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CHARACTERIZATION OF FLAKES MADE FROM BANGLE (*Zingiber cassumunar* Roxb.) RHIZOME AND RICE BRAN AS ANTIHYPERLIPIDEMIC FUNCTIONAL FOOD

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ABSTRACT

Bangle rhizome and white rice bran have antihyperlipidemic and antioxidant activities and have high potential to be used as active ingredients for antihyperlipidemic functional foods, such as flakes. This study aimed to determine the formulation of flakes made from bangle rhizome flour (BR), white rice bran flour (WRB), and sweet corn flour (SC) and to obtain the best formula based on hedonic values and chemical characteristics. Flakes were formulated into four formulas determined for the amount of BR and WRB (BR 0 g, WRB 80 g [F0]; BR 2.5 g, WRB 77.5 g [F1]; BR 5 g, WRB 75 g [F2]; BR 7.5 g, WRB 72.5 g [F3]). The flakes were evaluated through a hedonic test using a five-point hedonic scale and proximate test (moisture, ash, fat, protein, carbohydrate, and crude fiber content). The results of the proximate test were reviewed according to the criteria for antihyperlipidemic functional food and the quality requirements of SNI 2886:2015 (Extruded Snacks). Hedonic and proximate test data were statistically analyzed using Analysis of Variance (ANOVA). F3 was the finest flake, containing 4.00% water, 6.08% ash, 16.92% fat, 12.68% protein, 60.32% total carbohydrates, and 11.11% crude fiber. Flakes F3 were organoleptically acceptable to the hedonic test panelists, with a total mean hedonic value of 3.72.
Keywords: Bangle, flakes, hedonic determination, proximate determination, rice bran

INTRODUCTION

Hyperlipidemia is an elevation of one or more of cholesterol, cholesterol esters, phospolipids, or triglycerides (P et al., 2021). Based on the study by Lee et al. (2021), Indonesia is one of the three countries with a high prevalence of high LDL cholesterol (Australia 33.2%, Indonesia 41.9%, and the Philippines 47.5%) and has a high prevalence of total cholesterol and triglycerides, at 35.9% and 24.9%, respectively. Hyperlipidemia is a risk factor for cardiovascular disease.

Bangle rhizome has been used empirically as a traditional medicinal ingredient by the Indonesian people and scientifically proven to have antihyperlipidemic, antioxidant, and other pharmacological activities (Han et al., 2021; Hasimun et al., 2018). Ethanol macerate 96% of the rhizomes of this plant has an inhibitory effect on endogenous cholesterol biosynthesis and increases antioxidant activity (Hasimun et al., 2018; Sari et al., 2020). The inhibitory activity of the macerate is similar to the mechanism of action of statin drugs in reducing blood cholesterol levels.

In addition to bangle rhizomes, white rice bran has also been proven to have antihyperlipidemic activity. White rice bran can reduce LDL cholesterol and triglyceride levels in the blood, as well as increase antioxidant capacity in hyperlipidemia subjects (Bumrungpert et al., 2019; Mahdi et al., 2020). Optimized rice bran ethanol-water extract in the study by Son et al. (2023) significantly suppresses lipase activity, high-fat diet-induced weight gain, hyperlipidemia, and hepatic steatosis in mouse model (in vitro and in vivo), as well as inhibits lipid accumulation in HepG2 liver cells. White rice bran is rarely used as a functional food. This rice by-product is generally used as animal feed. With its potential, white rice bran has the criteria to be formulated into antihyperlipidemic functional foods, along with bangle rhizome.

Objective diet such as functional foods intake is one of the nonpharmacological therapies for hyperlipidemia. Antihyperlipidemic functional food products can be defined as products that have a high fiber content with low saturated fat and have added ingredients with antihyperlipidemic and/or antioxidant activity. Mahfudh et al. (2023) developed functional food product in the form of biscuits made from bangle rhizome and purple sweet potato which have proven its antihyperlipidemic activity. In the current study, food products in the form of flakes were formulated using ingredients with antihyperlipidemic activity, such as bangle rhizome and white rice bran.

Putro (2019) has successfully made flakes from white rice bran flour and corn starch. Flakes are a practical and common breakfast dish. In general, making flakes uses ingredients containing complex carbohydrates and high protein (Ratnawati & Afifah, 2017). White rice bran and sweet corn were intended to be the sources of complex carbohydrates and proteins from flakes in the current research. Based on the success of previous research regarding the use of bangle rhizomes in functional foods, the current study aims to process bangle rhizomes, white rice bran, and sweet corn into antihyperlipidemic food in the form of cereal flakes.

RESEARCH METHOD

Tools and Materials

The materials used to make the flakes were bangle rhizomes (*Zingiber cassumunar* Roxb.). and sweet corn (*Zea mays* L.) from Beringharjo Market Yogyakarta and white rice bran (*Oryza sativa* L.) flour (Bekatul Prima Sehat).

Methods

1. Preparation of Bangle Rhizome Flour and Sweet Corn Flour

The first step in making bangle rhizome flour is rinsing the bangle rhizome with clean water. Bangle rhizomes were sliced and dried in a cabinet dryer at 50°C for 3 × 24 hours. The resulting simplicia was then crushed into flour using a grinder. Bangle rhizome flour was sifted using an 80 mesh sieve. The yield was then calculated.

Sweet corn flour was prepared using a dry method. The first step was to weigh the sweet corn kernels and then dry them in an oven at 60°C for 5 × 24 hours, followed by weighing the dry kernels. The moisture content of the dry sweet corn kernels was ± 17%. After that, grinding was carried out to separate the epidermis, organ, and endosperm (Ambarsari et al., 2015). The milled results were weighed, and the yield was calculated. Coarse corn flour was sifted using a 60 mesh sieve. Based on SNI 3727:2020 (Tepung Jagung), the maximum moisture content of corn flour is 14%.

2. Preparation of the Flakes

Flakes were made into four formulas (F0, F1, F2, and F3) based on differences in the ratio of bangle rhizome flour (BR) and white rice bran flour (WRB) with the same amount of sweet corn flour (SC) for each formula. The four formulas, as presented in **Table I**, are settled from researches by Mahfudh et al. (2023) and Putro (2019), with modifications.

Table I. Flakes Formulas Containing Bangle Rhizome and Rice Bran

Materials	Flakes Formula (g)			
	F0	F1	F2	F3
Bangle rhizome flour (BR)	0	2.5	5	7.5
White rice bran flour (WRB)	80	77.5	75	72.5
Sweet corn flour (SC)	88	88	88	88
Margarine	33	33	33	33
Egg white	33	33	33	33
Stevia sweetener	10	10	10	10
Salt	4	4	4	4
Baking flour	1.5	1.5	1.5	1.5
Vanilla	0.5	0.5	0.5	0.5
Total amount	250	250	250	250

This process consists of three stages: batter making, cooking stage I (cooking with a gas stove), and cooking stage II (cooking with an oven). The first step of batter making was weighing all the ingredients based on the four formulas, followed by mixing WRB, SC, and baking flour together with the amount of each formula until homogeneous. Mineral water that had been heated to 80°C was slowly added to the mixture until its consistency was thin (mixture A). Mixture A was maintained for 15—30 minutes. Meanwhile, the egg whites and stevia sweetener were placed into another bowl and stirred using a mixer until the egg whites expanded, which was marked by the color changing to white and a dense texture (mixture B). Within a maximum of 30 min, mixture A was mixed into mixture B until homogeneous using a low-speed mixer. BR, salt, and vanilla were added, followed by the slow addition of diluted margarine using a low-speed mixer.

The batter was poured onto teflon, covered with a lid, and maintained for a few minutes. The batter was flipped when it was dense enough, covered, and maintained for a few more minutes. The solid batter was set aside and quickly cut into triangles. Immediately after cutting, the half-finished flakes were placed on an aluminum tray and placed in an oven at 100°C for 75 minutes. Once finished, the flakes were cooled to room temperature and packaged along with silica gel.

3. Hedonic Test

The hedonic test in this research was used a scoring method on thirty untrained panelists (SNI SNI 01-2346-2006; SNI ISO 11136-2014). The panelists were individuals who met the inclusion criteria, including those aged 18—30 years, healthy, not color blind, not hungry, not smoking, not pregnant or breastfeeding, willing to complete the procedure to the end, and domiciled in DI Yogyakarta. The panelist exclusion criteria were allergies to one or more components of the product and inability to attend the test location. The panelists provided hedonic values to the flakes samples based on a five-point hedonic test scale (5 = strongly liked; 4 = liked; 3 = indifferent; 2 = disliked; 1 = strongly disliked).

4. Proximate Test

The proximate test of the flakes was carried out with several determinations, including moisture, ash, fat, protein, carbohydrate, and crude fiber contents. The moisture content was determined using a moisture content analyzer at 105°C for 30 minutes. The ash content was determined by gravimetric method (AOAC, 2005). The fat content was determined by soxhlet method with hexane (AOAC, 2005). The protein content was determined by kjeldahl method (AOAC, 2005). The carbohydrate content was determined by total carbohydrates by difference method (SNI 4270:2021). The crude fiber content was determined by extraction which previously separated using acid dan base solution (AOAC, 2005).

Data Analysis

The data from the hedonic and proximate tests were analyzed for the significance and the total mean of each formula using Analysis of Variance (ANOVA), followed by Duncan's test if the results were significant ($p < 0.05$). Both tests were performed using IBM SPSS Statistics. Other than that, the data from proximate tests had been compared with quality requirements of flakes from SNI 2886:2015 (Extruded Snacks).

RESULTS AND DISCUSSION

1. Organoleptic of the Flakes

Figure 1. Flakes Based on Four Formulas

The four flakes made from bangle rhizome flour, white rice bran flour, and sweet corn flour are shown in **Figure 1**. The samples were observed organoleptically based on color, aroma, texture, and taste parameters. The results of these organoleptic observations are presented in **Table II**.

Table II. Organoleptic Observation Result of the Flakes Containing Bangle Rhizome and Rice Bran

Organoleptic Parameters	Observation Result			
	F0	**F1**	**F2**	**F3**
Color	Brownish yellow	Brownish yellow	Brownish yellow	Brownish yellow
Aroma	Typical of vanilla and WRB	Typical vanilla and WRB, vaguely BR	Typical vanilla and WRB, quite strong BR	Typical vanilla and WRB, strong BR
Texture	Crispy	Crispy	Crispy	Crispy
Taste	Sweet and tasty	Sweet and tasty, a faint BR aftertaste	Sweet and tasty, a typical quite strong BR aftertaste	Sweet and tasty, a strong BR aftertaste

The color similarity between flakes F0, which does not contain BR, and the three flakes containing BR can be caused by the color of the materials that have the same basic color. BR has a turmeric yellow color affected by its high content of curcumin (Han et al., 2021). Sweet corn contains carotene and xanthophyll pigments (Siyuan et al., 2018). Carotene produces an orange color in corn kernels, whereas xanthophyll produces a yellow color. White rice bran has a cream color. Therefore, the mixture of these three materials causes the flakes to be yellow-brown and does not have a dominant color difference. Furthermore, the color similarity of the four flakes was caused by the similar amounts of BR-WRB-SC content in each formula. However, some parts of the flakes in one formula were browner than others due to uneven teflon temperatures from cooking using a low-heat stove. The brown color of the flakes was caused by the protein content. The higher the protein content, the darker the color of the flakes produced due to the Maillard reaction, namely the interaction between reducing sugar and melanoidin (Ratnawati & Afifah, 2017).

The four flakes did not have significantly different odors. The aroma of Flake F0 was obviously different from those of the other three flakes, which contained BR. Increasing the BR content in flakes F1, F2, and F3 intensified the aroma of the bangle rhizomes. Furthermore, the four flakes have a distinctive aroma of vanilla and WRB. However, flakes F2 and F3 had a stronger BR aroma than vanilla and WRB because of the dominant content of essential oils in the bangle rhizome. Bangle rhizome essential oil contains several compounds such as monoterpenoids, sesquiterpenoids, and phenylbutanoids (Han et al., 2021). The aroma that comes from a product is caused by the presence of volatile compounds that are slightly soluble in water and fat (Sari et al., 2020).

The four flakes had a similar texture, so the addition of BR in the amounts of F1, F2, and F3 did not significantly influence the texture of the flakes. The crispness of flakes is influenced by water and sugar content (Mahfudh et al., 2023). Sugar recrystallization can increase flake hardness. The level of hardness is related to the protein content in the flakes (Rakhmawati et al., 2014). An increase in flakes hardness is equivalent to a decrease in their crispness (Ratnawati & Afifah, 2017). The interaction between protein and water reduces the amount of water, thereby thickening the batter. Furthermore, the starch in WRB and SC influences the viscosity of the batter. SC and WRB contain more amylopectin than amylose does. The ratio between amylose and amylopectin affects the ability of the starch in the batter to thicken and form a gel (Rahman, 2018). Amylopectin has a longer branched chain structure than amylose, which reduces the tendency of starch to form gels. The higher the amylopectin content, the more difficult it is for the gel to form. Amylopectin also absorbs water for a longer duration than amylose. In addition, amylopectin is more difficult to get out of granules than amylose (Rahman, 2018). This causes starch with a higher amylopectin content to exhibit a higher gelatinization temperature. Therefore, to obtain a crispy flake structure, SC and WRB in the batter must first be dissolved using hot water. The gelatinization temperature of corn starch is 62—74°C (Rahman, 2018).

The dominant sweet and tasty flavor of the four flakes can be greatly influenced by the composition of sugar, salt, and margarine. The increase in BR levels in F1, F2, and F3 affected the taste of the flakes. The addition of 2.5 g of BR increased the intensity of the bangle rhizome taste, which also appeared as a bitter taste at the end of consumption. In addition, the WRB taste was also appeared in the four flakes, especially in the F0 flakes. However, the SC taste was not prominent in any of the four flakes. This could be caused by the composition of SC and WRB which are not much different. Therefore, the WRB taste is more dominant than the SC taste.

2. Hedonic Test

The mean hedonic test data are presented in **Table III**. Based on one-way ANOVA, the taste parameters when consumed without milk and the taste when consumed with milk were significantly different ($p < 0.05$) for each formula. However, no significant differences were observed in color, aroma, texture, and overall parameters.

Table III. Mean Hedonic Value of the Flakes Containing Bangle Rhizome and Rice Bran

Hedonic Parameters	Mean Hedonic Value				P
	F0	F1	F2	F3	
Color	4.00	4.20*	3.93	3.90	0.490
Aroma	4.06	4.16	3.93	4.20*	0.623
Texture	4.23*	4.03	3.93	4.16	0.566
Taste when consumed without milk	4.03	4.10*	3.63	3.10	0.000#
Taste when consumed with milk	4.13*	4.06	3.66	3.40	0.005#
Overall	4.00	4.10*	3.86	3.60	0.076
Total Mean	4.07	4.11*	3.82	3.72	-

Notes:
(*) = highest hedonic value.
(#) = significant differences between the test parameters in each formula ($p < 0.05$).
The five-point hedonic scale included 5 (strongly liked), 4 (liked), 3 (indifferent), 2 (disliked), and 1 (strongly disliked).

There was no significant difference in the color preferences of the four flakes (0.490 > 0.05). However, the color of flakes F1 was the most liked color on the mean hedonic test results, while F3 was the least liked. Therefore, F1 was the flake with the best color according to the panelists. The BR concentration in the flakes did not cause visible color differences in organoleptic observations. However, the difference in the level of liking for the color of the flakes may have been influenced by the uneven color of each of the four flakes. This is caused by cooking using a gas stove, where the temperature is uneven, resulting in some flakes having a browner color.

Based on the analysis of the hedonic test results using one-way ANOVA, there was no significant difference in the aroma liking of the four flakes (0.623 > 0.05). However, F3 was the flakes with the most liked aroma on the mean hedonic test results, while F2 was the least liked. This level of preference was most likely influenced by the BR content of the flakes. The essential oils in BR add a favorable aroma, so F3 was preferred over the other flakes. Meanwhile, F2, which had the lowest level of liking, may also be influenced by the cooking stage on the stove. Uneven hot temperatures caused the surface of the flakes to have different doneness, so some parts of the flakes were browner than other parts, especially after they were cooked in a 100°C oven. This brown part has a burnt aroma and less of the typical WRB and BR aroma.

Based on the analysis of the hedonic test results using one-way ANOVA, the taste liking of flakes when consumed without milk was significantly different (0.000 < 0.05). Since the ANOVA test results showed significant differences, the analysis was continued with the Duncan test. The Duncan test results showed that flakes F0, F1, and F2 did not have significant differences between each other, while F3 was significantly different from the other flakes. The most liked flakes was F1, while the least liked was F3. The high BR content in F3 flakes imparts a strong and distinctive BR taste. Bangle rhizome has a spicy taste causing its simplicia flour is not much different so that affect the taste of the flakes. This level of liking is similar to the results of hedonic tests on biscuits made from bangle rhizome and purple sweet potato (Mahfudh et al., 2023). The higher the BR content, the lower the preference for the taste of the flakes.

The results of one-way ANOVA showed no significant difference in the texture liking of the four flakes (0.566 > 0.05). This result is consistent with the results of the organoleptic observations. However, F0 had the highest liking for texture; thus, F0 had the best texture. Flakes F0 contain the highest WRB, indicating that WRB has a dominant influence on the level of preference for the flakes texture. In addition, the texture of flakes can be influenced by their protein, water, sugar, and starch content.

Based on one-way ANOVA, the liking for the taste of flakes with plain UHT milk was significantly different between the formulas (0.005 < 0.05). Therefore, the analysis was continued using the Duncan test. The Duncan test showed that the preference for the taste of F0 with milk was not significantly different from that of F1, F1 was not significantly different from F2, and F2 was not significantly different from F3. However, significant differences were found between flakes F0-F2 and F1-F3. On average, F0 was the most preferred flakes. These results were influenced by milk. The essential oils contained in the flakes can transfer into the milk. This caused the addition of milk to further enhance the distinctive taste of BR, which ended up being less acceptable on the tongue.

Analysis of the hedonic test results using one-way ANOVA showed that the overall liking for the flakes was not significantly different among the formulas (0.076 < 0.05). The overall value was based on the panelists' assessment of their liking of the flakes. Hence, based on the six hedonic parameters (color, aroma, texture, taste when consumed without milk, taste when consumed with milk, and overall), F1 was the flake with the highest hedonic value, and was the most liked by the hedonic test panelists. Meanwhile, F3 with the lowest mean total hedonic value, was the least liked flakes. However, all the mean total hedonic values of the flakes were greater than 3 on the five-point hedonic scale of the hedonic test. Therefore, the four flakes were accepted by the hedonic test panelists based on their hedonic criteria.

3. Proximate Test

The chemical content of the flakes was analyzed through proximate tests, including moisture, ash, fat, protein, carbohydrate, and crude fiber content. The data from the test are in wet basis units; therefore, they need to be converted to dry basis units for statistical analysis. The dry base test results are presented in **Table IV**.

Table IV. Proximate Test Result of the Flakes Containing Bangle Rhizome and Rice Bran

Proximate Parameters	Test Result (% dry basis)				SNI	P
	F0	F1	F2	F3		
Moisture content	3.95 ± 0.02*	0.000#	4.74 ± 0.04	4.00 ± 0.12*	4.00	0.000#
Ash content	5.55 ± 0.05	0.000#	5.95 ± 0.04	6.08 ± 0.03	-	0.000#
Fat content	17.12 ± 0.08*	0.376	16.94 ± 0.12*	16.92 ± 0.16*	30	0.376
Protein content	12.87 ± 0.04	0.000#	12.62 ± 0.02	12.68 ± 0.02	-	0.000#
Carbohydrate content	60.51 ± 0.06	0.000#	59.74 ± 0.10	60.32 ± 0.07	-	0.000#
Crude fiber content	7.98 ± 0.09	0.000#	10.74 ± 0.02	11.11 ± 0.06	-	0.000#

Notes:
(*) = meet the quality requirements of SNI 2886:2015 (Extruded Snacks).
(#) = significant difference between the test parameters in each formula ($p < 0.05$).

The moisture content of flakes can affect their texture, taste, and shelf life. Water can dissolve components such as salt, water-soluble vitamins, and minerals. (Basuki et al., 2019). Therefore, the moisture content can influence other proximate parameters (ash, fat, protein, carbohydrate, and crude fiber content). F3 had the lowest moisture content but the highest ash, protein, carbohydrate, and crude fiber content. The moisture content of the four flakes meets the quality standards of SNI 2886:2015 (Extruded Snacks), namely a maximum of 4%. The one-way ANOVA test showed a significant difference in the moisture content of the four flakes formulas (0.000 < 0.05). The Duncan test results show that F0 and F3 were significantly different from F1 and F2. Moreover, research on flakes formulations made from white rice bran flour and corn starch by Putro (2019) produced flakes with a moisture content of 2.46% (formula A1B3). Flakes by Putro (2019) were steamed for 15 minutes at 100°C then cooked in an oven at 160°C for 10 minutes, while the flakes in the current study were cooked using a frying pan on a low heat stove and then baked again in an oven at 100°C for 75 minutes. Therefore, the cooking temperature affects the moisture content of the flakes. The moisture content of the ingredients used to make the flakes and the storage period of the flakes in the packaging can also affect the moisture content of the flakes because of their hygroscopic nature.

The ash content of the flakes indicates the amount of inorganic compounds they contain. In general, the inorganic components contained in a material are minerals such as potassium, calcium, sodium, magnesium, iron, and manganese (Rahman, 2018). The high levels of ash in the four flakes can be influenced by several factors. The use of water in the washing process of basic materials can reduce the availability of minerals in the material because water-soluble minerals will dissolve during the washing process (Rahman, 2018). In addition, water can bind with minerals, so high water levels will cause low mineral levels in the flakes. The ash content of the four flakes was significantly different (0.000 < 0.05). The Duncan test proved that each flake formula had the same significant differences. SNI 2886:2015 (Extruded Snacks) does not provide quality standards for the ash content in extruded snack foods. However, the ash content of flakes in the current study is higher than the ash content of biscuit made from bangle rhizome and purple sweet potato in the study by Mahfudh et al. (2023) which contained 3.00% ash (formula F3). In addition, the flake ash content in the current study increased with increasing BR concentration. This may be influenced by the inorganic compound content of BR.

The fat content of the four flakes was not significantly different (0.376 > 0.05). The fat content of flakes meets SNI 2886:2015 (Extruded Snacks), namely a maximum fat content of 30%. As the fat content of the flakes decreased in all formulas containing BR, the levels of other proximate parameters (ash, protein, carbohydrates, and crude fiber) increased. The decrease in fat content in F1 and F2 was inversely proportional to the decrease in moisture content. However, this relationship is not observed in F3 because the water and fat contents are directly proportional, namely, they are the lowest values of all formulas containing BR. This can be influenced by cooking using a gas stove, which causes the doneness of each flake in one formula to be uneven, thus affecting the moisture content of the flakes. Besides that, there is an influence of the amount of composition WRB on the fat content of the flakes. The higher the amount of WRB in the formula with the addition of BR, the higher the fat content of the flakes. According to Putro (2019), flakes made from white rice bran flour and corn starch (formula A1B3) contain 5.59% fat. This amount is three times lower than the flakes in the current study. This can be influenced by BR, WRB, SC, and margarine in the flakes. Meanwhile, biscuit made from bangle rhizome and purple sweet potato by Mahfudh et al. (2023) contains 18.30% fat, more than the flakes in the current study.

There is a significant difference in the protein content of the four flakes (0.000 < 0.05). The duncan test proves that F0 is significantly different from F1, F2, and F3. There is no quality standard regarding the protein content in SNI 2886:2015 (Extruded Snacks). However, the protein in F0 is slightly more than the other three formulas which contain BR. This is likely caused by the protein content in WRB. The increase in protein levels in flakes is directly proportional to the increase in carbohydrate levels. Moreover, the flakes by Putro (2019) had a protein content of 10.16% (formula A1B3) which is less than the flakes in the current study. The variance of corn flour used can affect the protein content of the flakes.

The carbohydrate content of the four flakes has a significant difference (0.000 < 0.05). Duncan test shows that flakes F0 and F3, F0 with F1 and F2, and F3 with F1 and F2 were significantly different. SNI 2886:2015 (Extruded Snacks) does not provide quality requirements regarding carbohydrate content. Flakes F0 contains the highest carbohydrate content which is 60.51%. This is likely due to the higher WRB composition, namely 88 g.

However, among the formulas that added by BR, F3 has the highest carbohydrate content (60.32%), so it is known that the combination of BR and WRB affects the carbohydrate levels in the flakes. In addition, the increase in carbohydrate levels in formulas containing BR is directly proportional to the ash, protein and crude fiber content. Moreover, in research by Mahfudh et al. (2023), bangle rhizome and purple sweet potato biscuit had a carbohydrate content of 66.16% (F3) which is greater than the flakes in the current study. The use of carbohydrate ingredients such as white rice bran, sweet corn, and purple sweet potato affects the carbohydrate content of the product produced. The carbohydrate content in this test shows the total carbohydrate group compounds in the flakes. These carbohydrates can be monosaccharides, disaccharides and polysaccharides (including crude fiber and dietary fiber). Monosaccharides and disaccharides have hygroscopic properties caused by polyhydroxyl groups which can hydrogen bond with water (Kusnandar, 2019).

The quality requirements for crude fiber content are not regulated in SNI 2886:2015 (Extruded Snacks). The increase of crude fiber content in flakes containing BR is directly proportional to the ash, protein and carbohydrate content. Meanwhile, the fat content is inversely proportional. The highest crude fiber content is in F3 which has the highest BR composition. Therefore, BR likely influences the crude fiber content in flakes. This is similar to research by Mahfudh et al. (2023). The highest levels of crude fiber in bangle rhizome and purple sweet potato biscuit is in the formula with the highest BR composition. Furthermore, the crude fiber content of the four flake formulas in this study is significantly different based on the one way ANOVA test (0.000 < 0.05). The duncan test shows that each flakes formula has the same significant difference.

The proximate content of flakes is one of the product evaluation parameters needed in antihyperlipidemic functional food making. The criteria for flakes based on SNI 2886:2015 (Extruded Snacks) is that it contains a maximum of 4% moisture and a maximum of 30% fat. Combination flakes of WRB and BR that meet these criteria is flakes F1 (0 g BR, 80 g WRB) and F3 (7.5 g BR, 72.5 WRB).

CONCLUSION

Bangle rhizome (*Zingiber cassumunar* Roxb.) flour and white rice bran (*Oryza sativa* L.) flour can be formulated into flakes. The four formulas (F0, F1, F2, F3) contain sweet corn (*Zea mays* L.) flour, margarine, egg white, stevia sugar, salt, baking flour, and vanilla. F3 (7.5 g BR, 72.5 g WRB) is the finest flakes formula based on hedonic and proximate tests. Flakes F3 contains 4.00% water, 6.08% ash, 16.92% fat, 12.68% protein, 60.32% total carbohydrates, and 11.11% crude fiber. The total mean hedonic value of F3 is 3.72 so that the flakes is accepted organoleptically by the hedonic test panelists. The physicochemical properties of these flakes still require further research so that the best material composition and methods can be determined. Moreover, further investigation regarding the potential antihyperlipidemic properties of flakes made from bangle rhizomes, white rice bran, and sweet corn is needed.

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