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PROXIMATE COMPOSITION AND GELATINIZATION PROPERTIES OF RICE ANALOGUES FROM BREADFRUIT, MUNG BEAN AND CARROT FLOURS AT VARIOUS DOUGH COMPOSITIONS AND DRYING TIME

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ABSTRACT
The serious threat of rice supply in many parts of the world and high demand for more nutritious rice have driven the efforts on the production of rice analogues from other food sources. This research was aimed to study the effect of dough composition and drying time on the nutrition and physical characteristics of rice analogues from breadfruit flour with carrot and mung beans flours as nutrient fortificants. To achieve that aim, variations in the composition of breadfruit flour with the addition of carrots and mung beans flours during extrusion and drying time in rice analogues manufacturing were investigated. As quality indicators of the rice analogues, the nutrition contents, which include moisture, ash, protein, lipid, dietary fiber, carbohydrate and amylose contents were analyzed. In addition, the physical properties of the rice analogues which consist of hardness and gelatinization temperature were also determined. Based on those quality criteria, the best rice analogues could be obtained upon the extrusion of flour composite dough comprising breadfruit flour 80% w/w, mung bean flour 10% w/w and carrot flour 10% w/w, and followed by oven drying at 70ºC for 7 hours. The consumption of such product is a highly promising especially for people residing in dry rural areas and those with high needs in protein and vitamin A.

1. Introduction

Rice is one of most important staple foods in the world as it sustains two-thirds of the world's population by providing 20% of the world's dietary energy supply. However, rice contains a low content of protein but the higher content of starch. This low protein content has triggered deficiencies of protein and some essential amino acids of people who take it as primary diet (Mishra et al., 2012). As the living standards of people improve from time to time, more attention has been devoted to providing better rice quality. Unfortunately, rice is commonly consumed in the form of grains without milling. Therefore, micronutrient fortification on rice is technically more difficult. Another problem on rice arises from climate change, which has been reported to badly impact the rice production and consequences on food security per se. Peng et al. (2004) reported that rice yields decreased by 10% for every 1°C increase in temperature. The temperature rise is predicted to cause rice yield falls by about 50% in 2100 relative to the 1990 level in South East Asia, especially Indonesia, Philippines, Thailand and Vietnam. One approach to overcome the aforementioned problems is by preparing rice analogues (Mishra et al., 2012).

Rice analogues are imitation of conventional paddy rice, which has very close similarity in both appearance and nutrition content. Rice analogues could be developed as a new value added product using different types of carbohydrate sources, such as tubers and cereals with added nutrients and functionalities (Herawat et al., 2014). In addition to its main function as a substitute for paddy rice, rice analogue can be designed as a special food for patients of some diseases, such as diabetes, hypertension, and others. The nutritional content of the rice analogues can be enriched by incorporation of various types of foodstuffs through fortification process, which will allow consumers to benefit without experiencing major changes in their dietary habits. Several methods have been proposed to manufacture fortified rice analogues, however hot extrusion and cold extrusion are the most popular processes (Li et al., 2009). Various sources of carbohydrates have been used to manufacture rice analogues, such as soybean flour, corn flour and tapioca starch (Herawat *et al*., 2014), and low amylose rice and seeded banana flour (Borah *et al*., 2015). There have not been any reports on the use of bread fruit flour as a source of carbohydrate in the manufacture of rice analogues.

Breadfruit (*Artocarpus altilis*) is an essential source of carbohydrates,lipid, protein, fiber, vitamins and minerals such as vitamin C and potassium, respectively (Ma et al., 2012). Studies have been carried out in the utilization of breadfruit as a component of weaning diets and found to be a good source of carbohydrate with complementary protein content. Successful substitution of 10% w/w of wheat flour by breadfruit flour in bread making process has been reported by Ma et al. (2012). Based on their investigation on extrusion of breadfruit flour dough, Nochera and Moore (2001) concluded that the product formed is almost equal to the product produced from rice flour.

Carrot (*Daucus carota* L) is one of the most important sources of dietary carotenoids, and China is the world's leading carrot producing country. Carrot is rich in β-carotene, ascorbic acid and tocopherol, and is therefore classified as vitaminized food (Hashimoto and Nagayama 2004). Due to appreciable content of various bioactive compounds present, carrots are considered as a functional food with significant health-promoting properties (Hager and Howard 2006). Carrot intake may enhance the immune system, protect against stroke, high blood pressure, osteoporosis, cataracts arthritis, heart diseases, bronchial asthma and urinary tract infection (Hager and Howard 2006). With regard to those reports, the consumption of carrot and its products have increased steadily in the last few decades.

Mung bean (*Vigna radiate* (L.) Wilczek), also called green gram is an important short season summer-growing legume grown widely throughout the tropics and subtropics (Thomas et al., 2004). It constitutes important cereal-based diets to many people in Asia, particularly in Thailand, India, Pakistan, Indonesia, the Philippines, and China. It is a rich source of protein and amino acid, specifically lysine and thus can supplement cereal-based human diets. Coffmann and Garcia (1977) found mung bean flour to contain higher protein content (28.0%) than the whole seed (26.3%) or bran seed (11.0%). The high protein levels and high lysine/low methionine amino acid profile of mungbean complement the high carbohydrate and low lysine/high methionine content of cereals to form a much balanced amino acid diet.

This study aimed to manufacture rice analogues from breadfruit flour via hot extrusion cooking process. To enrich the nutrient content in the rice analogues, carrot flour and mung bean flour were incorporated as fortificants. The study also aimed to investigate the effect of the dough composition (flour mixture) and drying time on proximate composition and gelatinization properties of the rice analogues.

2. Materials and methods

2.1. Materials

Breadfruit flour as the raw material for this study was obtained from Gunung Kidul, Yogyakarta-Indonesia, while carrots and mung beans were purchased from local market Peterongan in Semarang-Indonesia. Food grade sodium tripolyphosphate (STPP) and distilled water were purchased from an authorized supplier of cake and bakery materials in Semarang-Indonesia. Other chemicals of analytical grade with purity ≥ 98% w/w were purchased from Sigma-Aldrich Singapore Pte. Ltd. through an authorized chemicals distributor in Semarang-Indonesia.

2.2. Methods

2.2.1. Flour preparation

Mung beans as fortificant were washed, boiled, oven-dried, milled and sieved to obtain mung bean flours. Carrots tubers were washed, shredded, oven-dried, milled and sieved to obtain carrot flour.

2.2.2. Rice analogues preparation

The rice analogues were manufactured according to the method developed by Widara (2012) with slight modification. A set of experiments were conducted at various dough compositions to ensure sufficient content of nutrients in the rice analogues obtained. In addition, various drying times (3 to 8 hours) were investigated to find the best drying time, which results in nutritious and good shape rice analogues. To find the optimum dough composition, breadfruit flour, mung bean flour, and carrot flour were mixed to obtain flour composites according to the composition presented in Table 1. The flour composites with addition of a predetermined amount of sodium tripolyphosphate were then mixed with water (50% w/w) for 5 minutes to create approximately 33% w/w moisture content to facilitate complete gelatinization. The dough obtained was then heated at a temperature of 65-75^{o}C for 15 minutes to let the starch in the dough being pre-gelatinized. The pre-gelatinized dough was then molded into rice analogues by extrusion machine (Figure 1) at 65-75^{o}C, and immediately dried in an electric oven at 70^{o}C for 5 hours.

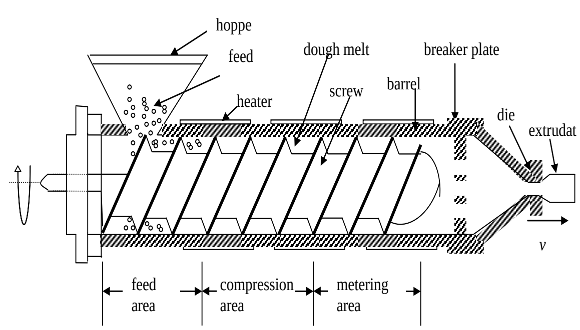

Figure 1. The Schematic Diagram of Extrusion Machine

After being equilibrated to ambient temperature, the rice analogues obtained was then stored in an air tight container for further chemical and physical analyses. To determine the optimum drying time, a variation of drying time (3 hours, 4 hours, 5 hours, 6 hours, 7 hours, and 8 hours) was investigated in the manufacture of rice analogues using optimum dough composition obtained from the preceding step.

2.2.3. Analysis

Proximate composition and physical characteristics of the rice analogues were used as quality parameters in the determination of optimum dough composition and drying time. Proximate composition analysis included moisture (AOAC, 2000), ash (AOAC, 2000), protein (AOAC, 2000), lipids (AOAC, 2000), dietary fiber (Bellucci, 1932), carbohydrates (AOAC, 2000), fatty acid (AOAC, 2000) and amylose (Juliano, 1972). While physical analysis included hardness test as the breaking force that acted on a unit area of the curved surface of the rice analogues under compression in accordance with ASAE Standards (ASAE, 2004) and gelatinization temperature determination by differential scanning calorimeter. A comparison with IR-36 paddy rice was subjected to proximate composition and physical characteristics of the rice analogues obtained. The IR-36 paddy rice was chosen as the representative characters of the rice consumed by the low-middle class family in Indonesia.

2.3.4. Statistical analysis

All of the experiments were performed in triplicates. One way analysis of variance (ANOVA) and Tukey's multiple range tests with a confidence interval of 95% were applied by means of statistical software (SAS v 9.2, The SAS Institute, USA) to report the significant differences between the obtained results.

3. Results and discussions

3.1. Effect of dough compositions

Starch, proteins, lipids, low molecular sugars, and fibers are food components that play an important role in the extrusion cooking processes. The proximate compositions of the rice analogues obtained from various dough compositions are presented in Table 1.

Free moisture contained in the spaces between cells, inter-granular and pores, and weakly bound moisture adsorbed on the surface of macromolecular colloids such as proteins, pectin starches, and cellulose are the main targets of drying process. Table 1 shows that the moisture contents of all of the rice analogues are lower than that of IR-36 paddy rice. The moisture contents of the rice analogue are also significantly different with that of IR-36 paddy rice ($p < 0.05$). This is because the grains of rice analogues are visually more porous than IR-36 paddy rice from which moisture removal is easier and faster during drying process. This observation agrees well with Cheftel (1986), who explained that extrusion cooking causes swelling and rupture of the granules as well as deterioration of the starch crystallinity. In addition, during extrusion of starches, factors such as temperature, moisture content before extrusion, amylose content and lipid content may all lead to structural modifications of starch granules. Increasing both moisture and lipid contents of the dough resulted in higher moisture content of the extrudate. To obtain extrudates with moisture content lower than 7% w/w, the initial moisture content of the dough should not higher than 12% w/w (Hoan et al., 2010). When the moisture content of the dough is higher than 12%, the rice analogues grains obtained by extrusion process are not in good shape. On the other hand, when the moisture content of the dough is below 12%, the extrusion process leads to the production of broken grains.

Table 1. Proximate composition of breadfruit flour, mung bean flour, carrot flour and rice analogues dried in an electric oven at 70°c for 5 hours.

Biomaterials	Moisture (% w/w)	Ash (% w/w)	Carbohydrates (% w/w)	Protein (% w/w)	Dietary Fiber (% w/w)	Lipid (% w/w)
Flours						
Breadfruit (BF)	5.09±0.07	2.50±0.04	87.21±0.21	2.10±0.13	2.80±0.06	0.30±0.02
Mung Beans MBF)	5.99±0.03	3.81±0.06	59.13±0.17	26.36±0.10	3.90±0.05	0.81±0.02
Carrot (CF)	2.44±0.03	5.37±0.04	69.85±0.21	0.68±0.02	20.39±0.15	1.27±0.01
Dough Compositions BF:MBF:CF						
100:0:0	10.53±0.03^{e}	5.69±0.06^{c}	75.92±0.20^{b}	3.84±0.09^{f}	2.90±0.06^{f}	1.11±0.15^{b}
90:5:5	10.41±0.02^{d}	5.37±0.02^{b}	72.45±0.02^{b}	6.72±0.10^{e}	3.83±0.04^{e}	1.20±0.10^{b}
80:10:10	10.36±0.03^{b}	5.35±0.03^{b}	69.87±0.21^{b}	8.63±0.06^{d}	4.76±0.20^{d}	1.03±0.02^{b}
70:15:15	10.33±0.07^{b}	5.36±0.06^{b}	68.17±0.28^{b}	9.07±0.08^{c}	5.85±0.15^{c}	1.20±0.03^{b}
60:20:20	9.45±0.10^{c}	5.39±0.05^{b}	66.58±0.65^{b}	10.89±0.17^{b}	6.61±0.10^{b}	1.18±0.02^{b}
IR-36 paddy rice[a]	12.58±0.10^{f}	0.20±0.01^{d}	78.86±0.26^{b}	7.39±0.01^{g}	0.78±0.05^{g}	0.19±0.02^{c}

[a](Purwaniet al., 2007). The values with the same superscript-small letter in the same column within each food product were not significantly different (P>0.05).The represented values are mean ± SD of three replicates.

Generally, extrusion cooking influences the existence of macromolecules. Smaller molecules may be affected upon by either the extrusion process itself or by the changes in larger molecules, which in turn alter the content other compounds present in the food (Singh et al., 2007). Table 1 shows that the ash contents of the rice analogues do not change significantly with dough compositions and are all higher than the IR-36 paddy rice. In addition, the ash contents of the rice analogue are also significantly different with that of IR-36 paddy rice ($p < 0.05$). The use of sodium tripolyphosphate as dough improver seems to affect the mineral content of the rice analogues. Sodium tripolyphosphate does its function by binding nutrients, which are soluble in saline solution such as protein, vitamins, and minerals. Minerals are heat stable and unlikely to become lost in the steam distillate at the die (Singh et al., 2007).

Generally, mild heat treatment of vegetable proteins improves digestibility due to inactivation of protease inhibitors and other antiphysiological substances and denaturation (Bjorck and Asp, 1983). During extrusion, protein structures may be

Table 2. The hardness and gelatinization temperature of rice analogues at various dough compositions

Biomaterials	Amylose Content (% w/w)	Hardness (MPa)	Onset Gelatinization Temperature (ºC)	Peak Gelatinization Temperature (ºC)	Conclusion Gelatinization Temperature (ºC)
Flours					
Breadfruit (BF)	25.00±0.10	n.a	67.00±0.09		
Mung Beans MBF)	41.43±0.04	n.a	70.10±0.28		
Carrot (CF)	15.64±0.01	n.a	57.70±0.13		
100:0:0	18.24±0.07[d]	3.30±0.17[e]	71.90±0.10[f]	76.36±0.40[e]	81.90±0.01[e]
90:5:5	15.92±0.02[c]	2.90±0.02[d]	72.96±0.04[e]	77.22±0.17[c]	81.96±0.04[e]
80:10:10	15.88±0.11[c]	1.60±0.05[c]	73.61±0.11[d]	78.20±0.02[d]	81.61±0.11[d]
70:15:15	17.48±0.05[b]	1.10±0.02[b]	74.62±0.03[c]	77.50±0.28[c]	82.62±0.05[c]
60:20:20	17.88±0.12[b]	0.90±0.03[b]	77.19±0.14[b]	80.83±0.09[b]	87.19±0.09[b]
IR-36 Paddy rice[a]	27.30±0.05[e]	6.53±0.12[f]	81.96±0.10[g]	n.a.	n.a.

[a] (Purwaniet al., 2007). The values with the same superscript-small letter in the same column within each food product were not significantly different (P>0.05).The represented values are mean ± SD of three replicates.

Table 3. Effect of drying time on proximate composition of rice analogues dried in an electric oven at 70°c

Drying Time (hours)	Moisture (% w/w)	Ash (% w/w)	Carbohydrates (% w/w)	Protein (% w/w)	Dietary Fiber (% w/w)	Lipid (% w/w)
3	19.63±0.04[e]	6.04±0.07[d]	61.12±0.34[e]	8.28±0.10[d]	4.10±0.11[f]	0.83±0.02[d]
4	10.37±0.03[d]	5.90±0.02[d]	69.52±0.61[d]	8.60±0.05[c]	4.58±0.06[e]	1.03±0.04[c]
5	10.36±0.09[d]	5.35±0.06[c]	69.87±0.16[d]	8.63±0.01[c]	4.76±0.20[d]	1.03±0.02[c]
6	10.44±0.04[d]	5.48±0.05[c]	69.54±0.15[d]	8.73±0.05[b]	4.77±0.13[d]	1.04±0.06[c]
7	9.30±0.09[c]	5.65±0.07[b]	69.28±0.32[c]	8.77±0.04[b]	6.03±0.02[c]	0.97±0.02[c]
8	7.02±0.03[b]	5.74±0.01[b]	69.03±0.18[b]	8.81±0.01[b]	8.45±0.01[b]	0.95±0.06[b]
IR-36 paddy rice[a]	12.58±0.10[f]	0.20±0.01[e]	78.86±0.26[f]	7.39±0.01[e]	0.78±0.05[g]	0.19±0.02[e]

[a] (Purwani et al., 2007). The values with the same superscript-small letter in the same column within each food product were not significantly different (P>0.05).The represented values are mean ± SD of three replicates.

disrupted and altered under high shear, pressure, and temperature (Perez et al., 2008). As a result, large molecules proteins may become dissociated into smaller subunits. Table 1 indicates that the protein content of the IR-36 paddy rice falls in the range of protein content of all rice analogues. However, the protein contents of the rice analogue are significantly different with that of IR-36 paddy rice ($p < 0.05$). The protein content of mung beans flour is higher than breadfruit and carrot flours. Therefore, rice analogues from dough of flour composite containing 20% w/w mung beans flour showed the highest protein content. In contrast, rice analogues manufactured from dough of breadfruit flour only has the lowest protein content. It can be concluded that the dough composition significantly affects the protein content of rice analogues. The increased protein content also showed no protein denaturation during the extrusion of dough flour composite to manufacture of rice analogues from bread fruit, mung beans and carrot flours.

During processing the nutritional value of lipids might be affected through different mechanisms such as oxidation, polymerization, cis-trans isomerization or hydrogenation (Rokey and Plattner, 1995). Table 1 shows that lipid contents of rice analogues are not significantly affected by dough composition and are higher than IR-36 paddy rice ($p > 0.05$). This fact can be linked to the use of lipid as lubricant in the extrusion process. Lipid reduces the friction between the particles in the mixture and between the surface of the thread and the sleeve with the dough. In addition, extrusion may inactivate lipase and lipoxidase present in foods, resulting in less oxidation of fatty acids during extrusion and storage (Stroucken et al., 1996). The lipid contents of the rice analogue are significantly different with that of IR-36 paddy rice ($p < 0.05$). Fatty acids composition analysis revealed that all of the rice analogues and IR-36 paddy rice contained five essential fatty acids for humans, which are palmitic, stearic, oleic, linoleic, and linolenic. However, rice analogues do not contain myristic, palmitoleic, gadoleic, eicosadienoic and lignoceric acids, which are found in IR-36 paddy rice. This fact supports the hypothesis that oxidation of fatty acids during extrusion is minimal (Stroucken et al., 1996).

Cooking and gelatinization of starch are known to increase the susceptibility to amylase hydrolysis, mainly due to hydration of starch granules and partial solubilization of starch molecules (Bjorck and Asp, 1983). Table 1 shows that carbohydrate contents of the rice analogues were lower than the IR-36 paddy rice. However, the values of carbohydrate content of the rice analogues are not significantly different ($p > 0.05$) from the IR-36 rice. The reduction of breadfruit flour composition in the dough flour composite resulted in decreased of carbohydrate content of the rice analogues. Similar phenomenon was also reported by Anuonye *et al*. (2007) for effect of extrusion on amylose content. Due to extrusion, starch is gelatinized and therefore its structure is being degraded and more accessible to enzyme in stomach.

Very few studies have been made on the effect of extrusion cooking or other processes on dietary fiber. Table 1 reports a significant increase ($p < 0.05$) of dietary fiber content with the increase of mung bean and carrot flours in the dough flour composite. High dietary fiber contents of mung bean and carrot flours may be one of the reasons. However, severe extrusion-cooking of flours may also cause an apparent increase in dietary fiber due to the formation of amylase-resistant starch fractions (Cheftel, 1986). Similar results were reported by Vasanthan et al. (2002) where extrusion cooking increased the total dietary fiber of barley flours. They suggested that the change in dietary fiber profile during extrusion of barley flour may be attributed, primarily, to a shift from insoluble dietary fiber to soluble dietary fiber, and the formation of resistant starch and enzyme-resistant indigestible glucans formed by transglycosidation.

Amylose content affects quality and texture of cooked rice. Rice with low amylose content produces rice, which is sticky, soft shiny, not expand, and still coagulate after cooled. In contrast, rice containing higher amylose content is normally more resistant to hydration and gelatinization (Yadav and Jindal, 2007). Therefore, starch that is high in amylose swells more slowly and exhibits a loss of order within the granule, followed by its destruction. This type of rice also gives more viscous flour dispersion during water cooking, and is firm and fluffy when cooked.

Table 1 shows that the amylose contents of the rice analogues were 31.19% to 41.83% lower than that of IR-36 rice, and these amylose contents are different significantly ($p < 0.05$). The low amylose content in the rice analogues has two possible causes. The first is due to the destruction of amylose during the extrusion process. Amylose degradation occurs due to breakdown of amylose chains to such an extent due to the pressure inside the extruder that helices could not be formed (Bhatnagar and Hanna, 1994). The second is the formation of amylose–lipid complex evident during extrusion. The amount of decrease was directly proportional to degree of complexing, which is dependent upon both starch and lipid type present in a food (Bhatnagar and Hanna, 1994). Monoglycerides and free fatty acids are more likely to form complexes than triglycerides, when added to high-amylose starch (Bhatnagar and Hanna, 1994). Addition of mung bean and carrot flours caused an increase in lipid content, which triggered more lipid-amylose interaction at elevated temperatures. This phenomenon leads to decrease the amylose content of the rice analogues.

Texture is an important factor in consumer acceptance of food products. The principal effect of the thermo mechanical treatment resulting from extrusion is to rupture the granular structure of starch. In addition, the complex formation between amylose and lipids during extrusion cooking plays important role in the development of structure, texture and other functional properties of the extrudate (de Pilli et al., 2011). The textural property (hardness) of the samples was determined by measuring the force required to break the rice analogues grain as reported in Table 2. The hardness values of the rice analogues obtained in this work are all far lower than the hardness of paddy rice IR-36, and therefore found to be significantly different ($p < 0.05$). Low strain and hardness values indicate weaker and more brittle particles that have a higher porosity.

In this study, the main source of carbohydrates is breadfruit flour, while mung beans flour and carrot flours are richer in lipid contents. The higher carbohydrate content in the dough should produce rice analogues with higher hardness value. The lower hardness value for rice analogues from dough flour composite with higher lipid content is in good agreement with Ruy et al. (1994) who demonstrated that emulsifier addition provided wheat flour extrudate with more uniform, larger cell (pore) sizes and therefore lower hardness and bulk density. The change in these properties is likely caused by an alteration in the ratio of free amylose to amylopectin by the formation of amylose-lipid complexes. Ruy et al. (1994) also found that the breaking or shearing strength of the extrudate decreased as a result of lipid addition to the dough.

Table 2 shows that the rice analogues and IR-36 paddy rice have high gelatinization temperatures ranging from 71.90^{o}C to 81.96^{o}C. No significant difference between gelatinization temperature of the rice analogues and IR-36 paddy rice ($p > 0.05$). It is also clearly observed in Table 2 that rice analogues with high amylose content also have higher gelatinization temperature. Rice with higher amylose content may absorb more water during cooking resulting higher gelatinization temperatures so that the cooking time is longer than the rice with a low gelatinization temperature. Our investigation gave similar results as a study on maize starches with varying amylose content (0 to 66.1% w/w), which indicated that the gelatinization temperatures increased with increasing amounts of amylose (Park et al., 2007).

However, rice analogues manufactured from breadfruit flour without incorporation of mung bean flour and carrot flour has lower gelatinization temperature (71.9^{o}C) although it has higher amylose content (18.24% w/w) than any other rice analogues. This finding is contradictive to the positive correlation of amylose content to onset, peak and conclusion gelatinization temperatures reported by Park et al. (2007). Sasaki et al. (2000) explained that starch with higher amylose content contains more amorphous and less crystalline regions, leading to a lower gelatinization temperature and enthalpy. In addition, other factors such as starch structure and nutritional composition could have influenced the gelatinization temperature of rice analogues.

In comparison to paddy rice IR-36 nutrition quality, all of the rice analogues obtained in this work meets the standard for moisture, ash, lipid and dietary fiber contents. However, none of them meets the minimum carbohydrate content. If the rice analogues are being consumed by people and patients demanding to healthy diet, then the carbohydrate contents of the rice analogues are still acceptable. The protein content of paddy rice IR -36 is below protein content of rice analogues manufactured from dough flour composite comprising 80% w/w breadfruit flour, 10% w/w mung bean flour and 10% w/w carrot flour. The use of more mung bean flour and carrot flour definitely increases the protein content of the rice analogues, but it will be compensated by higher price. The texture of the rice analogues obtained from 80% w/w breadfruit flour as represented by hardness is still acceptable, whereas addition of more mung bean flour and carrot flour results in brittle rice analogues. It can be concluded that dough composed of breadfruit flour 80% w/w, mung bean flour 10% w/w and carrot flour 10% w/w is the best formulation over the other dough compositions. This dough composition is further used for the study of the effect of drying time.

3.1. Effect of dough compositions

It is already well known that drying process may affect the physicochemical properties of materials, as well as the functional properties of their active ingredients because of the distinction of temperature, drying time and other conditions. Rice analogues in this study were dried in an electric oven at 70°C with a variation of the drying time. Drying at temperatures higher than 70°C was not preferred as the gelatinization temperatures of the rice analogues were ranged from 71.90^{o}C to 77.19^{o}C. The proximate composition of the rice analogues can be seen in Table 3.

Table 3 shows that the moisture contents of all of the rice analogues are lower than those of IR-36 paddy rice. The moisture contents of the rice analogues are also significantly different with that of IR-36 paddy rice ($p < 0.05$). The values decreased with the increase of drying time. During oven drying process, moisture is mainly removed from the food in the form of water vapor. Longer drying time promotes higher intensity of the contact between the food material and the hot air. This condition leads to better removal of moisture from foodstuffs. Most of moisture in the foodstuff is contained in the form of free moisture, which resides in the spaces between cells, inter-granular and pores; therefore it is easily removed by drying process. While the rest of the moisture is contained in the foodstuff either being weakly bound on the surface of macromolecular colloids such as proteins, pectin starches, and cellulose, and/or strongly bound moisture as hydrate. The strongly bond moisture is relatively difficult to be removed or evaporated.

In practice, a moisture content of 10% w/w is generally specified for flours and other related products to increase storage stability. It should be pointed out that when these food products are allowed to equilibrate for periods of more than one week at 60% relative humidity and at room temperature, their moisture content might increase (Adegunwa et al., 2011). For that reason, drying of freshly extruded dough at 70^{o}C for 7 hours is the best drying method in this work as it may achieve 9.3% w/w moisture content (< 10% w/w).

The ash content reflects the total amount of minerals present within a food. Table 3 shows that the ash content of the rice analogues does not change significantly with drying time. Long drying time does not affect the ash content because minerals contained in food are heat stable (Singh et al., 2007). Minerals also have a low volatility compared to other food components, which makes them unlikely to become lost during drying process. However, the ash contents of the rice analogues are higher than that of IR-36 paddy rice and all are also significantly different with that of IR-36 paddy rice ($p < 0.05$).. This is due to the mineral content of the IR-36 paddy rice is affected by pre-harvest conditions and varieties, while the mineral content in rice analogues affected by raw materials that contain different type and level of minerals. The increase in mineral content in this study could be as a result of moisture removal, which leads to increase the concentration of other nutrients.

In Table 3, protein content of rice analogues is higher than the IR-36 paddy rice. The protein contents of the rice analogues are also significantly different with that of IR-36 paddy rice ($p < 0.05$). Table 3 also shows an increase in protein content and proves that no protein is denatured. Hot air drying could significantly reduce the drying time and improve the crude protein content of the dried products. High temperatures can reduce enzyme activity, preventing protein from enzymatic decomposition (Duan et al., 2014).

As presented in Table 3, lipid content increased with drying time from 3 hours to 6 hours. However, lipid content started to decrease as drying time exceeds 6 hours. The lipid contents of the rice analogues are different significantly with that of IR-36 paddy rice ($p < 0.05$).The lower lipid content observed during long period of drying is associated to oxidation of lipid. The lipid oxidation is known to increase as influenced by many factors such as heat, light and radiation (Savage et al., 2002). The low fat content is desirable because it will enhance the storage life of the flour due to the lower chance of rancid flavor development. Lipid content in all of the rice analogues is still higher than that of IR-36 paddy rice. The use of lipid in the extrusion process is likely the cause of this phenomenon. In the extrusion process, the lipid acts as a lubricant because it is able to reduce the friction between the particles in the mixture and between the surface of the thread and the sleeve with molten mixture.

Table 3 shows no significant increase of carbohydrate content of the rice analogues with the increase of drying time ($p > 0.05$). However, the carbohydrate contents of the rice analogues are significantly different with that of IR-36 paddy rice ($p < 0.05$). The reduction of the moisture content will result in the concentration of compounds contained in such as carbohydrates, proteins, and minerals into higher. However, after 6 hours drying time, the carbohydrate content decreased gradually. Such decrease in carbohydrate content may be attributed by degradation of polysaccharides and Maillard reaction, which results in complex changes in food due to the reaction between carbohydrate and protein (Wiriya et al., 2009).

The dietary fiber content is significantly affected by drying time. Table 3 presents significant increase of dietary fiber content with the increase of drying time ($p < 0.05$). in addition, the dietary fiber contents of the rice analogues are also significantly different with that of IR-36 paddy rice ($p < 0.05$). The increase in dietary fiber content in this study could be as a result of moisture removal, which leads to increase the concentration of other nutrients, such as dietary fiber and ash.

Economic consideration in term of energy used and technical consideration in term of moisture content were counted for the determination of optimum drying time. Longer drying process will consume more energy and higher operation cost. A moisture content of 10% is generally specified for flours and other related products to increase storage stability. Therefore, drying of freshly extruded flour composite dough at 70^{o}C for 7 hours is the best drying method in this work as it may achieve 9.3% w/w moisture content (< 10% w/w) and lower lipid content (0.97% w/w).

4. Conclusions

Nutritious rice analogues have been successfully made from breadfruit flour, mung bean flour and carrot flour composites dough through extrusion cooking process. The fortification process has also been proven to be applicable in the process of rice analogues manufacturing. The dough composition and drying time were found to significantly influence the nutrition and gelatinization properties of rice analogues. Based on the results of this study, the best rice analogue was obtained upon extrusion of flour composite dough consisting of 80% w/w breadfruit flour, 10% w/w mung bean flour and 10% w/w carrots flour and drying in an electric oven at 70°C for 7 hours.

5.References

Adegunwa, M.O., Alamu, E. O. and Omitogun, L. A. (2011). Effect of processing on the nutritional contents of yam and cocoyam tubers. *Journal of Applied Bioscience*, 46, 3086–3092.

Anuonye, J.C., Badifu, G. I.O, Inyang, C. U. and Akpapunam, M. A. (2007). Effect of extrusion process variables on the amylose and pasting characteristics of acha/soybean extudates using response surface analysis. *American Journal of Food Technology*, 2, 354-365.

AOAC. (2000). Official methods of analysis. (17th ed.). Gaithersburg: Association of Official Analytical Chemists.

ASAE. (2004). Compression test of food materials of convex shape. St. Joseph: American Society of Agricultural Engineers Standards, Engineering practices, and Data.

Bellucci, C. (1932). The determination of the cellulose in wheat flour and by-products. *Annali di Chimica Applicata*, 22, 25.

Bhatnagar, S. and Hanna,M. A. (1994). Extrusion processing conditions for amylose-lipid complexing. *Cereal Chemistry*, 71(6), 587-593.

Bjorck, I. and Asp, N. G. (1983). The effects of extrusion cooking on nutritional value - a literature review. *Journal of Food Engineering*, 2,281-308.

Borah, A., Mahanta, C. L. and Kalita, D. (2015). Quality attributes of extruded breakfast cereal from low amylose rice and seeded banana (Musa Balbisiana , ABB). *Journal of Food Research Technology*, 3 (1), 23-33.

Cheftel, J. C. (1986). Nutritional Effects of Extrusion-Cooking. *Food Chemistry*, 20, 263-283.

Coffmann, C. W., Garcia, V. V. (1977). Functional properties and amino content of a protein isolate from mung bean flour. *International Journal of Food Technology*, 12, 473-484.

De Pilli, T., Derossi, A., Talja, R. A., Jouppila, K., Severini, C. (2011). Study of starch-lipid complexes in model system and real food produced using extrusion-cooking technology. *Innovative Food Science and Emerging Technologies*, 12(4), 610–616.

Duan, X., Ren, R. Y., Liu, L. L., Zhu, W. X., Liu. Y. H. (2014). The influences of drying process on crude protein content of naked oat cut herbage (Avena nuda L.). *Drying Technology*, 32, 321–327.

Hager, T. J., Howard, L. R. (2006). Processing effects on carrot phytonutrients. *Horticultural Science*, 41, 74–79.

Hashimoto, T., Nagayama, T. (2004). Chemical composition of ready-to eat fresh carrot. *Journal of the Food Hygienic Society of Japan*, 39, 324–328.

Herawat, H., Kusnandar, F., Adawiyah, D., Budijanto, S. , Rahman, M. S. (2014). Thermal characteristics and state diagram of extruded instant rice analogues. *Thermochimica Acta*, 593, 50–57.

Hoan, N. V., Mouquet-Rivier, C., Treche, S. (2010). Effects of starch, lipid and moisture contents on extrusion behavior and extrudate characteristics of rice-based blends prepared with a very-low-cost extruder. *Journal of Food Process Engineering*, 33, 519–539.

Juliano, B. O. (1972). A simplified assay for milled rice - amylose. *Cereal Science*, 16, 334-336.

Li, Y. O., Lam, J., Diosady, L. L., Jankowski, S. (2009). Antioxidant system for the preservation of vitamin A in ultra rice. *Food and Nutrition Bulletin*, 30, 82–89.

Ma, H., Pan, Z., Li, B., Atungulu, G. G., Olson, D. A., Wall, M. M., McHugh, T. H. (2012). Properties of extruded expandable breadfruit products. *LWT - Food Science and Technology*, 46, 326–334.

Mishra, A., Mishra, H .N. and Rao, P. S. 2012. Preparation of rice analogues using extrusion technology. *International Journal of Food Science and Technology*, 47, 1789–1797.

Nochera, C. L., Moore, G. (2001). Properties of extruded products from breadfruit flour. *Cereal Foods World*, 46 (10), 488-490.

Park, I. M., Ibanez, A. M., Zhong, F., Shoemaker, C. F. (2007). Gelatinization and pasting properties of waxy and non-waxy rice starches. *Starch-Starke*, 59 (8), 388-396.

Peng, S. B., Huang, J. E., Sheehy, J. E., Laza, R .C., Vispera, K. H., Zhong, X. H., Centeno, S., Khush, G. S., Cassman, K. G. (2004). Rice yields decline with higher night temperatures from global warming. Proceeding of the National Academy of Science U.S.A. 101, 9971–9975.

Perez, A. A., Drago, S. R., Carrara, C. R., De Greef, D. M., Torres, R. L., Gonzalez, R. J. (2008). Extrusion cooking of a maize/soybean mixture: Factors affecting expanded product characteristics and flour dispersion viscosity. *Journal of Food Engineering*, 87, 333–340.

Purwani, E. Y., Yuliani, S., Indrasari, S. D., Nugraha, S., Thahir, R. (2007). Physicochemical properties of rice and its glycemic index. *Jurnal Teknologi Industri Pangan*, 18: 59-66.

Rokey, G., Plattner, B. (1995). Process description: pet food production. Sabetha: Wenger Mfg, Inc.

Ruy, G. H., Neumann, P. E., Walker, C. E. (1994). Effect of emulsifiers on physical properties of wheat flour extrudates with and without sucrose and shortening. *LWT - Food Science and Technology*, 27, 425-431.

Sasaki, T., Yasui, T. and Matsuki, J. 2000. Effect of amylose content on gelatinization, retrogradation, and pasting properties of starches from waxy and non-waxy wheat and their F1 seed. *Cereal Chemistry*, 77(1), 58-63.

Savage, G. P., Dutta, P. C., Rodriguez,-Estrada, M. T. (2002). Cholesterol oxides: their occurrence and methods to prevent their generation in foods. *Asia Pacific Journal of Clinical Nutrition*, 11, 72-78.

Singh, S., Gamlath, S., Wakeling, L. (2007). Nutritional aspects of food extrusion: a review. *International Journal of Food Science and Technology*, 42, 916–929.

Stroucken, W. P. J., van der Poel, A. F. B., Kappert, H. J., Beynen, A. C. (1996). Extruding vs pelleting of a feed mixture lowers apparent nitrogen digestibility in dogs. *Journal of the Science of Food and Agriculture*, 71, 520–522.

Thomas, Robertson, M. J., Fukaic, S., Peoples, M. B. (2004). The effect of timing and severity of water deficit on growth, development, yield accumulation and nitrogen fixation of mungbean. *Field Crop Research*, 86 (1), 67–80.

Vasanthan, T., Gaosong, J., Yeung, J., Li, J. (2002). Dietary fibre profile of barley flour as affected by extrusion cooking. *Food Chemistry*, 77, 35–40.

Widara, S. S. (2012). A study on the preparation of rice analogues from various carbohydrate sources using hot extrusion technology. Bogor, Indonesia: Bogor Agriculture University, MSc thesis.

Wiriya, P., Paiboon, T., Somchart, S. (2009). Effect of drying air temperature and chemical pretreatments on quality of dried chili. *International Food Research Journal*, 16, 441-454.

Yadav, B. K., Jindal, V. K. (2007). Water uptake and solid loss during cooking of milled rice (*Oryza sativa* L.) in relation to its physicochemical properties. *Journal of Food Engineering*, 80 (1), 46–54.

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