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Chemical, physical, and sensory characteristics of analog rice developed from the mocaf, arrowroof, and red bean flour

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Abstract. This research was aimed to analyze the chemical, physical, and sensory characteristics of the analog rice developed from a composite formula consisting of mocaf, arrowroot, and red bean flour. Experiment was designed into 5 different composition types i.e B_1 (90%: 0%: 10%), B_2 (80%:10%: 10%), B_3 (70% : 20% : 10%), B_4 (60%: 30%:10%), and B_5 (50%: 40%: 10%) which in each type was repeated in 4 times. Carrageenan was used as a binder in the making process of those analog rice. Investigation procedure was carried out into several stages such as preparation and characterization of raw materials, production of analog rice in composite formula, then the testing of its chemical and sensory properties. Chemical characteristics were evaluated about the level of starch, amylose, dietary fiber, and resistant starch while sensory characteristics were examined about the texture, flavor, and aroma. The result showed that based on the sensory test, the best composite formula of rice analog was B_2 (ratio flour of mocaf: Arrowroot: Red bean = 80:10:10). In addition, B_2 formula possessed the chemical characteristics similar with the truth rice either in water content (12.18%), ash (2.63%), protein (6.17%), fat (1.31%), carbohydrate (89.88%), starch (73.29%), amylose (24.91%), total dietary fiber (7.04%), or resistant starch (6.71%). Furthermore, the higher of arrowroot flour proportion, the greater of amylose, dietary fiber and resistant starch containing in the rice analog. In the opposite, its starch content was getting down.

***Keywords**: analog rice, mocaf, Arrowroot, red bean, flour, composite formula*

1. Introduction

Food diversification in Indonesia as one of efforts to reach the food sovereignity is still inhibited by the high consumption of rice [1]. This is indicated by the high level of community dependence on a single source of carbohydrates only, whereas the potency of local carbohydrates sources such as group of tubers and grains in Indonesia are quite diverse. Therefore, the optimization of carbohydrate sources other than rice should be encouraged to reduce rice dependence, which in the last decade rice is an imported food commodity.

Analog rice has become an alternative solution in optimizing the utilization of local carbohydrate sources recently. Analog rice is non-rice ingredients with carbohydrate content approaching or even exceeding than rice such as mocaf, arrowroot, corn, sorghum, and sago and tubers flour are shaped like a rice [2]. It is often regarded as functional rice because of its raw material properties related to the health aspects. Analog rice from mocaf and arrowroot flour have been shown to have a texture like rice in general with the functional properties such as lower in glycemic index that is suitable as a diet for people with Diabetes Mellitus [3]. Previous research by [4] states that red beans combined with mocaf are able to produce rice analogue with a higher nutritional value due to the content of red bean protein amounted to 23.2%. Thus, mocaf, arrowroot and red bean flour are potential to be the local raw material for functional analog rice. As a consecuency, effort to improve its utilization still needs to be done optimally.

This study developed new analog rice through the composite formula of some raw materials such as mocaf, arrowroot, and red bean flour. Mocaf and arrowroot flour which are rich in amylose content mixed with the high protein content in red beans. It is expected to produce the analog rice with a better quality both in texture and functional properties with the result that can be used as determination of consumer acceptance level. The physicochemical properties of raw materials and analog rice products from several combinations of the three raw materials were studied for its optimization. Furthermore, the sensory characteristics of analog rice resulted in this study also were examined to determine which composite formula is most acceptable to consumers. The development of mocaf, arrowroot and red bean flour based analod rice in this study was expected could increase the utilization of local food sources in order to meet the age of food sovereignty.

2. Material and Methods

2.1. Preparation of raw materials

Mocaf flour production was made by using culture method as described earlier [4]. For Arrowroot flour was made by peeling, washing, and slicing arrowroot that continued by blanching it on 80 ^{o}C for 5 minutes. Before grinding process in 80 mesh sieve, blanched arrowroot was drained and dried on 50 ^{o}C for 12 hours. Meanwhile, red bean flour was purchased directly from the farmer around the the farm land in the Temanggung sub-district, Central Java Province.

2.2. Analog rice production

Analog rice production was initiated by making composite flour consisting of five different ratio on mocaf : arrowroot : red bean i.e. 90%: 0% : 10% (B_1), 80%:10%: 10% (B_2), 70% : 20% : 10% (B_3), 60%: 30%; 10% (B_4) and 50%: 40%: 10% (B_5). Ingredients used for emulsifier were GMS, salt, distilled water, coconut oil, and carrageenan. Those ingredients were mixed with composite flour, homogenized for 5 minutes, and steamed for 15 minutes. Steamed materials were directly inserted into an extruder in order to shape analog rice. After granules were formed, they were dried in a dryer cabinet at a temperature of 50°C for 12 hours.

2.3. Experimental Analysis

The basic materials mocaf flour, arrowroot flour and red bean flour were analyzed according to its gelatinization properties by using Rapid Visco Analyzer (RVA) and water absoption [5]. Analysis of chemical characteristic on analog rice such as proximate content and starch content were conducted by using acid hydrolysis method [6], while dietary fiber by using enzymatic method [7], amylose content by using spectrophotometry method [6] and resistant starch content was performed by using the method that was modified by Goni [8]. The produced analog rice would be tested its sensory characteristics by using multiple comparison test [9] and proximate test. Determination of selected formula was conducted by using exponential comparison method. Exponential comparison method is a technique in decision making by deciding ranking from alternative decision with various criteria [10].

2.4. Statistical analysis

Data resulted from this experiment were analyzed statisticaly by using SAS Software version 9.2 to perform General linier Models (GLM) procedure. Duncan Multiple Range Test (DMRT) was carried out to get more insight about a significant difference among several formulas at the level of 5% [11].

3. Result and discussion

3.1. Physical Characteristics of Raw Material and Composite Flour

The higher amount of arrowroot flour, composite flour would have peak viscosity, hot paste viscosity, decreased viscosity because of heating, final viscosity, and the increase of viscosity because of cooling process was lower (Table 1). This was shown that there was negative slope from composite flour if all viscosity parameters were illustrated in curve. Gelatinization properties of mixed flour were effected by gelatinization properties of its basic materials. Heating in gelatinization caused irreversible swelling of starch granule in the water so that it occurred the increase of viscosity [12]. Gelatinization temperature of material determine the best temperature used during extrusion, because before extrusion process might occur gelatinization on partial material.

Table 1. Physical characteristics of raw material and composite flour

Flour Type	**Viscosity (cp)**					**Peak time (min)**	**Gelatinization Temperature (^oC)**
	Peak	**Hot Paste**	**Breakdown**	**Final**	**Setback**		
Arrowroot	4749	2201	2548	3423	1222	7.47	80.60
Mocaf	6508	1912	4596	3214	1302	6.20	68.40
Red bean	207	207	0	481	274	13	Undetected
B_1	6543	2292	4251	3644	1352	7	67.95
B_2	5663	2008	3655	3394	1386	6.6	68.4
B_3	4930	1744	3186	3061	1317	6.53	68.85
B_4	4504	1663	2841	2767	1104	6.67	69.25
B_5	4030	1500	2530	2493	993	6.8	70
Slope							
Composite Flour	-618.5	-192.9	-425.6	-292.9	-100	0.495	-0.033

B_1, B_2, B_3, B_4, and B_5 are kind of samples ratio (mocaf flour: arrowroot flour: red bean flour) as a composite formula i.e (90:0:10); (80:10:10); (70:20:10); (60:30:10); (50:40:10), respectivelly.

Gelatinization temperature was effected by several factors, such as granule size, amylose, amylopectin, heating instrument condition, and also food material content like fat, dietary fiber, resistant starch and protein. Component like protein and fat can be bound with amylose and form precipitation, so it increases temperature of gelatinization [13]. Amylose content of arrowroot flour was higher than mocaf flour, it might cause the difference of gelation temperature in both materials. The aligned chain amyloses which form double stranded crystallites were resistant to amylases. The intra- and inter-strand hydrogen bonding results hydrophobic structure with low solubility [14].

The amylose content of red bean flour was high, but it was undetected gelatinization temperature, it might be caused by material handling process such as soaking, blanching for 30 minutes, and drying red bean in red bean flour production. Those phase was assumed to cause starch gelatinization in red bean flour had been passed. Mocaf flour had lower gelatinization temperature, breakdown viscosity (stability of starch paste on high temperature), and higher setback viscosity. When starch was heated in sufficient water, the stability of double helix structured hydrogen bonding in crystalline would be damaged and replaced by water hydrogen bonding, amylose would be released from starch granule.

After that amylose and amylopectin would hydrate, therefore viscosity was increasing until it reached the peak and starch suspension became clearer [15]. Peak viscosity showed starch ability to swell freely before it had breakdown. The value of peak viscosity was effected by amylose and amylopectin content in material. The higher amylose content, the lower its peak viscosity. This was caused by amylose binding and fat to form amylose lipid complexes so that swelling of granule was suspended [16].

3.2. Chemical characteristics of basic material

The chemical characteristic of basic material identified in this research was various nutritional components as well as non-nutritional components which was assumed to effect on physical properties of flour. The chemical characteristics identified were water content, ash content, fat content, protein content, carbohydrate content, amylose content, amylopectin content, energy content, and dietary fiber content. Chemical characteristics were only analyzed on its basic component, however the components of composite weren't analyzed. Chemical characteristics of basic material are displayed in Table 2.

Table 2. Chemical characteristics of basic material

Chemical characteristics	Arrowroot flour	Mocaf Flour	Red Bean Flour
Water (%)	7.12	6.43	13.64
Ash (%)	4.14	0.59	2.69
Fat (%)	0.63	0.76	3.20
Protein (%)	6.14	0.74	27.64
Carbohydrate(%)	81.97	91.48	66.45
Energy (Cal/100g)	358	376	405
Amilylose (%)	26.37	22.48	58.28
Amylopectin (%)	73.63	77.52	41.72
Starch (%)	58.70	78.76	43.25
Dietary fiber (%)	6.76	3.78	14.38
Insoluble dietary fiber (%)	4.49	-	8.79
Soluble dietary fiber (%)	2.27	-	5.59

3.3. Organoleptic assessment of analog rice

Organoleptic test was carried out on 20 semi-trained panelists. The results of organoleptic test are shown in Table 3. Determination of selected formula was conducted by using exponential comparison method. Exponential comparison method is a technique in decision making by deciding ranking from alternative decision with various criteria [10]. Aroma, taste, and texture data of analog rice are tabulated by giving high ranking based on certain criteria. The parameters of product are arranged from the lowest ranking to the highest ranking. The lower ranking shows the exacted value. The lowest ranking product is the best product [17].

Table 3. Mode value of texture, taste, and aroma

Organelptic test	Texture	Taste	Aroma
B1	$-0.25^{a} \pm 1.07$	$-0.35^{ab} \pm 1.18$	$-0.25^{a} \pm 1.37$
B2	$-0.10^{a} \pm 1.48$	$0.30^{b} \pm 1.13$	$0.15^{a} \pm 1.49$
B3	$-0.10^{a} \pm 1.48$	$-1.00^{a} \pm 0.79$	$-0.60^{a} \pm 1.50$
B4	$-0.35^{a} \pm 1.57$	$-0.90^{a} \pm 1.33$	$0.20^{a} \pm 1.39$
B5	$0.65^{a} \pm 1.73$	$-0.95^{a} \pm 1.19$	$-0.55^{a} \pm 1.54$

B_1, B_2, B_3, B_4, and B_5 are kind of samples ratio (mocaf flour: arrowroot flour: red bean flour) as a composite formula i.e (90:0:10); (80:10:10); (70:20:10); (60:30:10); (50:40:10), respectivelly.

Based on ranking test conducted, B1, B2, B3, B4, and B5 products had 7, 4, 11, 7, and 12 total ranking, respectively. The sequence of total ranking for B1, B2, B3, B4, and B5 was 2, 1, 3, 2 dan 4. The purpose of exacted value is the lower ranking, the more exacted product will be. The selected formula was B2, it was an analog rice with 80:10:10 mocaf flour, arrowroot flour, and red bean flour ratio. The pictures of mocaf arrowroot red bean flour analog rice from those formulas are displayed in Figure 1.

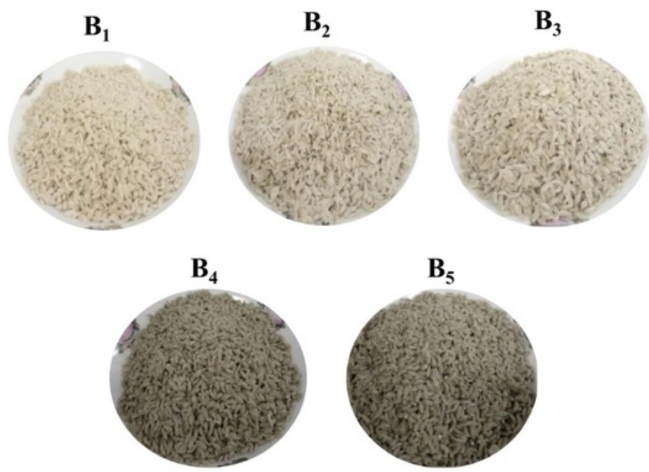

Figure 1. Performance of analog rice developed from mocaf, arrowroot and red bean flour in 5 different composit formulas (mocaf:arrowroot:red bean) such as B_1 (90:0:10), B_2 (80:10:10), B_3 (70:20:10), B_4 (60:30:10), and B_5 (50:40:10).

B2 analog rice had advantage in taste parameter which had positive value. Positive value shows that the product had better taste than standard (rice). The more arrowroot flour proportion caused the taste of analog rice was more disliked. B2 analog rice had disadvantage in texture parameter. This selected formula had -0,10 texture value. Negative value in multiple comparison test shows that selected formula had lower quality than standard (rice). Negative value in multiple comparison test shows the selected formula had lower quality than standard (rice). Amylose content affected on rice texture. Overall B2 analog rice was closest to the most common rice on taste, texture, aroma parameters. Rice with high amylose would tend to be firm. B1 and B4 analog rice had the second lowest total ranking. B1 and B4 analog rice had negative value on aroma, texture, and taste. This was shown that B1 and B4 formula had lower quality than standard (rice).

B3 analog rice had third total ranking. B3 formula rice had negative value on multiple comparison test. Negative value shows that aroma, taste, and texture qualities of product were lower than standard (rice). B3 analog rice had disadvantage in taste, the value was -1,00. The lower its value, the lower quality product would be than rice. B5 analog rice had the highest total ranking from all formulas. The highest total ranking showed the lowest ranking. B5 analog rice had disadvantage in taste parameter. This formula had -0,95 in taste parameter.

3.4. Chemical characteristics of analog rice

Chemical composition of analog rice was influenced by some factors, such as chemical composition of its ingredients (mocaf flour, arrowroot flour and red bean flour), the effect of extrusion process by using high temperature and pressure, steaming before extrusion, other technical factors during processing. The results of the analysis of the chemical characteristic of mocaf analog rice are displayed in Table 4. All of analog rice formulas had a water content below 14%. Food products which had 14% or 15% water content would ease microbes to grow. The water added in the preparation of analog rice significantly affected its water content. This was caused by the more water added during the production of analog rice, the higher the water content of analog rice granules would be after the drying process. In this research, the water added was 50% of the total amount of starch and flour [18]. Analog rice with higher arrowroot percentage tend to have higher water content. Water content in food material will determine the ease of food material to have damage. As the higher water content in food material, then it tends to be easily damaged.

Tabel 4. Chemical characteristics of analog rice

Chemical test (% dry basis)	**Treatments**				
	B_1	**B_2**	**B_3**	**B_4**	**B_5**
Water	12.61^{a}±0.04	12.19^{b}±0.08	12.95^{c}±0.05	13.33^{d}±0.09	12.96^{c}±0.06
Ash	2.44^{a}±0.04	2.64^{b}±0.01	2.83^{c}±0.01	3.05^{d}±0.02	3.12^{d}±0.09
Protein	6.41^{a}±0.06	6.17^{a}±0.07	6.34^{a}±0.10	6.29^{a}±0.01	5.46^{a}±1.59
Fat	1.38^{c}±0.01	1.31^{b}±0.03	1.39^{c}±0.03	1.26^{a}±0.02	1.59^{d}±0.05
Carbohydrate	89.77^{c}±0.03	89.88^{c}±0.09	89.44^{b}±0.15	89.41^{b}±0.04	89.04^{a}±0.04
Starch	74.54^{d}±0.44	73.29^{c}±0.16	72.53^{b}±0.28	72.23^{b}±0.95	70.98^{a}±0.88
Amylose	24.60^{a}±0.07	24.91^{b}±0.07	25.65^{c}±0.03	26.40^{d}±0.003	26.27^{e}±0.09
Amylopectin	49.93^{e}±0.51	48.38^{d}±0.09	46.87^{c}±0.25	45.83^{b}±0.09	44.71^{a}±0.18
Resistant starch	6.65^{a}±0.15	6.71^{ab}±0.16	6.98^{ab}±0.14	7.16^{ab}±0.60	7.25^{b}±0.34
Soluble dietary fiber	2.74^{a}±0.03	2.88^{b}±0.02	3.07^{c}±0.02	3.29^{d}±0.01	3.73^{e}±0.09
Insoluble dietary fiber	3.69^{a}±0.05	4.16^{b}±0.06	4.61^{c}±0.05	4.98^{d}±0.06	5.41^{e}±0.05
Total dietary fiber	6.43^{a}±0.08	7.04^{b}±0.08	7.67^{c}±0.03	8.27^{d}±0.07	9.15^{e}±0.04
Water absorption	214.24^{a}±0.43	230.48^{b}±0.69	239.79^{c}±0.52	249.23^{d}±0.58	256.89^{e}±0.31

Means on the same column with different superscript are significantly different at ($p < 0.05$)

Ash content in analog rice was ranged between 2.4363% and 3.1173%. The more arrowroot flour proportion added to B4 and B5, they had equal ash content to 10 % sago red bean flour analog rice, the ash content was (3.06%) [19]. Based on the test of variance, composite flour ratio displayed significant differences on ash content of mocaf analog rice (p=0,002). The higher arrowroot flour content of mocaf analog rice, the ash content was higher. Ash content in food material can show high mineral content in food material. Ash content showed the amount of mineral and organic substance which were contained in product [20]. The higher ash content resulted the higher mineral content. The results of a research conducted by [10] showed ash content of IR64 rice was 0.56% (dry basis). Mineral content of rice was highly effected by pre harvest condition and variety so that there was possibility of ash content variance.

The protein content of mocaf analog rice was ranged between 5.4572% and 6.4089%. Composite flour ratio do not have significant effects to the protein content of mocaf analog rice ($p > 0.05$). This shows that the amount of arrowroot flour in composite flour has no significant effects in protein content of mocaf analog rice. The protein content of analog rice was from red bean flour, which added constantly. Protein content in food materials can also effect on food glycemic index. The higher protein content, the glycemic index would tend to be higher [21]. All mocaf analog rice had protein content above 5%.

Fat is compound which has non-polar group so that it is insoluble in the water, however it is soluble in organic solvent. Fat content of analog rice reached 0.37%. This fat content was low category if it's compared to research conducted by [22] it ranged from 0.34% to 0.62%. [23] claimed that oxidative damage in high-fat food material was an important problem because it could lower organoleptic quality, i.e rancidity. The fat content of the produced mocaf analog rice was ranged between 1.2589% and 1.5910%. Analog rice with the highest fat content was B2 whereas the lowest one was B4. Fat contents of produced sago analog rice were all higher than granulated rice which made of sweet potato 0.70% - 0.90% [24]. This was caused by high fat content in food materials, particularly on red bean flour which reached up to 3.26%, while other materials were under 1%. High fat content can be used to estimate low glycemic index. The higher fat content in food material would lower its glycemic index [25].

Carbohydrates content of mocaf analog rice was ranged between 89.0382% (B5) and 89.8816% (B2). Composite flour ratio shows significant effect on carbohydrates content of mocaf analog rice ($p > 0.05$). Carbohydrates content of mocaf flour was higher than arrowroot flour, so the higher the amount of arrowroot flour added, the lower its content of carbohydrates would be. According to[26], Carbohydrate gave more than 50% calories with carbohydrate value 4 kcal/g. The slowly absorbed carbohydrate would produce low blood glucose peak and potentially control starch digestibility of rice which was effected by its amylose or amylopectin composition [27].

Composite flour ratio shows significant effect on amylose and amylopectin of mocaf analog rice. Amylose content of analog rice was approximately from 24.6047% (B1) to 26.4032% (B4). Amylopectin content of analog rice was ranged between 44.7073% and 49.9347%. Starch content of composite flour ratio shows significant effects on starch content of mocaf analog rice. Starch content of mocaf analog rice was ranged between from 70.9817% (B5) to 74.5394% (B1). The higher proportion of arrowroot flour in composite flour, the higher amylose content in mocaf analog rice. Arrowroot, mocaf, and red bean flour had high amylose content so that amylose content of produced analog rice was relatively high, it was higher than 20%.

Amylose content determined the texture of produced rice such as the firmness, the softness, and the stickiness of rice [28]. Amylose was polymer which was composed entirely of [1-4]-α-D-Glucopyranose [29]. Amylose affected on texture of rice. Amylose content could be used to estimate the firmness of flour paste gel which was made of rice. Amylopectin component in rice would affect gelatinization temperature and starch paste properties [30]. The higher proportion of arrowroot flour in composite flour would cause analog rice with lower amylopectin content. Amylose and amylopectin contents could be used to estimate glycemic index value of analog rice. The higher amylopectin of rice, the higher glycemic index. Whereas if the amylose content of rice was higher, the glycemic index would tend to be lower. The higher proportion of arrowroot flour in composite flour, the starch content was relatively lower. The value of starch content was calculated from the amount of amylose and amylopectin component.

Resistant starch content mocaf analog rice was ranged between 6.6548% and 7.2492%. Composite flour ratio do not have significant effects on resistant starch content of mocaf analog rice ($p>0,05$). This was caused by several factors, such as amylose content, particle size, and the effect of other compound [31]. The higher amylose content, its resistant starch content will be higher. The result of this research is related to its amylose content. Amylose had linear chain structure on compact matrix so that it lowered accessibility of enzyme [32]. Resistant starch can be used for investigating functional food [33], because resistant starch has characteristic and physiological function like dietary fiber, its slow digestibility can postpone the increase of blood glucose, control glycemic response, give a longer feeling of satiety, as a result it can lower value of glycemic index of that food [32,35].

Total dietary fiber is the total amount of insoluble fiber and soluble fiber content. Composite flour ratio has significant effect on total dietary fiber, soluble dietary fiber, and insoluble dietary fiber content of mocaf analog rice. Analog rice with higher arrowroot flour proportion tended to have higher insoluble dietary fiber content. Insoluble dietary fiber content of analog rice was higher than insoluble dietary fiber of grinded rice which ranged 2.27% to 5.68% [36]. Total dietary fiber content of mocaf analog rice was also higher than total dietary fiber content of grinded rice (4.67% - 7.57%). Soluble fiber content of mocaf analog rice was ranged from 2.7404% to 3.7308%. Grinded rice had lower soluble fiber content than mocaf analog rice (1.57% - 2.95%) [36].

Dietary fiber in human body would be digested become indigestible component and short-chain fatty acid, water, CO_2, methane [37]. Fiber metabolism is related to bacteria activity in colon. The fiber significant effects on metabolism are increasing feces volume, shortening transit time in intestine, softening feces consistency, and producing short chain fatty acid which is useful for health.

Composite flour ratio significantly affected on water absorption of mocaf analog rice. Water absorption content of mocaf analog rice was ranged between 214.2380% (B1) and 256.8897% (B5). The effect of increasing starch content on value of water absorption was related to amylose-amylopectin composition role in starch. [38] claimed that food material with high starch content would be easier to absorb water because of amylopectin molecule availability which was reactive to water molecule, so the amounts of absorbed water in food material.would be higher

Water absorption is affected by some factors, such as fat content, dietary fiber content, amylose and amylopectin content of food material. High amylose and dietary fiber content could increase water absorption [12]. Water absorption characteristic of analog rice was analyzed to find out the effect of flour ratio in composite flour on water absorption and water holding ability in dough. These data were used to estimate water addition during analog rice cooking process. Based on analysis, it shows that the higher proportion of arrowroot flour in composite flour would increase its water absorption. This was assumed because of its high dietary fiber content in arrowroot flour. Dietary fiber influenced on food material ability to absorb and hold the water. Water absorption was inverse compared to water content. The lower water content would increase the water absorption. [39] claimed that the high water absorption is caused by absorbed water in molecules so that it increases water absorption in material and disconnects intermolecular hydrogen bonds, so the water is easier to enter into flour. Absorbing water would be intensive as its increased heating temperature, the granule swells therefore the swelling point of starch granule was irreversible (couldn't return to initial form) [40]. Water absorption ability could be affected by protein component and crude fiber [41, 42].

4. Conclusion

Mocaf flour and red bean utilization on analog rice production can result fine textured rice and similar to the most common rice. According to the sensory test, analog rice made from mocaf flour, arrowroot flour, and red bean flour with ratio of 80:10:10% is the best due to its texture that is almost similar with the common rice, high acceptance by panelists for taste and aroma parameters. Chemical composition of the best analog rice was 12.1890% water content, 2.6376% ash content, 6.1688% protein content, 1.3119% fat content, and 89.8816% carbohydrate content.

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