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ANALOGUE RICE AS THE VEHICLE OF PUBLIC NUTRITION DIVERSITY

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Abstract

Analogue rice is artificial rice product made from non-rice raw material by extrusion technique, which can be the vehicle of public nutrition diversity. The objectives of this research were to formulate and characterize analogue rice made from of sorghum, mocaf and other additional material. The method of analogue rice production is by twin screw extruder hot extrusion done in 2013. The research steps were the formulation of analogue rice, sensory evaluation to choose the best formula, and physico-chemical characterization of the best formula. The best two samples that were chosen are analogue rice made from 30% sorghum flour, 15% cornstarch, and 15% arenga starch (analogue rice B) and analogue rice made from 30% mocaf and 30% cornstarch (analogue rice F). Analogue rice B has 21.72% of amylose (medium) with 4% of dietary fiber while analogue rice F has low amylose which is 14.49%, make it more sticky, with 4.21% of dietary fiber.

Introduction

The dependence of Indonesian people on rice as their staple food causes ineffective food diversification program, as the majority of Indonesian diet plan serves rice as the main source of carbohydrates. Eventhough, Indonesia is actually rich of other carbohydrate sources such as corn, cassava, sorghum, and other tubers crop. Those materials are often used as foodstuffs, but still can not replace rice as staple food. Another constraints in food diversification are the unavailability of foodstuffs (other than rice) in easily processed form, the lack of knowledge about the nutritional value, people are psychologically unprepared to replace their staple food, and the low availability of food products that suits public taste. The way to increase non-rice foodstuffs consumption as staple food can be done by processing the foodstuffs into products that can be consumed the same way as rice.

One of the carbohydrates source processed product that has been developed lately is artificial rice or analogue rice. Mishra (2012), stated that analogue rice can be partially or whole-made of non-rice ingredients. Zhuang (2010), made analogue rice from broken rice (groats), whereas Budijanto (2012), made the analogue rice from non-rice ingredients. Analogue rice can be consumed with other side dishes the same way as rice, which is expected to increase the effectiveness of staple food diversification program without changing people's eating habits. Moreover, since analogue

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rice can be made from non-rice ingredients (such as sorghum, corn, mocaf) which contain functional properties that are good for health, analogue rice can indirectly be a vehicle of public nutrition diversity.

Some methods to manufacture artificial rice or analogue rice are granulation method (Herath, 2009), and the extrusion method (Moretti 2005; Zhuang, 2010; Mishra, 2012; Budijanto, 2012; Herawati. 2013). The difference of these methods will lead to the final product different form. The analogue rice will have a rounded shape like sago pearls in the granulation method and oval shape with close resemblance to rice grain in the extrusion method. We used the extrusion-based technology in this research. The extrusion type we used is hot extrusion, which performed at a high temperature (over 70° C), and can be done through pre-conditioning (pre-heating) of the batter or heat transfer process through the barrel heating using steam. We used a Twin Screw Extruder (TSE) tool to make the process more efficient and starch gelatinization occurs more perfect (Budijanto, 2012).

The selection process of raw materials is very important in analogue rice manufacturing since it will affect the characteristics of the final product, both physically and chemically. We used sorghum flour, mocaf (modified cassava flour), cornstarch, and arenga starch. Sorghum flour has a high potential as a source of carbohydrates and functional properties such as antioxidants, which is a potential anti-cancer properties, especially for colon cancer (Awika, 2009). Mocaf is modified cassava flour through a process of fermentation by lactic acid bacteria with preferred taste over cassava flour (Subagyo, 2008). Corn flour, cornstarch, and arenga starch are additional ingredients we use in the analogue rice formulation to get the desired characteristics.

The general objective of this study was to get formulation of analogue rice using a Twin Screw Extruder that acceptable by the sensory consumers. Specifically, this study aimed to get the best formula through sensory testing and physical and chemical characterization of selected analogue rice.

Method

Materials for the manufacture of analogue rice consisted of sorghum flour (chisel varieties) comes from BATAN, mocaf, corn flour, cornstarch, arenga starch, water and GMS (Glycerol monostearate). Material for analysis consisted of analogue rice and materials for chemical analysis. Tools we used to manufacture analogue rice were Twin Screw Extruder (Berto BEX-DS-2256, Indonesia), disc mill, rice milling apparatus (Satake, Japan), and a drying oven. Some tools for analysis were the soxhlet, UV-Vis spectrophotometer (Shimadzu, Japan), chromameter (CR 300 Minolta, Japan), analytic scales, and other glass tools.

This study consisted of several stages, i.e. (1) analogue rice formulations, (2) sensory test phase, and (3) chemical and physical characteristics analysis of the selected analogue rice.

In this study, six analogue rice formulations were made, used 30% sorghum flour and 30% mocaf formulations, three formulations each. In addition to differences in the flour type, two different types of starch (arenga starch and cornstarch) are also used. The complete formulations were shown in Table 1. Additional materials used in each formulation are 40% corn flour. Based on previous research results, 50% water and 2% of total GMS flour dough as fixed component were added to each formula (Budijanto, 2012). The making process of analogue rice started with weighing ingredients based on the formulations. Then, we mixed the dry ingredients include flour, starch and GMS with a dough mixer for 10 minutes. We added water gradually until the dough is smooth. We continued it with the extrusion process using a Twin Screw Extruder Berto BEX-DS-226 with temperature T1 = T2 = T3 = 85 ° C and the auger speed = 18Hz, screw speed = 15 Hz and 50Hz speed cutter. Then, we dried the extruded product in an oven dryer at 60 ° C for 4 hours.

The analogue rice that we obtained then went into the best formula selection through a hedonic rating sensory test (Meilgard, 1999). Sensory tests conducted on the rice samples and analogue rice were in the attributes of colour, scent, flavor (rice only), texture and general acceptance. We used the lines scale as long as 15 cm. The responses we took were from untrained panelists as many as 70 people.

Chemical and Physical Characteristic Analysis of the Selected Analogue Rice

The selected analogue rice formula were analysed based on its chemical and physical characteristics. The chemical characteristics included proximate analysis (AOAC, 2006), enzymatically dietary fiber method (Asp et al. 1983), *luff school* starch analysis method, and amylose (Juliano, 1971). Physical characteristics analysis we did were colour analysis using Chromamater Minolta CR 300 (Minolta, Japan), density Kamba, and 1000 grain weight.

Results and Discussion

Formulation phase is the most important stage in the manufacture of analogue rice. The main ingredients in analogue rice are rice flour, starch, water, and a binding agent in the form of emulsifier (Budijanto, 2012). Sorghum flour, mocaf and cornstarch were flour that added to the manufacturing of analogue rice. In preliminary studies it is known that the use of only one type of flour whether it is sorghum flour or mocaf produces sticky, dark-coloured and dull products. Therefore, in addition of 30% sorghum flour and mocaf we also added cornstarch as much as 40% in order to reduce the stickiness and brighten the colour.

Table 1. Analogue Rice Formulation

Formula	Flour (30%)	Starch (30%)
A	Sorghum	Arenga starch
B	Sorghum	Arenga starch 15%, Cornstarch 15%
C	Sorghum	Cornstarch
D	Mocaf	Arenga starch
E	Mocaf	Arenga starch 15%, Cornstarch 15%
F	Mocaf	Cornstarch

We added 30% starch and the type of starch used is cornstarch and arenga starch. In preliminary studies, the addition of cornstarch provides good leverage to lighten the colour of the analogue rice, while the addition of arenga starch improves the texture of the rice produced.

Water is an important factor in the formation of analogue rice because water plays a role in the process of gelatinization. Binding agent used in the manufacture of analogue rice was emulsifier Glycerol Mono Stearate (GMS). Based on previous research, the amount of 50% water and 2% GMS were added of the flour dough (Budijanto, 2012). GMS served to bind the material, became a lubricant during extrusion, prevented any development of extrudates, made extrudates did not stick to each other, and reduced product loss during the cooking process into cooked rice (Kaur, 2004).

We did a sensory test to select the best formula of the analogue rice. We held a hedonic rating sensory test analysis of cooked analogue rice and analogue rice grains sample from 70 panelists response. The best formula was described as analogue rice with the highest preferred value in the form of cooked rice and analogue rice sample. Parameters assessed in the sample were the colour, shape, scent, flavor (especially analogue rice), texture, and overall.

The results of analogue rice sample sensory analysis showed the average scores as shown in Table 2. At the colour parameters, rice that had the highest preferred values are B and F. The product colour of the analogue rice was dark yellow. Yellowish colour of the rice came from β-carotene obtained from corn (Welch, 2004), while the brightness of the rice was also influenced by other components. Sorghum flour substitution in rice can caused dark colour since they still contained tannin. This was due to the process of milling sorghum flour that still be able to save at least 25% of the initial tannin levels (Suarni, 2001).

Analogue rice B and F owned the highest value on rice shape parameter. The shape of analogue rice is strongly influenced by the stage of printing in the extrusion process. Analogue rice shape is determined by the die extruder, cooking temperature, and water content in the dough. In Figure 1 we can see that the analogue rice form is slightly different from the usual rice grain. Analogue rice is round and shorter than the rice grain which is long and oval. Analogue form of rice is still not perfect, but as the technology has been developed we can manufacture rice with more appropriate shape in the future.

Analogue rice B and F owned the highest scent parameter's value. Analogue rice scent is strongly influenced by the ingredients used

Table 2. Analogue Rice Sensory Test Result

Analogue Rice	Test Parameter*				
	Colour	Shape	Scent	Flavour	Texture
A	4,84a	6,49a	6,42a	7,40	5,95a
B	9,26c	9,12cd	8,70b	8,60	9,20c
C	7,94b	8,11bc	6,99a	8,28	7,84b
D	4,76a	6,40a	6,93a	9,10	6,36a
E	7,98b	7,78b	8,21b	7,88	8,26b
F	9,47c	9,28d	8,53b	8,28	9,45c

* Figures in the same column followed by different letters indicate significantly different samples at the test level of 5% (Duncan Difference Test)

in the formulation. Corn scent dominated the analogue rice overall scent since its proportion was also higher than any other ingredient (about 40%). Sorghum flour, mocaf, and starch tend to not having a pungent scent, but after going through the mixing and cooking process, an interaction can occur and will shows a distinctive scent. Analogue rice D and B had the highest value for the texture parameter, each had a value of 9,09 and 8,59, despite all the treatments did not leave a real impact on texture parameter scores. Based on consumer preference value on texture, which was 7-9, it can be seen that consumers liked the texture of the product. The overall parameter of analogue rice B and F were also had the highest preferred value.

Next, sensory test was carried out on cooked analogue rice. Analogue rice cooking methods was not much different from cooking usual rice. The tool used to cook analogue rice in this study is a rice cooker. The amount of water added to the rice was two parts by volume of the analogue rice. The steps were, measuring 200 ml of the analogue rice, and then measuring 400 ml of the water. We poured the water into the rice cooker and turned on the appliance. We put in the analogue rice after the water boils. The cooking time was ± 15 minute. We counted the rice as cooked when there were no white specks in the middle of the rice and the texture was chewy.

The analogue sensory test results average score was shown in Table 2. Cooked analogue rice B, E and F had the highest value for colour parameters. Analogue rice was golden brown coloured and a bit different from the usual white rice colour. But the yellow colour of the cooked rice was more faded than the colour of the rice. The colour changes occured because the cooking process causes the starch gelatinization. The brownish colour of the rice with sorghum flour substitution can be caused by tannin content (Dykes, 2006).

Cooked analogue rice E and F owned the highest preferred value on shape parameters. The shape of cooked rice was larger than the analogue rice grain. The cooking process that

a

b

Figure 1. Shape comparison of Analogue Rice (a) and Rice Grain (b)

Table 3. Cooked Analogue Rice Sensory Test Result

Cooked Analogue Rice	Test Parameter*					
	Colour	Shape	Scent	Flavour	Texture	Overall
A	6.0671a	5.8129a	6.6143b	6.8657a	6.9214a	6.6543a
B	7.6457bc	6.4943ab	6.5143b	8.0629b	7.9943bc	8.0000c
C	7.0157b	6.8829ab	4.3886a	6.9057a	7.0886ab	6.8971ab
D	5.5114a	6.0929ab	5.6243b	7.0971ab	7.6386ab	6.8686ab
E	7.9657bc	7.2414b	6.1543b	7.7557ab	8.0643bc	7.7514bc
F	8.2514c	7.0200b	6.0671b	7.7629ab	8.7057c	7.9300c

* Figures in the same column followed by different letters indicate significantly different samples at the test level of 5% (Duncan Difference Test)

used water caused the changed shape of the rice. Most of the analogue rice components are carbohydrates in the form of starch, thus the process of swelling occured because of the starch gelatinization (Winarno, 2008). Starch heated along the water will absorb water to break down the structure of the starch. Once the structure of starch broken down, starch will absorbed the water and increase the viscosity. The heating process will also bind the water molecules in the starch so that the cooked rice will take the larger size. Table 3 also showed that cooked analogue rice A and B owned the highest value in scent parameters. Scent is one of the most important parameters in the acceptance of the rice. Analogue rice scent predominantly influenced by the scent of corn because of its higher proportion. It can be the reason why the panelists' acceptance on the analogue rice scent was still below neutral / moderate. Analogue rice B, E and F had the highest value of the texture parameter. Texture of the rice is also an important factor in the acceptance of the rice. Rice texture value included rice fluffier texture and stickiness. Cooked rice B and F had the highest parameter value in flavor and overall.

Based on the results of sensory tests on samples of analogue rice grain and cooked analogue rice, analogue rice B and F frequently had the most preferred value score on the parameters of colour, shape, scent, taste and texture. Moreover, analogue rice B and F also had the overall parameter highest score that indicate well overall acceptance. Therefore, analogue rice B and F selected as the best analogue rice formula. Analogue rice B was rice with a composition of 30% sorghum flour, 15% cornstarch, 15% arenga starch, and 40% corn flour, while analogue rice F is rice with a composition of 30% mocaf, 30% cornstarch, and 40% of corn flour.

Chemical characteristics analysis performed on selected analogue rice were proximate levels, dietary fiber, total starch, and amylose (Table 4). The water content of the rice B and F were already lower than the safe water levels for storage which is <12% on wet materials (13.63% on dry materials), and can prevent the growth of mold that often live in cereals / grains. Proteins are amino acid polymer compounds that are important for the body. The protein content of analogue rice B and F are still lower than milled rice. The protein content of analogue rice produce is very dependent on the raw materials used. The protein content is very important for the body because it can affect blood glucose levels. Protein can extend the gastric emptying rate thus slowering the digestion and absorption rate in the small intestine and lowering the glycemic response (Alsaffar, 2011). To meet the shortage of protein, analogue rice consumption shall be accompanied with other protein sources such as eggs, meat, fish, and nuts.

Fat is an ester glycerol and fatty acids polymer compound. Fat content of analogue rice B and F was lower than the fat content of milled rice. Low fat content can prevent the rice to easily rancid and may longer the storage time span. Carbohydrates are the components that contribute energy to the body. Analogue rice B and F (dry ingredients) carbohydrates level

Table 4.Selected Analogue Rice Chemical Characteristics

Proximate Level	Formula B	Formula F	Milled rice
Water Content (dry)	10.58	11.37	11.22*
Ash Content (dry)	0.52	0.52	0.56*
Fat Content (dry)	1.12	0.86	1.46*
Protein Content (dry)	6.95	5.75	7.40*
Carbohydrate Content (dry)	91.60	94.70	89.56*
Soluble Dietary Fiber (%)	1.52	1.75	0.6*
Insoluble Dietary Fiber (%)	2.48	2.46	<0.5*
Total Starch (%)	66.48	65.10	68.18**
Amylose (%)	21.72	14.49	20.65**

*Ohtsubo et al. (2005)
**Wulan et al.(2007)

exceeded the carbohydrate content of milled rice as shown in Table 4. High carbohydrate levels are caused by the domination of flour and starch as the main ingredients which are a source of carbohydrates. Based on the chemical properties of analogue rice that has been obtained we can conclude that the nutritional content of analogue rice is not much different from the usual rice grain and analogue rice can be an alternative staple food sources of carbohydrates.

Levels of soluble and insoluble dietary fiber of analogue rice B and F higher than milled rice. Source of fiber derived from corn flour and sorghum flour which is the main constituent of analogue rice. High fiber content is good for health. Dietary fiber has important characteristics that are required in the formulation of functional foods (Cuenca, 2008). Soluble dietary fiber is associated with decreased glycemic response (Widowati, 2006; Elleuch, 2011). Soluble dietary fiber in the digestive tract will form a kind of gel texture, thus slowing the speed of digestion in the gut, provide satiety longer, and slow the appearance of blood glucose. It also can maintain stable blood sugar levels due to less insulin requirement to transfer glucose into cells and converted into energy (Alsaffar, 2011). The of insoluble dietary fiber function is to prevent various diseases, particularly those associated with the digestive tract, such as hemorrhoids, diverticulosis and colon cancer (Eckel, 2003). According to the CAC (2009), a food is a source of dietary fiber if it contains at least 3% fiber, and is called high in fiber if it contains at least 6% dietary fiber. Analogue rice produced had a fiber content of 4% (analogue rice B) and 4,21% (analogue rice F) and were classified into the food source of fiber.

Amylose is a glucose polymer compound which has a straight-chain and unbranched. Both of the analogue rice had higher amylose content than the milled rice. Amylose content of rice B was 21,72% with the addition of sorghum flour 30%, considered moderate amylose content (20-24%),with moderate fluffier rice characteristic. Rice F containing amylose content of 14,49% classified to the low amylose rice (10-20%) that considered as fluffier rice (Yusof, 2005). Some researchers have reported that the rice with high amylose content has low glycemic index (GI) (Hu, 2004; Widowati, 2006; Denardin, 2007; Denardin, 2012; Srikaeo, 2014). The higher the amylose contents of rice, the lower the glycemic index. The reason is because amylose is an unbranched polymer compound (with compact linear structure) so that the bond is strong and not easily digested by enzymes (Ek, 2011).

Based on its chemical characteristic, analogue rice is especially suitable for adults with weight problems. Foods containing dietary fiber may be helpful in patients with obesity, which is one of the major risk factors for diabetes (Sanada, 2012) and high cholesterol

(Listiyana, 2013). Obesity can be caused by high calorie intake, unhealthy diet, lack of physical activity, as well as the impact of modern lifestyle (Listiyana, 2013). Analogue rice produced had higher dietary fiber content than usual rice grain, so it can be used as alternatives of staple food to meet the dietary fiber needs of society. But analogue rice produced was still less suitable for consumption by children at the age of growth, since children need high energy and protein intake to support the process of growth and high physical activity (Pahlevi, 2012).

Physical characteristic analysis we did was the colour (value L *, + a, + b) 1000 grain weight, and Kamba density (g / ml) (Table 5). Analysis of the analogue rice colour was done using Chromameter tool. Notation L * indicated the brightness level of a product. Analogue rice B and F with darker colour product had lower value of L compared to milled rice. The a and b value obtained for both analogue rice and the milled rice was positive. This means all three products contained different intensities of red and yellow colours. The level of brightness and colour of analogue rice originating form the dominating raw material used, which were sorghum flour with brownish colour and corn flour with yellowish colour. Corn flour contained beta-carotene so analog rice has a dominant yellowish colour (Welch, 2004).

1000 grain weight of rice is usually known to determine the size uniformity of the rice grain. The test results showed that the 1000 grains weight of analogue rice is lower than the milled rice (Setianingsih, 2008). This can be due to the smaller size of analogue rice than milled rice. The analogue rice weight per grain can be influenced by the printing process of analogue rice using an extruder. The most influential process parameters are the screw speed and cutter speed. The combination of both parameters can determine the shape of analogue rice. If the speed was reduced, the size of analogue rice will larger and vice versa. Analysis of the analogue rice weight per grain is related to the Kamba Density analysis to determine the rice volume and porosity.

Kamba Density is specific gravity of dry product calculated by its weight in a container. Kamba Density of analogue rice is known to determine the rice volume and porosity. Kamba Density of a product is measured to determine how much volume is needed for these products at a certain weight. Based on the analysis of Kamba Density, analogue rice B and F had a lower density than milled rice, thus analogue rice had a lighter weight and higher porosity than milled rice at the same volume. The lighter weight can be caused by a high temperature of extruder barrel for extrusion process and the addition of water affects the shape of the product resulting in a product swelling. To prevent an over swell, the addition of water is only 50% the total dough. High porosity on analogue rice can be obtained as a result of the drying process in the making process of analogue rice. Drying process can make rice analog losing its water content and the analogue rice matrix becomes more shafts.

Conclusion

Based on the sensory test of the analogue rice formulas, the most preferred analogue rice formula is analogue rice B which consists of 30% sorghum flour, 15% cornstarch, and 15% arenga starch and analogue rice F which consists of 30% mocaf and 30% cornstarch. Analogue

Table 5. Physical Characteristic of Selected Analogue Rice

Characteristics	Analogue Rice B	Analogue Rice F	Milled rice
L*	53.8	57.38	80.54*
+a	+4.57	+4.25	+0.25*
+b	+25.52	+27.54	+15.38*
1000 grain weight (g)	18.37	16.24	19.00*
Kamba Density (g / ml)	0.65	0.70	0.80**

*Noviasari et al. (2013); ** Hawa et al. (2011)

rice B and F contain higher carbohydrate and fiber levels than milled rice. However, the levels of fat, protein, and ash of analogue rice B and F are lower than milled rice. We classify analogue rice B as moderate fluffier rice since its amylose content is 21.72%, while analogue rice F which contains low amylose (14,49%) as fluffier rice. The brightness level of analogue rice B and F is lower than milled rice for its darker coloured grains, and has a different intensity of yellow-red colour. Based on the results of the Kamba Density and 1000 grains weight analysis, analogue rice B and F are smaller than milled rice, which may be caused by the process of extrusion and drying.

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