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The Study of Sorghum (*Sorghum bicolor* L.), Mung Bean (*Vigna radiata*) and Sago (*Metroxylon sagu*) Noodles: Formulation and Physical Characterization

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Abstract
Noodles play an important role as a potential alternative staple food in Indonesia. The nutritious non-wheat noodles are potentially develop through utilizing Indonesia's abundant local commodities, such as sorghum, mung bean and sago noodles Besides that the different characteristics of starch types in these raw materials will produce the different quality of noodles. Thus, the aim of this study is to determine the physical characteristics, cooking quality and sensory quality of various noodle formulas. Five formulas with different proportions of sago and sorghum flour are used in this study, 50:20 (F1), 40:30 (F2), 30:40 (F3), 20:50 (F4), 10:60 (F5), respectively. The results show that three raw materials have higher dietary fiber than the wheat flour has. Sorghum, mung bean and sago contain resistant starch of 9.50, 9.63 and 10.58 mg/100g, respectively. F1 Noodle formula with Sorghum: Mung Bean: Sago proportion of 20: 30: 50 has closer sensory quality (taste, aroma and texture) to the wheat noodle. F1 composite flour have better pasting properties than other formula, with the pasting temperature about 78.20^{o}C, peak viscosity 1799 RVU, breakdown 768 RVU, final viscosity 1632 RVU and peak time 4.4 min. The F1 noodle formula has the highest cooking loss value, and the highest texture compared to the other formulas. The conclusion of this study is F1 formula has the potential opportunities as an alternative non-gluten functional food product development with physical and sensory quality close to wheat noodles, nevertheless it has high cooking loss value.

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Introduction

Noodle is in consumer's demand because of its easy serving, practical and varied, therefore it is often used as an alternative to be staple food. Noodle's production in Indonesia has increased through several years, it was recorded 1.6 million tons in 2008 to 2 million tons in 2013.[1] Basically, noodle is made from wheat flour or non-wheat flour accompanied by starch.[2] Research on the development of noodle as a product has been done in order to add the variety of tastes or to increase the nutritional value. As what is done by Pakhare *et al.,* (2016) in increasing the nutritional value of noodle is by the substitution of defatted rice bran flour and soy flour.

Nowadays, consumer behavior is not only focus on delicious taste and nutritious products, but they also consider the aspects of health. Noodle research sustainably grows to produce the interest and nutritious products which have functional benefits for health. One of them is making mung bean noodles. Mung bean is potentially used as raw material to make noodle. Mung bean noodles have good characteristics which is not easily crushed since mung bean has the high content of amylose content about 30-34%.[4] Mung bean noodle is considered to have a good cooking quality and eating quality. Gelatinized mung bean starch acts as a binder so the noodle's dough can be formed and cooked. Mestres *et al.,*[5] learned that the crystallite amylose starch content in mung bean flour was resistant to boiling water and binds to each other because of their junction zone, this can replace the function of gluten tissue in non-wheat noodles. Dried mung bean starch noodle produces crystalline structure and color change from white to brown.[6] The mung bean noodle has been studied have low glycemic index value and inhibit high blood glucose intake.[7] Mung bean has a low glycemic index value of 42, the dietary fiber of 19.38-27.81% and also resistant starch of 16.1-22.3%.[8-10] Mung bean can also reduce glucose and blood cholesterol.[11]

Besides mung bean, sorghum has also been developed as an alternative raw material for gluten-free products. Sorghum has been researched as a potential raw material for making noodle or as a substitute for wheat noodle up to 50%[12-15] Sorghum has functional characteristics which are the low glycemic index of 43-47.38 16,17, the total dietary fiber of 7.55-9.19%,[18] and resistant starch of 0.31-65.66%.[19] Sorghum has been researched for reducing cholesterol risk, obesity and cancer.[20]

The different characteristics of starch in forming noodle's dough based on the use of flour replacement to improve the paste properties and to produce the better noodles. In previous research, the characteristic of sorghum flour paste to produce noodle has very high peak viscosity value which is needed to do the substitution with the flour which has a lower break down characteristic such as mung bean and sago. The high break down value results the non-resistance and unstable starch granule groups in cooking. The usage of sago (*Metroxylon* spp.) starch has some functions as a binding material in making noodle and it can improve the quality of the noodle that is produced. Sago contains 23% amylose and 77% amylopectin.[21] The development research of noodle made from local raw materials still needs to be developed. In this research, the physical formulation and characterization of noodles made from sorghum, mung beans and sago were done to produce noodle which has acceptable characteristics by consumers.

Materials and Methods

Materials

The main materials, sorghum (*Sorghum bicolor* L.) and mung bean (*Vigna radiata*) flour were obtained by from the local farmer. While, sago starch (*Metroxylon sagu*) was purchased from Selat Panjang, Riau. The chemical used were hydrochloric acid (HCl), sodium hydroxide (NaOH), potassium sulfate (K_2SO_4), copper sulfate ($CuSO_4$), sulfuric acid (H_2SO_4), boric acid, petroleum ether, buffer phosphate, α-amylase, pepsin, and pancreatin by Sigma-Aldrich, Co. (USA).

Sample Preparation

Each flour was weighed according to the formula (Table 1). The three ingredients (soghum, mung bean and sago flour) were mixed in equal proportion and 30% water was added. The mixture was steamed (pre gelatinization) for 35 minutes, and cooled. Furthermore, the dough was molded and dried at 50oC for 17 hours. Dry noodles were packaged using poly ethylene plastics.

Table 1: The Composite Flour and Noodles Formula

Formula Code	Sago (%)	Sorghum (%)	Mung Bean (%)
F1	50	20	30
F2	40	30	30
F3	30	40	30
F4	20	50	30
F5	10	60	30

Proximate Analysis

The raw materials of sorghum flour, mung bean flour and sago starch were analyzed through the proximate analysis.[22] The carbohydrate content was calculated as the percentage difference with the following equation :

Carbohydrate (%) = 100% - [Moisture (%) + protein (%) + fat (%) + Ash (%)]

Determination of Dietary Fiber

Dietary fiber of the raw materials were analyzed by enzymatic method according to Asp *et al.,*[23] This procedure initiates with the gelatinization process by heating in the presence of amylase that is stable to heat, then incubated with pepsin in acidic pH for 1 hour, and incubated with pancreatin at neutral pH for 1 hour. Insoluble dietary fiber is filtered with celite and insoluble dietary fiber is deposited from the filtrate with ethanol.

Determination of Resistant Starch

The determination of resistant starch is carried out through enzymatic digestion using α-amylase, amyloglucosidase, and protease referring to Goñi *et al.,*[25] with slight modification.

Determination of Pasting Properties

The Noodle composite flour were analyzed for the pasting properties using Rapid Visco Analyzer (RVA).

Determination of Cooking Quality

The cooking quality characteristics identified by cooking time,[26] cooking loss,[26] texture.[27] Cooking time was indicated the time at which the white core in the central portion of the noodle strand disappeared when crushed between two pieces of glass. The cooking loss was identified the ratio of residue weight after cooking to noodle's weight dry basis. The texture of the noodles after cooking is evaluated by measuring the cutting strength using a texture analyzer.

Determination of Sensory Analysis

Sensory analysis used multiple comparison test with 25 untrained panelist.[28]

Data analysis

The data analysis used completely randomized design with 3 replications. The mean differences were statistically analyzed by one-way analysis of variance (ANOVA) that performed through Statistical Package for Social Sciences (SPSS) version 20.0. If there was a significant difference, it will be continued with Duncan's Multiple Range Test (DMRT) at the 5% level.

Results and Discussion

Chemical Characteristics of Raw Materials

The primary ingredients used in this study are sorghum, mung bean and sago to produce noodles. These three commodities are Indonesian local commodities which have functional characteristics so they potentially developed into functional food. Sorghum has a total dietary fiber of 10.37% db, with 5.30% db soluble dietary fiber and 5.07% db insoluble dietary fiber (Table 1). Mung beans and sago contain the total dietary fiber of 16.35% db and 11.07% db, respectively (Table 1). The use of cereals and legumes can increase the content of dietary fiber and resistant starch in noodles product compared to commercial wheat flour noodle 29. The resistant starch content of raw materials are 9.50, 9.63 and 10.58 mg / 100g, respectively in sorghum, mung bean and sago (Table 1). The high content of dietary fiber and resistant starch in the noodle was desirable because it can increase its functionallity value. Some research reported that dietary fiber and / or resistant starch provide a good effect on health, resisting the increase in blood glucose, cholesterol, cancer risk, cardiovascular disease, obesity and improving the health of the digestive tract.[30–32] Wahjuningsih *et al.,*[33] studied that sago and red bean-based rice analogue with resistant starch and dietary fiber about 18.31% and 2.54%, respectively, can improve lipid profile through low cholesterol in diabetic rats. Both resistant starch and dietary fiber can fermented in colon produce short chain fatty acid (SCFA) such us acetate, propionate and butirat, that have beneficial effect to reduce patogen bacteria and inhibit cancer risk, specially colon cancer. This SCFA also play a role in inreasing insulin sensitivity so that increasing glucose uptake from blood and inhibit lypolisis.[32]

Table 2: Chemical Analysis of Raw Material

Composition	Wheat Flour	Sorghum Flour	Mung Bean Flour	Sago Flour
Moisture Content (%)	12.87±0.64^{c}	12.13±0.10^{b}	10.41±0.00^{a}	14.22±0.16^{d}
Ash (%)*	0.68±0.01^{c}	0.52±0.01^{b}	3.59±0.01^{d}	0.19±0.00^{a}
Protein (%)*	19.07±0.15^{c}	8.89±0.10^{b}	22.89±0.28^{d}	0.54±0.03^{a}
Fat (%)*	1.45±0.02^{b}	1.76±0.03^{c}	1.81±0.02^{d}	0.79±0.02^{a}
Carbohydrate (%)*	78.22±0.01^{b}	88.83±0.23^{c}	71.71±0.31^{a}	98.49±0.13^{d}
Total Energy (kcal/100g)	350.46±0.64^{b}	357.39±0.22^{d}	353.6±0.08^{c}	345.88±0.70^{a}
Energy from Lipid (kcal/100g)	11.39±0.14^{b}	13.91±0.23^{c}	14.58±0.18^{d}	6.08±0.14^{a}
Starch (%)*	67.53±0.06^{b}	74.30±0.05^{c}	48.54±0.03^{a}	81.74±0.03^{d}
Amylose (%) *	27.31±0.10^{b}	30.00±0.07^{c}	20.66±0.03^{a}	39.69±0.07^{d}
Amylopectin (%)*	40.22±0.03^{b}	44.30±0.02^{d}	27.88±0.01^{a}	42.05±0.03^{c}
Total Dietary fiber (%)*	8.69±0.00^{a}	10.37±0.00^{b}	16.35±0.04^{d}	11.07±0.02^{c}
Soluble fiber (%)*	5.16±0.01^{b}	5.30±0.02^{c}	3.80±0.01^{a}	8.73±0.02^{d}
Insoluble fiber (%)*	3.52±0.01^{b}	5.07±0.02^{c}	12.56±0.06^{d}	2.34±0.00^{a}
Resistant starch (mg/100g)	14.70±0.06^{d}	9.50±0.01^{a}	9.63±0.03^{b}	10.58±0.06^{c}

Note: The data are represented as mean values ± standard deviation. Different letters within the same row indicate statistically significant differences ($p < 0.05$).* = dry basic (db).

Protein may have an effect on the quality of processed food ingredients. The protein content of wheat flour is quite high, it is about 19.07% db, higher than sorghum and sago flour, which are about 8.89 and 0.54% db (Table 1). Hence, substitution is needed with other raw materials that have high protein content. Mung bean is used as substitute material with the protein content of 22.89% db (Table 1). Protein can bind the molecule of water by strong hydrogen bonds, this power is caused by the proteins which have hydrophilic cluster.[34] When the flour is mixed with water, the expanding parts of protein do hydrophobic interaction and react the sulfydryl-disulfide exchange that produce bonds such as polymers.[35] Besides the protein content, other factors that play a role in quality of the noodle shape are amylose and amylopectin content. The amylose content of sorghum flour, mung bean and sago is about 30.00, 20.66 and 39.69% respectively. While the amylopectin content is 44.23, 27,88 and 42.05 % in sorghum, green beans and sago respectively. The component amylose is related to the water absorption and the process perfection of gelatinization product, in which the higher of the amylose content, the water absorption will increase and hard to be gelatinized.[36] The component of amylopectin will highly determine swelling power and starch solubility.[36]

Starch Pasting Properties of Raw Materials and Noodle's Composite Flour

Pasting properties of starch may affect the quality of the product, such as the quality of shape and the quality of consuming noodle, so that this case can be a major consideration for industrial scale.[6]

To determine this pasting characteristic uses Rapid Visco Analyzer (RVA) model. The results showed that the different flour formulations indicate different pasting characteristics (Table 2).

Table 3: The Pasting properties of raw materials and noodle's composite flour

Code	Water Content (%)	Pasting Temperature (°C)	Pasting Properties (RVU)			Peak Time (Min)
			Peak Viscosity	Breakdown	Final Viscosity	
Wheat Flour	14,27	89.55	1314	531	1489.00	6.00
Sorghum Flour	11,04	83.15	2297	408	2699.00	5.60
Mung bean Flour	11,60	79.85	658	82	1138.00	4.53
Sago Flour	11.23	79.10	3513	1993	2564	4.13
F1	10,86	78.20	1799	768	1632.00	4.40
F2	11,13	79.85	1745	683	1688.00	4.60
F3	10,96	79.80	1795	621	1882.00	5.00
F4	10,72	79.90	1925	632	2098.00	5.00
F5	10,91	81.50	1950	463	2461.00	5.27

Note: The data are represented as mean values by triplicates. F1= 50% sago:20% sorghum:30% mung bean, F2= 40% sago:30% sorghum:30% mung bean, F3= 30% sago:40% sorghum:30% mung bean, F4= 20% sago:50% sorghum:30% mung bean, F5= 10% sago:60% sorghum:30% mung bean.

Pasting temperature is the temperature recorded while the viscosity starts to increase. The low value of pasting temperature indicates the faster swelling power, whereas the lower value indicates the longer of the existence of amylopectin chain.[37] Raw materials for noodle making are sorghum, mung bean and sago, these have lower pasting temperature value than wheat flour. The Composite flour Noodle also shows the lower pasting temperature value than wheat flour (Table 2).

The viscosity's peak is the point in which starch gelatinization reaches the maximum viscosity during heated in the water. That case shows the power of starch to bind the water.[38] The addition with the higher sorghum flour indicates the increasing value of peak viscosity of composite flour noodle (Table 2). The low peak viscosity value indicates low power to expand and occurs separation polymer during heating (it occurs amylose leaching).[39]

Breakdown viscosity is a simple measurement of cooked starch to disintegrate.[40] In this research F1 composite flour noodle indicates the highest breakdown value compared to other formulas. The higher breakdown values studied provide the higher taste.[41,42] The higher breakdown viscosity value indicates that the starch is less resistant to the heating and stirring. During the process of cooling, it causes re-association between starch molecules (setback), so that the gel is formed and the viscosity back to increase until it reaches the final viscosity. Final viscosity is a parameter that shows the power of starch to form re-gel after cooking.[43] Cereal flour with high viscosity will increase the strength of paste and this nature related to the tendency of starch to retrograde. Composite flour noodle F1 shows the lower final viscosity value compared to other formulas (Table 1).

Noodles Characteristics

The quality of cooking noodle can be seen through cooking time, cooking loss and texture (Table 3). Cooking time can be calculated by calculating starting time when ingredients began to cook, until it is cooked or ready to be consumed. Five formulas produced had cooking time and cooking loss respectively ranging about 7-12 min and 11.86-27.24%. The five formulas produced have greater cooking loss than wheat noodles (9.48%). It can be related to the gluten content on wheat flour that has power to form three-dimensional tissue and can inhibit the release of starch granules. Gluten has a negative correlation to the cooking loss.[44] High cooking loss can be caused by the low degree formation of protein tissue during the mixing paste.[45] The texture has an effect on the result of eating noodle quality. Wheat noodle has a higher texture compared to F1-F5 (Table 2). The lower texture value can be caused by the replacement of wheat flour with non-gluten flour, so that the power of protein binding is lower.[46]

Table 3: Cooking time, cooking loss, moisture and texture of noodle formulas

Code	cooking loss (%)	Moisture (%)	Noodles Texture (gf)
F1	27,24	7,45	14,130
F2	11,86	7,13	13,530
F3	13,03	6,50	12,672
F4	23,34	7,59	12,843
F5	20,72	6,79	10,186
FC	9.48	7.61	18.032

Note: The data are represented as mean values by triplicates.

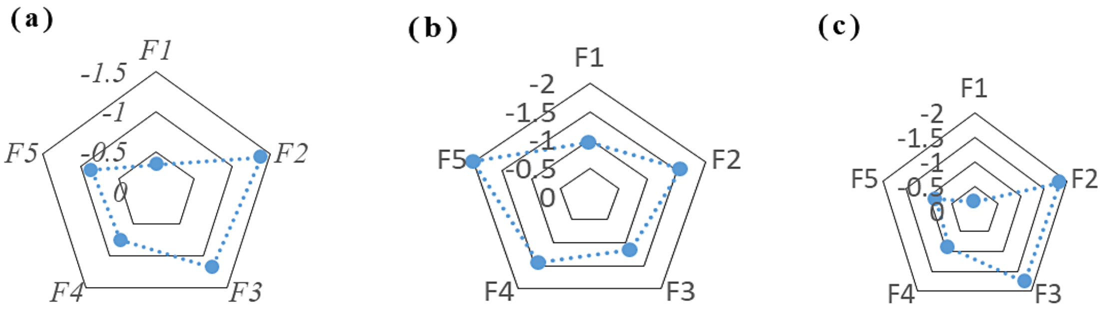

Fig. 2: Sensory multiple comparison test (a) taste, (b) aroma and (c) texture of the noodle formulas. The data are represented as mean values through 25 panelists

Different proportions of sorghum flour, soy flour and sago flour affected the sensory quality of noodle's production. This research used sensory testing with multiple comparison method by using wheat noodle as Control. The results showed that F1 has a sensory quality of taste, aroma and texture that are close to wheat flour (Figure 2). F1 has a lower final viscosity value compared to other formula (Table 2) hence it has not really hard texture. The value of breakdown viscosity F1 formula is lower than other formula that may affect eating quality to be better.

Conclusion

The use of Sorghum, mung bean and sago has a potential effect to improve the functional properties of the noodle's product. It was indicated by their high fiber and resistant starch content from those three materials. However, the pasting properties of these raw materials were different, hence it needs an appropriate formula to form a noodle product in accordance with consumer preferences by cooking quality and sensory quality. Formula F1 (Sorghum: Mung Bean: Sago = 20: 30: 50) has the highest texture characteristics close to the wheat noodle texture. Through the sensory analysis, F1 formula has the closer taste, texture and aroma to the wheat noodle. Studying from the pasting properties, F1 formula has the highest breakdown value and the lowest final viscosity as compared to the other formulas. The final viscosity value showed that

F1 composite flour was close to wheat flour that related to the texture and sensory quality. However, F1 Noodle Formula has a fairly high cooking loss of 27.24%, hence further studies are needed to minimize it.

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Conflict of interest

The authors do not have any conflict of interest.

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