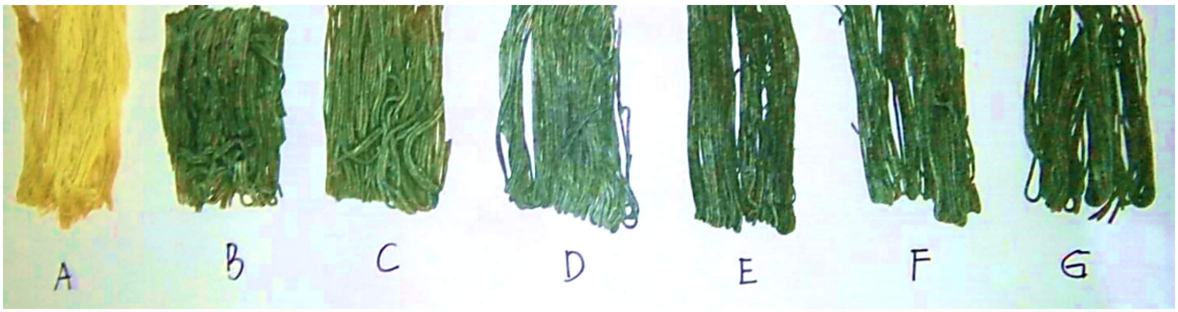

Figure 1. Control dry noodle and dry noodles fortified with *Spirulina*.

Panels have the habit of generating perceptions of other sensory parameters after seeing a product's appearance (Heymann and Lawless, 2010). The appearance of the noodles was related to the shape of the cooked dry noodles seen by the panel. Kruskal Wallis analysis showed that fortification of spirulina had no significant effect on the appearance of dry noodles ($p>0.05$). The average value of acceptance of the appearance of dry noodles fortified with spirulina was 2.7 - 3.18 with the highest score being for dry noodles fortified with 6% spirulina. The shape of the cooked dry noodles is symmetrical and the surface is smooth. However, the surface of cooked dry noodles without the addition of spirulina was not evenly distributed so it was not liked by the panel. Panelists tend to like interesting foods (Utari *et al*., 2016).

The texture is one of the parameters that can be touched and felt by the senses. Food texture is the response of the parts in the oral cavity to food. The texture is a combination of several physical properties which include the size and shape of a food product (Tarwendah, 2017). Spirulina fortification had a significant effect on the texture of dry noodles ($p<0.05$). The average value of the texture acceptance of spirulina fortified dry noodles was 2.65 - 3.28 with the highest score dry noodles fortified with 6.5% spirulina. The moisture content of the dry powder of spirulina is very low. Thus, the water in the noodles is pulled by the spirulina, so the texture of the noodles is chewy. The texture of the noodles is strongly influenced by the protein network. According to Kusnadi *et al*. (2012), gelatinization involves the process of binding water and tissue to the chain of starch and protein molecules.

Aroma is the response generated when volatile compounds enter the nasal cavity and are captured by the olfactory system (Tarwendah, 2017). Spirulina fortification had a significant effect on the aroma of dry noodles ($p<0.05$). The average value of receiving the aroma of spirulina fortified dry noodles was 2.60 - 3.15 with the highest score for dry noodles without spirulina. Panel assessment of the aroma of dry noodles decreased with increasing concentrations of spirulina. This is because the higher the concentration of spirulina is added, the fishier the cooked dry noodles are. Aguero *et al*. (2003) stated that there are 54 volatile compounds in spirulina and 23 carbonyl compounds that are volatile, there are heptanal and aromatic ketones which cause off-flavor.

Flavor compounds are mixtures of compounds that can affect the sense of taste (Tarwendah, 2017). Spirulina fortification had a significant effect on the taste of dry noodles ($p<0.05$). The average value of taste acceptance of spirulina fortified dry noodles was 2.60 - 3.28 with the highest score of dry noodles with 6% spirulina fortification. Panel assessment of the taste of dry noodles increased with the addition of spirulina concentration up to 6% and decreased at a concentration of 6.5%. This is because as the spirulina concentration increases, the taste of cooked dry noodles is richer and saltier. According to Wulandari *et al*. (2016) the fat and protein content.

Color is a perception arising from light detection after interacting with an object (Heymann and Lawless, 2010). Fortification of spirulina did not have a significant effect on the color of dry noodles ($p>0.05$). The average value of taste acceptance of spirulina fortified dry noodles was 2.78 - 3.20 with the highest score of dry noodles with 5% Spirulina fortification. Panel assessment of the color of dry noodles increased with the addition of spirulina concentration up to 5% and decreased at a concentration of 5.5% to 6.5%. This increase in the panelist's assessment could occur because the panel liked the bright green color of dry noodles but decreased at a concentration of more than 5% because the color of the dry noodles was getting darker.

CONCLUSION

The addition of spirulina with a concentration of 4% - 6.5% had a significant effect on the physical and chemical properties of dry noodles. The higher the fortification concentration of spirulina in dry noodles, the higher the elongation value and tensile strength. So is the value of protein, moisture, fat, ash, and dietary fiber content. The sensory evaluation showed that the panel tended to like dry noodles with a fortification of 6% spirulina. The dry noodles produced are in accordance with the standard of dry noodles (SNI 8217, 2015). The results of this study can be used for the purposes of food fortification of spirulina. This is to improve and or increase nutritional value, especially food fiber and protein as an effort to support the increase of diversification and food security in Indonesia.

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