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The Characteristics of Functional Analog Rice Made from Modified Arrowroot Starch and Corn Flour with Seaweed

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Abstract

The modification of starch with the heat moisture treatment (HMT) method increases the level of type 3 resistant starch, which is used to develop functional foods such as analog rice. Therefore, this study aims to analyze the physicochemicals of analog rice made of modified arrowroot starch (*Maranta arundinacea* L.) and corn flour (*Zea mays* L.) with seaweed (*Gracilaria* sp.). It was conducted using a factorial randomized block design method of two factors. The first factor was the difference in the ratio of the composition of modified arrowroot and corn flour, which consisted of three levels, namely 30:70, 40:60, and 50:50. Meanwhile, the second factor was the concentration of seaweed porridge with three levels, namely 1 %, 2 %, and 3 %. The results showed that increasing the proportion of modified arrowroot starch and the concentration of seaweed porridge reduced water, fat, protein, and ash contents but increased analog rice resistant starch levels. Furthermore, the antioxidant activity of analog rice also increased after steaming. This study has proven that using modified arrowroot starch, corn flour, and the addition of seaweed can improve the functional properties of analog rice.

Keywords: Antioxidant activity, Artificial rice, Fitobentos, Functional food, *Gracilaria* sp., *Maranta arundinacea* L., Modified starch, *Zea mays* L.

1. Introduction

In Indonesia, the Central Statistics Agency stated that rice production decreased from 33.94×10^6 t in 2018 to 31.31×10^6 t in 2019 (Central Statistics Agency, 2020). This decline was caused by extreme weather in early 2019 and a long mid-year drought. Rice is the staple food for most Indonesians, as its consumption was 29.13×10^6 t in 2017 and is expected to increase with the population (Anggraeni, 2020).

The decline in rice production has forced the Indonesian goverment to import the commodity; meanwhile, people are being promoted to diversify their food to reduce importation. A food diversification product that has the potential to be developed is analog rice. It is a product in the form of rice but made from non-rice ingredients, with a carbohydrate content close to or exceeds the rice produced from local food flour and is cooked in the same way as rice (Damat *et al*., 2021; Mishra *et al*., 2012; Wahjuningsih *et al*., 2018). Analog rice has almost the same or more nutritional content as rice and functional properties according to the raw materials used. On the other hand, it is an artificial product made from non-rice carbohydrate sources with high contents such as sweet potatoes [*Ipomoea batatas* (L.) Lam.], cassava (*Manihot esculenta* Crantz.), sago (*Cycas revoluta* Thunb.), sorghum [*Sorghum bicolor* (L). Moench.], and other ingredients (Sumardiono *et al*., 2014).

Several studies on analog rice that have been carried out include analog rice of composite flour (Sumardiono *et al*., 2014), sorghum (Budijanto and Yuliana, 2015; Wahjuningsih *et al*., 2018; Wahjuningsih *et al*., 2018), taro [*Colocasia esculenta* (L.) Schott.] and seaweed (Wahjuningsih and Susanti, 2018), from sweet potato and carrot flour [*Daucus carota* subsp. sativus (Hoffm) Schübl. & G. Martens] (Anggraini *et al*., 2016), from sago flour and arrowroot starch (Pudjihastuti *et al*., 2019), from sweet potato flour, avocado (*Persea americana* Mill.) seeds, tofu pulp (Putri and Sumardiono, 2020), from sago and red beans (*Phaseolus vulgaris* L.) (Wahjuningsih *et al*., 2020), and analog rice from corn flour and seaweed grass (*Gracilaria* sp.) (Purwaningsih *et al*., 2020). However, there are no studies on analog rice made from a mixture of modified arrowroot starch using the heat moisture treatment (HMT) method and corn flour with seaweed porridge as a source of antioxidants.

Therefore, this study used modified arrowroot starch to increase resistant starch content in analog rice. Resistant

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starch is the fraction that resists hydrolysis of digestive enzymes and can be approximately 22.56 % in arrowroot starch (Astuti *et al*., 2018). The compact structure of resistant starch molecules also prevents digestive damage by enzymes, namely blood glucose; hence, it is considered suitable for people with diabetes (Damat, 2013; Damat *et al*., 2019; Ferng *et al*., 2016; Joslowski *et al*., 2015; Saari *et al.,* 2017).

Corn flour is added to improve the shape of the rice lost during cooking and reduce the stickiness because of the high content of 4.93 % fat in white corn flour (Hidayat *et al*., 2017). Furthermore, composite components can be added to manufacture artificial rice as needed.

Seaweed is the primary source of hydrocolloids and contains functional components such as high dietary fiber, which absorbs water and binds glucose. Therefore, it reduces glucose availability and stabilizes and lowers blood glucose in the body (Carlson *et al*., 2018). It is also rich in antioxidants, nucleic acids, amino acids, and vitamins A, B, C, D, E, and K (Khan *et al*., 2019; Rocha *et al*., 2019). A previous study showed that seaweed is an abundant source of antioxidants such as carotenoids, pigments, and polyphenols, with various polysaccharides (Sreejamole and Greeshma, 2013). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks from free radicals that cause damage (Damat *et al*., 2020; Queralt *et al*., 2015; Setyobudi *et al*., 2019; Setyobudi *et al*., 2022). Therefore, the use of seaweed flour is expected to increase the functional properties of analog rice. The aim of this study is to determine analog rice made from modified arrowroot starch, corn flour, and seaweed porridge as well as analyze the physicochemical of antioxidant-rich.

2. Materials and Methods

2.1. Preparation of study materials

The materials used in the manufacturing of analog rice included arrowroot starch from farmers in Junrejo District, Batu City, East Java, corn flour from CV Makmur Sejati Malang, East Java. Arrowroot starch is made from arrowroot tubers, and prepared using the Damat *et al*., (2019) method. *Gracilaria* sp. type seaweed from CV Agar Sari Jaya Malang, East Java. Glycerol monostearate (GMS) – one stearyl for one glycerol – (Pro Analytic), and water. Other materials used in this study were a solution of H_2SO_4 (Pro Analytic, Merck), Na_2SO_4 (Pro Analytic, Merck), HgO (Pro Analytic, Merck), distilled water, boric acid (Pro Analytic, Smartlab), HCl (Pro Analytic, 37 %, Merck), petroleum benzene (Pro Analytic, Merck), ethanol 96 % (Technical), and DPPH (Pro Analytic, Merck), Bovine serum albumin (BSA) (Sigma-Aldrich), and NaOH.

2.2. Preparation of seaweed porridge

Seaweed (*Gracilaria* sp.) was dried, sorted, and cleaned of dirt such as salt, sand, shellfish, and other impurities by washing, repeatedly. A total of 100 g of seaweed was soaked in 2 L of solution for 24 h, containing whiting (1.5 % w v^{-1}), rice flour (2.5 % w v^{-1}), and lime juice (0.3 % v v^{-1}). Next, the neutralization process was carried out by washing the seaweed in running water, followed by soaking the seaweed in a 25 % alum solution for 4 h to remove the fishy smell.

The size of the seaweed was reduced to one cm after obtaining clean and odorless seaweed. Subsequently, the seaweed was mashed using a Blender Maspion Set MT 1206 with the addition of 1:1 water. Finally, the delicate seaweed was heated for 15 min at a temperature of 50 °C to 60 °C.

2.3. Arrowroot starch modification

Modification of starch using the heat moisture treatment (HMT) was carried out using the method by Liu *et al*. (2016). After adding distilled water, the water content became 30 %, and the sample was left at 4 °C for 24 h in a closed container. Next, the samples were heated at 105 °C for 16 h using the UN-55 Memmert Universal Drying Oven and cooled to room temperature. Furthermore, the samples were dried using a cabinet dryer type AM-TD12 at 40 °C until the water content was less than 10 % (db). After drying, the starch was crushed and sifted using a 100 stainless mesh sieve.

2.4. Preparation of analog rice

The analog rice preparation implemented extrusion technology, where modified arrowroot starch and corn flour were mixed, with the composition according to the treatment. The mixture was added with 1 %, 2 %, and 3 % of seaweed porridge and 20 % (w v^{-1}) water. Subsequently, the mixture was steamed using a Maspion SKU 15448 steamer for 30 min at 80 °C and later molded into rice grains using the Barata Indonesia extruder model BA-05. Finally, the analog rice grains were dried in a Maksindo drying cabinet at 50 °C for 20 h.

Table 1. Formulation of analog rice

Treatment	The proportion of modified arrowroot starch:corn flour	Seaweed porridge (% v w^{-1})
R1C1	30:70	1
R2C1	40:60	1
R3C1	50:50	1
R1C2	30:70	2
R2C2	40:60	2
R3C2	50:50	2
R1C3	30:70	3
R2C3	40:60	3
R3C3	50:50	3

2.5. Analysis of physicochemical properties of analog rice

The physicochemical properties of analog rice included analysis of water content, fat content using Soxhlet, protein content using the Kjeldahl method, and carbohydrate content using the method McCleary *et al*. (2020). In addition, the fiber content of analog rice was analyzed using the Yu *et al*. method (Yu *et al*., 2014). In contrast, the levels of resistant starch were analyzed using the method described by McCleary (McCleary *et al*., 2020).

2.6. Antioxidant activity analysis

The antioxidant activity test was conducted using the Saluri and Tuvikene method (Saluri and Tuvikene, 2020). In this study, 25 g of analog rice was added to 1 mL of 90 % m methanol (MeOH) 0.56 acetic acid and mixed for

1 min on sonication by centrifugation at 3×10^3 rpm for 10 min (1 rpm = 1/60 Hz), which was used as the supernatant. Subsequently, 0.2 mL of the samples from each treatment was taken with a measuring pipette, put in a test tube, and 3.8 mL of previously prepared 500 µM DPPH solution was added. The solution was homogenized with a Vortex Mixer model no. VM-300 and incubated in a dark room for 30 min. The sample was adsorbed using a UV-Vis spectrophotometer Shimadzu UV-1800 with a maximum wavelength of DPPH. Meanwhile, the antioxidant activity of examples that have reacted with free radicals from DPPH is determined using the Equation (1) below:

$$\% \text{ Inhibition} = \frac{\text{Abs.blank} - \text{Abs.sample}}{\text{Abs.blanko}} \times 100\ \% \quad (1)$$

Notes:

Abs. Blank = Absorbancy of DPPH 50 µ

Abs. Sample = Absorbancy of the sample

2.7. 4 Resistant starch determination

As described by McCleary *et al.* (2020), the resistant starch was determined using the 2002.02 AOAC method. A sample of 0.50 g was weighed into a screw cap test tube measuring 16 mm × 125 mm, and 4 mL of pancreatic amylase solution (10 mg mL^{-1}) (3 µ mL^{-1} amylo-glucosidases/sodium azide 0.03 %) was added to each sample. The tubes were closed and incubated at 37 °C with continuous shaking at 100 rpm for precisely 16 h to allow the dissolution of non-resistant starch and hydrolysis to D-glucose.

The reaction was stopped by adding 4 mL of absolute ethanol, and the resistant starch was removed by centrifugation (2 000 × *g*, 10 min at room temperature). Furthermore, the pellets were washed twice with 8 mL 50 % ethanol at 4 °C and centrifuged (2 000 × *g,* 10 min at room temperature), which was later dissolved by adding 2 mL of 2 M KOH and stirred evenly. The solution was neutralized with 8 mL of 1.2 M sodium acetate buffer (pH 3.8), and 0.1 mL of amyloglucosidase was immediately added. The sample was incubated at 50 °C and shaken for 60 min, and the content of the tube was diluted at 1:10 with distilled water. The supernatant from each solution was centrifuged (1 500 × *g*, 10 min), and the 40 L supernatant was mixed with a 1.2 mL glucose oxidase-peroxidase-4-amino antipyrine reagent (megazyme resistant starch assay, Megazyme International Ireland Ltd., Co. Wicklow, Ireland) and incubated at 50 °C for 20 min. The supernatant was further calibrated using a spectrophotometer (Shimadzu UV-1800) at a wavelength of 510 nm.

2.8. Study design

This study used a randomized block design with Duncan's follow-up test. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016). Each experimental treatment was repeated three times.

3. Results and Discussion

3.1. Raw material analysis

In this study, the raw materials used included modified arrowroot starch, corn flour, and seaweed (*Gracilaria* sp.). Based on the proximate analysis of raw materials shown, the moisture content of modified arrowroot starch, corn flour, and seaweed are 7.02 %, 9.18 %, and 87.30 %. Respectively, moisture content plays an essential role in determining the material's shelf life. Since seaweed has a relatively high moisture content, storage was carried out at cold temperatures (5 ºC). Therefore, storage at low temperatures can prevent the growth of bacteria and fungi and inhibit metabolism and chemical reactions (Frau *et al.*, 2021). Each material's ash content, such as modified arrowroot starch, corn flour, and seaweed, ranged from 0.18 % to 0.65 %. Meanwhile, the highest ash content was discovered in seaweed, which showed that it has the highest mineral content.

The fat content of the ingredients ranged from 1.98 % to 3.46 %, where the corn flour has the highest, which is discovered in many parts of the treatment (Hidayat *et al.*, 2017). Protein is among the macronutrients needed in the body, while its content in the material ranged from 0.86 % to 3.55 %, whereas seaweed had the highest. Furthermore, the carbohydrate content in the material ranged from 6.13 % to 91.49 %, and the lowest was in seaweed.

3.2. Proximate composition of analog rice

The results of the proximate analysis of analog rice are shown in Table 2.

Table 2. Proximate analysis of analog rice

Treatment	Water content (%)	Ash content (%)	Fat content (%)	Protein content (%)	Carbohydrate content (%)
R1C1	13.56^{h}	0.51^{c}	0.81^{g}	0.44^{bc}	85.09^{a}
R2C1	10.62^{g}	0.46^{b}	0.73^{de}	0.46^{bcd}	87.80^{b}
R3C1	10.14^{f}	0.48^{bc}	0.66^{c}	0.38^{ab}	88.40^{c}
R1C2	9.85^{e}	0.33^{a}	0.76^{f}	0.44^{bc}	88.70^{d}
R2C2	9.45^{c}	0.52^{d}	0.71^{d}	0.30^{a}	88.94^{e}
R3C2	8.20^{b}	0.52^{d}	0.58^{b}	0.37^{ab}	90.17^{f}
R1C3	9.63^{d}	0.56^{e}	0.75^{ef}	0.49^{cd}	88.58^{c}
R2C3	8.06^{a}	0.52^{d}	0.66^{c}	0.55^{d}	90.03^{f}
R3C3	9.44^{c}	0.51^{cd}	0.40^{a}	0.50^{cd}	88.77^{de}

Note: The average value followed by the same letter showed that it was not significantly different from the 5 % DMRT test.

Water content was one of the essential factors in the manufacture of analog rice because high water content easily damages the analog rice. Based on the analysis of variance, there was an interaction between differences in flour composition and the addition of seaweed porridge. The water content test ranged from 8.06 % to 13.56 %, where the highest was in the proportion of modified arrowroot starch: corn flour, in a ratio of 30:70, with 1 % seaweed porridge. The lowest water content was from the formulation of 40 % modified arrowroot starch, 60 % corn flour, and 3 % seaweed porridge. All treatments applied fulfilled the Indonesian National Standard (SNI 6128-2015), with the maximum water content of milled rice being 14 % (Anggraini, 2020).

Ash content in analog rice was also an indicator of the number of mineral elements (Wahjuningsih and Susanti, 2018). The results showed an interaction between differences in flour composition with the addition of seaweed porridge. The ash content of analog rice ranged from 0.33 % to 0.56 %, where the highest was discovered in the proportion of modified arrowroot starch:corn flour, in a ratio of 30:70 with seaweed porridge 3 % to 0.56 %. Meanwhile, the lowest was in the proportion of modified arrowroot starch: corn flour, in a ratio of 30:70, with the addition of 2 % seaweed porridge of 0.33 %. Although according to Chan and Matanjun (2017) seaweed (*Gracilaria* sp.) contained an ash content of 8.09 %, another study showed that seaweed had vitamins, amino acids, nucleic acids, and macro minerals such as calcium and iodine (Rocha *et al*., 2019). Meanwhile, it is assumed that seaweed contained minerals, specifical iodine as a trace element, and and also ash content of 3.24 %. Modified arrowroot starch contained 0.21 % ash content (Astuti *et al*., 2018), while in this study its value was 0.65 %.

Fat is a compound that is insoluble in water but soluble in organic solvents. In this study, there was an interaction between differences in flour composition with the addition of seaweed porridge. The fat content of analog rice ranged from 0.40 % to 0.81 %, and the highest content was discovered in the proportion of modified arrowroot starch:cornflour in a ratio of 30:70 with a 2 % seaweed porridge of 0.81 %. Meanwhile, the lowest was in the proportion of modified arrowroot starch: corn flour in a ratio of 50:50 with 1 % seaweed porridge. Corn flour contained fat of 4.93 % (Hidayat *et al*., 2017). In addition, the source of fat in analog rice came from the GMS, which is derived from oil palm and prevents extrudates from sticking to each other (Damat *et al*., 2019). The fat content in corn flour can be used as a lubricant in the extruder, which facilitates the formation of the dough (Hidayat *et al*., 2017).

Protein is one of the crucial macronutrients that the body needs (Setyobudi *et al*., 2019, 2021). In this study, there was an interaction between the differences in flour composition with the addition of seaweed porridge. Furthermore, the protein content of analog rice ranged from 0.30 % to 0.55 %, where the highest was discovered in the proportion of modified arrowroot starch:corn flour in a ratio of 30:70 with 3 % seaweed porridge of 0.55 %. Meanwhile, the lowest was in the proportion of modified arrowroot starch: corn flour in a ratio of 50:50 with an additional 3 % seaweed porridge of 0.30 %. The amount of protein used was 3.55 %, different from the 16.83 %, a study by Zhang *et al*. (2020). A previous study by Chan and Matanjun (2017) suggested that *Gracilaria* sp. contained a minimum of 0.3 % protein. The protein content was much lower than milled rice because the analog rice raw materials of starch and flour were also low in protein.

Carbohydrates are the primary source of energy that the body needs for activity. The results showed that the carbohydrate content of analog rice ranged from 84.57 % to 90.32 %. There was an interaction between differences in flour composition with the addition of seaweed porridge. Furthermore, the carbohydrate content of analog rice ranged from 84.57 % to 90.32 %, with the highest content in the modified arrowroot starch:corn flour in a ratio of 40:60 with 2 % seaweed pulp of 90.32 %. However, the lowest was in the proportion of modified arrowroot starch:corn flour in a ratio of 30:70 with 1 % seaweed porridge of 84.06 %. The carbohydrate content in analog rice was relatively high because of the source, which was the raw materials in starch and flour. All treatments still had carbohydrate levels above milled rice, which is 78.90 % (Anggraini, 2020).

Antioxidants are compounds that counteract free radicals, and in this study the moderate antioxidant activity of pre-cooked rice was lower than cooked rice. Also, there was an interaction between differences in flour composition with the addition of seaweed porridge. Based on the results, the antioxidant activity of pre-cooked rice ranged from 20.18 % to 26.79 %, while cooked rice ranged from 34.38 % to 43.91 %. The highest antioxidant activity of pre-cooked rice was discovered in the proportion of modified arrowroot starch:corn flour in a ratio of 40:60 with 1 % seaweed porridge of 26.79 %. Meanwhile, the lowest was in the proportion of modified arrowroot starch:corn flour in a ratio of 30:70 with the addition of 3 % seaweed pulp of 20.18 %. Similarly, the highest antioxidant activity in cooked rice was in the formulation of modified arrowroot starch: corn flour in a ratio of 30:40 with the 3 % seaweed porridge of 43.91 % while the lowest was in proportion with a ratio of 40:30 with the addition of 1 % seaweed porridge of 34.38 %. The results of the antioxidant activity are shown in Table 3.

Table 3. Antioxidant activity of analog rice, steamed rice from analog rice, and resistant starch (RS) content of analog rice

Treatment	Antioxidant activity (%) of pre-cooked rice	Antioxidant activity (%) of cooked rice	RS Content (%)
R1C1	25.54±0.28[e]	34.38±0.26[a]	10.74±0.07[a]
R2C1	26.79±0.06[f]	37.57±0.02[c]	12.23±0.07[b]
R3C1	26.11±0.12[ef]	36.39±0.31[b]	14.23±0.39[d]
R1C2	22.89±0.26[bc]	38.65±0.28[d]	13.55±0.19[c]
R2C2	23.93±0.36[d]	38.65±0.18[d]	14.78±0.78[e]
R3C2	23.67±0.17[cd]	40.3±0.211[f]	16.52±0.18[g]
R1C3	20.18±0.57[a]	38.19±0.05[d]	15.88±0.06[f]
R2C3	23.46±0.27[cd]	43.91±0.06[g]	16.51±0.04[g]
R3C3	22.37±0.42[b]	39.74±0.26[e]	17.81±0.18[h]

Note: The average value followed by the same letter showed that it was not significantly different from the 5 % DMRT test.

Analog rice becomes a functional food category when it contains active compounds that benefit the body. In addition to beta-carotene, other sources of antioxidants also came from the addition of seaweed, which contained enzymes, pigments, carotenoids, tannins, flavonoids, terpenes, steroids, and polysaccharides in high amounts (Sreejamole and Greeshma, 2013). Meanwhile, a previous study showed that there were 1 776 μg of carotenoids from 100 g of algae (Rocha *et al*., 2019). The antioxidant activity decreased by an increase in the concentration of seaweed since antioxidant compounds such as pigments, carotenoids, and flavonoids were still in the cells and did not come out entirely due to a cell wall in seaweed. The increase in seaweed reduced the proportion of other projected ingredients and also contained antioxidants such as corn flour.

After the gelatinization process occurs, the antioxidant content of seaweed reaches the maximum point. The antioxidant compounds such as phenolic compounds in cell walls ruptured due to heat generated from collisions and friction between material particles (Chan *et al*., 2015; Chan and Matanjun, 2017). The heating process breaks the cell walls of seaweed for the antioxidants to be maximized due to its hemicellulose degradation (Rocha *et al*., 2019). According to Verni *et al*. (2019), the lowest antioxidant activity was obtained at a temperature of 5 °C at pH 12. Only a small amount of antioxidant compounds was extracted due to the difficulty in penetrating the cell wall. In addition, corn flour used in the manufacturing of analog rice was a source of antioxidants. Corn contains beta-carotene, a type of antioxidant (Setyobudi *et al*., 2019, 2021). Carotenoid pigments can also scavenge peroxyl radicals, be converted into carotenoid peroxide radicals, and are easily decomposed, so they are not harmful to live cells (Sedjati *et al*., 2020).

3.3. Resistant starch (RS) content of analog rice

The body needs resistant starch (RS) to maintain digestive health (Damat *et al*., 2019; Setyobudi *et al*., 2022). Based on the results, there was an interaction between differences in the composition of modified arrowroot starch: cornflour and the addition of seaweed porridge on the levels of analog rice resistant starch. Resistant starch levels in analog rice ranged from 10.74 % to 17.81 % (Table 3), which increased with the increasing proportion of modified arrowroot starch. The highest RS content was discovered in analog rice with the formulation of modified arrowroot starch: cornflour in a ratio of 50:50 and 3 % seaweed porridge. Meanwhile, the lowest was in the formulation with a ratio of 30:70 and 1 % seaweed porridge, which was 10.74 % due to the addition of modified arrowroot starch.

Analog rice with high levels of resistant starch (RS) can be developed into functional food. In the large intestine, it is fermented by lactic acid bacteria (LAB) to produce several types of short-chain fatty acids (SCFA), which have good effects (Damat, 2013; Wahjuningsih and Susanti, 2018). Food products with much resistant starch are digested slowly to reduce postprandial sugar levels (Damat *et al*., 2021).

The modified arrowroot starch granules were of 88 591 μm, which is larger than the natural ones (Damat *et al*., 2021). Meanwhile, changes in the size of starch granules can cause an increase in the content of resistant starch and decrease its digestibility (Pasquale *et al*., 2021). This occurance was due to the incorporation of amylose in the cooling process to form crystals different from natural starch. In addition, starch modified by HMT, followed by cooling, made the surface of the starch grains uneven as an effect of passing through gelatinization and retrogradation, causing changes in structure, viscosity, solubility, and swelling power (Dundar and Gocmen, 2013; Lin *et al*., 2020; Liu *et al*., 2016; Tako *et al*., 2014). Therefore, starch becomes more heat and shear-resistant, which causes a lower viscosity (Dhital *et al*., 2017). In addition, modification of starch by HMT also leads to the formation of type 3 resistant starch (Espinosa-Solis *et al*., 2021).

The use of modified arrowroot starch can cause an increase in the granule size of analog rice. The granule size increases with the proportion of modified arrowroot starch added (Damat *et al*., 2021) due to differences in granule size and resistant starch content in analog rice. Similar results were also described by Ratnaningsih *et al*. (2019) which showed that the ability of enzymes to hydrolyze starch is influenced by amylose, resistant starch, and granule size. Food products with a high resistant starch (RS) content have a hypoglycemic effect and a low glycemic index (Aprianita *et al*., 2014; Vrancheva *et al*., 2020). Aforementioned qualities are why the products are called functional foods.

In analog rice, resistant starch levels increase with the addition of seaweed, a dietary fiber source. It has been discovered that seaweed (*Gracilaria* sp.) contained 9.76 % (% w w^{-1}) dietary fiber and 29.94 mg L^{-1} iodine (Chan and Matanjun, 2017). Dietary fibers in cooked rice are smaller than in raw rice because it contains a higher water content. Furthermore, cooked rice passes through a starch gelatinization process which causes the starch granules to expand due to the entry of water, and the result is irreversible (Astuti *et al*., 2018). Therefore, *Gracilaria* sp. is a source of dietary fiber in analog rice, which contains 54.4 % galactan and 19.7 % (Rosemary *et al*., 2019).

3.4. Shape of analog rice

In general, the appearance of rice from all treatments was relatively the same. The shape of cooked rice is complete and resembles milled rice (Figure 1). Milled rice has a slightly oval shape and is whole when cooked. The addition of *Gracilaria* sp. also functions as a gelling agent so that when the cooking process, the shape of the rice produced is not lost (Figure 2). The addition of *Gracilaria* sp. also affects the appearance of analog rice. Agar cannot dissolve in cold water and, when heated, will form cross-links that affect the gelation process. After cooking, a single helix or double helix bond is formed. The helix bond will occur after folding and cooling (Tako *et al*., 2014). According to Ramadhan and Wini (2017), gelatin can form a triple helix network where the network can simultaneously trap water and reduce fluid flow from the dough so that it can strengthen the gel in a jam.

Figure 1. Analog rice shape

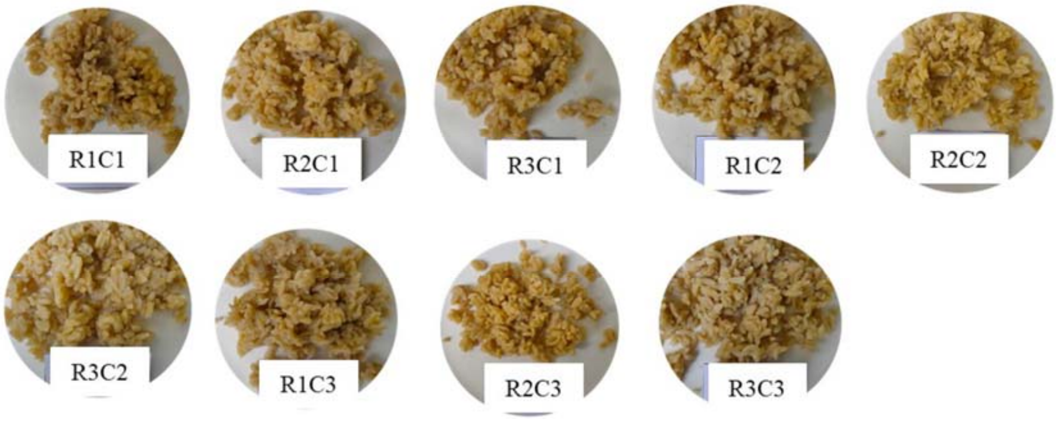

Figure 2. Rice shape from analog rice.

4. Conclusion

The results showed that increasing the proportion of modified arrowroot starch and the concentration of seaweed (*Gracilaria* sp.) porridge can reduce the water, fat, protein, and ash contents. The addition also enhances the resistant starch and allows an increase in antioxidant activity of analog rice after steaming. It is therefore conclusive that using modified arrowroot starch, corn flour, and the addition of *Gracilaria* sp. can improve the functional properties of analog rice.

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