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Physicochemical and Sensory Properties of Gluten-Free Yam (*Dioscorea alata*) Bread

Ulyarti Ulyarti[1,2*], *Rimelvani* Damanik[1], *Satiti Kawuri* Putri[1], *Lisani* Lisani[1], *Mursyid* Mursyid[1], *Daniel* Tua Purba[3], and *Nazarudin* Nazarudin[2,4]

[1]Department of Agricultural Technology, Faculty of Agriculture, University of Jambi, Jambi, Indonesia
[2]Centre of Excellence on Bio-Geo Material and Energy (PUI BiGME), University of Jambi, Jambi, Indonesia
[3]Program in Food Science and Technology, School of Food Industry, King Mongkut's Institute of Technology, Bangkok, Thailand
[4]Department of Chemical Engineering, Faculty Science and Technology, University of Jambi, Jambi, Indonesia

Abstract. The development of a gluten-free yam bread aims to support the diversity of food products and meet the needs of gluten-sensitive consumers. Purple yam (*Dioscorea alata L.*), which is rich in fiber and bioactive compounds, has the potential as a substitute ingredient that can improve the quality and nutritional value of gluten-free bread. This study was conducted to determine the effect of milk powder on the physicochemical and sensory properties of gluten-free yam bread. The sensory properties were evaluated by 25 semi-trained panelists using 5-point hedonic scales. A completely randomized design was applied using six concentrations of milk powder (0%, 2%, 4%, 6%, 8%, and 10%) and three replications. The results showed that the concentration of milk powder has a significant effect on two main quality attributes of bread: specific loaf volume and porosity. The gluten-free yam bread with 10% milk powder appeared to be of the highest quality, with a specific loaf volume of 2.20 cm^3/g, slightly higher than that without milk powder. Although the higher milk powder concentration in bread formulation decreased both porosity and anthocyanin content, the sensory evaluations showed an increased hedonic value for aroma, texture, and taste. Based on these findings, the addition of 10% milk powder is recommended for gluten-free yam bread.

1 Introduction

The production of gluten-free bread requires a different approach due to the absence of gluten, which provides structure and elasticity to the dough. Gluten-free bread needs components that can form a satisfactory bread structure, such as hydrocolloids and proteins [1]. Hydrocolloids not only improve the texture and elasticity of the dough but also help

* Corresponding author: ulyarti@unja.ac.id

retain moisture and increase bread volume. Meanwhile, the addition of proteins from other sources can enhance the nutritional value of the final product.

Purple yam (*Dioscorea alata* L.) is widely cultivated in several regions of Indonesia, particularly Sumatra [2]. It can be found in the Pulau Tengah Village, Jangkat District, Merangin [3]. This fact indicates a strong availability of raw materials, which supports its potential for sustainable gluten-free product development. It is rich in bioactive compounds and contains high levels of soluble and insoluble dietary fiber [3]. The nutritional content of purple yam includes a complete composition of nutrients, including carbohydrates (17.10–29.37%), protein (1.29–3.00%), fat (0.29%), fiber (6.70–11.62%), ash (0.85–1.44%), moisture content (65.47–82.46%), and amylopektin (88,93%) [2], [4]. This natural hydrocolloid is expected to be beneficial in producing good-quality gluten-free bread.

Several protein sources can be used to produce nutritious gluten-free bread, such as milk, cereals, and legumes, at a proportion of up to 20% [5]. In addition to the aforementioned ingredients, skim milk powder and whole milk powder have traditionally been used in several bakery products. Milk powder is known to be rich in protein, fat, and sugar. The addition of milk powder can improve water absorption, provide additional nutritional value, and enhance texture. Furthermore, recently, dairy ingredients such as skim milk powder, caseinates, whey, and dry milk have been used as key additives in studies aimed at developing gluten-free bread [6]. Therefore, this research gap is filled by evaluating both physicochemical and sensory responses of gluten-free yam bread enriched with milk powder.

The concentration of milk powder in the dough affects its characteristics, which in turn influences the quality of the final product [7]. According to Burnaz [7], the addition of milk powder at certain ratios can impact bread quality, such as bread volume. According to their reported findings, adding milk powder at a higher level (10%) resulted in bread that received high preference scores from panelists. However, excessive addition of milk powder can lead to a decline in bread quality characteristics, making it important to determine the right balance in the amount added.

2 Material and methods

2.1 Materials

Yam tubers were harvested from wild plants in the local forest, Merangin, Jambi Province. Other materials such as rice flour, mocaf, milk powder, sugar, coconut oil, salt, yeast, and eggs were purchased from local stores, whereas millet flour was purchased online. The chemicals were of analytical-grade.

2.2 Research Design

The experiment was arranged using a Completely Randomized Design (CRD) consisting of six levels of milk powder concentration (0%, 2%, 4%, 6%, 8%, and 10%) with three replications for each treatment.

2.3 Formulation of gluten free yam bread

The tubers of yam were peeled, steamed and mashed into a paste. The paste was mixed with rice flour and mocaf and dried in the oven at 60ºC until at least 10% water content was reached. The product is called yam's premix flour. The preparation of gluten-free bread started with yeast activation. 1.5 g instant yeast was dissolved in 50 grams of lukewarm water and 4 g sugar for 10 minutes. 110 g of yam premix flour was mixed with other dry ingredients (50 g millet flour, 1 g salt, and a certain amount of milk powder depending on the treatment). Into this mixture, 25 g of oil and 50 ml of water were added, followed by the activated yeast mixture and wet mixture of 50 g of eggs and 4 g of sugar which had previously been beaten. Finally, the batter was poured into baking pans where fermentation was taking place at room temperature for 45 minutes, after which they were baked at 180°C for 45 minutes. Once the bread is fully baked, it is removed from the pan and allowed to cool. The concentration of milk powder was varied from 0% (without milk powder), 2%, 4%, 6%, 8%, and 10%. The concentration was calculated based on the total amount of flour (yam's premix flour and millet flour).

2.4 Specific loaf volume (SLV) [8]

Specific loaf volume was calculated by using the equation below. The volume of bread was measured by using the seed replacement method.

$$\text{SLV} = \text{Volume of bread} / \text{Weight of bread} \quad (1)$$

2.5 Porosity [8]

Porosity of the bread was carried out using ImageJ software by cutting a 4x4 cm section from the inner part of the bread, then scanning the bread slice using a scanner. Each sample image was further trimmed to a size of 3x3 cm. The image was imported into ImageJ and converted to 8-bit format. The porosity was expressed as a percentage area, was calculated as the total pore area divided by the total image area.

2.6 Physicochemical and sensory evaluation

Water and protein content were measured following AOAC methods [9]. Anthocyanin content was measured using the pH differential method as described previously [10] and calculated using equation 3.

$$A = (A510 – A700\text{nm})\ \text{pH } 1.0 – (A510 - A700\text{nm})\ \text{pH } 4.5 \quad (2)$$

$$\text{Anthocyanin (mg/g)} = [(A \times MW \times FP \times 1000\ \varepsilon \times L)] \quad (3)$$

Where:
A = Absorbance
DF = Dilution factor
ε = Absorptivitas molar anthocyanin (29,600L/mol.cm)
MW= Molecular weight
L = cuvette width

Sensory evaluation was performed using a 5-point hedonic scale (1 = dislike very much, 5 = like very much). A total of 25 semi-skilled panelists aged 21–22 years participated in the evaluation, which was conducted at the Sensory Laboratory, University of Jambi. The attributes evaluated included color, aroma, texture, taste, and overall acceptability.

2.7 Data analysis

The experiment on different milk powder concentrations in gluten-free bread formulation was carried out in triplicate, and the values were reported as mean ± standard deviation. The statistical analysis of the data for all experiments was conducted using ANOVA to test the significance of each variable ($p < 0.05$), followed by comparisons using Duncan's test with the statistical software IBM SPSS 25.0.2.2.

3 Result and discussion

3.1 SLV and porosity

Specific loaf volume (SLV) and porosity are the main parameters for bread. While SLV measures how much bread rises during proofing and baking, porosity measures how much air cell presence there is in the bread. In many cases, the higher porosity leads to a higher SLV [11], [15]. However, sometimes a high porosity is observed in low SLV bread [16]. In other cases, the relationship between porosity and SLV depends on the formulation used in the study [17]. In the current study, both SLV and porosity are affected by the concentration of milk powder. The increase in milk powder concentration increased SLV but decreased porosity (Table 1).

Table 1. Physicochemical properties of gluten-free bread at different concentrations of milk powder.

Milk powder (%)	SLV (cm^3/g)	Porosity (%)	Water (%)	Protein (%)	Anthocyanin (mg/g)
0	$2.06±0.02^{a}$	$51.17±0.71^{d}$	$39.33±1.49^{b}$	$12.72±1.26^{a}$	$10.02±1.76^{a}$
2	$2.07±0.07^{a}$	$50.30±1.27^{cd}$	$38.45±3.57^{b}$	$13.17±0.62^{ab}$	$9.57±3.09^{ab}$
4	$2.08±0.05^{a}$	$48.85±2.13^{bcd}$	$37.59±0.85^{ab}$	$13.58±0.61^{abc}$	$8.02±1.30^{ab}$
6	$2.11±0.04^{ab}$	$47.49±2.27^{abc}$	$35.29±1.35^{ab}$	$13.60±0.60^{abc}$	$7.29±1.67^{ab}$
8	$2.13±0.05^{ab}$	$46.14±0.95^{ab}$	$35.24±1.92^{ab}$	$14.91±0.01^{bc}$	$6.01±3.40^{b}$
10	$2.20±0.09^{b}$	$45.38±1.02^{a}$	$33.71±2.88^{a}$	$15.34±0.62^{c}$	$5.07±0.34^{b}$

Note:
Numbers in a column followed by the same superscript are significantly different according to DnMRT 5%.

The presence of milk powder in the dough, increases water absorption, which later evaporates during baking, leaving some more pores in the dough and increasing bread volume. Therefore, the initial absorption of water during dough processing affects both the water content of the bread and the bread volume (Table 1).

Milk powder contains 23% protein, which may contribute to the Maillard reaction, enhancing crust formation and leading to retaining gas longer during baking (higher SLV). This also may affect the size of pores making them even larger and causing the porosity to be reduced. The inverse relationship between SLV and porosity in the current study can be explained by the uniformity of pores produced in the bread (Fig. 1).

3.2 Anthocyanin content

Yam tubers have a purple flesh color and contain significant amounts of anthocyanin [18], [19]. Anthocyanin is an unstable compound, and its stability can be influenced by various factors such as pH, temperature, light, concentration, presence of metal ions, and oxygen [20], [21]. The addition of milk powder in the gluten-free bread dough decreased the anthocyanin content in the bread (Table 1). However, as seen in **Fig. 1** and **Table 2**, the colors of the gluten-free yam breads are similar, indicating no significant changes occur in the anthocyanin presence of the bread with different concentrations of milk powder. The author suggests that the anthocyanin binds to milk protein [22] and therefore cannot be extracted for measurement.

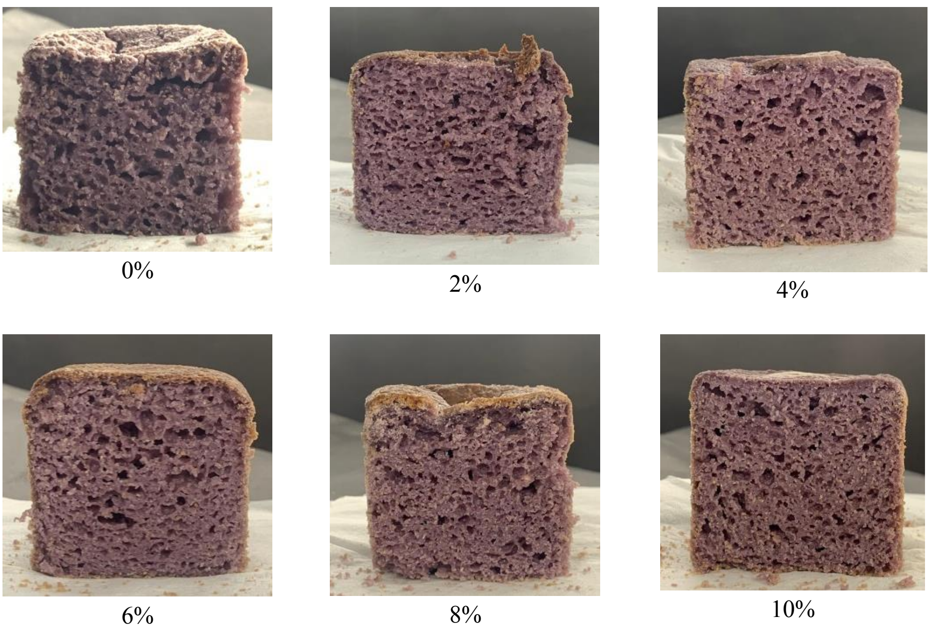

Fig. 1. Gluten-free yam bread at different concentration of milk powder

3.3 Hedonic test

The sensory evaluation of the gluten-free yam bread was carried out using a 5-scale hedonic test, and the results are presented in **Table 2**. The result showed that the unpleasant aroma from yam in gluten-free yam bread cannot be diminished by the addition of milk powder. That remains a problem in gluten-free yam bread production. However, the addition of milk has increased the hedonic texture of the bread, in line with the increase in SLV. Although the taste hedonic quality is increased by the increase of milk powder concentration, it does not affect the overall acceptance of the yam bread. The bread's color may primarily influence the acceptance of gluten-free yam bread.

Table 2. The hedonic quality for gluten-free bread at different concentrations of milk powder.

Milk powder (%)	Color	Aroma	Texture	Taste	Overall acceptability
0	3.44±0.91	3.44±0.65[ab]	3.44±0.71[ab]	3.16±0.85[a]	3.32±0.80
2	3.48±0.71	3.40±0.70[ab]	3.20±0.76[a]	3.24±0.77[a]	3.32±0.90
4	3.56±0.76	3.68±0.62[ab]	3.64±0.70[ab]	3.48±0.65[ab]	3.52±0.58
6	3.72±0.79	3.48±0.87[ab]	3.68±0.74[ab]	3.48±0.77[ab]	3.32±0.94
8	3.56±0.76	3.24±1.01[a]	3.52±0.91[ab]	3.40±0.76[ab]	3.48±0.87
10	3.92±0.86	3.80±0.86[b]	3.84±0.89[b]	3.84±0.98[b]	3.84±1.02

Note:
Numbers in a column followed by the same superscript are significantly different according to DnMRT 5%. Score 1 = dislikes very much, 2 = dislikes, 3 = rather likes, 4 = likes, and 5 = likes very much

4. Conclusion

The concentration of milk powder has a significant effect on SLV, porosity, water content, protein content, anthocyanin content, and hedonic values for aroma, texture, and taste of gluten-free yam bread. An increase in milk powder concentration increases SLV but decreases porosity and anthocyanin content in the bread. The hedonic values for aroma, texture, and taste of the gluten-free yam bread tend to improve as the concentration of milk powder increases. Therefore, gluten-free yam bread with 10% milk powder is recommended as the best formulation, producing bread with the highest specific loaf volume of 2.20 cm^3/g.

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The data presented in this manuscript are available and can be given whenever necessary.

Author contribution:
Ulyarti Ulyarti : Design and conception of the research, drafting the manuscript
Rimelvani Damanik *:* Data collection and analysis
Satiti Kawuri Putri : Critical revision of article, background and discussion in particular
Lisani Lisani : Supervision during data collection
Mursyid Mursyid : Supervision during analysis and drafting manuscript
Daniel Tua Purba : Critical revision on background and discussion section
Nazarudin Nazarudin : Concept of research analysis

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