Effect of glucomannan addition on physical and sensory characteristic of gluten-free muffin from modified cassava flour and maize flour

P S Dewi, D Ulandari, and N S Susanto

Department of Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Indonesia
Email: putri.satika@gmail.com

Abstract Muffins are generally prepared from wheat flour, which is not produced in Indonesia. This study was carried out to explore the utilization of local resources to reduce the dependency on wheat flour. The gluten-free muffins were prepared from modified cassava flour (mocaf) and maize flour blend. Glucomannan was added to improve the physical characteristic of gluten-free muffins. The purpose of this study was to find out the physical and sensory properties of gluten-free muffins using different proportions of mocaf and maize flours, and different concentrations of glucomannan addition. This study used Randomized Complete Block Design with two factors: the addition of glucomannan (0%-0.5%) and the proportion of mocaf and maize flour. The result showed that the addition of glucomannan and different proportions of gluten-free flours significantly affected sensory, colour index (L*, a*, b*), specific volume, hardness, and porosity. Based on the physical and sensory characteristics tested, the best treatment was obtained from the calculation using the Zeleny method. The gluten-free muffins prepared from the blends of 80% mocaf and 20% maize flour with the addition of 0.5% glucomannan being the most preferred by panelists.

1. Introduction
Muffins are sweet baked products made from wheat flour as the main ingredient and are known as quick bread because of its short and simple making process. The main raw material for muffins is wheat flour, which is not produced in Indonesia. Based on data of BPS-Statistics Indonesia (2019), Indonesia imported 10,693 million tons of wheat grains annually [1]. Meanwhile, according to the Food Consumption Statistics issued by the Indonesian Ministry of Agriculture (2018), wheat flour consumption in Indonesia is 2.638 kg/capita/year [2]. It makes Indonesia the 5th largest wheat importer country in the world [3]. Hence, there is a need to propose alternative raw materials as substitutes for wheat flour from local potential such as mocaf and maize flour.

In bakery products, wheat flour as their main ingredient contains starch in the complex form of carbohydrates, also contains proteins in the form of gluten that plays a role in making dough tough and elastic. While in the making process of gluten-free muffins, mocaf flour which contains 84.44% starch works as a source of starch, and maize flour contains 7.82-12.02% protein so it can be used as a
source of protein [4] [5]. The nature of elasticity of gluten occurs due to a reaction between proteins in flour with water [6].

In the making process of gluten-free muffins, hydrocolloids that can bind water are needed to help the development process and improve the physical quality of gluten-free muffins. Glucomannan (water-soluble hydrocolloid) was used in this study to form the interactions between starch, protein, and water in the batter, which can improve the texture and rheological properties of the raw material [4]. Glucomannan has been approved as a GRAS (Generally Recognized as Safe) food additive by the US FDA (Food and Drug Administration) and also approved by EU (European Commission Regulation) No. 231/2012 [5]. Glucomannan can expand in water up to 138 - 200% while starch can only expand as much as 25% [6]. The addition of 0.5% glucomannan in gluten-free bread has been reported to be the best treatment in the previous research [7].

2. Materials and Methods

2.1 Material
Glucomannan is obtained from Indonesian Porang Research and Development Center, Malang City. Modified Cassava Flour Malang variety 6 from a home industry in Dau, Malang Regency. Maize flour from maize milling in Sukosari District, Bondowoso Regency. Other supporting materials such as eggs, bread yeast (Saccharomyces cerevisiae) brand “fermipan”, margarine, full cream milk, and muffin cups are obtained from Pasar Besar Kota Malang.

2.2 Methods
This research is arranged by using the factorial Randomized Complete Block Design (RCBD) method which contains two factors. The first factor is the addition of glucomannan which consists of 2 levels and the second factor is the different formulation of mocaf flour and maize flour with 5 combinations. 10 combinations of treatments are obtained, which is repeated three times. Glucomannan treatment combination factors: the proportion (%) of mocaf and maize flour (0: 100 and 0); (0: 90 and 10); (0: 80 and 20); (0: 70 and 30); (0: 60 and 40); (0.5: 100 and 0); (0.5: 90 and 10); (0.5: 80 and 20); (0.5: 70 and 30); (0.5: 60 and 40).

2.2.1 Glucomannan preparation
Glucomannan flour was weighted 1 g and dispersed in 100 ml water. The glucomannan solution was heated using a magnetic stirrer for 1 hour (45°C) with constant stirring to form a gel. The gel then weighed as much as 0.5% of the 200 grams of total mocaf flour and maize flour used then added in the making of gluten-free muffins.

2.2.2 Gluten-free muffin preparation
All ingredients were weighed according to muffin making formulations. Mocaf and maize flour was blended. The milk heated to a temperature of 45°C and yeast added, then stirred and let stand for 15 minutes. Furthermore, the margarine was melted by steam. In a different place, egg and sugar mixture using a mixer at low speed for 5 minutes, then add the milk and yeast, mixed again until it is well mixed. The flour blend was added into the batter slowly and stirred thoroughly. Glucomannan gel was added and mixed (for treatment with glucomannan addition). After that, put melted margarine and stir again until well mixed. The mixture is poured into a muffin cup (7 × 5.5 × 5cm) until it is ¾ full. Proofing the muffin batter for 30 minutes then baked in an oven at 170°C for 30 minutes.
Table 1. Gluten-free muffins formulation.

| Material (g) | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-------------|----|----|----|----|----|----|----|----|----|----|
| Maize flour | 0  | 20 | 40 | 60 | 80 | 0  | 20 | 40 | 60 | 80 |
| Mocaf flour | 200| 180| 160| 140| 120| 200| 180| 160| 140| 120|
| Milk (ml)   | 120| 120| 120| 120| 120| 120| 120| 120| 120| 120|
| Butter      | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Sugar       | 100| 100| 100| 100| 100| 100| 100| 100| 100| 100|
| Egg         | 200| 200| 200| 200| 200| 200| 200| 200| 200| 200|
| Yeast       | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
| Glucomannan | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  |

2.2.3 **Specific volume** [7]

The loaf volume is the ability of the batter to form and hold the gas produced during the processing. Muffin batter before fermentation and muffin after baking were measured in volume. The calculation results are entered into the formula:

\[
\% \text{ Specific Volume} = \frac{\text{muffin volume} - \text{batter volume}}{\text{batter volume}} \times 100\%
\]

2.2.4 **Porosity** [8]

Porosity is the pores found in the muffin after going through the roasting process. Porosity testing uses ImageJ software. Slice a sample with a thickness of 1-2cm and a length and width of 3x3cm on the scan. The scanned image was analyzed using ImageJ software. This parameter unit is mm$^2$/cross-sectional area.

2.2.5 **Hardness** [7]

Hardness was measured using Texture Analyzer. Slice a sample with a thickness of 7 cm and a length and width of 3x3cm was placed on the instrument then three points were penetrated and averaged. This parameter unit is N.

2.2.6 **Colour** (L* a* b*) [9]

Colour was measured using Color Reader. A piece of muffin sample was analyzed using a color reader on three sides. The color values were indicated by parameters L*, a*, b* and then averaged on each parameter.

2.2.7 **Sensory characteristic** [10]

Sensory characteristic was determined using hedonic tests and scoring tests from 40 panelists used 10 samples. Sensory observation parameters of the hedonic method including taste, aroma, color, porosity and texture.

3. Results and Discussion

3.1 **Specific volume**

The specific volume of the gluten-free muffin is ranged from 18.84% to 36.67% (Table 2). The specific volume of gluten-free muffins increased with glucomannan addition, where glucomannan which is hydrophilic will bind water and retain the water in the bread during the baking and baking process, so it will remain inside and maintain the bread volume. 1 gram of glucomannan can absorb 100 grams of water and the presence of glucomannan heating treatment to form a gel will cause glucomannan insoluble in water [12].

Glucomannan was used to increase WHC (Water Holding Capacity) [13]. The increase in WHC that occurs in the batter can affect the ability of glucomannan to hold water so that the increase in
glucomannan will affect the level of specific volume. So the higher the concentration of glucomannan the more water is absorbed during the gelatinization process, so there will be swelling of the starch granules which can cause an increase in the volume of gluten-free muffins. On the other hand, the proportion of mocaf and maize flour did not show any significant effect in muffins. Two-way ANOVA also indicated that the addition of glucomannan had a significant effect ($\alpha = 0.05$) on the specific volume of muffins.

### Table 2. Specific volume, porosity and hardness of free-gluten muffin.

| Proportion (%) | Specific Volume (cm$^3$/g) | Porosity (mm$^2$) | Hardness (N) |
|----------------|-----------------------------|-------------------|--------------|
| Mocaf : Maize Flour | Glucomannan | 100 : 0 | 0 | 18.84 ± 0.26$^b$ | 27.2 ± 0.14$^{ab}$ | 2.60 ± 0.56$^{abc}$ |
| 90 : 10 | | 20.23 ± 0.42$^b$ | 28.05 ± 0.45$^{ab}$ | 2.90 ± 0.70$^{abc}$ |
| 80 : 20 | | 20.00 ± 0.06$^b$ | 30.66 ± 0.39$^{ab}$ | 3.23 ± 0.46$^{abc}$ |
| 70 : 30 | | 18.24 ± 0.18$^b$ | 29.03 ± 0.79$^{ab}$ | 3.70 ± 0.79$^{ab}$ |
| 60 : 40 | | 20.39 ± 0.22$^b$ | 29.03 ± 0.97$^{ab}$ | 4.03 ± 0.86$^a$ |
| 100 : 0 | 0.5 | 36.53 ± 0.98$^a$ | 25.53 ± 0.31$^b$ | 2.23 ± 0.21$^c$ |
| 90 : 10 | 0.5 | 35.25 ± 0.39$^a$ | 26.03 ± 0.55$^b$ | 2.50 ± 0.46$^{abc}$ |
| 80 : 20 | 0.5 | 36.31 ± 0.69$^a$ | 30.09 ± 0.32$^b$ | 2.40 ± 0.36$^{abc}$ |
| 70 : 30 | 0.5 | 36.67 ± 0.34$^a$ | 29.47 ± 0.16$^b$ | 2.40 ± 0.36$^{abc}$ |
| 60 : 40 | 0.5 | 35.22 ± 0.85$^a$ | 34.47 ± 0.29$^a$ | 2.67 ± 0.57$^{abc}$ |

Notes: average of 3 replications ± SD; mean values in each column show differences ($\alpha = 0.05$).

3.2. Porosity

Porosity is the pores found in bread after the roasting process. The formation of pores was caused by the release of gas that is formed when proofing and leaving the bread when baking. The addition of maize flour and the addition of glucomannan significantly affected the porosity of gluten-free muffins (Table 2). A high porosity value was found in the treatment of adding 0.5% glucomannan and the proportion of mocaf : maize flour (80: 20). While the lowest porosity value is in the treatment of adding 0.5% glucomannan and the proportion of mocaf : maize flour (100: 0). The low value of muffin porosity without the addition of glucomannan treatment is due to the high starch content and the absence of gluten in mocaf flour.

![Figure 1. Porosity of gluten-free muffins (proportion (%) of glucomannan : mocaf flour, maize flour); Comparison of pore size of scanned gluten-free muffins (left), and analysis results with Image J software (right).](image-url)
pores. While the addition of glucomannan affects the porosity of gluten-free muffins. The higher the glucomannan added, the more water is absorbed [15]. This is because in addition to increasing the specific volume of bread, the addition of glucomannan can also improve the porosity of the bread. The addition of hydrocolloids in the making of gluten-free bread will affect the pores formed, besides having water-binding ability, glucomannan also improve the interfacial activity in the dough structure during proofing and gel tissue formation during bread making, where the complex structure formed in the dough will increase viscosity and strengthen the dough structure bond so that the gas formed will be retained in the dough [16].

3.3. Hardness
The hardness is defined as the test force divided by the apparent area of the indentation at maximal force. The hardness of gluten-free muffins ranged from 2.23N to 4.03N (Table 2). The highest gluten-free muffin hardness was obtained in the addition of 0% glucomannan treatment and the proportion of mocaf : maize flour (60:40). The lowest mean hardness was obtained in the treatment of the addition of 0.5% glucomannan and the proportion of mocaf : maize flour (100:0). The low value of gluten-free muffin hardness is influenced by the addition of glucomannan to the texture of gluten-free muffins, the more glucomannan is added, the muffin hardness will be lower (soft). This is because glucomannan is hydrophilic which will bind water and retain it in the bread during the proofing and baking process so it will remain inside and maintain the soft texture of the bread, ie per 1 gram of glucomannan can absorb 100 grams of water [12]. The higher water content in the dough, then the specific volume in gluten-free bread would be higher [17]. The hardness of bread is also related so the less material available to form pore cell walls so that the resistance of bread at the time of penetration is reduced [18].

3.4. Color
Color is an important parameter in bakery products. In this study, the colors tested included the parameters of brightness (L *), redness (a *), and yellowness (b *). The color of the brightness (Whiteness Index) is a whitish value that shows the brightness of the measured sample, the brighter the sample being measured, the L value will be closer to 100. Conversely, the darker the sample the L* value will be closer to 0 [19].

The average brightness of gluten-free muffins is different from the addition of maize flour and the addition of glucomannan. The data obtained ranged from 58.91 - 63.69. The highest color brightness of gluten-free muffins was obtained by adding 0.5% glucomannan and the proportion of mocaf : maize flour (80:20). While the lowest average color of gluten-free muffin brightness was obtained in the treatment of adding 0.5% glucomannan and the proportion of mocaf : maize flour (60:40), the more maize flour added causes the low brightness value of the gluten-free muffin, because maize contains carotenoid pigments that can affect the color of the product [20]. The carotenoids of maize decompose in the presence of oxygen [21] the results of this study are the same as previous studies that carotenoid pigments contribute to bread crust and crumb yellow color [22].

In the redness color parameters, the data obtained ranged from 2.51 - 3.70. The value of a is the chromatic color measurement parameter of the red-green mixture. If the value of a is positive (+) then
the sample tends to be red. Conversely, if the value of a is negative (-) then the color of the sample tends to be green [19]. The highest redness color of gluten-free muffins was obtained by adding 0.5% glucomannan and the proportion of mocaf : maize flour (60: 40). The lowest reddish color of gluten-free muffins was obtained in the treatment of adding 0% glucomannan and the proportion of mocaf : maize flour (90:10). This is because the addition of maize flour will affect the formation of color in gluten-free muffins. Other factors that influence the color of bread are the maillard reaction (reaction between carbohydrates with protein in the product) and caramelization (the sugar contained in the product is exposed to heat) at the time of baking bread [23].

The yellowness color of gluten-free muffins obtained ranged from 25.23 - 31.47. The value of b is the chromatic measurement parameter of the yellow-blue mixture. If the value of b is positive (+) then the color of the sample tends to be yellow, whereas if the value of b is negative (-), then the sample tends to be blue [19]. In some treatments with the addition of high maize flour will also have a high yellowness value as in the addition of 20% and 40% maize flour with 0.5% glucomannan respectively 31.47 and 31.26. The highest yellowness color of gluten-free muffins was obtained by adding 0.5% glucomannan and the proportion of mocaf : maize flour (70:30). The lowest average yellowness color of gluten-free muffins was obtained in the treatment of adding 0% glucomannan and the proportion of mocaf flour: maize flour (90:10). This is caused by the presence of maize flour which can affect the yellow color of the muffins that are formed. However, the formation of color in bread can also be caused by several factors such as the Maillard reaction (reaction between carbohydrates with protein in the product) and caramelization (the sugar contained in the product is exposed to heat) during baking [23].

3.5 Hedonic sensory (preference)
The hedonic test aims to determine the level of preference of a panelist on a product. The hedonic test uses various parameters namely, taste, flavor, color, texture, porosity, and overall preference of gluten-free muffins. Sensory results in the form of spider charts in Figure 3.

![Figure 3. Spider chart of hedonic sensory of gluten-free muffin.](image-url)
4. Conclusions
The addition of glucomannan treatment had a significant effect ($\alpha = 0.05$) on the characteristics of texture (hardness), specific volume, color ($L^*, a^*, b^*$) and did not significantly affect the porosity of the gluten-free muffins. Based on the physical and sensory characteristics tested, the best treatment with the addition of 0.5% glucomannan and the proportion of mocaf flour: maize flour (80:20).

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