Effect of glucomannan and xanthan gum proportion on the physical and sensory characteristic of gluten-free bread

A Sutrisno, S S Yuwono and I Ikarini
Faculty of Agricultural Technology Universitas Brawijaya, Indonesia
E-mail: imroahikarini@gmail.com

Abstract. The increasing consumption of white bread causes the demand for raw materials, especially wheat flour to be increased. Whereas the availability of wheat as wheat flour raw material still depends on import supply. Gluten-free bread processing, which is not depending on wheat flour, is necessary to suppress excessive wheat import. As alternatives, flour derived from cereals and tubers, such as rice, corn, potato, and cassava, can be used in bread processing. The absence of gluten from the bread composition results in pale, less fluffy bread and firm crumb, and therefore it is necessary to modify the batter to improve gluten-free bread quality. This research aims to know the effect of the supplement of hydrocolloids glucomannan and xanthan gum on gluten-free batter properties and bread quality. Breads were made of rice flour, potato flour, corn and cassava starch. Batter consistency, bread specific volume (SV), crumb analysis, crust colour, crumb firmness, firmness, cohesiveness and panellists’ preference were determined. This study showed that the combination of xanthan gum: glucomannan on proportion 0.75:0.25 was the highest batter consistencies, highest specific volume, lower firmness, highest cohesive, and most preferred by panellists.

1. Introduction
White bread is one of foods containing high carbohydrates, made of wheat flour as the main component by yeast fermentation process and baking and has been accepted by the society. The problem is wheat as the raw material of wheat flour can only be cultivated in certain countries. For some countries, such as Egypt, the Philippines, and other tropical countries especially Indonesia, wheat should be imported from producing countries. Besides the problem of availability, gluten in wheat causes allergic for some people. Gluten allergic is called as celiac. Protein in wheat (gluten and gliadin) causes no response to the immune system in celiac patients. Celiac is suffered by 1 in 200 people in the world [1]. Thus, it is needed to make alternative bread without taking gluten as one of the materials to be consumed by celiac patients.

Gluten plays the role to create elasticity on bread batter, increasing batter capacity in holding CO₂, recovering texture, flavor, and appearance [2]. Shittu et al. [3] stated the bread batter made without gluten has the capacity of holding low gas, this causes low bread volume and hard texture with random big pores.

The quality of gluten-free bread can be increased by making variations on the essence, hydrocolloid addition. Hydrocolloid in gluten-free formula is used to imitate viscoelastic from gluten, elastic batter has a soft crumb texture with the same pores. Hydrocolloid is a carboxyl methyl cellulose (CMC), guar gum, carrageenan, alginate, glucomannan and xanthan gum normally used in a gluten-free bread recipe [4]. The solvent which consists of two hydrocolloids on optimum ratio can create an...
elastic gel that is strong and reversible when heated. Such hydrocolloids can create bread with a high specific volume and are accepted in sensory [5]. Additional xanthan gum for 1.5% combined with 0.9% glucomannan creates a higher specific volume in bread compared to the bread processed by adding 1.25% hydrocolloid xanthan gum. [6]

This research is aimed to learn about the effect of the use of hydrocolloid proportion glucomannan and xanthan gum on specific volume characteristics, texture profile, pore similarity, and sensory reception of gluten-free white bread from the composition of rice flour, potato flour, corn starch, and cassava starch.

2. Material and methods

2.1. Material

The materials used in this study were: 1) Rice flour (11.14% water content, 1.15% ash content, 0.53% fat content, 6.7% protein content, 80.28 carbohydrate content); 2) Potato flour (7.33% water content, 0.67% ash content, 0.35% fat content, 5.81% protein content, 82.43 carbohydrate content), 3) Corn starch (10.43% water content, 0.7% ash content, 0.25% fat content, 4.67% protein content, 84.74 carbohydrate content); and 4) Cassava starch (8.12% water content, 0.83% ash content, 0.28% fat content, 5.26% protein content, 84.74 carbohydrate content). The other materials are sugar, butter, salt and full cream milk, all these ingredients were supplied by Primarasa store, Malang. Xanthan gum and glucomannan were supplied by Kridatama store, Malang. The utensils used in gluten-free breadmaking were a 17 x 6 x 5.5 cm aluminum baking pan, mixer (Philips), oven (Kirin), Texture Profile Analyzer CT-3 (Brookfield), glassware (Pyrex) and Color Reader (Minolta).

2.2. Methods

The experiment consists of the following stages, including (2.2.1.) White bread preparation, (2.2.2.) Texture analysis, (2.2.3.) Specific volume analysis, (2.2.4.) Firmness analysis, (2.2.5.) Cell Similarity Analysis, (2.2.6.) Sensory analysis and (2.2.7.) Statistical analysis.

2.2.1. White bread preparation. All dry ingredients were mixed with butter and eggs using the mixer for 30 seconds. After the water was added, the mixing was continued for 4 minutes. Next, the bread batter was poured into a 17 x 6 x 5.5 cm baking pan and covered with plastic wrap. The batter was then proofed for 45 minutes and it was continued by oven baking at 150°C for 20 minutes.

2.2.2. Texture analysis. Butter consistency was determined using a Texture Analyser sample was poured into the extrusion vessel, and the air pockets were removed with a spoon. The extrusion force was measured at a test speed of 1.0 mm/sec to a distance of 25 mm [7].

2.2.3. Specific volume analysis. Specific volume analysis was calculated by using the ratio between bread volume and bread weight. Bread volume calculation was performed by rapeseed displacement test, it was modified using sesame seed as rapeseed substitute. Specific volume was calculated based on the following formula:

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\text{Specific volume} = \frac{\text{Bread volume}}{\text{Bread weight}} \quad (1)
\]

2.2.4. Firmness analysis. Firmness analysis was performed using Texture Profile Analyzer TAXT2. Five pieces of samples were prepared for each analysis repetition, a sample was cylindrical with 5 cm in diameter and 3 cm in height. The aluminum cylinder probe used in this study was 75 mm in diameter with 50% pressure, test speed was 2 mm/s, the test was paused for 30 seconds between the first and second pressure. The data obtained was firmness.
2.2.5. **Cell similarity analysis.** Crumb bread was cut in the size of 5 x 5 cm and then scanned using HP Deskjet D1050 scanner in 50 dpi resolution. The scan results were then opened with Image J application to count number and size of the bread cells.

2.2.6. **Sensory analysis.** Sensory analysis with hedonic systems, involving 60 inexpert panelists. Analysis with hedonic system involves the attributes of color, flavor, taste, texture and overall. The hedonic scale ranged from 1 to 5 (1 = very dislike, 2 = dislike, 3 = fairly like, 4 = like, 5 = very like).

2.2.7. **Statistical analysis.** All experiments were performed in triplicates and the results were analyzed by ANOVA two factors. The data were analyzed using MINITAB 17 program. It was followed by Tukey test (Honestly Significance Difference) if there was a significant difference. All data were displayed from the average score and standard deviation (SD).

3. **Results and discussion**

3.1. **Consistency of batter**

The characteristic of batter can be identified from the consistency value. Batter consistency is the magnitude of the force required to deconstruct the batter [7]. The average batter consistency of gluten-free bread batter is displayed in Table 1.

| Proportion | Consistency (g) |
|------------|-----------------|
| Xanthan gum | Glucomannan      |                |
| 0          | 0               | 6.833 ± 0.058^d|
| 1          | 0               | 11.333 ± 0.577^b|
| 0.75       | 0.25            | 13.977 ± 0.166^a|
| 0.5        | 0.5             | 13.600 ± 0.173^a|
| 0.25       | 0.75            | 8.600 ± 0.173^c|
| 0          | 1               | 6.700 ± 0.173^d|

Note: the number followed by the same letter shows that average of observation result is not significantly different at the significance level α = 0.05.

Table 1 shows that the addition of hydrocolloid proportion was able to improve the batter consistency, compared with the control. The addition of hydrocolloid to gluten-free bread batter may increase viscoelasticity of the batter due to hydrocolloid ability to form gel [8]. Xanthan gum added to the formula increased the batter consistency from 6.8 to 11.3. Xanthan gum can form a very rigid double helix intramolecular conformation [9]. High-weight molecules of the xanthan gum can form an aggregate complex through obligation hydrogen bonds and the involvement of polymer, resulting in high Newtonian viscosity at a low shear rate which increases the batter consistency [7]. Among CMC, HPMC and Alginate that are often used in the production of gluten-free bread, xanthan gum shows the best results in increasing batter consistency [5]. Escudier et al. [10] tested batter with the addition of CMC and xanthan gum at room temperature, the result was batter with xanthan gum addition has higher consistency than that with CMC addition.

From Table 1, it can be seen that the highest batter consistency of 13.9 grams is obtained in the proportion of xanthan gum and glucomannan 0.75 : 0.25. Hydrocolloid used in balance proportion could improve the consistency of the batter. The single addition of xanthan gum is unable to form a gel. However, when it is combined with glucomannan at the right ratio, the two hydrocolloids will interact synergistically to form a strong gel. Hydrocolloids, like xanthan gum, are not able to form a gel if added separately. However, when combined with glucomannan in the right ratio, the two
hydrocolloids will interact synergistically to form a strong gel [11]. The gel formed by hydrocolloid will result in batter with high viscosity [12]. A strong gel formation may increase the viscosity of the batter; the consistency of the batter will increase if the viscosity increases [13].

3.2. Specific volume

Glutenin and gliadin fraction which is capable of forming gluten in wheat flour can create an elastic and extensible bread batter. It will help the batter to trap lots of carbon dioxide gas generated during the fermentation so that it will produce is fluffy and soft bread [14]. In gluten-free bread, the absence of gluten causes the bread to lose essential elements such as low volume, crude bread fibre and other poor physical parameters [15].

Table 2 shows that the range of specific expansion volume of the gluten-free bread was 1.961 – 2.702 cm3/g. Single use of xanthan gum in the batter increases the specific volume compared to the control. It is assumed that xanthan gum may act as a binding agent that increases the batter viscoelasticity [16]. The batter that has viscoelasticity property will easily trap the gas during fermentation hence the volume during baking is high [17]. Gomez et al. (2007), stated with the increase in the amounts of glucomannan, the volume and specific volume of steamed bread increased [25].

Table 2. Effect of hydrocolloid on specific volumes.

| Proportion | Xanthan gum | Glucomannan | Specific volume (cm3/g) |
|------------|-------------|-------------|------------------------|
| 0          | 0           | 0           | 2.1101 ± 0.0219⁵      |
| 1          | 0           | 0           | 2.5808 ± 0.0949⁴      |
| 0.75       | 0.25        | 0.25        | 2.7023 ± 0.1436⁴      |
| 0.5        | 0.5         | 0.5         | 2.2557 ± 0.0294⁵      |
| 0.25       | 0.75        | 0.75        | 1.7781 ± 0.0960⁶      |
| 0          | 1           | 1           | 1.9613 ± 0.0184⁶      |

Note: the number followed by the same letter shows that average observation result is not significantly different at the significance level α = 0.05.

Specific expansion volume of the bread is higher when glucomannan and xanthan gum were used in the proportion of 0.25 : 0.75. The right proportion of glucomannan and xanthan gum hydrocolloid combination will form elastic and strong gel [18]. The formation of elastic and strong gel will create a more compact structure of the batter so that the batter consistency increases. A high consistency batter will be able to trap plenty of CO2 gas during fermentation and maintain it during the baking process, resulting in bread with high volume [19].

3.3. Texture profile

Single-use of xanthan gum might increase the firmness texture of the gluten-free bread. It is most likely because xanthan gum is not able to form gel, yet it has a very high solubility rate which causes an increase in the batter viscosity at a low shear rate. It results in a batter which is firm quickly so it has hard crumb [8].
The firmness of the bread decreased into 351.8 grams when xanthan gum was combined with glucomannan. A combination of xanthan gum and glucomannan in bread batter will form a synergistic bond. The backbone structure of glucomannan will bind to the helix structure of xanthan gum, the mixture can dissolve and form an elastic gel when it is heated. The presence of elastic gel in gluten-free bread batter is necessary because it is assumed that gel can imitate the viscoelastic property of gluten [12]. The formation of a strong gel is able to create a strong tissue to hold gas during fermentation leading to the bread volume increase. The increasing volume resulted in the softer texture of the bread [7].

Springiness value is determined by the distance of the product movement at the second pressure to achieve its maximum force value compared to the distance of the product movement at the first pressure to achieve its maximum force value [20]. Xanthan gum and glucomannan proportion of 0.75:0.25 increased the springiness value. It is presumably due to the combination of glucomannan and xanthan gum in the right proportion can form a strong and elastic gel [13]. Based on the data of batter consistency in Table 1, the batter made with xanthan gum and glucomannan proportions of 0.75:0.25 resulted in the highest consistency. High consistency batter has an excellent ability to trap the gas formed during fermentation [7]. This condition affects the increase of crumb springiness.

Cohesiveness is an indicator of the internal bond strength that composes food. In comparison with the control, the cohesiveness of gluten-free bread increased by a single addition of xanthan gum with xanthan gum and glucomannan proportion of 0.75:0.25. However, the increase was not statistically significant. Demirkesen et al. [21] stated that the addition of hydrocolloids of xanthan gum, guar gum, CMC and HPMC has an effect on increasing cohesiveness of the bread made of brown rice flour. According to Schober et al. [22], hydrocolloids can create a strong gel structure, thereby increasing the cohesiveness of gluten-free bread.

3.4. Pore similarity
The fermentation process of the batter leads to the colloidal structure formed by gas dispersion to turn into foam and then the porous system will be formed [14]. Open tissue leads to the formation of different pores from the foam that is formed in closed tissues. When the batter is baked, the heat generated from the oven will result in a large expansion, called the oven spring. The average size of the pore was 13.276 – 74.543 mm2, and the number of pore was between 11.867 – 29.267 cm2. The control bread has a large but small number of pores while the bread made with combination of hydrocolloids has many smaller pores with uniform size.

Xanthan gum and glucomannan which were used in the proportion of 0.75:0.25 could decrease the pore size and increase the pore numbers compared to the other five treatments. It is presumably because such proportion of glucomannan and xanthan gum are capable of forming a thermo-reversible and stable gel, thereby increasing the batter viscoelasticity [12]. The elastic batter has a high capability in trapping and maintaining CO2 gas. The more CO2 trapped, the more air will be dispersed into bubbles, so the batter expands and forms many uniform pores [14].

### Table 3. Effect of hydrocolloid on texture profile.

| Proportion | Firmness (g)       | Springiness (mm) | Cohesive |
|------------|--------------------|------------------|----------|
| Xanthan gum | Glucomannan        |                  |          |
| 0          | 0                  | 835.77 ± 3.98    | 3.546 ± 0.0702 | 0.903 ± 0.035 a |
| 1          | 0                  | 871.40 ± 3.55d   | 3.810 ± 0.0794b | 0.906 ± 0.030a |
| 0.75       | 0.25               | 351.83 ± 3.55e   | 3.973 ± 0.0985c | 0.920 ± 0.017 a |
| 0.5        | 0.5                | 947.33 ± 3.76b   | 3.653 ± 0.0321c | 0.893 ± 0.015 ab |
| 0.25       | 0.75               | 1134.47 ± 3.91 a | 3.613 ± 0.1250d | 0.853 ± 0.025 b |
| 0          | 1                  | 1138.53 ± 4.56 a | 3.570 ± 0.1058 c | 0.853 ± 0.015 b |

Note: the number followed by the same letter shows that average of observation result is not significantly different at the significance level α = 0.05.
Table 4. Effect of hydrocolloid on pore similarity.

| Proportion | Pore size (mm²) | Count (cm²) |
|------------|-----------------|-------------|
|            |                 |             |
| Xanthan gum| Glucomannan     |             |
| 0          | 0               | 74.543 ± 3.095 \(^a\) | 13.200 ± 1.02 \(^a\) |
| 1          | 0               | 13.606 ± 0.422 \(^e\) | 24.680 ± 0.12 \(^a\) |
| 0.75       | 0.25            | 13.276 ± 0.452 \(^e\) | 29.267 ± 1.041 \(^a\) |
| 0.5        | 0.5             | 34.214 ± 0.774 \(^d\) | 16.450 ± 1.028 \(^b\) |
| 0.25       | 0.75            | 40.342 ± 4.690 \(^c\) | 23.860 ± 1.050 \(^a\) |
| 0          | 1               | 59.993 ± 2.027 \(^b\) | 11.867 ± 0.320 \(^b\) |

Note: the number followed by the same letter shows that average of observation result is not significantly different at the significance level \(\alpha = 0.05\).

The increase of glucomannan proportion resulted in a small number of larger pore. It is presumably because the proportion formed weak gel. The formation of weak gel leads to the weak batter viscoelasticity so that it is not able to maintain CO2 [24].

3.5. Sensory preference

The result of colour assessment on gluten-free bread by the panellist ranged from 3.116 – 4.250. The higher value indicated that the panellists were fond of the bread colour. The result of analysis of variance indicated that the treatment of hydrocolloid combination affected the panellists’ preference for the colour of gluten-free bread, since the p value (0.041≤0.05). The increase proportion of glucomannan and the decrease proportion of xanthan gum in the formulation resulted in the decrease of panellists’ preference.

![Figure 1. Hedonic scale of gluten-free bread.](image)

The result of analysis of variance indicated that the treatment of hydrocolloid combination affected the panellists' preference for the texture of gluten-free bread, since the p value (0.00≤0.05). The overall attributes describe the panellists’ preference of gluten-free bread in all attributes. The highest-rated bread was that with xanthan gum and glucomannan proportion of 0.25: 0.75. This is presumably because from all sensory parameters tested, bread in that proportion had the highest preference value, so the panellists were very fond of the bread. Barcenas and Rosel research [23] also stated that the addition of hydrocolloids may increase the panellists’ acceptance of gluten-free bread.
4. Conclusions
Combination of xanthan gum:glucomannan on proportion 0.75:0.25 was the highest batter consistencies, highest specific volume, lower firmness, highest cohesiveness, and most preferred by panellists. Hydrocolloid combination treatment gave a significant effect (α=0.05) on the value of dough consistency, specific volume, pore uniformity, firmness, springiness, cohesiveness, crust and crumb colour, scoring of pore uniformity, sensory scoring (elasticity, firmness, cohesiveness), and sensory preference for gluten-free white bread. A combination formulation of the best hydrocolloid was obtained in the proportion of xanthan gum and glucomannan 0.75: 0.25. This formula produces white bread with the highest specific volume, lowest firmness, high elasticity, low cohesiveness, bright white crumb, brown crust and most accepted sensory.

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