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Original article

Characteristics of Red Bean-Mocaf biscuits as alternative high-fiber low-sugar snacks

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Abstract. *Background and aim:* Biscuits are very popular in Indonesia, but the most common types in the market have low nutritional value. Meanwhile, red bean flour and Mocaf (Modified Cassava Flour) are rich in nutrients, especially fiber, and their combination is expected to form a biscuit product that is nutritious and highly liked. Therefore, this study aims to analyze the nutritional value, organoleptic quality, resistant starch and digestibility starch, as well as the shelf life of red bean and Mocaf biscuit. *Methods:* A total of four formulation of red bean flour to Mocaf ratio were compared, 44:0 (F1), 31:13 (F2), 22:22 (F3), and 13:31 (F4). *Results:* F2 was the best formulation which had protein (12.38%), dietary fiber (14.95%), and total sugar contents (4.09%) appropriate to the quality requirements of biscuits according to SNI and it shelf life was 31 days at a temperature of 25 ° C. *Conclusions:* The addition of Mocaf in the biscuits increased starch digestibility and resistant starch, thus formula without Mocaf had the highest resistant starch (2.07%) and the lowest starch digestibility (43.61%).

Key words: nutritional value, starch digestibility, shelf life, red beans, Mocaf

Introduction

The majority of foods often consumed by Indonesians tend to be high in sugar and low in fiber (1). Meanwhile, alternative snacks high in fiber and low in sugar are not widely available (2). High fat and sugar intake can reduce insulin sensitivity and raise blood sugar levels that can lead to degenerative diseases, particularly type 2 diabetic mellitus (T2DM) and obesity (3–5). Consuming fibre has various health advantages, including the prevention of obesity and T2DM (6).

Biscuits are widely consumed in Indonesia (7) revealed by the Indonesian Basic Health Research survey in 2013, where 13.4% of the population consumed more than once a day (8). The biscuit consumption per capita in 2018 was almost tripled compared to 2014 (9). Biscuits are typically high in fat and sugar while poor in fibre and protein contents (7,10,11). As a result, biscuit modifications with high fibre and low sugar were required to boost the nutritional value of the biscuit. Red bean flour and Mocaf are two local ingredients that have the ability to increase the value of biscuits (12,13).

Red bean flour is often used because it contain high contents of protein and fiber, low fat as well as glycemic index, and is also rich in micronutrients (14).

It is also widely available. The production of red beans in Indonesia reached 67,876 tonnes in 2018 (15). The processing of red beans into biscuits is expected to increase red bean consumption.

Mocaf is a product made from cassava flour by fermenting cassava cells, where the role of microbial enzymes is dominant during the fermentation. It is used because it has characteristics similar to wheat flour, but have higher complex carbohydrates and fiber content (10). Cassava and its derivatives are considered to have a low glycemic index which is recommended for people with diabetes (16). Furthermore, raw materials for Mocaf flour are readily available in Indonesia (17,18).

Biscuits can be formulated using special medical needs food (SMNF) requirements for diabetes (19). Foods are categorized as low in sugar when they do not contain monosaccharides or disaccharides above 5g/100g (20). Meanwhile, they are categorized as high in fiber as they contain at least 6 grams per 100 grams (20).

Based on this background, this study aims to analyze the nutritional value comprising sugar, dietary fiber, carbohydrates, protein, fat, ash, and water contents; organoleptic quality, starch digestibility, and shelf life of combined red bean and Mocaf biscuit. Organoleptic quality was determined using hedonic test. Meanwhile, the digestibility of starch was analyzed to determine the value of the glycemic index in a food product. The product's shelf life was determined based on the parameters of water and free fatty acid content.

Material and method

Biscuit formulation

Raw materials

Red bean flour (Keola) and mocaf (Lingkar Organik) were obtained by considering organic and safety claims through the Home Industry Food Certificate Number. Meanwhile, other raw materials such as cornstarch (Maizenaku®), Rice flour (Rose Brand®), Cinnamon (Kupu-Kupu®), Liquid Skimmed Milk (Greenfield®), Oil (Bimoli®) were obtained from supermarkets and department stores in Semarang city.

Biscuits formulation and production

The biscuits were prepared by mixing all the ingredients, starting with the dry ingredients (red bean flour, Mocaf flour, corn starch, rice flour, and cinnamon) then the wet ingredients (coconut oil, egg white, egg yolk, sorbitol, and skim milk) were added and the mixture was stirred until all components were well mixed. Afterward, the biscuit dough was molded and baked at a temperature of 150°C for 20 minutes. Table 1 showed the red bean and Mocaf formulation.

Table 1. Red Bean Flour biscuits and Mocaf formulation.

Biscuit Ingredients	F1 (44:0)	F2 (31:13)	F3 (22:22)	F4 (13:31)
Red Bean Flour (%)	44	31	22	13
Mocaf Flour (%)	0	13	22	31
Cornstarch (%)	5.9	5.9	5.9	5.9
Rice flour (%)	5.9	5.9	5.9	5.9
Cinnamon (%)	0.7	0.7	0.7	0.7
Liquid Skimmed Milk (%)	19.2	19.2	19.2	19.2
Egg White (%)	5.9	5.9	5.9	5.9
Egg Yolk (%)	8.8	8.8	8.8	8.8
Oil (%)	5.9	5.9	5.9	5.9
Sorbitol (%)	2.9	2.9	2.9	2.9

Nutritional content

The chemical analysis carried out included the water and ash content using gravimetry method, sugar content by the Nelson Somogyi, and protein by Kjeldahl method. Furthermore, the fat content analyzed by Soxhlet method, carbohydrate content by difference and total dietary fiber by enzymatic method (21).

Organoleptic quality

In total thirty panelists, undergraduate students of the Universitas Diponegoro, Nutrition Program participated in the organoleptic quality testing. The organoleptic quality was tested using a hedonic analysis for taste, color, aroma, and texture in five scales, namely 1 = Very dislike, 2 = Dislike, 3 = Slightly like, 4 = Like, and 5 = Very like (22). This study was registered with ethical clearance number 273/EC/KEPK/FK-UNDIP/VII/2022.

Starch content and digestibility

The starch content was determined with the Direct Acid Hydrolysis method (23), while the amylose content was assessed using the IRRI method (24). The amylopectin content was calculated from the difference between the starch and amylose content values, while the resistant starch content was determined using a combination of the AOAC method (25) and Direct Acid Hydrolysis (23). The starch digestibility was measured with the AOAC method (26).

The best formulation determination

Determination of the best formulation was obtained by multi-attribute decision using compensatory model, additive weighting technique (27). Starting with the parameter with the highest importance, this method assigns a weight to each variable on a scale of 0 to 1. Determine the effectiveness (Ne) value for each variable. For each retrieved variable, calculate the outcome value (Nh). The best formulation chosen was the one with the highest total Nh when all Nh variables were added together. Only the nutritional contents and organoleptic tests variables were used for the best formulation determination.

Shelf life

The shelf life was determined using the best formulation based on nutritional value and organoleptic quality, namely F2. The shelf life was performed using the Accelerated Shelf-Life Testing (ASLT) method at 25°C, 35°C, and 45°C with the Arrhenius model (28). Ten degrees increasement was chosen based on Q10 approach. Q10 is defined as the ratio of the reaction rate constant with a temperature interval of 10 ° C. This model can describe how fast the reaction proceeds when the product is stored at various temperatures (29).

The application of mathematical modelling can describe the effect of the storage temperature on the desired quality attributes (30). The major quality attributes affected during storage of biscuit are the moisture and free fatty acid. The orde 1 and 0 model was compared on the slope (k), intercept (constant), and correlation coefficient (R^2) values. Subsequently, the value of k for each storage temperature against the selected factors was determined. The value of k increases with increasing temperature (28). The daily degradation rate at a particular temperature were calculated using eq.1 (28).

$$k = k_0 . \, exp \; -\frac{E_\alpha}{RT} \quad \text{(eq.1)}$$

The red bean and Mocaf biscuit shelf life were estimated using the Arrhenius equation with order 0 (eq.2) and order 1 (eq.3) (28).

$$t = \frac{At - A0}{k} \quad \text{(eq.2)}$$

$$t = \frac{LnAt - LnA0}{k} \quad \text{(eq.3)}$$

Statistic analysis

The data normality was determined using Shapiro-Wilk. The effect of the red bean flour and Mocaf formulations in energy, water, ash, protein, fat, total fiber, water soluble fiber, insoluble fiber, carbohydrate, reducing sugar, sucrose was determined using One Way ANOVA with Duncan meanwhile total sugar, aroma, taste texture, and colour using Kruskal-Wallis with Mann-Whitney post hoc tests. The statistical analysis of amylose, amylopectin, starch, resistant starch, and starch digestibility was done using Two Way ANOVA with the Post Hoc test. SPSS was used to perform the statistical analyses.

Results

Nutritional content

Table 2 showed that the water content in all biscuit formulations was more than 5 %, which is exceeding the required by Indonesian National Standard (SNI) biscuit quality. The protein content in all biscuit formulations was more than 5% met the SNI biscuits quality. The ash contents of F3 and F4 complied with the SNI biscuits quality, while F1 and F2 did not exceed the maximum ash content of 1.5%. The biscuits met the requirements for high fiber (6%) and low sugar (5%) except for F1 because it had total sugar more than 5% (7.63 ± 2.62%).

Organoleptic quality

Based on the results of the color hedonic test, F1 had the highest average value (3.93 ± 0.90) and F4 had the lowest color preference (2.63 ± 0.928) (Table 3). The taste hedonic test showed that F3 had the highest mean value (3.10 ± 0.99) and F1 had the lowest taste preference (2.80 ± 0.925). Based on aroma parameters, F1 was the most preferred formula with an average of 3.63 ± 0.66 and F4 with an average of 3.10 ± 1.0 was the least preferred biscuit formulation. Meanwhile, the texture hedonic test showed that F3 had the highest value (2.77 ± 1.13) and F4 had the lowest preference (2.47 ± 0.97).

Based on the results of statistical tests, it can be concluded that there were no significant differences in the taste, aroma and texture of the biscuits, but there were significant differences in the color of the biscuits. The color indicator showed panelist liked biscuit with darker color.

Starch content

Red bean and Mocaf biscuit contained starch of 43.36-49.50%, their amylose contents were 8.14-13.28%, amylopectin contents were 34.90-36.24%, resistant starch contents were 0.97- 2.07%, and starch

Table 2. Red bean and Mocaf flour biscuits nutritional content. Numbers followed by different superscript letters (a, b, c, d) show a significant difference.

Nutrients	F1	F2	F3	F4	*p*	Standard
Energy (Cal/100g)	$281±1.8^a$	$296±6.1^b$	$329±3.5^c$	$341±15^d$	0.000*	-
Water content (%)	21.29±0.45	20.25±1.75	18.36±1.89	17.71±4.33	0.083	Max 5 (31)
Ash Content (%)	$2.30±0.070^d$	$1.88±0.07^c$	$1.52±0.07^b$	$1.14±0.08^a$	0.000*	Max 1,5 (32)
Proteins (%)	$14.69±0.28^d$	$12.38±0.22^c$	$9.73±0.49^b$	$7.40±0.24^a$	0.000*	Min 5 (31)
Fat (%)	$9.36±0.25^a$	$9.28±0.23^a$	$11.55±1.34^c$	$10.46±0.1^d$	0.000*	-
Total Dietary Fiber (%)	$17.64±0.52^d$	$14.95±0.51^c$	$11.33±0.55^b$	$7.56±0.13^a$	0.000*	Min 6 (33)
Soluble Dietary Fiber (%)	$0.87±0.06^d$	$0.62±0.06^c$	$0.40±0.03^b$	$0.31±0.04^a$	0.000*	-
Insoluble Dietary Fiber (%)	$16.77±0.51^d$	$14.33±0.54^c$	$10.94±0.58^b$	$7.25±0.12^a$	0.000*	-
Carbohydrates (%)	$34.73±0.55^a$	$41.27±1.4^b$	$47.50±3.12^c$	$55.73±4.0^d$	0.000*	-
Total Sugar (%)	$7.63±2.62^a$	$4.09±0.26^b$	$3.56±0.22^c$	$2.46±0.19^d$	0.000*	Max 5 (33)
Reducing Sugar (%)	$1.56±0.05^c$	$1.28±0.05^b$	$1.21±0.06^b$	$1.07±0.04^a$	0.000*	-
Sucrose (%)	$6.07±2.8^b$	$2.81±0.27^a$	$2.35±0.23^a$	$1.39±0.24^a$	0.000*	-

Table 3. Organoleptic test results of Red Bean and Mocaf Flour biscuits. Numbers followed by different superscript letters (a, b, c, d) show a significant difference.

Formula	Acceptance (Average ± Standard Deviation)			
	Colour	Taste	Aroma	Texture
F1	3.93±0.90^{a}	2.80±0.925	3.63±0.66	2.57±0.77
	(like)	(quite like)	(like)	(quite like)
F2	3.83±0.83^{a}	2.93±1.0	3.50±0.77	2.57±0.93
	(like)	(quite like)	(like)	(quite like)
F3	3.27±0.74^{b}	3.10±0.99	3.40±0.81	2.77±1.13
	(like)	(like)	(like)	(quite like)
F4	2.63±0.928^{c}	3.03±0.99	3.10±1.0	2.47±0.97
	(quite like)	(like)	(like)	(quite like)
p	0.000**	0.634**	0.091**	0.784**

Abbreviation: (**) Kruskal Wallis Test.

Table 4. Results of starch, amylose, amylopectin, resistant starch, and starch digestibility on red bean and Mocaf Flour biscuits. Numbers followed by different superscript letters (a, b, c, d) show a significant difference.

Formulation	Starch (%)	Amylose (%)	Amylopectin (%)	Amylose-Amylopectin Ratio	Resistant Starch (%)	Starch Digestibility (%)
F1	43.36±0.24^{a}	8.14±0.07^{d}	35.22±0.16^{a}	1:4.32	2.07±0.01^{a}	43.61±0.41^{a}
F2	45.78±0.15^{b}	10.87±0.05^{c}	34.90±0.10^{a}	1:3.21	1.36±0.02^{b}	50.38±0.16^{b}
F3	47.59±0.15^{c}	11.34±0.02^{b}	36.24±0.14^{b}	1:3.20	1.06±0.02^{c}	55.32±0.17^{c}
F4	49.50±0.41^{d}	13.28±0.05^{a}	36.22±0.38^{b}	1:2.73	0.97±0.02^{d}	54.33±0.23^{d}

digestibility range was 43.61-55.32%. The results of Table 4 showed that there were significant differences between the levels of starch, amylose, amylopectin, resistant starch, and starch digestibility in the four formulations of red bean and Mocaf biscuit.

Best formulation

Based on calculations using multi-attribute decision using compensatory model, additive weighting technique, on Table 5, the highest total Productivity Value (NP) shows F2 with the addition of 31% red bean flour and 13% Mocaf as the best formulation results.

Shelf life

Water content

The water contents of red bean and Mocaf biscuit for 30 days were shown in Figure 1. The results indicated that higher drying temperature lowered

Table 5. Calculation results for determining the best formulation.

Formulation/ Productivity Value (NP)*	F1	F2	F3	F4
Texture	0.01	0.01	0.04	0.00
Taste	0.00	0.01	0.04	0.03
Color	0.04	0.04	0.02	0.00
Aroma	0.04	0.03	0.02	0.00
Water content	0.00	0.02	0.05	0.06
Ash content	0.05	0.03	0.02	0.00
Protein content	0.05	0.04	0.02	0.00
Fat content	0.05	0.05	0.00	0.02
Insoluble dietary Fiber content	0.09	0.06	0.03	0.00
Soluble Dietary Fiber content	0.09	0.05	0.01	0.00
Total Dietary Fiber Content	0.09	0.06	0.03	0.00
Carbohydrate	0.05	0.04	0.02	0.00
Energy	0.07	0.05	0.01	0.00
Total Sugar	0.00	0.06	0.07	0.09
Sucrose content	0.00	0.05	0.06	0.09
Reducing Sugar Level	0.00	0.06	0.07	0.09
Total	0.63	**0.67**	0.53	0.38

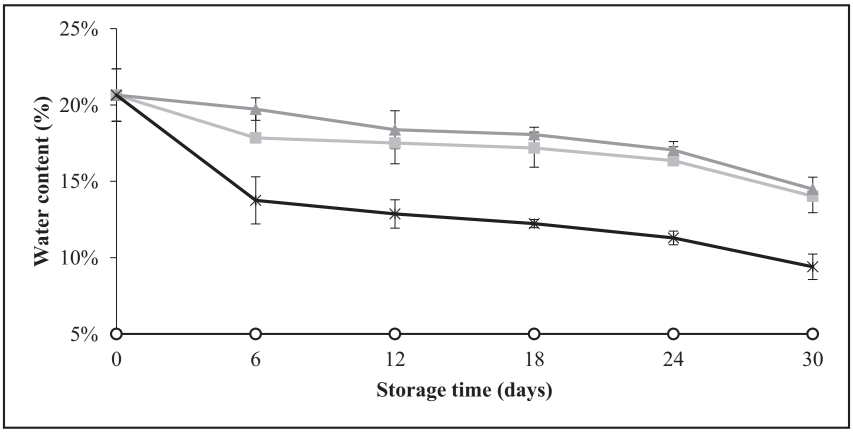

Figure 1. Graph of the decline in biscuit quality relationship on water content parameters. Abbreviations: Storage at 25ºC (■); storage at 35ºC (▲); storage at 45ºC (×); critical limit of water content based on Indonesian National Standard (○); The error bar represents the standard deviation (SD); n = 9 (3 replicates of experiment x 3 replicates of analysis).

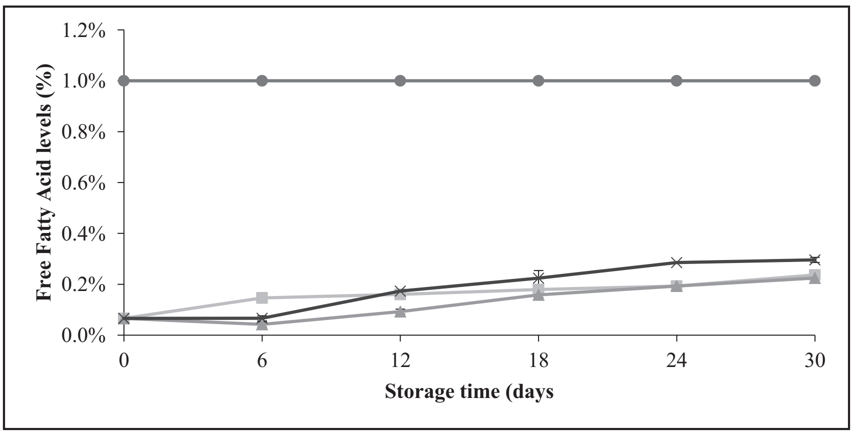

Figure 2. Graph of the relationship between biscuit quality decline on free fatty acid parameters. Abbreviations: Storage at 25ºC (■); storage at 35ºC (▲); storage at 45ºC (×); critical limit of free fatty acid content based on Indonesian National Standard (●); The error bar represents the standard deviation (SD); n = 9 (3 replicates of experiment x 3 replicates of analysis).

water content of the biscuits. Similarly, snack bars were stored at 15 ° C, 30 ° C, and 45 ° C for 35 days, with observations every seven days showing decreased water contents of 22.7%, 17.83%, and 17.19% in the fifth week (34).

The water content of red bean and Mocaf biscuit decreased because the product experienced evaporation due to temperature and length of storage which accelerated the evaporation process. High temperature and air velocity accelerated the evaporation process on the surface and inside of the particles due to differences in the vapor pressure of the liquid (35).

Free fatty acid

Observation of free fatty acids showed increased free fatty acid levels during storage, with the highest of 0.296% (Figure 2). Table 6 showed the free fatty acid contents of the biscuits at the three temperatures were below the maximum limit based on the SNI Biscuit Quality No. 01-2973-2011, which is 1% (31).

An increase in storage temperature can accelerate the decline in the quality of biscuits, leading to shorter shelf life. Higher storage temperature leads to faster reaction rate of various chemical compounds

Table 6. Decreasing the rate of free fatty acid content (k) of biscuits. Abbreviations: temperature (T); natural logarithm (ln); a constant or frequency factor that does not depend on temperature or intercept (k0); slope (-Ea/R); activation energy (cal/mol) (Ea); ideal gas constant (1,986 cal/molK) (R); exponential function (exp); and the rate of deterioration constant (k).

T(°C)	ln ko	ko	-Ea/R	-Ea/RT	$exp^{-Ea/RT}$	k
25	0.0264	1.0267	-2422.9	-8.1305	0.00029	0.00030
35				-7.8666	0.00038	0.00039
45				-7.6192	0.00049	0.00050

Table 7. Linear regression equations and R^2 Order 0 and Order 1.

Parameter	Order	T (°C)	y = bx + a	R^2
Water content	0	25	y = -0.0018x + 0,1997	0,8858
		35	y = -0.0019x + 0,2086	0,9376
		45	y = -0.0031x + 0,1795	0,7888
	1	25	y = -0.0105x + 1,6052	0,8849
		35	y = -0.0106x + 1,5587	0,9120
		45	y = -0.0218x + 1,7164	0,8645
Free Fatty Acid content	0	25	y = 0.0003x + 0.0009	0,8981
		35	y = 0.0004x + 0.0004	0,9127
		45	y = 0.0005x + 0.0005	0,9427
	1	25	y = 0,2094x + 7,0071	0,7815
		35	y = 0,3206x + 7,6130	0,8313
		45	y = 0,3469x + 7,3307	0,8812

Abbreviations: temperature (T); linear regression equation (y = bx + a); correlation coefficient (R^2).

in foodstuffs, hence, the temperature factor must be considered for estimating the speed of deterioration (34). This is consistent with previous studies which assessed free fatty acid contents in the Mocaf formulation and corn flour stored for four weeks at 60°C, 50°C, and 40°C to be 4.86%, 3.75%, and 3.73%, respectively (36).

Shelf life estimation

Shelf life was determined using Arrhenius methods by plotting the results of quality changes for 30 days on quality change and time curve for selecting the reaction order. Linear regression equations and coefficient of determination order 0 and order 1 of water and free fatty acids contents are shown in Table 7. Order 0 was selected to determine the Arrhenius equation in the relationship of decreasing water content with time because its coefficient of determination value was greater than that of order 1. The relationship between ln K and 1/T of order 0 and order 1 based on water content parameters is shown in Figure 3.

The shelf life is determined based on the highest coefficient of determination value (37). The parameter with the highest coefficient of determination (R^2 = 0.9971) in red bean and Mocaf biscuit was the free fatty acid content (the equation was y = -2422.9x +0.0264) showed in Figure 4.

This parameter also had the lowest activation energy, indicating that the parameter was the easiest to deteriorate so can be selected as parameter in estimating shelf life. The activation energy is the lowest collision energy required to form an activated complex molecule for the reaction to take place (28). Table 8 showed the values of the coefficient of determination and activation energy based on the selected order.

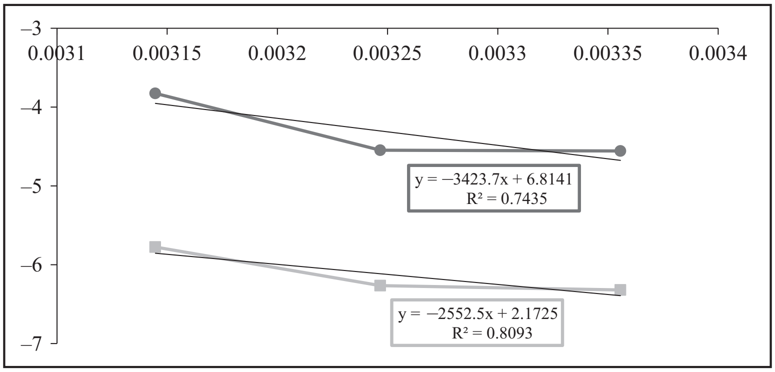

Figure 3. Relationship between Ln K and 1/T Water Content on Order 0 and Order 1. Abbreviations: Linear regression equation on the order of 0 (■); linear regression equation of order 1 (●); linear line (—).

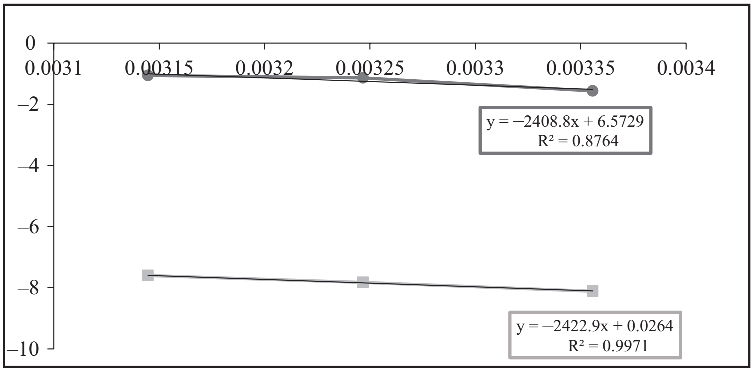

Figure 4. Relationship between Ln K and 1/T Free Fatty Acid content on Order 0 and Order 1. Abbreviations: Linear regression equation on the order of 0 (■); linear regression equation of order 1 (●); linear line (—).

Table 8. Value of correlation coefficient (R^2) and activation energy (Ea) of each parameter by chosen order.

Test Parameters	y = bx + a	R^2	Ea (kcal/mol)
Water content	y = -2552.5x + 2.1725	0.8093	5068.7
Free fatty acid content	y = -2422.9x + 0.0264	0.9971	4811.9

Notes: linear regression equation (y = bx + a); correlation coefficient (R2); activation energy (kcal/mol) (Ea).

Discussion

Nutritional content

Protein

The results showed that the protein content decreased along with the reduction of red bean flour. This was because red bean flour contained higher protein than Mocaf. The protein content of F1-F4 biscuits met the quality requirements according to the SNI, namely at least 5% (31). Furthermore, the protein content in the biscuits on the market was 6.14% (38), lower than all of the formulated red bean and Mocaf biscuit formulations.

Fat

The fat content in biscuits experienced a fluctuating increase from F1-F4. This is due to several factors, including the difference in the location of the biscuits in the oven and the use of two different ovens, which might cause variations in the temperature (39). Higher temperature led to lower fat content. Fat can melt or evaporate due to the breakdown of fat components into volatile products such as ketones and hydrocarbons (40). According to previous studies (38), the average fat content of biscuits from the market was 20.32%, higher than all of the formulated red bean and Mocaf biscuit.

Carbohydrate

The results showed that the carbohydrate content increased from F1-F4 along with the increase of Mocaf. Mocaf have a higher carbohydrate content than red bean flour. These results are in line with a previous study in which cookies had a higher carbohydrate content as well as a higher percentage of Mocaf (41).

Fiber

The results showed that the contents of total dietary fiber, soluble, and insoluble fibers decreased from F1-F4, along with the decrease in the percentage of red bean flour. This is because red bean flour has a higher fiber content than Mocaf, especially insoluble fiber. Having more than 6% of dietary fiber, enable the formulated biscuit categorized into high fiber food (19).

Ash content

The ash content decreased from F1-F4 along with the reduction of red bean flour content since red bean flour had higher ash content than Mocaf. Ash content is correspondence to the minerals content in a product (42). Red beans are rich in minerals such as potassium, iron, calcium, and magnesium, this causes the amount of ash reduces along with the reduction in red bean flour percentage (43). The ash contents of F3 and F4 were meet the biscuit quality standard according to the SNI, which has a maximum of 1.5% (32).

Water content

The water content decreased from F1-F4 along with the decline in the red bean content. The results of the insignificant water content were suspected because the biscuits contained the same amount of supporting ingredients. Besides, the water content in the main ingredients was not significantly different due to the variations in the formulations. The quality of the foodstuff is affected by the water content, which also determines the product's acceptability, shelf life, and freshness. High water content causes yeast, bacteria, and molds to breed easily and accelerate decay (44). Furthermore, the water content of the F1-F4 formulations exceeded the SNI biscuit quality requirement limit (5%) (Badan Standarisasi Nasional Indonesia, 2011). The high-water content was probably caused by the raw materials used. Therefore, it was necessary to optimize the temperature and baking time (13).

Total sugar

The total and reducing sugars, as well as sucrose content, decreased from F1-F4, along with the percentage of red bean flour. The red bean flour contained more total sugar, reducing sugars, total sucrose than Mocaf. The sugar content in the F2-F4 biscuit formulation was appropriate to the low sugar claim except in F1 (20). The total sugar content in biscuits was affected by the basic and other supporting ingredients such as sweeteners. This study used sorbitol instead of sucrose as a sweetener since it had fewer calories and can be used to generate a sweet taste in low-sugar products.

Energy

The energy of red bean and Mocaf biscuit increased from F1-F4 along with the percentage of Mocaf. Mocaf had a higher energy content than red bean flour. The energy content in the biscuit products fulfilled the recommendation for snacks, which was 10% of the average total energy requirement in a day of approximately 200 kcal. One serving of red bean flour and Mocaf of up to nine biscuits (67.5 grams) contained 189-229 kcal (45).

Organoleptic properties

Color

The color of the biscuit formulation was acceptable to the panelists and the most preferred was F1 for brown products. This color in the biscuit products came from red bean flour due to its anthocyanin content (46). The high-temperature around 140°C – 165°C accelerate the process of Maillard reaction between reducing sugars and amino acids, thereby leading to the formation of a brown color (47).

Taste

Overall, the taste of the biscuit formulation was acceptable to the panelists. This was presumably due to the addition of equal amounts of sweeteners to each F1-F4 formulation. The sweetness level of sorbitol is 0.5 to 0.7 times that of sucrose (31). Furthermore, the unpleasant beany taste of red bean was thought to be greatly reduced/masked due to the roasting process and the addition of cinnamon powder. This made all biscuits have an acceptable taste to the panelists (48).

Texture

The biscuit texture was acceptable to the panelists, although with a preference level of slightly like (neutral). The texture of biscuits was affected by several factors including amylopectin, amylose, fiber, and water contents. High water content in the biscuits formed a plastic structure, thereby making it difficult to break (46). Meanwhile, high fiber content reduced crunchiness because fiber bound water and hindered the starch gelatinization process. This was also affected by other ingredients such as rice flour and cornstarch which contained amylose.

Aroma

Overall, the aroma of the biscuit formulation was acceptable to the panelists. This was due to the roasting process and the addition of cinnamon powder which removed the unpleasant beany aroma (48). According to previous studies, processing red bean flour can eliminate the unpleasant beany taste and aroma caused by the activity of the lipoxygenase enzyme that was naturally found in red beans. Meanwhile, lipoxygenase enzymes hydrolyzed peanut fat and produced hexanol compounds that caused an unpleasant taste and aroma.

Starch content

Starch, amylose, and amylopectin contents

The total starch, amylose, and amylopectin contents in red bean and Mocaf biscuit showed a significant difference (α=0.05). Based on the results, the reduced red bean flour and the high Mocaf content increased the total starch and amylose contents in the biscuits. In other words, the reduced red bean flour content and the increased Mocaf content caused the amylose-amylopectin ratio to increase. Previous studies stated that higher amylose content and amylose-amylopectin ratio related to a lower glycemic index (49). However, there was no significant difference in all group. The addition of 13% Mocaf (F2) did not affect amylopectin levels. However, at higher content, the addition of 22% Mocaf (F3) produced a significant change in amylopectin levels, while 31% (F4) also did not induce a significant difference compared to the previous formula (F3).

Resistant starch and starch digestibility

The analysis results of the resistant starch content and digestibility in red bean and Mocaf biscuit showed a significant difference (α=0.05). Based on the results, less red bean flour and more Mocaf used reduced resistant starch in the biscuits. The resistant starch contents in the formulations ranged between 0.97-2.07 %. Resistant starch can be metabolized by the body 5-7 hours after consumption which causes a decrease in postprandial blood sugar levels and insulinemia. A previous study stated that consuming resistant starch for four weeks up to 30 g per day can improve insulin sensitivity (50). This implied that the resistant starch content in red bean and Mocaf biscuit was low.

Reduced red bean flour and increased Mocaf content increased starch digestibility. F1 had the lowest starch digestibility value because it contained the highest percentage of red bean. Red beans were known to contain complex carbohydrates and a high dietary fibre content, making starch digestion low. The highest resistant starch content and the lowest starch digestibility were found in F1 with values of 2.07% and 43.61%, respectively. This is consistent with previous studies, that food with a high content of resistant starch will easily control blood sugar, hence it is safe for people with diabetes mellitus (51).

Shelf life

The shelf life of a product is the time interval between production and spoilage. The product is considered to be in a satisfactory condition based on the main characteristics that are acceptable for consumption. The shelf life of red bean and Mocaf biscuits and was 31 days at 25° C, 24 days at 35°C, and 19 days at 45°C.

Food shelf life depends on intrinsic and extrinsic factor. Intrinsic factors include pH, water activity, enzymes, microorganisms and concentration of reactive compounds. Extrinsic factor including the environment to which the product is exposed during distribution and storage. Therefore, product shelf life can be controlled by the selection of raw materials, changing product formulation, processing, packaging and environmental factors. However, the main factors that affect shelf life the most are the selection of packaging materials and product formulation (52).

Conclusions

Variations in biscuit formulations affected the energy, ash content, protein, fat, total dietary fiber, soluble dietary fiber, insoluble dietary fiber, carbohydrates, total sugar, reducing sugar, sucrose, and colour. The best formulation was F2 (31:13) which had protein, dietary fiber, and total sugar contents meet to the biscuit quality requirements according SNI. It also had high fiber and low sugar which in line with the National Agency of Drug and Food Control, while the shelf life was 31 days at a temperature of 25°C. However, the highest resistant starch and the lowest digestibility were found in the F1 biscuit formulation with values of 2.07% and 43.61%, respectively.

Abbreviations: A_0: initial (%); ASLT: Accelerated Shelf-Life Testing; At: critical (%); Ea: activation energy (J mol^{-1}); k: rate constant (day^{-1}); k_0: preexponential factor (day^{-1}); Ne: effectiveness value; Nh: outcome value; NP: total Productivity Value; Q10: the ratio of the reaction rate constant with a temperature interval of 10°C; R: gas constant (J mol^{-1} K^{-1}); R^2: correlation coefficient; SMNF: special medical needs food; SNI: Indonesian National Standard; t: time (days); T: temperature (K); T2DM: type 2 diabetic mellitus.

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References

1. Ministry of Health Republic of Indonesia. Baseline Health Research 2013. 2013.
2. Sardi M, Tobing MNB, Putri A widani, et al. Nutritional Claim in Different Types of High Fiber Snack: Literature Review. Andaliman Jurnal Gizi Pangan, Klink dan Masyarakat. 2021;1(13):39–45.
3. Aini FY, Affandi DR, Basito. Kajian Penggunaan Pemanis Sorbitol sebagai Pengganti Sukrosa terhadap Karakteristik Fisik dan Kimia Biskuit Berbasis Tepung Jangung (*Zea mays*) dan Tepung Kacang Merah (*Phaseoulus vulgaris L.*). Jurnal Teknologi Hasil Pertanian. 2016;9(2):22–32. doi:10.20961/jthp.v9i2.17460.
4. Ekpenyong CE, Udokang N, Akpan EE, Samson TK. Double Burden, Non-Communicable Diseases And Risk Factors Evaluation In Sub-Saharan Africa: The Nigerian Experience. European Journal of Sustainable Development. 2012;1(2):249. doi:10.14207/ejsd.2012.v1n2p249.
5. Hastuti AR, Afifah DN. Analisis Aktivitas Antioksidan, Analisis Kandungan Gizi, Uji Organoleptik Snack Bar Sesame Seed Dan Tepung Labu Kuning Sebagai Alternatif Makanan Selingan Dengan Tinggi Antioksidan. Journal of Nutrition College. 2019;8(4):219–30. doi:10.14710/jnc.v8i4.25835.
6. Lattimer JM, Haub MD. Effects of dietary fiber and its components on metabolic health. Nutrients. 2010;2(12):1266–89. doi:10.3390/nu2121266.
7. Sari LN, Rowa SS, Suaib F. Daya terima dan kandungan zat gizi makro biskuit substitusi tepung kacang merah dan tepung talas. Media Gizi Pangan. 2019;26(1):37–45. doi:10.32382/mgp.v26i1.473.
8. Ratnasari D, Yunianta. Effect of mung bean flour, pumpkin flour, margarine on physico-chemical and organoleptic biscuit. J Pangan dan Agroindustri. 2015;3(4):1652–61.
9. Yanis M, Handayani Y, Waryat. Diversifikasi Pangan Dari Tepung Sukun Untuk Mengurangi Konsumsi Tepung Terigu Di Kepulauan Seribu, Provinsi Dki Jakarta. Buletin Pertanian Perkotaan. 2014;4(1):13–9.

10. Kesuma CP, Adi AC, Muniroh L. Pengaruh substitusi rumput laut (Eucheuma cottonii) dan jamur tiram (*Pleurotus ostreatus*) terhadap daya terima dan kandungan serat pada biskuit. Media Gizi Indones. 2015;10(2):146–50. doi:10.20473/mgi.v10i2.146-150.
11. Karmilah, Ervianingsih, Maryam S. Formulasi dan evaluasi biskuit tepung biji (Persea semen) sebagai makanan alternatif penderita diabetes melitus. Jurnal Warta Farmasi. 2016;5(1):37–49.
12. Kustanti I. Formulasi Biskuit Rendah Indeks Glikemik (Batik) Dengan Subtitusi Tepung Pisang Klutuk (Musa Balbisiana Colla) Dan Tepung Tempe. Jurnal Aplikasi Teknologi Pangan. 2017;6(1):12–8. doi:10.17728/jatp.217.
13. Arsyad M. Effect of Mocaf Flour Addition Towards The Quality of Biscuit Production. Jurnal Agropolitan. 2016;3(3):52–61.
14. Rosa D, Purwidiani N. Pengaruh Proposi Tepung Jagung dan Tepung Kacang Merah Terhadap Sifat Organoleptik Serta Kandungan Gizi Brownies Kukus. Jurnal Tata Boga. 2019;8(2):371–9.
15. Badan Pusat Statistik. Statistics of Seasonal Vegetable and Fruit Plants. Subdirektorat Statistik Hortikultura Subdirectorate of Horticulture Statistics, editor. Badan Pusat Statistik. Badan Pusat Statistik Republik Indonesia; 2018.
16. Arief R, Novitasari E, Asnawi R. Food Diversification of Cassava as Non-Rice Based Functional Food in Lampung. Planta Tropikal Journal of Agro Science. 2018;6(2):62–9. doi:10.18196/pt.2018.081.62-69.
17. Suprapto, Aliyah N, Kristiningrum E, Agus D, Anggraeni P. Parameter Utama Tepung Modified Cassava Flour (Mocaf) Kaya Beta-Karoten. Jurnal Standardisasi. 2020;22:153–62. doi:10.31153/js.v22i2.834.
18. Mubarokah B. Pengaruh Rasio Mocaf (Modified Cassava Flour) Dengan Tepung Terigu Dan Penambahan Tepung Daun Kelor Terhadap Sifat Fisik, Kimia, Dan Organoleptik Biskuit. Brawijaya; 2012.
19. Indonesian Food and Drug Authority. Peraturan Kepala Badan Pengawas Obat dan Makanan Republik Indonesia Nomor 13 Tahun 2019 Batas Maksimal Cemaran Mikroba Dalam Pangan Olahan. 2018.
20. Indonesian Food and Drug Authority. Peraturan Kepala Badan Pengawas Obat Dan Makanan Republik Indonesia Nomor 13 Tahun 2016 Tentang Pengawasan Klaim Pada Label Dan Iklan Pangan Olahan. 2016.
21. AOAC. Official methods of analysis of AOAC International. 18th ed. Vol. 15 th, Association of Official Agricultural Chemists. Washington, D.C. Gaithersburg Md.: AOAC International; 2005. 136–138 p.
22. Watts BM, Ylimaki GL, Jeffery LE, Elias LG. Basic Sensory Methods for Food Evaluation. Development Research Centre (Canada); 1989. 1–164 p.
23. AOAC. Official methods analysis of the associations of official analitical chemist. Association of Official Analitycal Chemists. Washington, DC; 1970.
24. Juliano BO. A simplified sssay for milled rice amylose measurement. J Cereal Sci Today. 1971;16:334–6.
25. AOAC. Official Methods of Analysis of The Association of Official Analytical Chemists. Washington DC, USA; 1995.
26. AOAC. Official Methods of Analysis of The Association of Official Analytical Chemists. 18th ed. Washington DC; 2007.
27. Sullivan WG, Wicks EM, Koelling CP. Engineering Economy. 17th ed. Pearson Education; 2019. 635–43 p.
28. Asiah N, Cempaka L, David W. Pendugaan umur simpan produk pangan. UB Press. Jakarta Selatan: UB Press; 2018. 1–133 p.
29. Singh TK, Cadwallader KR. Ways of measuring shelf-life and spoilage. Understanding and Measuring the Shelf-Life of Food. USA: Woodhead Publishing Series in Food Science, Technology and Nutrition; 2004. 165–183 p. doi:10.1533/9781855739024.2.165.
30. Ayustaningwarno F, Verkerk R, Fogliano V, Dekker M. The pivotal role of moisture content in the kinetic modelling of the quality attributes of vacuum fried chips. Innovative Food Science & Emerging Technologies. 2020 Jan 1;59:102251. doi:10.1016/j.ifset.2019.102251.
31. National Standardization Agency of Indonesia. Biskuit (SNI 2973:2011). Jakarta: Badan Pusat Statistik; 2011. 1–41 p.
32. National Standardization Agency of Indonesia. SNI 01-2973- 1992. Bsn. 1992;1–5.
33. Indonesian Food and Drug Authority. Peraturan Kepala Badan Pengawas Obat Dan Makanan Republik Indonesia Nomor 21 Tahun 2016 Tentang Kategori Pangan. 2016.
34. Surahman DN, Ekafitri R, Desnilasari D, et al. Snack Bar Shelf Life with Different Storage Temperatures Using Arrhenius Method. Biopropal Indonesia. 2020;11(2):127. doi:10.36974/jbi.v11i2.5898.
35. Ismawati I. Pendugaan umur simpan menggunakan metode accelerated shelf life test (ASLT) model arrhenius pada jamu "Sari Rapet Super." Journal of Food Technology and Agroindustry. 2019;1(2):37–42. doi:10.24929/jfta.v1i2.781.
36. Diniyah N, Giyarto, Subagio A, Akhiriani RA. Pendugaan umur simpan "Beras Cerdas" berbasis MOCAF, tepung jagung menggunakan metode accelerated shelf-life testing (ASLT) pendekatan arrhenius. J Agro-based Ind. 2015;32(1):1–8.
37. Rahman T, Sulaiman NF, Turmala E, Andriansyah RCE, Luthfiyanti R, Triyono A. Shelflife prediction of biscuits prepared from modified suweg (Amorphophallus campanulatus B) flour using Arrhenius model. IOP Conference Series: Earth and Environmental Science. 2019;251(1). doi:10.1088/1755-1315/251/1/012035.
38. National Standardization Agency of Indonesia. Standar Nasional Indonesia Biskuit SNI 01-2973-1992 [Internet]. 1992. p. 1–6. Available from: http://sispk.bsn.go.id/SNI/DetailSNI/3324
39. Rohmah DUM, Luketsi WP, Windarwati S. Analisis Organoleptik Edible Straw Dari Buah Nanas (*Ananas Comosus L.*) Subgrade Varietas Queen. Agrointek : Jurnal Teknologi Industri Pertanian. 2020;14(1):24–35. doi:10.21107/agrointek.v14i1.5787.

40. Sundari D, Almasyhuri A, Lamid A. Pengaruh Proses Pemasakan Terhadap Komposisi Zat Gizi Bahan Pangan Sumber Protein. Media Peneliti dan Pengembangan Kesehatan. 2015 Dec;25(4):235–42. doi:10.22435/mpk.v25i4.4590.235-242.
41. Yenrina R, Anggraini T, Kadri A. Nutritional Value of Cookies made from the mixture of Mocaf flour (Modified Cassava Flour) and Ketapang seeds (Terminalia catappa L.). AJARCDE | Asian Journal of Applied Research for Community Development and Empowerment. 2020;4(1):48–53. doi:10.29165/ajarcde.v4i1.38.
42. Sulfiani S, Sukainah A, Mustarin A. Pengaruh Lama dan Suhu Pengasapan Dengan Menggunakan Metode Pengasapan Panas Terhadap Mutu Ikan Lele Asap. Jurnal Pendidikan Teknologi Pertanian. 2017;3:93. doi:10.26858/jptp.v3i0.5468.
43. Izwardy D, Mahmud MK, Hermana, Nazarina. Indonesian Food Composition Table 2017. Ministry of Health Republic of Indonesia. 2017. 1–135 p.
44. Utami AN, Anjani G. Substitusi Isolat Protein Kedelai pada Daging Analog Kacang Merah. Journal of Nutrition College. 2016;5(Jilid 3):402–11.
45. Ministry of Health Republic of Indonesia. Peraturan Menteri Kesehatan Republik Indonesia No 28 Tahun 2019. 2019.
46. Pujilestari S, Fajri S, Sabrina N. Beras (*Oryzae Sativa*) Dan Tepung Kacang Merah (*Phaseolus Vulgaris L.*) Terhadap Mutu Kue Kembang Goyang. Jurnal Teknologi Pangan Kesehatan. 2021;3(1):18–25. doi:10.36441/jtepakes.v3i1.531.
47. Riskiani D, Ishartani D, Rachmawanti D. Utilization of canna (*Canna edulis ker.*) flour as subsitution of wheat flour in production of high protein energy biscuit with addition kidney bean (*Phaseolus vulgaris L.*) flour. Jurnal Teknosains Pangan. 2014;3(1):96–105.
48. Wang R, Wang R, Yang B. Extraction of essential oils from five cinnamon leaves and identification of their volatile compound compositions. Innovative Food Science and Emerging Technologies. 2009;10(2):289–92. doi:10.1016/j.ifset.2008.12.002.
49. Nurhayati AD, Rimbawan R, Anwar F, Winarto A. Potensi Penggunaan Metode In Vitro dalam Memperkirakan Pemeringkatan Indeks Glikemik In Vivo pada Beberapa Varietas Beras yang Dimasak. Indonesian Journal of Human Nutrition. 2019;6(2):119–38. doi:10.21776/ub.ijhn.2019.006.02.6.
50. Fathurrizqiah R, Panunggal B. Kandungan Pati Resisten, Amilosa, Dan Amilopektin Snack Bar Sorgum Sebagai Alternatif Makanan Selingan Bagi Penderita Diabetes Mellitus Tipe 2. Journal of Nutrition College. 2015;4(2):562–9. doi:10.14710/jnc.v4i4.10163.
51. Syafii F, Yudianti. Analisis kadar pati resisten, total serat dan daya terima kabosol tersubstitusi tepung pisang kepok termodifikasi. Jurnal Kesehatan Manarang. 2022;8(1):43–50. doi:10.33490/jkm.v8i1.590.
52. Robertson GL. Packaging materials for biscuits and their influence on shelf life. Fourth Edi. Manley's Technology of Biscuits, Crackers and Cookies: Fourth Edition. Woodhead Publishing Limited; 2011. 247–267 p. doi:10.1533/9780857093646.2.247.

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