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Physico-Chemical Properties of Calcium-Fortified Analog Rice from Composite Flour (Cassava, Corn, and Snakehead Fish) for Osteoporosis Prevention

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Abstract - *In this study, composite flour made from cassava and corn flour were processed for producing analog rice. To meet the calcium needs for the elderly and to optimize the potential of cassava, corn, and snakehead fish, the analog rice will be fortified with calcium from cork fish. The aim of this work are to study the effect of composite flour composition and the extruxtion temperature on the physico-chemical properties of calcium-fortified analog rice. The parameter process studied were mocaf flour:snakehead fish flour (MF/SFF) mass ratio (100:0; 97:3; 94 6; 91:9; and 88:12) and extrusion temperature ranging from 50^{o}C, 70^{o}C, and 90^{o}C. The physico-chemical properties including bulk density, cooking time, proximate, calcium levels and its organoleptic were analyzed. The results showed that at 91:9 MF/SFF mass ratio and the extrusion temperature at 70^{o}C obtain the best effect on the nutrient content of analog rice which contain 14.34% of water, 0.85% of ash, 71.829% of carbohydrate, 11.236% of protein, 1.12% of fat , 1,113 ppm of calcium, and 2.427% of dietary fibre.*

Keywords *– analogue rice, composite flour, extrusion, snakehead fish, calsium*

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1. Introduction

The need of rice in Indonesia has continuously increased every year in line with its population growth. White rice has nutrient content about 40-80% of calories [1], 78.9% of carbohydrate, 6.8% of protein, 0.8% of iron in the absence of vitamins [2]. The increased of population growth and the reduced of the agricultural land in Indonesia cause the production of rice has not been able to meet its demand, thus Indonesian government need to import the rice [3]. The high dependence on rice in Indonesia will be a problem. Therefore a new solution is needed to solve the problem, one of which is by producing analog rice.

In Indonesia, the number of elderly households is 16.08 million or 24.50 percent of all households in Indonesia [4]. The physical condition and the ability of the elderly will decreased and easily attacked by disease, one of it was osteoporosis. Osteoporosis is a disorder of bone metabolism. Bone metabolism can be disrupted by a variety of conditions ie reduced estrogen, decreased calcium, decreased mechanical stimulation (inactive) in bone, and so on [5]. Calcium intake can be increased by adding these minerals to commonly consumed foods such as rice by fortification of food.

Food fortification is important by adding one or more nutrients to the food [6]. Foodstuffs used as a fortifikan matrix can be either ready-to-eat food or raw materials which require to be processed [7]. Fortification are able to provide greater value of food at relatively similar cost [8]. Rice is a staple food which consumed by more than 90% of the people in Indonesia [9], thus other basic food alternatives are needed. Various studies have been undertaken to produce a perfect analog rice [9-12].

More than 90% of Indonesian population are consume fish, so it has become a common menu. Snakehead fish is one of high calcium foods that can meet the nutritional needs of an elderly. Every 100 grams of snakehead fish contains at least 29 mg of calcium, 124 mg of phosphorus,

and 0.64 mg of iron [13]. Snakehead fish is relatively easy to find but not all of the households are able to process well the snakehead fish to be easily consumed. Therefore, an alternative product is needed that contains enough nutrients as a substitute for the usual processed snakehead fish. One of the efforts to create the substitution product is by making the staple food of fortified analog rice.

The production of cassava in Indonesia was abundant, it is amounted to 21,801,425 tons per year. Central Java itself ranks second in the production of cassava with 3,571,594 tons per year [14]. While, corn (*Zea mays sp*) is one of the viable alternative food potentials to be developed as Indonesia was the largest corn producer in Southeast Asia. Furthermore, in order to improve the utilization of cassava and corn in Indonesia, they will be used as main raw material in analog rice production to processed first into composite flour. To meet the calcium needs of the elderly and increase the variety of processed snakehead fish, analog rice will be fortified by calcium from cork fish. Thus, the production of analog rice has an advantage, with its nutritional content that has higher calcium levels, adding to food variations that can meet the needs of the elderly, and add food diversification to optimize the potential of cassava, corn, and snakehead fish as well.

The major objectives of this research are (1) to study the production process of analog rice by varying the composition of composite flour (cassava, corn and snakehead fish) on its nutrient content, (2) to study the effect of the extraction temperature towards its nutrient content, and (3) to study its characteristics. This research is expected to benefit: (1) create alternative food products for the elderly's nutritional needs, (2) increase food diversification, and (3) increase the calcium nutrient for the elderly.

2. Methodology

2.1. Materials

In this work, mocaf flour was obtained from Omah Tani, Gunung Pati, Semarang, Indonesia. Gliserol monostearat (GMS) was purchased from Sigma-Aldrich Pte. Ltd. (Singapore). Other materials such as snakehead fish, cornstarch and cooking oil were bought from traditional market in Semarang, Indonesia.

2.2. Procedure

2.2.1 Production of composite flour

Snakehead fish was cleaned and weeded. The scales and gills were removed and thereafter the snakehead fish was eviscerated. Then it washed, drained, and weighed. The clean snakeheadfish were then boiled for 15 minutes with water at snakehead fish : water (SF/W) mass ratio of 1: 1. Thereafter it was drained, and weighed again. The fish flesh was then separated from the bone and skin. A mass of 0.02% BHT antioxidants was added to the fish and stirred. The fish is pulverized, mixed with fish broth and weighed. Fish pulp was dried at 50^{o}C for 9 hours. The dried then smoothed with crusher and screened using sieve 80 mesh [15]. Preparation of composite flour was done by mixing cornstarch, mocaf, and snakehead flour by using mixer with mass ratio according to predetermined variable then mixed until it was evenly distributed.

2.2.2. Production of analog rice

Mocaf, snakehead fish flour, cornstarch and other ingredients such as water, GMS, and cooking oil with predeterminant mass were mixed for 20 minutes. The composite flour obtained then wrapped in a cloth, compacted and steamed for 30 minutes at 80-90^{o}C. The pre-condensed composite starch mixture was then put into the extruder. Drying was done at room temperature [16].

2.2.3 Phase Analysis of Results

Analog rice is analyzed by proximate analysis to determine its carbohydrate, protein, fat, moisture, ash, and calcium content. Organoleptic test using consumer's acceptance test method. The physico-chemical properties including bulk density and cooking time were also analyzed.

3. Results & Discussions

3.1. Proximate Analysis of Raw Material

According to Widowati [17], proximate analysis is a basic analysis of a food ingredient consists of moisture content, ash, protein, fat, dietary fiber content and carbohydrates. The result of proximate analysis of raw material are shown in Table 1.

3.2. Effect of MF/SFF mass ratio

As seen in Table 2, the highest protein content was was found at MF/SFF mass ratio of 88:12. The difference of protein content is influenced by the amount of snakehead fish flour content. At MF/SFF mass ratio of 88:12 ratio, the composite flour has the largest snakehad fish flour content. Protein needs for adult is more than 25g protein for each serving, where the male needs are greater than the women's needs [18]. The efficiency of cell function of the elderly's body will begin to decrease and their nutritional needs will increase [19]. Protein stimulates insulin secretion [20] so glucose in the blood can be well controlled. Therefore, food with high protein content has a lower glycemic index value than the lower one [21].

Table 2 shows that the highest carbohydrate content was at MF/SFF mass ratio of 100:0 with 72.219% while the lowest carbohydrate content was found at MF/SFF mass ratio of 88:12 with 70.591%. The difference in carbohydrate content is influenced by the differences in protein content. Protein and calcium content found in calcium-fortifed analog rice are higher than the ordinary rice, thus it reduce the carbohydrate content in the analog rice. However, the level carbohydrate content in calcium-fortified analog rice still be classified as staple food.

Calcium content at MF/SFF mass ratio of 91: 9 was the highest for each extrusion temperature, but its not much different with MF/SFF mass ratio of 88:12. The analog rice mixed with fish flour (calcium-fortified analog rice) have the higher calcium content than the unmixed one. SFF added to the analog rice composite flour can increase its calcium content.Based on the analysis.

Table 1. Proximate test of raw material (per 100 g)

Sampel	Calcium (ppm)	Carbohydrate (%)	Protein (%)	Fat (%)	Dietary Fiber (%)	Moisture (%)	Ash (%)
Mocaf	33	83.217	3.726	0.140	6.467	5.100	1.800
Fish Flour	1,361	38.050	54.556	0.060	6.314	0.680	0.840
Cornstarch	20	80.366	9.105	1.540	5.419	2.990	0.580

Table 2. Effect of MF/SFF mass ratio on proximate analysis results

Parameter	**MF/SFF mass ratio**				
	100:0	**97:3**	**94:6**	**91:9**	**88:12**
Protein (% wb)	7.953	9.201	8.848	9.527	10.227
Carbohydrate (% wb)	72.219	71.060	71.700	71.183	70.591
Fat (% wb)	0.853	0.747	0.733	0.880	1.020
Moisture (% wb)	14.250	14.250	14.250	14.250	14.250
Ash (% wb)	0.780	1.080	0.630	0.850	0.980
Calcium (ppm)	687.700	753.000	745.800	971.700	911.700
Dietary Fiber (% wb)	3.935	3.659	3.828	3.304	2.922

Table 3. Effect of Extrusion Temperature on proximate analysis results

Parameter	Extrusion Temperature (°C)		
	50	70	90
Protein (% w)	8.820	9.608	9.025
Carbohydrate (% w)	69.512	71.041	73.427
Fat (% w)	0.728	0.892	0.920
Moisture (% w)	16.500	14.340	11.930
Ash (% w)	0.708	0.990	0.900
Calcium (ppm)	804.300	827.600	810.200
Dietary Fiber (% w)	3.660	3.129	3.798

It is recommended to consume calcium as much as 700-1,200 mg per day for osteoporosis sufferer. Consumption of calcium more than 2,000 mg per day can cause hypercalcaemia [22-23].

In this research, the highest dietary fiber content was found at MF/SFF mass ratio of 100:0 (3.935%) iwhile the lowest dietary fiber content was found at MF/SFF mass ratio of 88:12 (2.922%). These results show that the analog rice of the study contains less dietary fiber than the commercial analogue rice. Based on the results, the more SFF added, the smaller the fiber content. For eldery people, fiber consumption patterns may affect their psychological activity, metabolism and microbiome function [24].

The fat content of calcium-fortified analog rice were varied. The lowest fat content was found at MF/SFF mass ratio of 94:6 (0.733%) while the highest fat content was found at MF/SFF mass ratio of 88:12 (1.020%) This fat content is lower when compared with commercial analogue rice containing about 2.180% fat. Consumption of foods containing fat needs to be considered since the limit of fat consumption should not exceed 30% of total energy (Sartika, 2008). The consumption of excess fat can lead the body to various diseases, one of which is obesity [25-26]. Obesity may also indirectly cause the risk of reducing bone strength and osteoporosis [27]. For the same extrusion temperature, the fat content in calcium-fortified analog rice proportional to the content of snakehead fish flour.

3.3. Effect of Extrusion Temperature

The process of extrusion was done at various temperatures. Based on the temperature of gelatinization, the extrusion process was carried out at 50°C, 70°C, and 90°C. Table 3 shows the effect of extrusion temperature to the proximate test results.

Increasing the extrusion temperature affects the carbohydrate content of analog rice. The higher the extrusion temperature, the higher the carbohydrate levels of analog rice. This is due to the chains of amylose and amylopectin molecules which are easily separated. Separation of amylose and amylopectin chains in analogue

rice affects the number of amylose and amylopectin molecules. The higher the temperature used, the more easily the amylose and amylopectin molecule to be separated, so the number of amylose and amylopectin molecules obtained is large. The number of amylose and amylopectin molecules in analog rice indicates that the carbohydrate levels was high [28].

The effect of temperature towards the calcium content on calcium-fortified analog rice is represented in Table 3. Increasing the extrusion temperature causes increased the levels of calcium. This is considered to be due to the gelatinization process which causes calcium minerals from snakehead fish flour is absorbed and nourishes the analog rice [29]. However at a temperature of 90° C there was a decreasion in calcium levels from 827.6 ppm to 810.2 ppm. Declined levels of calcium at high temperatures have a correlation with the gelatinization temperature of composite flour. Gelatinization temperature of composite flour is 80.7°C while the extrusion temperature used is 90°C. The higher temperatures used for extrusion caused the higher amylose levels, resulted in more dense amylose structures, and less water absorption capability, therefore the water penetration and calcium absorption to the rice be more difficult. In addition, high temperature extrusion may lead the dissolution of amylose and damage the amylose crystals. If the heating continues, amylose will be leached and the calcium that has been absorbed will come out of the tissue [30].

The results showed that the protein levels of analog rice was ranged from 8.820% to 9.608%. The highest protein content was obtained at 70° C and the lowest at 50° C. Increasing the extrusion temperature affect the incline of protein level, but at 90° C it will decreases. High temperature leads to reduced protein levels on analog rice. Analog rice production by extrusion method may cause protein denaturation. The mechanical process of extrusion and the addition of heat causes the breaking of amino acid bonds, except for the primary bond. Excessive warming, leads to breakdown the hydrogen bonds and non-polar hydrophobic interactions on analog rice. High temperatures increase the kinetic energy and cause protein molecules to move very quickly, so the amino acid bonds in the protein molecule are split. Breaking of amino acid bonds in proteins causes protein denaturation therefore the protein content in analog rice is decreases [31].

The analysis result of analog rice fat due to temperature influence were ranged from 0.728% to 0.920%. For the same cornstarch composition in composite flour, the high extrusion temperatures are able to maintain better fat content so the fat level is high. This is may also have affected by the leaching of moisture content contained on the analog rice during the extrusion process. Further, it will increase the fat content, because if one of the proximate components of a food decreases then other proximate components will increase to achieve the balance [32].

The result of dietary fiber analysis on the effect of temperature variables on analog rice were ranged from 3.129% until 3.798%. Dietary fiber level decreased from temperature at 50°C to 70°C. The decrease in dietary fiber is due to the decay of cell walls of analog rice during the extrusion process [33]. However there was an increasing of the dietary fiber level at 90° C. Increased levels of crude fiber are thought to occur as a result of decreasing of moisture content in the analog rice. During the extrusion, water in the analog rice will evaporate but the other compounds, such as carbohydrates was increase. As the carbohydate levels rise, the coarse fiber content of the ingredients will increase as well [34].

The results of moisture content analysis on the effect of temperature variables on analog rice were ranged from 11.930% to 16.500%. The variation of temperature shows that the higher extrusion temperature, the lower moisture content on analog rice. At 50°C, which is low temperature, the moisture content in composite flour is still quite a lot until it has become a rice. Meanwhile, at 90°C, some of the water in composite flour has evaporated during the extrusion process because the temperature approaches the boiling point of water at atmospheric pressure, therefore when it dried, the moisture content will reduce. The smaller moisture content in the analog rice can be explained that the formation of analog rice through the process of extrusion is done by increasing the temperature and grinding the rice. It can lead to structural changes in the depletion of food proteins which can cause the water leach out during the extrusion process. The discharge of water in the extrusion process results in a decrease in moisture content [35].

3.4 Physical Analysis of Analog Rice

3.4.1 Bulk Density

The bulk density of calcium-fortified analog rice was 0.51 g/mL, which lower than the mocaf based analog rice (0.70 g/mL). It can be concluded that the calcium-fortified analog rice has the higher porosity, which is influenced by the nutrient content of analog rice as well as its manufacturing process includes drying process. Drying process causes the losing of water content therefore the analog rice becomes more porous [36]. During the cooking process, the analog rice will be swell. The swelling process of analog rice increases the rice volume, but decreases the mass. Therefore, the higher the rice swelling rate, the lower the bulk density [37]. However, American government specifications in the military and defense fields set the standard for the density of rice cages ranging from 0.40 to 0.42 g/mL. Rice with bulk density lower than 0.36 g / mL will produce flabby products such rice porridge at the time of reconstitution [38]. It can be concluded that the calcium-fortified analog rice meet the analog rice criteria according to [38].

3.4.2 Cooking Time

The cooking time of calcium-fortified analog rice made from mocaf, cornstarch, and snakehead fish flour was 25-30 minutes, which is longer than the mocaf-based analog rice (15 minutes). This is due to the high protein content of the

calcium-fortified analogue rice, therefore it require more heat energy to obtain gelatinization for protein denaturation [39]. The greater the protein content, the longer the optimum time for cooking.

3.5. Consumer's Acceptance Test

Organoleptic test of calcium-fortified analog rice was analyzed using consumer's acceptance test by its texture, aroma, taste and color. Figure 1 shows the average results of organoleptic tests on analog rice.

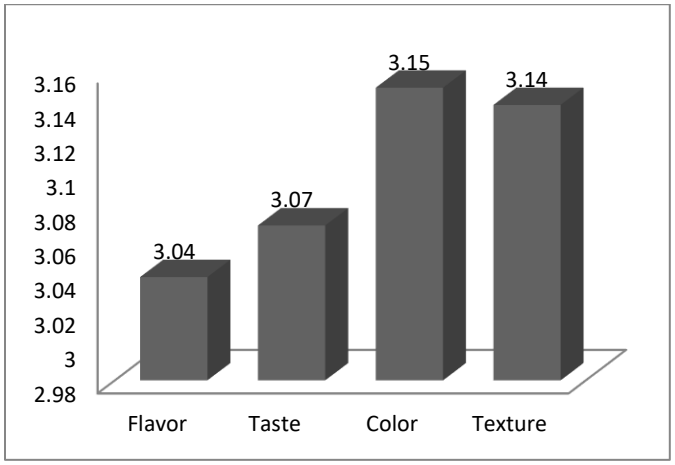

Figure 1. The results of organoleptic test

Figure 2. The best calcium-fortified analog rice based on nutrient content (formula : MF/SFF mass ratio of 91:9)

As shown in Figure 1, respondents gave the most ratings on the value of 3, which means that the analog rice is received as a substituent for regular rice. The taste of fish on analog rice, obtained from snakehead fish flour, was a relatively tasteless. Calcium-fortified analog rice has brownish color but still acceptable for respondents. It was relatively more coarse in texture than the regular rice.

4. Conclusion

From the results, sample 9 (MF/SFF mass ratio of 91 : 9 and extrusion temperature of 70^{o}C) was the best formulation for the production of calcium-fortified analog rice. It has the highest levels of calcium and carbohydrate levels which sufficient as a staple food. The results of chemical analysis showed that the best calcium-fortified analog rice in this study contained 14.34% of water, 0.85% of ash, 71.829% of carbohydrate, 11.236% of protein, 1.12% of fat, 1,113 ppm of calcium, and 2.427% of dieatry fiber.

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