Review article

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Analog rice: processing and nutrition value

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Abstract

Background and objective: Rice is of main dishes in different parts of the world. In rice processing plants, there is a lot of broken rice which is considered as waste and cannot be sold to the consumers. These broken particles can be used in the other parts as raw material and converted to value-added products. Accordingly, it helps waste management strategies intended by food industries in developed countries. This review article aimed to investigate processing and also nutritional characteristics of analog rice prepared by broken rice particles.

Results and conclusion: Broken grains of rice are enriched by additives and changed to analog rice. It is expected that analog rice has similar nutritional value with paddy rice. Researchers have developed analog rice products with improved nutritional and functional characters providing health benefits such as anti-diabetic, antioxidant, antihypertensive, and anticancer activity. In recent decades, several surveys have been done on processing of these products and have tried to enrich them with proteins, vitamins, and minerals. Extrusion is one of the most common methods in production of analog rice. Main features such as color, shape, size, texture, and cooking characteristics are adjusted by extrusion parameters. Our review revealed that analog rice can be used as a rice substitute rich in fiber and other nutritious ingredients especially by people seeking for variable food basket.

Keywords: Analog rice, extrusion, food security, nutritional value

1. Introduction

About half of people in the world consume rice daily as their main dish and two-third of people supply 20% of their energy from rice. Although, it contains low protein and lacks essential amino acids such as lysine required for body growth. It would be a concern in poor populations, in which the consumers suffer from malnutrition. One of methods to overcome this issue is production of analog rice, in which some nutrients are added to the product. Low price rice that is not accepted by the consumers is usually used for production of analog rice. It is included to broken rice grains produced in grinding process. Development of such products provides nutritional needs to the consumers without much additional cost [1].

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Analog rice is processed by granulation and extrusion. It is made of carbohydrate-based materials and its shape is similar to naturally produced rice [2]. Mishra et al. indicated that analog rice can be produced by starchy materials other than rice such as sorghum, corn, and modified cassava flour (Mocaf) [3]. In agreement, Budijanto et al. used non-rice resources in the process [4], while Zhiyuan et al. produced analog rice by broken rice (bulgur) [5].

Protein content of analogue rice is determined by raw materials used in the process. Noviasari et al. reported that amount of protein in the most of analog rice is higher than common rice pos-sibly due to the common proteinaseous ingrdients used in preparation of the product [6]. In addition, analog rice includes more fiber and affects digestion positively. The current study evaluates nutritional value of analog rice compared to the rice available in the markets and also overviews its production method.

2. Nutritional status of rice

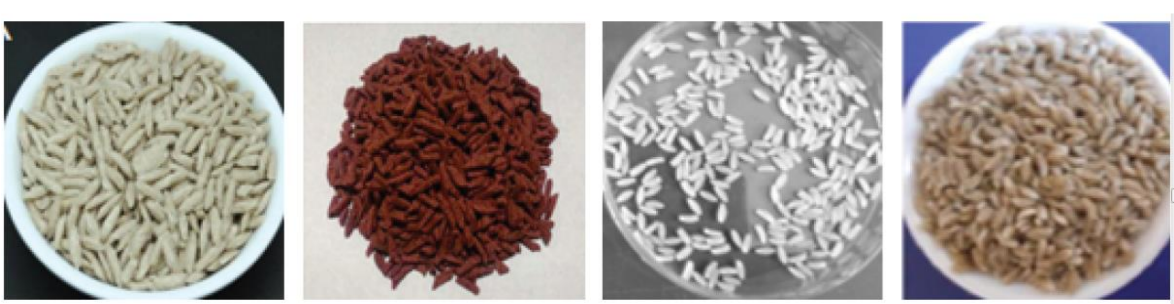
Today, malnutrition is a global challenge even in developed countries. Some societies encounter with high ratio of obesity and metabolic disorders such as diabetes and cardiovascular diseases due to overconsumption of simple carbohydrate and fat. In comparison, some other populations suffer from nutrients' deficiency. According to report of the Food and Agriculture Organization (FAO) in 2020, about 800 million people do not get enough calories in a day worldwide.

Micronutrients' deficiency is known as "Hidden Hunger". It is prevalent in some developed countries are not in trouble with providing energy requirement. Food enrichment should be done in staple foods in a way that does not change their organoleptic attributes significantly [7].

More than three billion people consume rice as their main dish. Most of micronutrients in rice grain are lost during dehulling process [7]. Therefore, it is a good candidate for enrichment and fortification purposes. Analog rice is produced by addition of nutrients to starchy matrix in order to restore the lost nutrients or enrich the product with other essential nutrients. Such product is usually developed by local resources and contains high fiber. In some cases, vegetables and fruits are added. Technically, what is important is that the nutrients do not loss during the process. In this regard, it was reported that extrusion (as the most common way of production) does not change significantly amount of added iron, zinc, vitamin B_{12}, and folic acid in the product [8-10].

Usually, analog rice has low glycemic index (GI) and is a good alternative for those suffer from obesity and diabetes. Analog rice may contain functional ingredients by which several health benefits are expected after consumption of rice owing to the bioactive compounds existed in primary resources. Some of health benefits are included to modulation of diabetes, lowering the blood pressure and cholesterol, antioxidant activity, and anti-cancer feature [11-12].

Occasionally, analog rice is enriched by waste products such as eggshell and fishbone to increase the calcium level. Examples of analog rice with health claim are presented in Figure 1.



A B C D

Figure 1- A) analog rice made of *Dioscoreahispi dadennst* flour for diabetic patients [12]; B) analog rice made of purple sweet potato flour and starch enriched with zinc [13]; C) analog rice made of corn flour with antioxidant activity and low GI [14]; D) analog rice made of sorghum flour enriched with spices [15].

3. Ingredients used in production of analog rice

Water and broken rice particles are the main ingredients for production. In some cases, other starchy materials such as potato, sorghum, corn, cassava, and Mocaf are used. Additives are included to dyes, flavorings, binders, lubricants, and antioxidants. The primary mixture (flour or broken rice and water) is necessary for production of rice, but other additives are used occasionally [8,16,17].

Selection of primary ingredients is important because it affects physical and chemical properties of the final product. As mentioned, broken, cracked, or damaged rice is of the main ingredients. Importantly, rice grain is preferred rather than other starchy resources to achieve the appropriate ratio of amylose to amylopectin [5,8]. In extrusion, starch containing high amylopectin melts instead of gelatinization. In comparison, starch with high amount of amylose gelatinizes well at high temperature due to entrapment of water molecules between polymer chains [5].

Flour of sorghum, soybean, and modified cassava as well as corn flour and *Arenga* starch are currently used in production of analog rice. Sorghum flour, soybean flour, and *Arenga* starch have antioxidants by anticancer activity against colorectal cancer. Mocaf is modified by lactic acid bacteria under fermentation process, through which flavor development is occurred compared to cassava flour [8,13].

Small amount of water results in high shear stress in the extrusion chamber and high degree of gelatinization. To produce analog rice, dough is composed of 12-25% water per weigh. If water content exceeds 25%, the mixture sticks to the extruder in cooking; while if water content was lower than 12%, more mechanical energy is required for extrusion and the mixture gelatinizes completely. Therefore, optimum water amount of 20% is required for dough making [3].

Use of dyes is optional in the process. Titanium dioxide is added to the mixture if a white color is expected. Otherwise, appropriate amount of permitted colors are used to achieve the intended formula [3].

Egg albumin might be used as flavoring. It should be added in one-eighth of water amount. Other flavorings are curry, chili powder, soybean derivatives, salt, vanilla, ginger, pepper, thyme, saffron, sage, cinnamon, cloves, garlic, and onion. Sodium chloride affects flavor and moisturizing property of the product [4].

Addition of binder to flour makes elastic dough, by which it retains its structure despite the changes in moisture and temperature. For example, sodium alginate is used as a binder, which can provide low (0.1-1 poise) or high viscosity (8-12 poise) in concentration of 5-11% w/v and 0.5-5% w/v in water, respectively. Other binders are chitin, pectin, casein, gelatin, and methylcellulose. A variety of gums such as xanthan, guar gum, and carrageenan are used as binder [18].

To enhance effectiveness of some binders and stabilize the mixture, chemicals such as calcium lactate and calcium chloride are added to the formula in range of 0.01-20% w/w of the binder [4]. Micronutrients are added to the final mixture by 0.1-5% w/w. Vitamins A, B_1, B_2, B_5, B_{12}, C, E, K, folic acid, niacin, and biotin and minerals of iron, zinc, calcium and selenium are commonly used. Oil soluble vitamins are added to the formula by an oily matrix [10].

Ascorbic acid, α-tocopherol, butylated hydroxyanisole, sodium bisulfite, potassium bisulfite, and gallate esters are of antioxidants added to the formula. A barrier is added to prevent movement of vitamins to the surface, where they are oxidized. It might be pork fat, palm oil as well as other types of saturated fats or stearates. Unsaturated oils are not used since they are unstable in the presence of free oxygen [10].

4. Production of analog rice

Analog rice is mainly produced by two methods of granulation [17] and extrusion [10,19,20]. Each method produces a different final product in shape. Analog rice produced by granulation is round and pearl-shaped, but it is oval and similar to the common rice in extrusion. However, extrusion is used frequently in processing of analog rice [19,21]. Therefore, it is explained by detail in this study.

4.1. Dough preparation and preconditioning

Broken rice or other starchy materials are grounded. Flour with smaller particles shows better results. Then, water is added and the paste is kneaded to obtain homogeneous dough. It is cooled down followed by addition of dyes, nutrients, and antioxidants. Micronutrients are added to dough but some of ingredients such as emulsifiers are added to flour. In some cases, preconditioning is done by heating the raw materials (before or after grinding) at 80-90 °C followed by addition of 15-40% v/w water. Then, emulsifiers and micronutrients are added. Dough is exposed to shear force and kneaded simultaneously for less than 5 min at 70-100 °C [6,19].

4.2. Extrusion

Hot extrusion is done at relatively high temperatures (above 70 °C) supplied by heat generated in preconditioning and also hot steam jackets. It results in completely or semi-cooked analog rice [21-23]. In comparison, no external thermal energy supplier is used in cold extrusion except for the heat generated in the process and temperature is below 70 °C. A simple shaping extruder, known as pasta press, is used in the process [9,23].

Time, temperature, and pressure are important factors in hot extrusion which affect gelatinization of starch granules and protein denaturation. Simple pass of dough at low temperature in the extruder helps a suitable shape in cold extrusion [9,23]. Starch gelatinization is important process affects quality of final product. It is controlled by moisture of dough other than mechanical energy, thermal energy, and storage time of the mixture in the extruder tank [23]. Extruded rice after drying in hot air (100 °C for 1 h) and its rehydration is shown in Figure 2 [24].

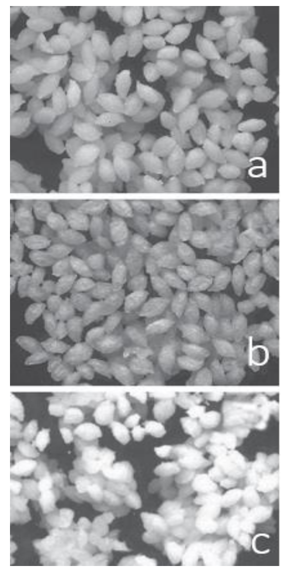


Figure 2- a) extruded rice, b) extruded rice after drying, c) extruded rice after rehydration [24]

Analog rice has same appearance as common rice. Longitudinal and transverse cutting are used in the extruder. To avoid sticking, blades are coated with a synthetic polymer such as polytetrafluoroethylene. Materials are forced to pass through a metal tube in 2 mm internal diameter. After 4 mm movement of conveyor, the blade cuts the extruded dough at a 45° angle. Therefore, each piece is 6 mm long and 2 mm in diameter with a conical end [24].

4.3. Post-extrusion treatment

If cold extrusion is used, the extruded pieces are sprayed with salts or cross-linkers solutions such as calcium salts. In some cases, the pieces are submerged in boiling water containing cross-linkers for 3-20 min. The particles are rinsed further to remove the excess chemicals and cool

the product. Then, they are retrograded by free-zing to set the product in its expanded form [3].
Drying is necessary in both cold and hot extruded rice to achieve the appropriate moisture (15%) and prolong shelf life. Fluidized bed dryer, tray dryer, conveyor belt dryer, and rotary cylinder are examples of the instruments used in this regard. Final product is packed in air tight and moisture barrier bags to prevent fungal growth [19].

5. Different formula used in production of analog rice

Mulyadi et al. examined cassava flour, glutinous rice flour (sticky flour), and cowpea flour in formulation of analog rice. Optimization was done by organoleptic attributes and physical/ chemical characteristics. Their best treatment contained cassava flour and rice flour at ratio of 80:20 and 30% w/w cowpea flour. It was composed of 69.49% starch, 19.70% amylose, 49.79% amylopectin, 9.05% protein, and 8.24% water [25].

Noviasari et al. prepared analog rice by sorghum flour, corn starch, *Arenga* starch, and Mocaf. Sample B containing 30% w/w sorghum flour, 15% w/w corn starch, and 15% w/w *Arenga* starch and sample F containing 30% w/w Mocaf and 30% w/w corn starch were preferred technically. Sample B contained 21.72% amylose and 4% fiber, while sample F contained 14.49% amylose and 4.21% fiber (which was stickier than sample B) [18].

Santoso et al. optimized production of analog rice by local tuber single screw extruder. Optimization was done by modulation of screw extruder design, speed regulation by controlling the input materials and cooking period, studying consumers' acceptance, and evaluation of cost effectiveness. In their study, the most important factors in production of analog rice similar to common rice were temperature, screw speed, and moisture of dough [26].

Optimized analog rice produced by Pudjihastuti et al. was composed of cassava flour, corn flour, and taro plant root flour. It showed 128.4% water absorption and contained 12.51% water, 71.94% carbohydrate, 8.5% protein, 1.1% fat, and 14.9% amylose [24].

Purwaningsih et al. prepared analog rice by agar flour derived from *Gracilaria* algae that is effective in suppression of diabetes. Agar flour affects color, texture, and aroma of the rice. The product contained 9.9-13.7% moisture, 1.1-4.3% ash, 0.3-3.7% fat, 2.7-5.9% protein, 77.7-80.3% carbohydrate, 0.11-0.95% fiber, and 0.11-0.2% tannin [11].

Ridwansyah et al. produced analog rice by sorghum flour, corn flour, and cassava starch. In their study, sample prepared by hulled sorghum was darker than sample made by germinated sorghum because more tannin is removed in the grain under germination process compared to hulling [16].

6. Commercial demand of analogue rice

There are several types of analog rice in the world mostly prepared by corn flour. Corn is free of gluten and such product helps people suffering from coeliac. Analog rice is superior to common rice because of its high dietary fiber and anti-oxidant as well as relatively low GI (suitable for diabetic patients) (Table 1). PT FITS Mandiri is known analog rice produced by corn in Indonesia. It was advertised in social media and the consumers had been familiar with the product [8]. Despite its high nutritional value, a lot of people do not know analog rice worldwide due to lack of information. In addition, the consumers are not accustomed with its sensory attributes especially color. On the other hand, high price of analogue rice makes its marketing more difficult. Therefore, traders of analog rice are faced with inconsistent sale [15]. However, several studies have been done to develop its trading. Development strategies focus on quality and health promotion, advertisement, and facilitated distribution. They also target low income people seeking for cost-effective meals. Analog rice might have higher price than common rice, but it is more nutritious and can provide nutritional requirements by itself with-out need to adjuvant dishes [8].

Table 1- Comparison of nutritional fact and GI in Mandiri analog rice and common rice

Parameter (in 100 g)	Common rice	Mandiri analog rice
Energy (kcal)	400.66	370.78
Dietary fiber (%)	6.82	10.34
Total carbohydrate (%)	88.01	77.42
Total Sugar (%)	0.12	Not reported
Protein (%)	5.78	10.85
Total fat (%)	0.58	4.22
Glycemic Index	70	52

7. Conclusion

Raw materials used in production of analog rice are classified as main ingredients and additives. Rice or other grains flour and water are main ingredients. Additives are included to dyes, flavorings, binders, cross-linkers, vitamins, minerals, and antioxidants. Production of analog rice is done by two methods of granulation and extrusion. These methods result in different shape in final product. Therefore, extrusion is more interested because it produces analog rice very similar to common rice in shape.

Production is included to dough preparation and preconditioning, dough extrusion at appropriate time, temperature, and pressure to help optimal gelatinization and protein denaturation, treating the extruded materials with chemicals, and drying analog rice. Depending on the additives used in production of analog rice, it can be a beneficial alternative to common rice to provide nutritional requirements in people consuming rice as main dish in a day.

8. Conflict of interest

The authors declare that they have no conflict of interest.

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