

Effect of Hydrocolloids on the Characteristics of Gluten-Free Bread from Coix Seed Flour

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Abstract

The demand for gluten-free bread had increased because of the healthier lifestyle. Some people were intolerant to gluten which led to celiac disease. However, the gluten-free bread typically performed low specific volume, dense and crumbly texture. Hydrocolloids were commonly used as an ingredient to replace gluten, leading to improvement of the gluten-free bread quality. This study aimed to develop gluten-free bread from coix seed flour with the addition of hydrocolloids. The effects of using different hydrocolloid types (Xanthan gum (XG) and Hydroxypropyl methylcellulose (HPMC)) and contents (0.5–2%) on the physical and sensory qualities of gluten-free bread were investigated. Hydrocolloid type and content affected the physical qualities of gluten-free bread. The hardness, specific volume, lightness and whiteness index of gluten-free bread containing XG were higher than those of gluten-free bread containing HPMC. Increasing hydrocolloid contents (XG 0.5–2% and HPMC 0.5–2%) significantly decreased the hardness ($p \leq 0.05$). In contrast, the springiness, specific volume, lightness and whiteness index were significantly increased ($p \leq 0.05$), whereas the water activity was not significantly different ($p > 0.05$). In sensory evaluation, the appearance, taste, aroma, flavor, softness, firmness and overall liking scores of all gluten-free breads were not significantly different ($p > 0.05$). The overall liking scores ranged from 5.70 to 6.14. Additionally, the gluten-free bread containing 1% HPMC was selected as the most appropriate formulation because it received the highest mean overall liking score (6.14) while maintaining desirable physical properties.

Keywords: Gluten-free bread, Hydrocolloid, Coix seed flour, Texture, Quality

ผลของไฮโดรคอลลอยด์ต่อคุณลักษณะของขนมปังไร้กลูเตนจากแป้งลูกเดี๋ย

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บทคัดย่อ

ความต้องการบริโภคขนมปังไร้กลูเตนเพิ่มขึ้นตามแนวโน้มการดำเนินชีวิตเพื่อสุขภาพมากขึ้น รวมถึงผู้บริโภคบางรายมีภาวะแพ้งลูเตนซึ่งอาจนำไปสู่โรคเซลิแอค (Celiac disease) อย่างไรก็ตาม ขนมปังไร้กลูเตนมักมีปริมาณจำเพาะต่ำ มีเนื้อสัมผัสที่แน่นและร่วน การนำไฮโดรคอลลอยด์มาใช้เป็นส่วนผสมเพื่อทดแทนกลูเตนจะช่วยปรับปรุงคุณภาพของขนมปังไร้กลูเตนได้ งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาขนมปังไร้กลูเตนจากแป้งลูกเดี๋ยที่เสริมไฮโดรคอลลอยด์ และเพื่อศึกษาผลของการใช้ชนิด (แซนแทน กัม (Xanthan gum, XG), ไฮดรอกซีโพรพิลเมทิลเซลลูโลส (Hydroxypropyl methylcellulose, HPMC)) และปริมาณ (0.5–2%) ไฮโดรคอลลอยด์ที่แตกต่างกันต่อคุณสมบัติทางกายภาพและทางประสาทสัมผัสของขนมปังไร้กลูเตนจากแป้งลูกเดี๋ย จากผลการศึกษา พบว่าชนิดและปริมาณไฮโดรคอลลอยด์มีผลต่อคุณสมบัติทางกายภาพของขนมปังไร้กลูเตน โดยขนมปังไร้กลูเตนที่เสริม XG มีค่าความแข็ง ค่าปริมาตรจำเพาะ ค่าความสว่าง และค่าดัชนีความขาวสูงกว่าขนมปังไร้กลูเตนที่เสริม HPMC การเพิ่มปริมาณไฮโดรคอลลอยด์ (XG 0.5–2% และ HPMC 0.5–2%) ส่งผลให้ค่าความแข็งลดลงอย่างมีนัยสำคัญทางสถิติ ($p \leq 0.05$) ขณะที่ค่าความยืดหยุ่น ค่าปริมาตรจำเพาะ ค่าความสว่าง และค่าดัชนีความขาวเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ ($p \leq 0.05$) ส่วนค่ากิจกรรมของน้ำไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p > 0.05$) สำหรับการประเมินทางประสาทสัมผัส พบว่า คะแนนความชอบด้านลักษณะปรากฏ รสชาติ กลิ่น กลิ่นรส ความนุ่ม ความแน่นเนื้อ และความชอบโดยรวมของขนมปังไร้กลูเตนไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p > 0.05$) โดยคะแนนความชอบโดยรวมอยู่ในช่วง 5.70–6.14 ทั้งนี้ ขนมปังไร้กลูเตนจากแป้งลูกเดี๋ยที่เสริม HPMC 1% ได้รับการคัดเลือกให้เป็นสูตรที่เหมาะสมที่สุด เนื่องจากมีคะแนนความชอบโดยรวมเฉลี่ยสูงสุด (6.14) และยังคงมีคุณสมบัติทางกายภาพที่เหมาะสม

คำสำคัญ: ขนมปังไร้กลูเตน ไฮโดรคอลลอยด์ แป้งลูกเดี๋ย เนื้อสัมผัส คุณภาพ

1. Introduction

The demand for gluten-free products has increased, particularly in the bakery industry, because of consumers' health-conscious lifestyles. Additionally, some people are intolerant to gluten which leads to celiac disease. This trend is reflected in the market growth of gluten-free products. The global gluten-free product market is valued at USD 6.45 billion in 2022 and is projected to grow at an annual growth rate of 9.8% from 2023 to 2030 [1, 2]. Following the demand for gluten-free products, producing high-quality of gluten-free bread (GFB) remains a major challenge due to the increasing number of gluten-intolerant individuals and health-conscious consumers. Gluten plays a critical role as a structure-forming protein in



the leavened baked products. Therefore, gluten-free bread has several disadvantages, including low loaf specific volume, dense and crumbly texture [2, 3].

Coix lachryma-jobi, commonly known as Job's tears, coix, Chinese pearl barley, and adlay, is a grain-bearing perennial tropical plant belonging to the Poaceae family [4]. It is widely cultivated in several Asian countries, including the Philippines, Myanmar, Sri Lanka, China and Thailand [5]. Compared with other cereals such as wheat, maize, and rice, it has a higher protein-to-carbohydrate ratio. Similar to maize and rice, it is naturally gluten-free and is used as an ingredient in gluten-free products for individuals with celiac disease [4]. Coix mainly contains carbohydrate (81.71%), protein (13.28%), lipid (3.21%), ash (1.12%), fiber (0.67%), as well as trace minerals and vitamins such as calcium, phosphorus, niacin, thiamine, and riboflavin. In addition, it exhibits several nutritional and health-promoting properties, such as inhibiting the growth of lung and liver cancer cells and reducing the risk of coronary heart disease. Furthermore, it has a lower glycemic index and glycemic load than brown rice [6].

To improve the quality of gluten-free bread, hydrocolloids have been widely used as binding agents and gluten substitutes. Hydrocolloids are hydrophilic, long-chain polysaccharides that bind with water to form a gel network structure. As a result, they increase intermolecular viscosity and strengthen the gas cells [7]. However, their functionality depends on factors such as molecular weight, structure, chain length, bond formation, and chemical modification [7,8]. In gluten-free batter, hydrocolloids help improve water-holding capacity, viscosity, foam stability, viscoelastic properties, and gas-holding capacity [7].

Xanthan gum (XG) and hydroxypropyl methylcellulose (HPMC) are the most used hydrocolloids in gluten-free bread. They increase loaf volume and porosity, leading to a softer texture. XG is an extracellular polysaccharide. It is soluble in cold water and forms intermolecular bonds, leading to a weakly bound network. Its viscous solutions perform highly pseudoplastic behavior [7, 9]. Moreover, the study of Chakraborty *et al.* [10] reports that the addition of xanthan gum improves the quality of gluten-free millet bread by enhancing its expansion, specific volume, and texture properties [7].

HPMC is formed by the chemical linkage of hydroxypropyl and methyl groups to the cellulose chain. It is soluble in cold water, has good water holding capacity, and forms solutions with shear-thinning behavior. Additionally, it forms stronger hydrophobic bonds at high temperatures, leading to the formation of a stronger thermo-reversible gel network [7]. The study of Zhao *et al.* [2] reports that the addition of HPMC improves the quality of gluten-free rice bread by increasing loaf and specific volume, enhancing dough expansion, and improving crumb softness. These improvements are mainly attributed to the gas-holding capacity and the viscosity of HPMC.

In this study, gluten-free bread from coix seed flour is developed using XG and HPMC at levels ranging from 0.5–2%. The physical properties (texture, specific volume, color and water activity) and sensory qualities of gluten-free bread are investigated. The findings of this study may be useful for developing the most appropriate formulation of gluten-free bread from coix seed flour and other gluten-free products for health-conscious consumers and individuals with celiac disease.

2. Material and Methods

2.1 Preparation of gluten-free bread

The formulations of gluten-free bread from coix seed flour with different hydrocolloid types (Xanthan gum (XG) and Hydroxypropyl methylcellulose (HPMC)) and contents were prepared according to the procedure of González *et al.* with some modification [11]. Briefly, the gluten-free bread were composed of coix seed flour (48–50 g/100 g sample), hydrocolloids (XG or HPMC, 0–2 g/100 g sample), butter (17.5 g/100 g sample), sugar (7 g/ 100 g flour), salt (3.5 g/100 g sample), yeast (3.5 g/100 g sample) and water (41 g/100 g sample). First, coix seed flour, hydrocolloids (XG or HPMC), sugar, salt, yeast and water were mixed at speed 1 for 4 min using an electric mixer (KitchenAid, MI, USA). Then, butter was added and mixed with the previous mixture at speed 1 for 1 min until a homogeneous batter was obtained. The batter was placed in the rectangular baking mold covered with non-stick paper. The batter was proved at 35 °C and 85% relative humidity for 30 min. Finally, the batter was baked at 175°C for 30 min by using an electric oven (Sharp, EO–42K, Thailand). After baking, the bread was cooled at room temperature (25±2 °C) and packed in a sealed plastics bag for further analysis.

2.2 Determination of physical properties

The hardness, springiness, and chewiness of the gluten-free bread were analyzed using a texture analyzer (TA Plus, Lloyd Instruments, UK). The center of each bread loaf was cut into cubes (2 × 2 × 2 cm). The measurements were performed using 35-mm diameter cylindrical probe at a constant test speed of 3 mm/s to compress the bread crumb to 50% deformation, according to Adzqia *et al.* with some modifications [12].

The specific volume (SV) was determined using the flaxseed displacement method described by González *et al.* with some modifications [11]. The weight of the bread and the displaced flax seeds were recorded. The apparent density (AD) of flax seeds was 0.6754 g/mL. The specific volume was calculated using Equation (1) as follows:

$$\text{Specific volume (mL/g)} = (\text{Displaced seeds weight} / \text{AD}) / \text{Bread weight} \quad (1)$$

The color of the bread crumb was measured using a Minolta colorimeter (Chromameter CR-400/410, Konica Minolta, Japan) according to the method of Awal *et al.* with some modifications [13]. The CIE Lab parameters, including L* (Lightness), a* (Green to Red) and b* (Blue to Yellow) were determined using illuminant D65 and 10° observer angle. The whiteness index (WI) was calculated to evaluate color changes in the bread crumb according to Equation (2):

$$WI = 100 - \sqrt{100 - L^* + a^* + b^*} \quad (2)$$

The water activity (a_w) of the crumb of gluten-free bread was measured at 25 °C using a water activity meter (AquaLab LITE, Decagon Devices, USA) according to the method of AOAC with some modification [14]. Before measurement, the bread crumb was ground and filled to one-third of the sample cup.

2.3 Determination of sensory qualities

Sensory evaluation of gluten-free bread was conducted by using a 9-point hedonic scale under normal lighting conditions at room temperature. The sensory evaluation was performed by 30 untrained panelists. The panelists evaluated their degree of liking for the appearance, taste, color, aroma, flavor, softness, firmness and overall liking of the gluten-free bread (1 = disliked extremely, 5 = neither liked nor disliked and 9 = like extremely) [15].

2.4 Statistical analysis

The experiment was designed as a factorial experiment in a completely randomized design (CRD) to determine the effects of hydrocolloid type and content on qualities of gluten-free bread from coix seed flour. Difference between means of all samples was analyzed using two-way ANOVA. Duncan's multiple range test was used to identify a significant difference ($p \leq 0.05$) by SPSS statistics.

3. Results and Discussion

3.1 Physical properties of gluten-free bread from coix seed flour

As shown in Figure 1, the two-way ANOVA revealed that hydrocolloid type, hydrocolloid content and their interaction (Type x Content) significantly affected the hardness, springiness, and chewiness of gluten-free bread ($p \leq 0.05$). In general, increasing the hydrocolloid content decreased hardness and chewiness but increased springiness. However, these changes depended on the hydrocolloid type.

With increasing hydrocolloid content, the hardness and chewiness of gluten-free bread containing 0.5–2% XG (33.80–50.03 N and 0.84–1.32, respectively) and 0.5–2% HPMC (27.61–43.83 N and 0.35–0.70, respectively) were significantly decreased ($p \leq 0.05$). In contrast, the springiness of gluten-free bread containing 0.5–2% XG (0.56–5.67 mm) and 0.5–2% HPMC (0.52–0.71 mm) was significantly increased ($p \leq 0.05$). These changes might be attributed to the water-binding capacity of hydrocolloids [11]. Additionally, the hardness of gluten-free bread containing XG was higher than that of gluten-free bread containing HPMC. Tamilselvan *et al.* [7], based on the findings of Mariotti *et al.* [16], reported that increasing XG content resulted in higher hardness and larger cell size because the gas cells rapidly expanded during proofing and baking. Additionally, XG increased the springiness of the bread crumb. The XG-added matrix had lower strength, causing gas bubbles to coalesce and collapse during proofing and baking. This resulted in larger air cells with thicker walls. In contrast, HPMC helped strengthen the gas cells, resulting in a finer crumb structure [17].

The specific volume of the gluten-free bread containing 0.5–2% XG (1.66–1.73 mL/g) and 0.5–2% HPMC (1.59–1.82 mL/g) was significantly increased ($p \leq 0.05$) with increasing hydrocolloid content. These findings were consistent with the study of Numfon [18], who reported that the incorporation of XG into

gluten-free bread prepared from small broken rice flour increased the specific loaf volume. Moreover, higher loaf volume was observed in bread containing 1–2% HPMC. This might be because HPMC formed elastic microgels by intramolecular mobility, thereby preventing air-cell coalescing. In contrast, XG performed higher batter resistance and consistency, reducing batter expansion during baking leading to lower loaf volume [7].

The water activity (a_w) of the bread crumb was not significantly different ($p > 0.05$). The a_w values of bread crumb containing 0.5–2% XG and 0.5–2% HPMC ranged from 0.958–0.960 and 0.961–0.966, respectively. This might be because all formulations contained the same amount of water, although hydrocolloids had water absorption properties. In addition, Renzo *et al.* [19] explained that the differences in a_w values among formulations were likely related to variations in moisture content. These results were consistent with the findings of Lazaridou *et al.* [20], who reported that the addition of hydrocolloids did not significantly affect the a_w values of bread crumb ($p > 0.05$).

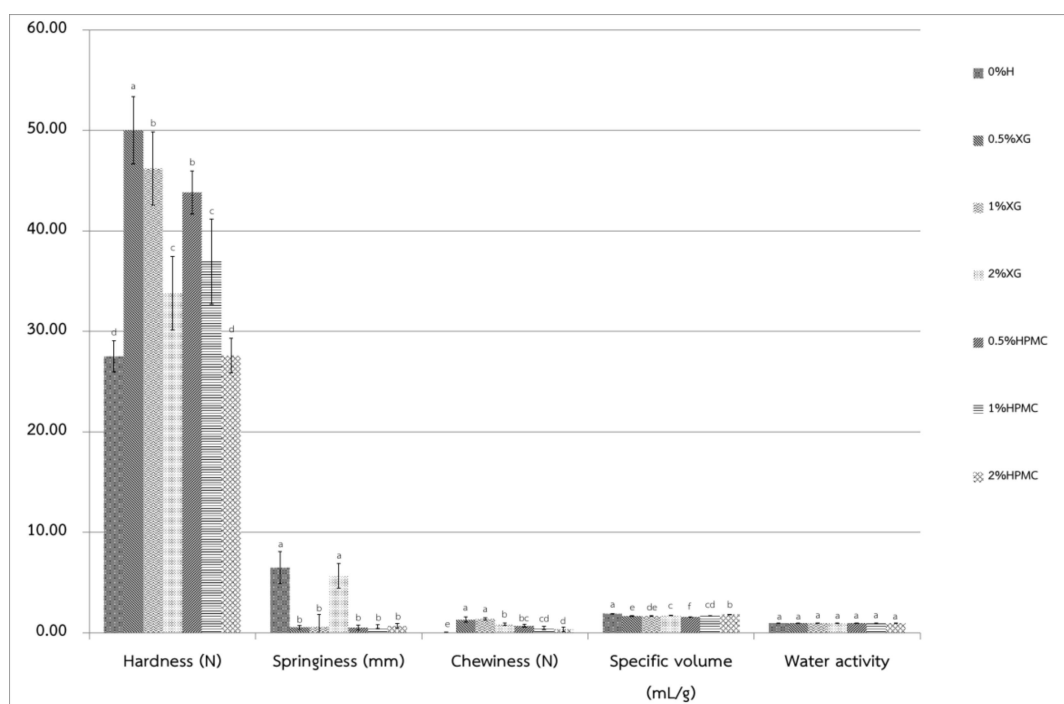


Figure 1 Texture, specific volume and water activity of gluten-free bread from coix seed flour

Regarding the color of gluten-free bread, the two-way ANOVA revealed that hydrocolloid type, hydrocolloid content and their interaction (Type $\times$ Content) significantly affected the whiteness index (WI) ($p \leq 0.05$). The significant interaction indicated that the effect of hydrocolloid content on WI depended on the hydrocolloid type. Specifically, increasing XG content resulted in higher WI values than increasing HPMC content. With increasing hydrocolloid content, the WI values of gluten-free bread containing 0.5–2% XG (50.48–57.37) and 0.5–2% HPMC (46.52–50.10) were significantly increased ($p \leq 0.05$). Similarly, the L^* values of gluten-free bread containing 0.5–2% XG (55.65–59.28) and 0.5–2% HPMC (50.66–54.29) were significantly increased ($p \leq 0.05$). In contrast, the a^* values of the gluten-free bread containing 0.5–2% XG (2.25–2.61)

and 0.5–2% HPMC (2.44–2.73) were significantly decreased ($p \leq 0.05$). The b^* values were not significantly different ($p > 0.05$). These findings were consistent with Torbica *et al.* [21], who reported that increasing hydrocolloid content increased L^* values (86.43–89.50). These results might be attributed to the reduction in Maillard reaction rate due to changes in water distribution caused by the addition of hydrocolloids, resulting in a lighter crumb color. Tamilselvan *et al.* [7] also reported that incorporating 0.5%–2% XG into proso millet flour gluten-free bread increased the L^* value of crumb, indicating a lighter crumb color. In the case of a^* and b^* values, Torres-Pérez *et al.*, [22] explained that the addition of hydrocolloids affected these values depending on the type of flour used.

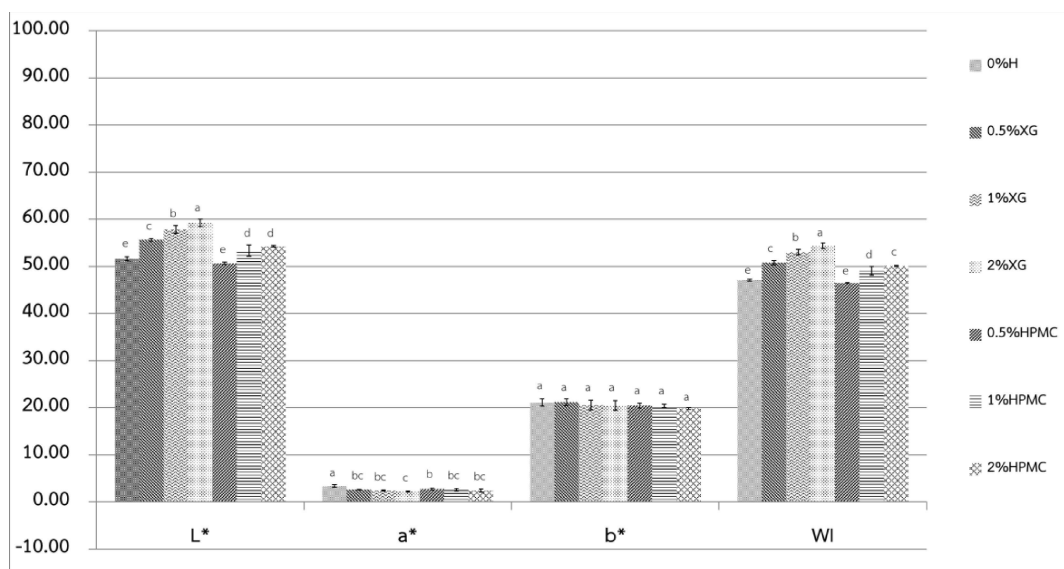


Figure 2 Color of gluten-free bread from coix seed flour

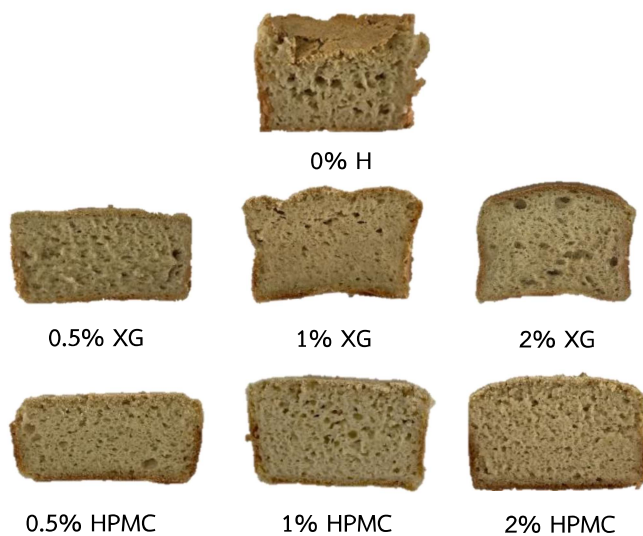


Figure 3 Photograph of gluten-free bread from coix seed flour using different hydrocolloid types (XG and HPMC) and contents (0.5–2%)

3.2 Sensory qualities of gluten-free bread from coix seed flour

In Table 1, the appearance, taste, aroma, flavor, softness, firmness and overall liking scores of all gluten-free bread samples were not significantly different ($p > 0.05$). The scores of all sensory attributes and overall liking were above 5, indicating acceptable sensory quality. Although no significant differences were observed, gluten-free bread containing HPMC tended to receive higher overall liking scores than gluten-free bread containing XG. These findings were consistent with Lazaridou *et al.* (2007) [20], who reported that the gluten-free bread containing hydrocolloids received average liking scores above 5 for all sensory attributes. Additionally, Sadat *et al.* [23] reported that the gluten-free bread made from corn starch and zein containing HPMC performed higher sensory scores than the gluten-free bread containing XG. Increasing XG content (0.5–2%) in the gluten-free bread tended to result in higher scores for appearance (6.02–6.24), taste (5.84–6.00), aroma (5.96–6.36), flavor (5.62–5.90), softness (5.86–6.06), and overall liking (5.78–5.98), comparing with the control bread (5.82, 5.62, 5.68, 5.32, 5.72, 5.52 and 5.70, respectively). Likewise, increasing HPMC content (0.5–2%) in the gluten-free bread tended to result in higher scores for appearance (6.06–6.76), taste (5.90–5.94), aroma (6.06–6.26), flavor (5.60–5.84), softness (5.74–6.24), firmness (5.70–5.82) and overall liking (6.02–6.14), comparing with the control bread. Among all formulations, gluten-free bread containing 1% HPMC showed the highest score in appearance (6.76), softness (6.24), and overall liking (6.14), although no significant differences were observed. A similar positive effect of HPMC was reported by Tabrizi *et al.* [24], who found that increasing HPMC (0.5%–1.5%) improved the overall acceptance score of gluten-free bread formulated from quinoa, grass pea, and chestnut flours.

Table 1 Sensory qualities of gluten-free bread from coix seed flour

Sample	Appearance ^{ns}	Taste ^{ns}	Aroma ^{ns}	Flavor ^{ns}	Softness ^{ns}	Firmness ^{ns}	Overall liking ^{ns}
0% H	5.82±1.84	5.62±1.71	5.68±1.83	5.32±1.86	5.72±2.01	5.52±1.85	5.70±1.96
0.5% XG	6.24±1.52	5.88±1.59	6.16±1.67	5.62±1.81	6.06±1.71	5.76±1.76	5.88±1.49
1% XG	6.06±1.80	6.00±1.53	5.96±1.74	5.90±1.72	5.96±1.73	5.52±1.94	5.98±1.52
2% XG	6.02±1.68	5.84±1.57	6.36±1.55	5.76±1.56	5.86±1.80	5.32±2.09	5.78±1.48
0.5% HPMC	6.30±1.47	5.94±1.66	6.26±1.61	5.60±1.67	5.94±1.68	5.82±1.61	6.02±1.37
1% HPMC	6.76±1.38	5.90±1.58	6.06±1.70	5.84±1.79	6.24±1.80	5.74±1.80	6.14±1.64
2% HPMC	6.06±1.74	5.94±1.62	6.24±1.65	5.74±1.74	5.74±1.75	5.70±1.81	6.04±1.63

Note: ns–Not significant.

4. Conclusions

This study provided guidance for recipe development and evaluated the quality of gluten-free bread from coix seed flour with the addition of hydrocolloids. The use of different hydrocolloids might result in positive effects depending on their type, content and structural properties. The results showed that hydrocolloid type and content influenced the physical properties of gluten-free bread. Increasing

hydrocolloid contents (0.5–2%) significantly decreased hardness ($p \leq 0.05$), whereas the springiness, specific volume, lightness and whiteness index of gluten-free bread significantly increased ($p \leq 0.05$). In contrast, the appearance, taste, aroma, flavor, softness, firmness and overall liking scores of all gluten-free bread samples were not significantly different ($p > 0.05$). In conclusion, gluten-free bread from coix seed flour containing 1% HPMC was selected as the most appropriate formulation because it provided the highest mean scores for appearance (6.76), softness (6.24), and overall liking (6.14) while maintaining desirable physical properties.

5. Acknowledgements

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