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Physical characteristics and nutritional value of cassava analogue rice with fortified protein tempeh and the addition of xanthan gum for healthy dieters

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Abstract. Food diversification is an initiative to diversify local foods in order to gain a wider range of nutrients. One kind of food diversification is the creation of analogue rice. Cassava has a high starch content and can be used to replace rice as a carbohydrate source. The purpose of this research is to assess the influence of tempeh flour fortification and the inclusion of xanthan gum produced with cassava flour on the physical properties and nutritional value of alternative analogue rice products for healthy dieters. The stage of this research was making cassava flour; the stage of making composite flour with the formulation of cassava flour 30 - 45 percent wt, tempeh flour 5 - 20 percent wt, xanthan gum 2 percent; analogue rice synthesis stage; and testing the characteristics of analogue. The results showed that the ratio of cassava flour: tempeh flour: xanthan gum (30%:20%:2%) was the best ratio to produce analogue rice, which contained 9.24 percent water content; ash 2.44 percent; fat 6.31 percent; protein 18.38 percent; carbohydrates 54.39 percent; fibre 9.24 percent, water absorption value 243.32 percent, swelling power 6.7 g/g, and bulk density 0,4214 g/ml, and rehydration time 6,10 minutes.

1. Introduction

The dependence of the Indonesian people on rice consumption ranks first as a food ingredient with the highest level of consumption. Based on data from FAO, the average rice consumption of Indonesia's population in 2017 reached 135 kilograms per capita per year. The FAO standard for world rice consumption is 54.6 kilograms per capita per year. This means that the Indonesian population's rice consumption has exceeded global adequacy standards. Therefore, it is necessary to diversify food by increasing local food consumption.

Analog rice is one of the efforts to diversify food. Analog rice is artificial rice from non-rice food based on carbohydrates, usually made from tubers whose shape and nutritional content are almost similar to rice [1]. One of the raw materials in the manufacture of analog rice is cassava. Cassava contains 38.06 g of carbohydrates per 100 grams [2]. This shows the potential of cassava as a source of carbohydrates and can be an alternative to rice and support food diversification. Cassava also has a fairly high amylopectin content of 83% and amylose content of 17% which is useful as a binder [3]. However, cassava has a low protein content of 0.32 g/100 g. One of the efforts to overcome protein deficiency is by fortification of food. Protein fortification can be done by adding tempeh flour protein to analog rice. Tempe flour contains a fairly high protein compared to soybeans, which is 46.1% w/w [4]. So, to increase the protein content in cassava analog rice, it can be done by adding tempeh flour.

In addition to tempe flour can increase the protein content in analog rice, other added ingredients are also expected to improve the physical characteristics of analog rice. Analog rice with high swelling power characteristics is expected with a small amount of cooking analog rice, large amounts of rice are produced so that it can be used for diet food and can provide a feeling of fullness to dieters. One of the additives to increase the swellability of analog rice is xanthan gum. Xanthan gum plays a role in increasing swelling power and affects the solubility, gelatinization of starch and maintains overall product quality [5]. So to increase the value of swelling power in analog rice, it can be done by adding xanthan gum.

This study was conducted to determine the effect of adding xanthan gum and fortification of tempeh protein formulated with cassava flour on the characteristics of analog rice produced using the cold extrusion method. The use of cassava raw material with a fairly high amylopectin content of 83% [3] and the addition of xanthan gum is expected to produce high swelling power in analog rice so that it can improve the characteristics of analog rice and can be used for food for dieters.

2. Methodology

2.1 Materials.

The raw materials used in this research were cassava that obtained from Gunungpati, Semarang, Indonesia. Tempe flour produced by Sekar Sari, Gunungpati, Semarang, Indonesia was used in this study, as well as the distilled water and other chemicals were supplied by Chemical Engineering Integrated Laboratory of Universitas Negeri Semarang, Indonesia., with independent variables and the formulation of raw materials used as follows:

2.1.1 Variables. Independent variables used in this research were as follows : Raw material base 300 grams, time of mixing flour were 5 minutes, water 50 % wt, pregelatinization temperature 60°C, steaming time were 20 minutes, steaming temperature 100°C, drying time 5 hours, drying temperature 60°C. The formulation is presented in Table 1.

Table 1. Research Formulation of Analog Rice

Sample	Cassava Flour (%wt)	Tempeh Flour (%wt)	Xanthan Gum (%wt)
1	45	5	0
2	40	10	0
3	35	15	0
4	30	20	0
5	45	5	2
6	40	10	2
7	35	15	2
8	30	20	2

2.2 Research Implementation Procedure

2.2.1 Stage of Making Cassava Flour The stage of making cassava flour is done by peeling cassava, washed with running water. Cassava is reduced to a cutting thickness of ± 2 mm to facilitate drying and crushing. Then washed again with running water and drained. Cassava that has been cut is dried in the sun for 1-2 days. The dried cassava is reduced again with a grinder so that the size is uniform.

Then sieved using an 80 mesh sieve. After that, the moisture content analysis of cassava flour was analyzed.

2.2.2 Composite Flour Making Stage. The stage of making composite flour is done by mixing the raw materials according to the ratio formulation in Table 1.

2.2.3 Analog Rice Synthesis Stage. At this stage, pregelatinization was carried out by heating 50% wt water at 60 °C, then mixed according to the composite flour ratio formulation in Table 1. The dough is stirred and kneaded until the dough becomes smooth. Then steamed using a steamer at a temperature of 100 ° C for 20 minutes. Steaming aims to make the rice half cooked. The resulting dough from steaming was printed using a pasta maker with a thickness of 2 mm, then cut using a knife with a length of 1 cm and dried in an oven at 60°C for 5 hours.

2.2.4 Analog Rice Characteristic Test Phase. The analog rice characteristic test phase consisted of water content test, fat content test, protein content test, carbohydrate content test, ash content, fiber content, rehydration time, bulk density, water absorption test, and swelling power test.

3. Results and Discussion

3.1 Cassava Flour Moisture Content Analysis.

The initial analysis of cassava flour was carried out by analyzing the moisture content of cassava flour. The result of the water content test in cassava flour was 10.72%. Previous studies have shown that the water content in cassava flour varies from 9.2 to 11.4% [6]. According to SNI 01-2997-1996 the water content of cassava flour is not more than 12% [7]. So that the cassava flour in this study met the quality requirements of cassava flour. Cassava flour with low water content can increase the swelling power value of analog rice. This is due to the low water content, which will increase the breakdown of starch so that the amount of water that enters the starch granules will be more and the swelling of starch will increase [8].

3.2 Analog Rice Water Absorption Analysis.

Water absorption is the ability of a material to bind water [9]. The main chemical compositions that increase water absorption capacity in food systems are proteins and carbohydrates due to their hydrophilic constituents such as polar or charged side chains [10]. The results of the analysis of water absorption content of analog rice can be seen in Table 2 as follows:

Table 2. Result of Water Absorption

Sample	Water Absorption (%)
1	110.00
2	148.04
3	155.28
4	158.08
5	125.56
6	181.40
7	193.80
8	243.32

Based on the data in Table 2, it was found that the absorption of analog rice water with each treatment ranged from 110.00% - 243.32%. The treatment that has the highest water absorption is the treatment of sample 8, which is 243.32%. The increase in water absorption in this study was caused by the high protein content in tempeh flour, protein was able to bind large amounts of water due to its ability to form hydrogen bonds between molecules and polar groups in the polypeptide chain [9]. This result is consistent with another study that composite flour from plantain and soybean has high water absorption with increasing substitution of soy protein in flour [11]. In addition, with the addition of xanthan gum, the water absorption capacity of cassava analog rice fortified with tempeh flour is also higher. This is because xanthan gum has hydrophilic properties so that it is easily soluble in water and has a large water absorption capacity [12]. This is supported by the statement [13] that the addition of hydrocolloids can increase water absorption so that the analog rice of this study will more easily absorb water. The water absorption capacity of mentik rice and IR64 is 250-295% [14], so that the analog rice in this study has a lower water absorption than rice and has a faster cooking time than rice.

3.3 Analog Rice Swelling Power Analysis.

Swelling power is the ability to absorb water from starch granules at hot temperatures. When the starch is dissolved and then heated to the gelatinization temperature, the starch granules swell and the volume increases [15]. Swelling power of a product is influenced by protein content, amylopectin content, and fat content in the product [16]. The results of the analysis of swelling power of analog rice can be seen in Table 3 as follows:

Table 3. Result of Swelling Power Analysis

Sample	Swelling Power (g/g)
1	6.9
2	6.8
3	6.8
4	6.4
5	7.6
6	7.5
7	6.9
8	6.7

Based on the data in Table 3, the swelling power value of analogue rice was obtained with each treatment ranging from 6.4 g/g – 7.6 g/g. The treatment that had the highest swelling power value was in sample 5. An increase in tempe flour substitution in analogue rice would reduce the swelling power value in analogue rice [17]. This is because the protein will experience denaturation, causing the analogue rice to be difficult to expand. Starch granules without protein will break easily and the amount of water that enters the starch granules will be more so that the development of starch will increase [16]. The decrease in swelling power of analogue rice was also associated with the addition of tempeh flour protein which has a lower gelling ability than starch and also the interaction between starch and protein that limits swelling power [6]. This is in accordance with Mohajan's research [9] which added soy protein to corn flour where by adding 20% soy protein flour to corn flour the swelling power value was lower than the addition of 5% soy protein flour to corn flour. In addition, the addition of xanthan gum to analogue rice also caused an increase in the value of swelling power compared to those not using xanthan gum. Xanthan gum functions as a water binder [17]. This is in accordance with Julianti's research [17] about composite flour from sweet potato, corn-starch, soybean flour, and xanthan gum where with the addition of xanthan gum to composite flour the swelling power value is higher than without the addition of xanthan gum. Xanthan gum facilitates the gelatinization of starch granules to stick together where the starch granules provide the power to withstand the pressure of increasing water absorption and therefore increase the swelling power of the granules [5]. So, it can be concluded that analogue rice in this study has a higher swelling power value than rice (5.03 g/g) [18].

3.4 Bulk Density Analysis.

Bulk density is one of the physical parameters of instant analogue rice. Low bulk density indicates a hollow or porous product, while high bulk density indicates a dense product structure [19]. The results of the analysis of bulk density of analogue rice can be seen in Table 4 as follows.

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Table 4. Result of Bulk Density Analysis

Sample	Bulk Density (g/ml)
1	0.4667
2	0.4623
3	0.4577
4	0.4574
5	0.4701
6	0.4614
7	0.4477
8	0.4214

Based on the data in Table 4, the density value of analogue rice bulk for each treatment ranges from 0.4214 g/ml – 0.4701 g/ml. The treatment that had the highest bulk density value was in the treatment of sample 5. The results showed that the density of bulk in each sample decreased with increasing levels of tempeh flour. This is because tempeh flour has a lower density of bulk than cassava flour. Bulk density is important in determining food packaging. In addition, xanthan gum has an effect on the density of bulk samples. This is because the hydrophilic group of xanthan gum in analogue rice grains can bind water during the cooking process. This bound water is then removed through a drying process, creating cavities in the analogue rice grains and lowering the density of the bulk. This is the same as research [19] Increasing the concentration of hydrocolloids, either singly or in combination, shows a pattern of decreasing the density of instant analogue rice bulk. This is thought to be related to the increasing number of hydrophilic groups of hydrocolloids in instant analogue rice grains which can bind water during the cooking process. Based on the results of the study [19] the density results of the bulk ranged from 0.39 to 0.56 g/ml. Based on these data, it can be concluded that analogue rice from cassava flour and tempeh flour with the addition of xanthan gum produced by this study is included in the criteria.

3.5 Analog Rice Rehydration Time Analysis.

Rehydration time is the time required for the material to reabsorb water so that a homogeneous texture is obtained [20]. The results of the analysis of rehydration time of analogue rice can be seen in Table 5 as follows:

Table 5. Result of Rehydration Time Analysis

Sample	Rehydration Time (menit)
1	5.40
2	5.45
3	5.49
4	6.02
5	5.43
6	5.55
7	5.58
8	6.10

Based on the data in Table 5, the analogue rice rehydration time for each treatment ranged from 5.40 minutes to 6.10 minutes. The treatment that had the highest rehydration time was in the treatment of sample 8. Starch that underwent gelatinization caused the water that was initially outside the granules and was free to move to be inside the starch grains and could not move freely. When starch is dried, the water component in the matrix will evaporate leaving the matrix and cause the starch to be porous and can easily reabsorb water [21]. The more starch content, the shorter the rehydration time [22]. The higher the thickener added in the manufacture of analogue rice, the rehydration time also increased [22]. So that the analogue rice in this study has a faster average rehydration time compared to 15-30 minutes of rice.

3.6 Analog Rice Proximate Analysis

3.6.1 Analog Rice Moisture Analysis. Moisture content plays an important role in determining the shelf life of food [23]. Moisture content is a measure of the total water content contained in a food product, usually expressed as a percentage by weight on a wet basis [24]. The results of the analysis of moisture content of analogue rice can be seen in Table 6 as follows:

Table 6. Moisture Content Analysis

Sample	Moisture Content (%)
1	2.75
2	2.78
3	1.87
4	10.47
5	11.76
6	12.07
7	11.06
8	9.24

Based on the data in Table 3.5, the water content of analogue rice for each treatment ranged from 1.87% - 12.07%. The average water content decreased gradually with the addition of tempe flour. This is because tempeh flour contains more total dry solids with higher emulsifying properties than other flours [25]. In addition, analogue rice sample 8 decreased in water content compared to analog rice sample 4. The binding of water by xanthan gum can result in a decrease in evaporation of water content, so that the free water that is evaporated is reduced [26]. The average water content of analogue rice obtained in this study has met the requirements for safe water content for rice according to SNI 6128:2008, which is < 14%, so it can prevent microbial growth during storage.

3.6.2 Analog Rice Protein Content Analysis. Protein is the main component after starch that affects food quality and nutritional quality in rice [23]. The results of the analysis of protein content of analogue rice can be seen in Table 7 as follows:

Table 7. Protein Content Analysis

Sample	Protein Content (%)
1	8.77
2	11.80
3	18.97
4	19.18
5	5.39
6	9.78
7	14.05
8	18.38

Based on the data in Table 7, the protein content of analogue rice in each treatment ranged from 5.39% - 19.18%. The treatment that had the highest protein content was the treatment of sample 4, which was 19.18%. The protein content in analogue rice increased with the addition of tempe flour. This is because tempeh flour contains a high protein content [25] which can improve the cassava analogue rice which is not sufficient in protein content. In addition, the addition of xanthan gum reduced the protein content of analogue rice. This is in accordance with research [27] with the addition of xanthan gum to the composite flour of cassava, potatoes, and soybeans will reduce the protein

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content. The high protein in analogue rice is very good for healthy dieters, with a high protein content, it can make you feel full longer. This is because protein secretes hormones that can suppress hunger, slow gastric emptying, and prevent a decrease in blood glucose levels [28].

3.6.3 Analog Rice Ash Content Analysis. Ash content is an indicator of mineral content and is used as a measure of flour quality in the food industry [29]. The results of the analysis of ash content of analogue rice can be seen in Table 8 as follows:

Table 8. Ash Content Analysis

Sample	Ash Content (%)
1	2.88
2	2.82
3	2.42
4	2.25
5	2.41
6	2.42
7	2.28
8	2.44

Based on the data in Table 8, the analogue rice ash content was obtained with each treatment ranging from 2.28% - 12.88%. Ash content in food indicates the amount of minerals that are not burned into volatile substances. The ash content in sample 8 rice has a higher ash content than analogue rice sample 4. This is because xanthan gum contains ash content of 7-12% so that it affects the final product of analogue rice [26]. The higher the ash content in the food, the higher the minerals contained in the food [30]. The percentage of ash content aims to determine the amount of mineral content contained in the analogue rice product produced. Based on other studies, the ash content of analogue rice from purple sweet potato produces an ash content of 2.62-2.82% [31]. From this study, the ash content produced was not much different from analogue rice in this study.

3.6.4 Analog Rice Fat Content Analysis. Fat is a compound that has a non-polar group so it is not soluble in water, it is soluble in organic solvents [32]. The results of the analysis of fat content of analogue rice can be seen in Table 9 as follows:

Table 9. Fat Content Analysis

Sample	Fat Content (%)
1	1.93
2	3.19
3	5.37
4	6.37
5	1.37
6	2.70
7	3.94
8	6.31

Based on the data in Table 9, it was found that the fat content of analogue rice with each treatment ranged from 1.37% - 6.37%. The average fat content increased gradually with the addition of tempeh flour. The highest fat content is in sample 4. This is because the fat content of each different material will affect the fat content in analogue rice, the fat content in tempeh flour is very high at 24.7% [33]. Therefore, the fat content in analogue rice is increasing. Xanthan gum also slightly affects fat content because xanthan gum is included in the hydrocolloid which plays a role in reducing fat content in a food that is usually used for low-fat foods [34].

3.6.5 Analog Rice Carbohydrate Content Analysis. Carbohydrates are the main source of calories for the human body. Carbohydrates are a very important factor in their role in the staple food, namely rice. The analogue rice shown for this staple food must have a high carbohydrate content so that it can replace the role of rice which has been the main staple food [35]. The results of the analysis of carbohydrate content of analogue rice can be seen in Table 10 as follows:

Table 10. Carbohydrate Content Analysis

Sample	Carbohydrate Content (%)
1	83.67
2	77.23
3	73.53
4	52.49
5	72.65
6	66.27
7	60.77
8	54.39

Based on the data in Table 10, it was found that the carbohydrate content of analogue rice with each treatment ranged from 52.49% - 72.65%. The carbohydrate content in analogue rice decreased with the decrease in the addition of cassava flour, and the increase in the addition of tempeh flour. This is in accordance with [30], total carbohydrates based on carbohydrate by difference are strongly influenced by ash, protein, and fat content, so that increasing the content of these nutrients can decrease or increase total carbohydrates. Carbohydrates are an important substance for humans because they are the main source of energy. High carbohydrates in analogue rice are due to the raw material derived from flour which is a source of carbohydrates [36]. The addition of xanthan gum also affects carbohydrate levels because xanthan gum is an extracellular polysaccharide from the secretion of the *Xanthomonas campestris* bacterium [37].

3.6.6 Analog Rice Fibre Content Analysis. Fibre is a complex component consisting of lignin, cellulose and hemicellulose [12]. The results of the analysis of fibre content of analogue rice can be seen in Table 11 as follows.

Table 11. Fibre Content Analysis

Sample	Fibre Content (%)
1	0.15
2	0.15
3	0.15
4	9.47
5	6.41
6	6.75
7	7.89
8	9.24

Based on the data in Table 11, the results of analogue rice fibre content with each treatment ranged from 6.41% - 9.47%. The average fibre content increased gradually with the addition of tempe flour. The highest fibre content in sample 4. This is because tempeh flour contains 2.5% fibre [33]. This is because the fibre content in analogue rice raw materials affects the fibre content in analogue rice. Xanthan gum has no specific effect, only slightly reduces the fibre content in analogue rice, because xanthan gum is a water-soluble polysaccharide [38]. So that it can reduce fibre content at high levels of tempeh flour.

4. Conclusions and Suggestions

Based on this research, it can be concluded that tempeh protein fortification and the addition of xanthan gum affect the physical and proximate characteristics of analogue rice. The results of the proximate analysis showed that the best analogue rice in this study was the formulation of 30% wt cassava flour, 20% wt tempe flour, and 2% xanthan gum. This is because it produces high levels of protein and fibre which are suitable for healthy dieters. The results of the analysis obtained 9.24% water content, 18.38% protein, 2.44% ash content, 6.31% fat, 54.39% carbohydrates, and 9.24% fibre, with the physical characteristics of water absorption of 243.32%, swelling power 6.7 g/g, density of bulk 0.4214 g/ml, and rehydration time of 6.10 minutes. Further research is needed to determine the shelf life of analogue rice.

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