Characteristics of Rice Analogue from Composite Flour and Seaweed Puree

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Abstract. . The research aimed to determine the interaction of corn flour formulation, yellow sweet potato, arrowroot starch, and concentration of *Gracilaria* sp. seaweed slurry on the physicochemical properties of rice analogue. This research was conducted using a factorial randomized group design. This research consists of two factors. The first factor is the composite flour formulation (corn flour: yellow sweet potato flour: arrowroot starch) with different ratios; the second is *Gracilaria* sp. seaweed slurry concentration, which consists of four levels, namely 0 %, 1 %, 2 %, 3 % (w w^{-1}). This research shows an interaction between the composite flour formulation and the concentration of *Gracilaria* sp. seaweed porridge on analogue rice's water, fat, fibre, and antioxidant content. Analogue rice is known to have a water content ranging from 6.10 % to 8.25 %, ash content ranging from 1.45 % to 4.09 %, fat content ranging from 2.40 % to 5.91 %, and protein content ranging from 1.31 % to 3.60 %; carbohydrate levels range from 80.96 % to 87.99 %. Besides that, the analogue rice fibre content ranged between 1.33 % to 4.48 %, and the antioxidant activity was 83.32 % to 86.46 %.

Keywords: Arrowroot starch, artificial rice, corn flour, healthy food, tubers flour.

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1 Introduction

Rice consumption in Indonesia is increasing, and rice imports are needed to meet this need. Population growth is one of the causes of increasing consumption volume or demand for rice. Currently, rice demand in Indonesia reaches (2.3 to 2.4) × 10^6 t mo^{-1} or (27.6 to 28.8) × 10^6 t yr^{-1}. Per capita rice consumption has fluctuated over the last 10 yr. Data shows that during 2010 to 2019, average rice consumption decreased by 1.5 % yr^{-1}, while total consumption also decreased by 0.3 %; on the other hand, the population grew by 1.3 % yearly. The number of rice imports also fluctuates, with the most significant import occurring in 2018, wich amounted to more than 2.5 × 10^6 t [1]. Apart from that, to meet food needs, the government also imports wheat. Since 2018, Indonesia has become the largest wheat importer in the world [2].

Efforts to meet food needs by importing can lead to dependence on other countries. Therefore, efforts to realize national food security by prioritizing local food ingredients must be given more attention by the government and society. Diversifying food from local raw materials is a necessity. Indonesia has great potential to achieve food security by reducing food imports. This is because our country has a variety of food ingredients. Several types of local plants have the potential to be developed to become the primary source of carbohydrates, including corn (*Zea mays* L.), potatoes (*Solanum tuberosum* L.,) pumpkin (*Cucubita moschata* Duch ex Poiret,), bananas (*Musa paradisiaca* L.), sweet potatoes (*Ipomoea batatas* (L.) Lam.), cassava (*Manihot esculenta* Crantz), arrowroot (*Maranta arundinacea* L). sago (*Cycas revoluta* Thunb.), kimpul/yellow ocumo (*Xanthosoma sag*ittifolium Schott.), breadfruit [*Artocarpus altilis* (Parkinson) Fosberg], and gembili/ lesser yam, (*Dioscorea esculenta* L.). Carbohydrate sources, as mentioned above, are known to have advantages. Some of the benefits include the following. Corn is known to be rich in fiber, carbohydrates, protein, vitamin B3, vitamin B5, vitamin C, and minerals in the form of potassium, iron, phosphorus, magnesium, and antioxidants.

Apart from that, Indonesia is also one of the largest seaweed producers in the world. Seaweed is the primary source of hydrocolloids, which can be applied to produce functional food because it contains high levels of dietary fiber, is rich in antioxidants, nucleic acids, amino acids, vitamins (A, B, C, D, E, and K), and also contains minerals, such as nitrogen, calcium, selenium, iron, manganese, and sodium. One type of seaweed that is well-known is *Graciliria* sp. [3].

One product that can be developed from local ingredients includes analogue rice. Analogue rice nutrients can be made according to their intended use, using raw materials according to needs [4, 5]. Several studies have been conducted on analog rice, including analog rice from composite flour [4], sorghum (*Sorghum bicolor* (L.) Moench) [6, 7], from sago flour and arrowroot starch [1], from sweet potato flour, avocado seeds (*Persea americana* Mill.), tofu dregs [9], from sago and red beans (*Phaseolus vulgaris* L.) [8], and rice analogs from corn flour and seaweed (*Gracilaria* sp.) [10]. However, until now, there has been no research on rice analogues made from composite flour from tubers and seaweed puree *Glacilaria* sp. This research aimed to determine the physicochemical properties of rice analogs from modified arrowroot starch, mocaf flour (modified cassava flour), and *Glacilaria* sp seaweed puree.

2 Materials and methods

The research was carried out at the Food Technology Laboratory, Faculty of Agriculture and Animal Science, University of Muhammadiyah Malang. The tools used in research on analogue rice are a Ba-0.5 type extruder (Indonesia), steamer (Maspion Steamer Bronita, Indonesia), cabinet dryer (AM12, aneka mesin, Indonesia), digital scale, baking sheet, and aluminum foil. The tools used for analysis are Pioneer Ohaus PA413 analytical scales (UK), desiccators, petri dishes, furnaces (FNC-TB1400 Series, China), mortars, hot plates (HPT-350 Series, China) , funnels, porcelain saucers, beakers, test tubes, erlenmeyer flasks, measuring pipettes, rubber bulbs, measuring cups, flasks fat, baking pan, oven, Simadzu UV-1800 spectrophotometer, Japan, Barnstead Thermolyne vortex (37600 Maxi Mix 2 Vortex Mixer, USA), and centrifuge (Wap Lab Type: WP-0412, China).

The ingredients used in making analog rice are corn flour, yellow sweet potato flour, arrowroot starch, water, GMS (Glycerol monostearate), *Gracilaria* sp. seaweed, rice flour, and whiting, which were obtained from the Landungsari market, Malang. The chemicals used for the research were distilled water (technical), HCl 0.02 % (p.a), NaOH 3.25 % (p.a), concentrated H_2SO_4, Na_2SO_4 1.25 % (p.a), ethanol 96 % (p.a), BSA (p.a), DPPH (p.a), petroleum benzene (p.a) obtained from the Food Technology Laboratory, Muhammadiyah University of Malang.

2.1 Research stage

The research is divided into two stages; the first is the process of making corn flour formulations, yellow sweet potato flour, arrowroot starch, and seaweed porridge. The second is making analog rice with differences in flour formulation and seaweed concentration. The analysis carried out on analog rice product ingredients includes protein content, water content, carbohydrate content, ash content, fat content, antioxidants, color intensity, water absorption, and fiber.

2.2 Process of making analogue rice

Analog rice is made using extrusion technology, adopting the method of Damat *et al.* [5]. Before molding it into rice grains, weighing is carried out, and then the composite shell is mixed with seaweed puree according to the treatment. Seaweed puree was added as much as 1 %, 2 %, 3 %, and 20 % water (v w^{-1}). Next, the dough is steamed using a Maspion SKU 15448 (Indonesia) steamer for 30 min at 80 °C and then molded into rice grains using a Barata model BA-05 extruder (Indonesia). Finally, the analog rice grains were dried in a Maksindo cabinet (Indonesia) at 50 °C for 20 h.

2.3 Research methods

This research was conducted using a factorial randomized group design. This research consists of two research factors. The first factor is the composite flour formulation (corn flour: yellow sweet potato flour: arrowroot starch), which consists of three levels of formulation, namely: (i) J1 = 30 % corn flour: 40 % yellow sweet potato flour: 30 % arrowroot starch, (ii) J2 = 40 % corn flour: 30 % yellow sweet potato flour: 30 % arrowroot starch, (iii) J3 = 35 % corn flour: 35 % yellow sweet potato flour: 30 % arrowroot starch.

The second factor is the concentration of *Gracilaria* sp. seaweed slurry which consists of four levels, namely: R0 = 0 %, R1 = 1 %, R2 = 2 %, R3 = 3 % (w w^{-1}). The data obtained were analyzed using Analysis of variance (ANOVA) and continued with the DMRT comparison test with a significance level of 5 % ($\alpha = 0.05$).

The physicochemical property parameters tested on analog rice included analysis of water content, fat content using Soxhlet, protein content using the Kjeldahl method, and carbohydrate content using the method of McCleary *et al.* [11]. The fiber content of analog rice was analyzed using the Yu *et al.* method [12], while antioxidant activity was analyzed using the Saluri and Tuvikene [13] method.

3 Result and discussion

3.1 Chemical analysis of analogue rice raw materials

The results of testing the water, ash, fat, protein, and carbohydrate content of raw materials for making analog rice are presented in Table 1. The corn flour results of this research are different from previous research in that corn flour has a water content of 11.46 %, an ash content of 1.86 %, a fat content of 3.15 %, a protein content of 12.60 %, and a carbohydrate content of 70.92 % [14]. This difference in result is influenced by the corn cultivars used as corn flour. Apart from that, it is also influenced by the processing process and pretreatment. Yellow sweet potato flour in this study is different from the results of research by Arief *et al.* [15], namely water content of 3.41 %, ash content of 1.16 %, fat content of 0.53 %, protein content of 3.13 %, and carbohydrate content of 91.77 %. The difference in the results of this study and previous research is likely due to the use of different cultivars, harvest age, and pretreatment.

Arrowroot starch in this study is similar to research by Damat *et al.* [16] that the water content of arrowroot starch was 11.85 %, the ash content was 0.44 %, the fat content was 1.29 %, the protein content was 0.38 %, and the carbohydrate content was 86.03 %. The results of this research are different from the results of the study by Princestasari and Amalia [17] that the water content of the seaweed *Gracilaria* sp. amounted to 88.65 %, ash content 17.09 %, fat content 3.17 %, protein content 16.83 %, and carbohydrate content 62.91 %. The difference between the results of this research and previous research is due to differences in the nutrient absorption process between seaweeds, cultivation methods, and added treatments.

Table 1. Chemical analysis of analogue rice raw materials.

Ingredients	Moisture content (%)	Ash content (%)	Fat content (%)	Protein content (%)	Carbohydrates (%)
Corn flour	9.18	0.47	3.46	0.97	85.92
Yellow sweet potato flour	9.08	2.76	1.99	1.42	84.75
Arrowroot starch	11.,85	0.44	1.29	0.38	86.04
Seaweed porridge	87.30	0.19	2.84	3.55	6.12

3.2 Proximate analysis of analogue rice

The treatment of composite flour formulation and seaweed slurry concentration significantly affected the water content of analogue rice. The average water content test is presented in Table 2. The water content of analogue rice ranges from 6.10 % to 8.25%. The water content of the research results is lower when compared to the research results of Pudjihastuti *et al.* [1], which had water content ranging from 10.75 % to 12.01 %. The water content tends to increase as the concentration of seaweed slurry increases. This is because seaweed puree is known to be composed of non-starch polysaccharides (NSP). NSP is known to have the ability to bind water better [18]. Based on the Indonesian National Standard (SNI - *Standar Nasional Indonesia*), the maximum water content for milled rice is 14 %. This means that the water content in this study meets the requirements of SNI.

The analogue rice protein content ranged from 1.31 % to 3.06 % (Table 2). The results of this study are no different from those of other studies [5, 8]. This is because the protein content in the raw material is relatively low, affecting analog rice's protein content. Apart from that, the low protein levels in this study are also thought to be caused by protein denaturation due to heating.

Table 2. Mean results of proximate analysis of analogue rice.

Treatment	Water content (%)	Protein content (%)	Fat content (%)	Ash content (%)	Carbohydrate content (%)
J_1R_0	6.10^{a}	1.43	2.40^{a}	2.07^{a}	87.99^{e}
J_1R_1	6.68^{bc}	2.09	2.50^{a}	2.53^{ab}	86.19^{d}
J_1R_2	6.53^{b}	2.08	2.71^{ab}	3.52^{b}	85.15^{c}
J_1R_3	7.44^{e}	3.06	2.91^{bc}	4.09^{c}	81.96^{a}
J_2R_0	6.21^{a}	1.47	3.09^{bc}	1.58^{a}	87.66^{e}
J_2R_1	6.76^{bc}	1.39	3.33^{c}	1.70^{a}	86.81^{d}
J_2R_2	7.10^{d}	2.44	4.59^{d}	2.06^{a}	83.81^{c}
J_2R_3	7.81^{f}	1.31	5.13^{e}	3.10^{ab}	82.65^{b}
J_3R_0	6.51^{b}	1.85	5.30^{e}	1.45^{a}	84.89^{c}
J_3R_1	6.86^{cd}	1.86	5.35^{e}	1.49^{a}	84.43^{c}
J_3R_2	7.46^{e}	2.90	5.37^{e}	1.61^{a}	82.65^{b}
J_3R_3	8.25^{g}	2.71	5.91^{f}	2.17^{a}	80.96^{a}

Note: Numbers followed by letters that are not the same indicate significant differences according to the Duncan α 5 % test.

J1 = 30 % corn flour: 40 % yellow sweet potato flour: 30 % arrowroot starch
J2 = 40 % corn flour: 30 % yellow sweet potato flour: 30 % arrowroot starch
J3 = 35 % corn flour: 35 % yellow sweet potato flour: 30 % arrowroot starch
R0 = seaweed puree 0 %; R1 = seaweed puree 1 %; R2 = seaweed puree 2 %;
R3 = seaweed puree 3 %

The fat content of analog rice tends to increase as the concentration of corn starch added increases. The results of the test for the fat content of analog rice are presented in Table 2. The research results of Wahjuningsih *et al.* [8] show that analog rice has fat content ranging from 1.37 % to 3.07 %. Differences in the composition of analog rice will cause differences in fat content results. The interaction between the proportion of composite flour and the concentration of seaweed slurry influences fat content. The higher the composition of corn flour and the higher the concentration of seaweed slurry added, the fat content tends to increase.

The ash content of analogue rice increases with the composition of yellow sweet potato flour and the concentration of seaweed slurry added to making analogue rice. This research results are similar to the study conducted by Damat *et al*. [16]. The highest ash content is known to be found in the J3R3 treatment (35 % corn flour, 35 % yellow sweet potato flour, and 30 % arrowroot starch, with the addition of 3 % seaweed puree, which is 4.09 % (Table 2). The higher the composition and concentration of yellow sweet potato flour, the more the ash content in seaweed porridge increases. Seaweed has the mineral iodine, and sweet potato has high levels of potassium and phosphorus [18, 19].

The carbohydrate content of analog rice from the results of this study is presented in Table 2. Based on this table, analogue rice's carbohydrate content ranges from 80.96 % to 87.99 % (Table 2). The results of this research are different from the results of another study. The carbohydrate content of analog rice, as a result of research by Budijanto and Yulianti [6]; AOAC [20], has an average carbohydrate content value of less than 85 %. Differences in the composition of raw materials can cause this difference. This difference was also caused by the relatively low water content of the analog rice in this study, so it affected the carbohydrate content. This research's analogue rice is also higher than the requirements for milled rice according to the Indonesian Ministry of Health 1992, which states that milled rice has a carbohydrate content of 78.90 %.

3.3 Analogue rice fiber content

Based on Table 3, it is known that the fiber content ranges from 1.33 % to 4.48%. Dietary fiber levels increase with the addition of seaweed. This is thought to be because *Gracilaria* sp. seaweed contains NSP (Non-Starch Polysaccharides), a dietary fiber component. Seaweed (*Gracilaria* sp.) has 9.76 % dietary fiber (% bw) [21]. This shows that *Gracilaria* sp. is a source of dietary fiber in analogue rice. Besides that, *Gracilaria* sp. also contains 54.4 % galactan and 19.7 % cellulose [22].

Seaweed is the primary source of hydrocolloids and contains functional components. One of the functional components is dietary fiber, which is known to have the ability to absorb water and bind glucose, which is essential for the body [23]. Seaweed is also rich in antioxidants, nucleic acids, amino acids, and vitamins A, B, C, D, E, and K [18, 19]. Previous research shows that seaweed is a source of antioxidants such as carotenoids, pigments, and polyphenols [24]. Antioxidants are chemical compounds that protect cells from attacks by free radicals that cause damage [25–27]. Therefore, using seaweed puree is expected to improve the functional properties of analog rice.

Table 3. Mean fiber content and antioxidant activity of functional analog rice.

Treatment	Fiber content (%)	Antioxidants activity (%)
J_IR_0	2.82^{e}	85.60^{d}
J_IR_1	3.05^{ef}	85.81^{d}
J_IR_2	3.19^{f}	86.03^{de}
J_IR_3	4.48^{g}	86.46^{e}
J_2R_0	2.15^{c}	85.33^{cd}
J_2R_1	2.17^{cd}	85.39^{cd}
J_2R_2	2.26^{d}	85.44^{cd}
J_2R_3	2.56^{de}	85.60^{d}
J_3R_0	1.33^{a}	83.32^{a}
J_3R_1	1.77^{ab}	84.38^{b}
J_3R_2	1.78^{ab}	84.70^{bc}
J_3R_3	1.87^{c}	84.96^{c}

Note: Numbers followed by letters that are not the same indicate significant differences according to the Duncan α 5 % test.

J1 = 30 % corn flour: 40 % yellow sweet potato flour: 30 % arrowroot starch
J2 = 40 % corn flour: 30 % yellow sweet potato flour: 30 % arrowroot starch
J3 = 35 % corn flour: 35 % yellow sweet potato flour: 30 % arrowroot starch
R0 = seaweed puree 0 %; R1 = seaweed puree 1 %; R2 = seaweed puree 2 %;
R3 = seaweed puree 3 %

3.4 Antioxidant activity of rice analogues

The results of the antioxidant activity test for rice and rice analogues are presented in Table 3. The average antioxidant activity ranged between 83.32 % to 86.46 %. Differences in raw material composition can cause this difference. Corn flour, sweet potato, and seaweed puree are rich in antioxidants. Corn contains vitamin A, carotenoids, and vitamin

E, which function as micronutrients and natural antioxidants. The highest antioxidant activity of analog rice was 86.46 %, namely in the treatment with a seaweed percentage of 3 %. Antioxidant activity increases with increasing percentage of seaweed puree. *Gracilaria* sp. is known as a producer of biologically active phytochemicals, namely carotenoids, terpenoids, xanthophylls, phycobilins, unsaturated fatty acids, polysaccharides, vitamins, sterols, tocopherol and phycocyanins [3]. This analog rice's antioxidant activity is higher than that of analogue rice from previous research [5].

4 Conclusion

Based on the results of this research, it is known that there is an interaction between the formulation of corn flour, yellow sweet potato flour, arrowroot starch, and seaweed puree concentration on water content, fat content, analogue rice fiber content, and rice antioxidant activity analogue rice. The treatment of corn flour, yellow sweet potato flour, and arrowroot starch, as well as the concentration of *Gracilaria* sp. seaweed, had a very significant effect on water content, ash content, fat content, carbohydrates, rice analogue fiber, the antioxidant activity of rice analogue rice, organoleptic taste, texture, appearance, and preferences.

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