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The Effect of Composite Flour Ratio (Cassava, Gembili, Koro Pedang, and Corn) and Extrusion Temperature on Analog Rice Production

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Abstract *– The growing population affects an increasing number of Indonesian people, influencing their rice consumption and encouraging Indonesia to import rice. One of the alternatives is to use raw materials such as potential non-rice tubers. In this study, raw material composite flour was made from cassava (Manihot esculenta), gembili (Dioscorea esculenta), koro pedang (Canavalia ensiformis), and corn (Zea mays), which is the basic ingredient of rice maker analog. This research aimed to examine the influence of the raw material composition on the value of nutrients, the physical-chemical properties of analog rice compared to a rice paddy, and the best temperature of analog rice using organoleptic tests. The process of producing analog rice consists of several stages of research, including the manufacturing of composite flour, the cooking of dough with composite flour, the production of analog rice, and the drying of analog rice. Based on the results, samples of 5 (60% cassava flour, 5% gembili flour, 10% koro pedang, and 25% corn flour) as an analog of rice with the best formulations in various compositions. Based on a proximate analysis of the effect of temperature, a temperature of 75 ˚C is the optimum temperature for the extrusion process. The results of the physical analysis of the best analog rice in this study have a density of 0.46 g/mL, water absorption of 60.52%, and a cooking time is 46 minutes. The analog rice has the same texture, aroma, and appearance as rice in general, although the rice from the analog composite flour tends to have a savory flavor arising from koro pedang. According to the results of this study, the analog rice could be used as a substitute to lessen dependence on paddy rice.*

Keywords: *analog rice; composite flour; extrusion temperature*

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INTRODUCTION

Rice is the primary food for the majority of Indonesians, which is also being impacted by the country's growing population. According to the National Statistics in 2022, Indonesia's population growth rate has increased from previous years, reaching 1.71% in 2022 with a mid-year population of 275,773.8 thousand people (Badan Pusat Statistika, 2022). The increase in population will be in line with the increase in the amount of rice consumed by the Indonesian people, which will encourage Indonesia to import rice. In 2021, it was recorded that Indonesia imported 407,741.4 tons of rice (Badan Pusat Statistika, 2021). This is due to the dependence of the Indonesian people, who are only focused on one food source, namely rice, so this dependence needs to be reduced gradually.

The high rice imports show that domestic production has not met the food needs of the Indonesian people. As a result, it encourages food diversification that resembles the Indonesian people's staple food, namely rice, with superior nutritional content. The potential for non-rice food sources in Indonesia is quite large, such as tubers as a source of carbohydrates, and legumes as a source of protein. However, the potential for non-rice foods has not been utilized optimally (Badan Ketahanan Pangan, 2012). Cassava (*Manihot esculenta*) is a potential alternative food that can be developed as a source of carbohydrates because cassava production has increased every year. Cassava production in Indonesia in 2020 reached 18,487,582 tonnes (Kementerian Pertanian, 2020). In addition, corn (*Zea mays* L.) also has food potential that can be developed. Corn production in Indonesia has also continued to increase. Corn production totaled 19 612 435 tons in 2015. The advantage is that corn does not increase blood sugar levels drastically and is cholesterol-free (Badan Ketahanan Pangan, 2012).

Another carbohydrate source that can be developed as an alternative food is gembili (*Dioscorea esculenta*). The national production of gembili is quite large, namely around 2 tons per hectare. Based on its nutritional content, gembili has a high carbohydrate content of up to 90% (Bernadheta & Rahayuni, 2013). However, gembili has not been utilized optimally. Generally, gembili is used as flour for processed foods such as biscuits or cookies. Gembili flour has advantages, such as being cheap and easy to obtain, and it can be used as composite flour with other types of flour with some improvements in its physicochemical properties (Pratiwi et al., 2016). Because the production of gembili is quite large and gembili has not been used optimally, gembili has the potential to be developed as an alternative food. Apart from carbohydrates, some substances are needed by the body, one of which is protein. Sources of protein can come from animal sources such as sea fish or vegetable sources such as nuts. One type of legume with a high protein content that can be developed into an alternative food is koro pedang (*Canavalia ensiformis* L.). This type of legume has a protein content that is no less high than that of green beans, reaching 23–27.6% (Gilang et al., 2013). Koro pedang protein content is 30.36% with average productivity of 7 tons/ha (Puslitbangtan, 2022). Therefore, the koro pedang can be used as an alternative source of protein (Susanti et al., 2013). It is this factor that encourages non-rice food diversification.

Analog rice is an imitation of rice derived from non-rice raw materials whose shape and nutritional composition approach or exceed rice (Budijanto & Yuliyanti, 2012; Machmur et al., 2011; Susi et al., 2019). Analog rice can be obtained from carbohydrate sources such as potatoes, tubers, and cereals (Budijanto & Yuliana, 2015; Hulliandini, 2014). In general, there are two methods for making analog rice, namely the granulation method (Hidayat et al., 2017) and the extrusion methods (Budijanto & Yuliyanti, 2012; Mishra et al., 2012; Zhuang et al., 2010). The difference between these two methods lies in the gelatinization of the dough and the printing stage. In the granulation method, the result of analog rice is in the form of granules. Whereas in the extrusion method, the results of analog rice are ovals resembling rice (Widara & Budijanto, 2012).

The dependence of the Indonesian people on rice as a staple food creates challenges in meeting the food needs of the people. As a result, it is necessary to diversify national food sources apart from rice by utilizing local commodities such as cassava (*Manihot esculenta*), gembili (*Dioscorea esculenta*), Koro pedang (*Canavalia enviformis* L.), and corn (*Zea mays* L.) to support Indonesia's food security program. So it is hoped that this analog rice innovation can be the right solution for Indonesia. Therefore, this research needs to be done to produce analog rice that has high quality, nutritional value, and good physicochemical properties compared to rice but at an affordable price in the community.

METHODOLOGY

Materials

The materials used in this study consisted of cassava flour (*Manihot esculenta*) supplied by PT Rumah Mocaf Indonesia, Temanggung Central Java, Indonesia, gembili flour (*Dioscorea esculenta*) supplied by "Kusuka" Ubiku, Bantul Yogyakarta, Indonesia, Koro pedang flour (*Canavalia enviformis* L.) supplied by DSS, Temanggung Central Java, Indonesia, and corn flour (*Zea mays* L.) supplied by Egafood, Jakarta, Indonesia, glycerol monostearate (GMS) supplied by the Riken Co., Tokyo, Japan, cooking oil supplied by PT Indofood Sukses Makmur, Jakarta, Indonesia, IR36 rice as standard/comparison rice, and distillate water. All chemicals used were at the analytical grade (Pro Analyst Grade; Merck, Darmstadt, Germany).

Preparation of Composites Flour

Cassava flour, gembili flour, koro pedang flour, and corn flour were mixed in a mixer according to the formulation (Table 1) until homogeneous. The dough was heated to 55°C before being mixed for 20 minutes with salt, cooking oil, GMS, and water.

Table 1. Raw material formulation of analog rice

Sample	Ratio of flour (wt.%)			
	Cassava	Gembili	Koro pedang	Corn
1	60	25	-	15
2	60	25	15	-
3	60	15	10	15
4	60	5	10	25
5	60	5	25	10

Extrusion Process

After homogeneous, the composites flour was then extruded into rice grains at various temperatures (65°C, 70°C, 75°C, 80°C, and 85°C). The granules obtained were dried under the hot sun for 10 hours.

Chemical and Physical Analysis

The chemical properties of the analog rice products were analyzed, including carbohydrates, fats, proteins, water, and ash. While the physical analysis of analog rice includes bulk density, water absorption, and cooking time. The consumer acceptance test method was used to analyze the organoleptic test of analog rice with texture, aroma, taste, and color parameters. Organoleptic testing was carried out by 20 random panelists selected from Undip students. This test was performed on a small scale in the campus environment to facilitate providing brief training, and it can be conducted at the same location and time each time. It is considered to have represented a broad consumer assessment. Panelists gave analog rice with the best formulation ratings ranging from dislike to really liking on a scale of 1-5.

Statistical Analysis

Statistical analysis was carried out using the Friedman Test with the SPSS 16 application.

RESULTS AND DISCUSSION

Proximate Analysis of Raw Materials

Analog rice raw materials are analyzed for water, ash, protein, fat, and carbohydrate content. According to the data in Table 2, the carbohydrate content of the composite cassava flour, gembili flour, and corn flour is higher than that of koro pedang flour. Carbohydrates are the primary source of calories for nearly the entire global population, particularly in Indonesia. Carbohydrates are important in determining the properties of food ingredients such as taste, texture, color, and so on. In addition, carbohydrates also play a role in preventing ketosis and helping fat and protein metabolism (Winarno, 1995).

Table 2. The nutritional content of raw materials

Flour	Carbohydrate (%wb)	Fat (%wb)	Protein (%wb)	Water (%wb)	Ash (%wb)
Cassava	82.30	3.53	0.53	13.3	0.32
Gembili	80.44	0.45	5.57	11.4	0.53
Koro pedang	45.30	18.7	24.4	7.08	3.88
Corn	73.94	2.46	8.35	6.00	5.97

Koro pedang flour has the highest fat content (18.7%), while gembili flour has the lowest fat content (0.45%). Fat provides energy to the body (Adicandra & Estiasih, 2016). The sword koro flour has the highest protein content, at 24.42%. Meanwhile, cassava flour had the lowest protein content, with 0.53%. With the addition of koro pedang flour, analog rice with a higher protein content is expected.

Each analog rice raw material has a water content of 13.3% for cassava flour, 11.4% for gembili flour, 7.08% for koro pedang flour, and 6% for corn flour. Paddy rice has a 11.4% water content. Noviasari et al. (2013) observed that a water content of 14% will prevent mold growth, which frequently interferes with cereals or grains during storage. It can extend the shelf life of analog rice if the levels are less than 14%. Cassava flour had an ash content of 0.32%, gembili flour had a content of 0.53%, koro pedang flour had a content of 3.88%, and corn flour had a content of 5.97%. It is hoped that by using these four flour raw materials, the analog rice produced will have a content comparable to rice.

The Effect of Composite Flour Ratio on Nutritional Content of Analog Rice

Table 3 shows the proximate composition of the analog rice produced.

Table 3. The nutritional content of analog rice in various compositions

Sample	Carbohydrate (%wb)	Fat (%wb)	Protein (%wb)	Water (%wb)	Ash (%wb)
1	82.64	0.26	5.72	7.61	3.25
2	82.76	1.36	7.42	5.80	1.94
3	84.27	0.50	6.10	7.49	2.01
4	83.02	0.95	6.93	5.01	3.41
5	81.34	0.54	7.86	7.88	2.30
IR 36	78.86	0.19	7.39	12.58	0.20

The carbohydrate content at various composition ratios ranged from 81.34% to 84.27%. The highest carbohydrate content was in sample 3 (84.27%) and the smallest in sample 5 (81.34%). This percentage is higher than the average carbohydrate content of rice, which is 78.86%. As a result, analog rice can be used as a staple food because the quality requirement for a staple food is that it contains carbohydrates in the amount of 70% by weight of the raw material (IrmaIkaIzzatul, 2014). Rice contains a lot of carbohydrates because rice is the main source of carbohydrates in most Indonesians' dietary habits. Additionally, carbohydrates are the primary source of energy for humans. Carbohydrates can provide 60-70% of the energy requirements of the body (Winarno, 2004).

The results of analog rice fat analysis at various compositions ranged from 0.26% to 1.36%. Sample 1 has the lowest fat content of 0.26%, while sample 2 has the highest fat content of 1.36%. When compared to the fat content of standard rice, analog rice has a lower fat content. In the research conducted by Sumardiono et al. (2021), analog rice was produced with a fat content of 1.35–2.55%. The low fat content can prevent analog rice from becoming rancid and sour and can extend its shelf life (Rasyid et al., 2017).

The results of the analog rice protein analysis produced ranged from 5.72% to 7.86%. This result is not much different from the standard protein content of analog rice, which is equal to 7.39%. The protein content of analog rice can exceed the protein content of paddy rice because it is made from a mixture of koro pedang flour, which has a fairly high protein content of 24.42%. Protein is a source of amino acids containing the elements C, H, O, and N. The main function of protein is to form new tissues and maintain existing ones. Protein also functions as a regulatory substance for the body's metabolic processes. Foods with high protein levels are thought to stimulate insulin secretion so that glucose in the blood is not excessive and under control (Afifah et al., 2020). Therefore, foods with high protein content have a lower glycemic index value than foods with low protein content (Rimbawan & Nurbayani, 2013).

The water content of analog rice from cassava, gembili, koro pedang, and corn flour ranges from 5.01% to 7.88%. Water content is one important parameter that is very influential in the rice storage process. Rice that has a high water content will be easily damaged and experience a decrease in quality. Based on SNI, the maximum water content of food ingredients is ≤14%. A water content of ≤14% will prevent mold growth, which often lives on cereals and grains. Rice with a water content of more than 14% will cause the rice to be easily damaged and rotten (Noviasari et al., 2013). This means that the water content of analog rice in this study has met the SNI requirements for long shelf life.

The results of the analysis of rice ash content in cassava, gembili, koro pedang, and corn flour in various compositions ranged from 1.94% to 3.41%. The highest ash content was found in sample 4, which was 3.41%, while the lowest was in sample 2, which was 1.94%. The ash content of a material indicates the number of minerals it contains (Winarno, 2004). Based on research on analog rice from white sweet potatoes with the addition of pumpkin flour conducted by (Pramono et al., 2021), the results showed an ash content of 0.61% to 0.64%. These showed that analog rice from cassava, gembili, koro pedang, and corn flour has a higher ash content. Therefore, it can be concluded that sample 5 is analog rice with the best formulation, with the highest protein content of 7.39% and the lowest carbohydrate content of 81.34%.

The Effect of Extrusion Temperature on the Nutritional Content of Analog Rice

Table 4 shows the proximate composition of the analog rice at various extrusion temperature.

Table 4. The nutritional content of analog rice at various extrusion temperatures

Parameter	Temperature (°C)				
	65	70	75	80	85
Water	9.68	8.74	7.90	7.84	7.40
Ash	1.46	1.56	1.21	1.74	1.36
Protein	14.2	14.2	14.1	13.9	13.6
Fat	2.79	1.88	1.19	1.49	2.50
Carbohydrate	70.6	71.2	73.3	71.0	71.9

The ash content shows the amount of mineral residue remaining after the combustion process at high temperatures (Winarno, 2004). The ash content of analog rice ranged from 1.21% to 1.74%, indicating that increasing the extrusion temperature did not result in significant changes in the ash content of analog rice. According to Lumba et al. (2012), research on analog rice from daluga tubers showed an ash content of 2.4% to 2.6%, which is not significantly different from the analog rice results of this study.

The carbohydrate content of analog rice varies depending on temperature, ranging from 71.60% to 74.3%. As a result, increasing the extrusion temperature affects the carbohydrate content of analog rice; that is, the higher the extrusion temperature, the higher the carbohydrate content of analog rice. Temperature increases the rate of gelatinization in the process. Amylopectin molecule chains are easily broken. The molecular weight of amylose and amylopectin can be reduced. The smaller the amylopectin molecule, the greater the decrease in molecular weight (Haryanti et al., 2014; Sukamto et al., 2019). Thus, increasing the temperature during the extrusion process can increase the carbohydrate content of analog rice.

The protein content of analog rice ranges from 13.6 to 14.2%. The protein content of analog rice decreases as the temperature rises. Extrusion cooking can result in protein denaturation. Protein is made up of amino acids, which are the primary components of protein. In proteins, amino acids form primary bonds, while secondary bonds hold other molecules together. Secondary bonds are broken during the mechanical extrusion process, and primary bonds are broken when heat is added. Protein denaturation is caused by the breakdown of primary and secondary bonds in proteins, resulting in a decrease in protein content in analog rice (Omohimi et al., 2013). However, when compared to paddy rice, the protein content of analog rice is still higher, at 3.35%.

The fat content of analog rice varies with temperature, ranging from 1.19% to 2.79%. The fat content of analog rice is unstable as a result of the increase in extrusion temperature affecting it. The instability of analog rice fat analysis results is possible because during the extrusion process, the carbohydrate and fat content in the raw material can form amylose-lipid complexes, and free fatty acids and monoglycerides can form complex bonds when compared to triglycerides (Pudjihastuti et al., 2021). According to the results of the analog rice proximate test on the effect of extrusion temperature at 75˚C is the optimum temperature for the extrusion process. At this temperature, analog rice has the highest protein content, which is similar to paddy rice.

Physical Properties of Analog Rice

Bulk density analysis on analog rice produced from cassava flour, corn flour, gembili flour, and koro pedang flour results in a bulk density value of 0.46 g/mL. This bulk density value is less than paddy rice's bulk density of 0.827 g/mL. Based on these results, it is possible to conclude that the analog rice produced in this study weighs less than paddy rice of the same volume. This indicates that analog rice has a higher porosity. The nutritional content of the grain, as well as the manufacturing process, which includes drying, influence the porosity of analog rice. The drying process causes analog rice to lose water, which makes it more porous (Widara & Budijanto, 2012). The American government's specifications in the fields of military and defense set standards for bulk density of rice ranging from 0.40 to 0.42 g/mL. The bulk density of rice, which is lower than 0.36 g/mL, will produce a soft product such as rice porridge during cooking (Carlson et al., 1976). Based on these data, it can be concluded that the analog rice from the composite of cassava flour, gembili flour, corn flour, and koro pedang flour produced in this study is included in the criteria according to Carlson et al. (1976).

Water absorption is a material's ability to absorb or bind water. The characteristics of a material affect its water absorption capacity. The results of the analysis show that testing the water absorption capacity of analog rice from a composite of cassava flour, gembili flour, corn flour, and koro pedang flour obtained the highest water absorption capacity in sample 5 of 60.52% and the lowest in sample 1 of 30.68%. In study conducted by Franciska et al. (2015) regarding the characteristic test for making analog rice made from cassava flour enriched with tuna fish protein obtained a water absorption capacity of 206.6-267.9%. Another study conducted by Dinarki et al. (2014) regarding the physical characteristic test of analog rice made from taro flour and cassava flour obtained water absorption ranges of 58.22–94.25%. The water absorption of Indonesian rice averages 2 to 2.5 times. The greater the water absorption value, the more water is needed to cook rice (Franciska et al., 2015). Analog rice from a composite of cassava flour, gembili flour, corn flour, and koro pedang flour has a lower absorption capacity than organic rice in Indonesia, namely 250-295% (Basito, 2010; Putri et al., 2021). So it can be concluded that the resulting analog rice has a low level of water absorption and requires less water to cook rice.

Cooking time indicates how long it takes to cook rice until it is tender. According to the results, the cooking time for analog rice made from cassava, gembili, koro pedang, and corn flour is 46 minutes. Rice type IR36 only takes 30 minutes to cook. The time needed for analog rice is longer than paddy rice because it has higher protein content. This higher protein content comes from the koro pedang flour, which includes legumes that are rich in protein. High protein levels have an impact on the quality of analog rice cooking time. This affects the gelatinization process because more heat energy is used for protein denaturation (Rahman, 2014). So the higher the protein, the longer the optimum cooking time.

Consumer Acceptances Level

The organoleptic test of analog rice shows consumer acceptance of analog rice. Figure 1 shows the aroma parameter has an average value of 3.15. Aroma has the function of increasing the desire to consume a food ingredient. Aroma is an aspect that is no less important for food requirements. Foodstuffs that have an overpowering aroma tend to be less attractive to the public for consumption, especially staple foods such as rice. Analog rice made from composite flour has a nutty aroma from koro pedang flour because the best formulation sample contains the highest amount of koro pedang flour.

The texture parameter has an average value of 3.20. The texture is one of the aspects that influences consumer consumption of the resulting analog rice. The softer rice texture is preferred because it is more similar to the texture of rice in general. The texture of analog rice, which can resemble the texture of paddy rice, has the potential to be used as a food substitute for rice. The texture of analog rice is strongly influenced by the fineness of the ingredients (cassava flour, gembili flour, koro pedang flour, and corn flour). This relates to the physical processes that occur during its production. The texture of the composite flour analog rice tends to have a rather fine texture, caused by the fine ingredients of koro pedang and gembili flour.

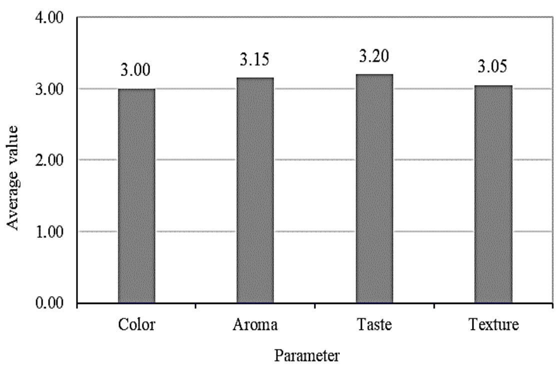

Figure 1. Results of the analysis of organoleptic tests

The color parameter in the organoleptic test has an average value of 3.00. Color is one of the aspects that influence product acceptance by consumers.

Consumers tend to like rice that has a color like paddy rice (clear white) or brown rice. The color produced from the composite flour analog rice is a brownish-yellow color that arises from the color of corn flour and koro pedang flour.

The analog rice taste parameter has an average value of 3.05. Indonesian people who are accustomed to consuming rice will prefer substitutes for rice that taste similar to rice in general (Wahjuningsih & Susanti, 2018). Therefore, if the analog rice produced has a different taste from rice in general, it is likely that it will be difficult for the public to accept or consume. Analog rice from composite flour in this study tends to have a savory taste obtained from koro pedang flour.

CONCLUSION

Determination of the best formulation of the analog rice based on nutritional composition was sample 5 with a formulation of 60% cassava flour, 5% gembili flour, 10% corn flour, and 25% koro pedang flour. The results of the chemical analysis showed that the best analog rice in this study contained 81.34% carbohydrates, 7.86% protein, 0.54% fat, 7.88% water, and 2.30% ash. Based on the proximate analysis of the effect of temperature, a temperature of 75˚C is obtained as the optimum temperature for the extrusion process. The results of the physical analysis showed that the best analog rice had a bulk density of 0.46 g/mL, a water absorption of 60.52%, and a cooking time of 46 minutes. In this sample, analog rice has a texture, aroma, and appearance that resembles rice in general, although analog rice made from composite flour tends to have a savory taste that arises from koro pedang.

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