Karadeniz Fen Bilimleri Dergisi, 15(1), 24-40, 2025. DOI: 10.31466/kfbd.1429775

KFBD

Karadeniz Fen Bilimleri Dergisi
The Black Sea Journal of Sciences
ISSN (Online): 2564-7377 https://dergipark.org.tr/tr/pub/kfbd

Araştırma Makalesi / Research Article

Effect of Hydrocolloids on Physical, Textural and Sensory Properties of Gluten-Free Bread Produced Using Home-Type Machine

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Abstract

This study aimed to examine the effect of different hydrocolloid types and combinations on the properties of gluten-free bread made using household type bread machine. In this content, four different hydrocolloids, xanthan gum (XG), hydroxypropyl methylcellulose (HPMC), carboxymethyl cellulose (CMC), and methylcellulose (MC), were used at concentrations of 3% and 5% to evaluate the moisture, baking loss, specific volume, color, texture, and sensory properties of gluten-free bread. Additionally, the quality attributes of gluten-free bread made with hydrocolloids were compared with the control bread without hydrocolloids and a commercial gluten-free mixture. As a result of the evaluations, it was determined that the control bread had the highest baking loss, and the gluten-free bread containing 5% MC had the lowest specific volume. An increase in the concentration of hydrocolloids led to an increase in specific volume, except for breads containing XG, CMC, and XG+CMC. Regarding hardness values, the control bread had the highest hardness, while gluten-free bread containing 5% HPMC+MC showed the lowest hardness. According to sensory evaluation results, gluten-free breads made with all hydrocolloids at 5% concentration provided the best results in terms of overall acceptability. Considering the results obtained, it was thought that the combination usage of different hydrocolloids was effective in improving the qualities and consumability of gluten-free bread.

Keywords: Celiac, Gluten-free bread, Hydrocolloid, Bread machine.

Hidrokolloidlerin Ev Tipi Makinelerle Üretilen Glutensiz Ekmeğin Fiziksel, Tekstürel ve Duyusal Özellikleri Üzerine Etkisi

Öz

Bu çalışmada, ev tipi ekmek makinası kullanılarak üretilen glutensiz ekmeğin kalite niteliklerine farklı hidrokolloid türleri ve kombinasyonlarının etkisinin incelenmesi amaçlanmıştır. Bu bağlamda dört farklı hidrokolloid, ksantan (XG), hidroksipropil metilselülöz (HPMC), karboksimetil selülöz (CMC) ve metilselülöz (MC), glutensiz ekmeğin nem, pişirme kaybı, spesifik hacim, renk, tekstür ve duyusal özelliklere etkisini değerlendirmek için %3 ve %5 konsantrasyonlarında kullanılmıştır. Ek olarak, hidrokolloidlerle yapılan glutensiz ekmeğin kalite özellikleri, hidrokolloid içermeyen ve ticari glutensiz karışım içeren kontrol ekmeğiyle de karşılaştırılmıştır. Yapılan değerlendirmeler sonucunda kontrol ekmeğinin en yüksek pişme kaybına sahip olduğu, %5 MC içeren glutensiz ekmeğin en düşük özgül hacime sahip olduğu tespit edilmiştir. Formülasyonda hidrokolloid konsantrasyonundaki artış, XG, CMC ve XG+CMC içeren ekmekler haricinde spesifik hacimde artışa yol açtığı saptanmıştır. Sertlik verileri incelendiğinde ise en yüksek sertlik kontrol grubunda, en düşük ise %5 HPMC+MC içeren örnekde tespit edilmiştir. Duyusal analiz sonuçlarına göre genel kabul edilebilirlik açısından en iyi sonuçlar %5 konsantrasyonda tüm hidrokolloidlerin beraber kullanılarak üretildiği glutensiz ekmeklerde belirlenmiştir. Elde edilen sonuçlara göre, glutensiz ekmek niteliklerini ve tüketilebilirliğini geliştirmede farklı hidrokolloidlerin kombinasyonlarının kullanımının etkili olduğu düşünülmüştür.

Anahtar Kelimeler: Çölyak, Glutensiz ekmek, Hidrokolloid, Ekmek makinesi.

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Geliş/Received: 01.02.2024 **Kabul/Accepted:** 24.02.2025 **Yayın/Published:** 15.03.2025

Öncel, B., Konur, H., Özer, M.S., (2025). Effect of Hydrocolloids on Physical, Textural and Sensory Properties of Gluten-Free Bread Produced Using Home-Type Machine. *Karadeniz Fen Bilimleri Dergisi*, 15(1), 24-40.

1. Introduction

Celiac disease is a food intolerance characterized by a gluten-sensitive intestinal system, which arises from the ingestion of prolamin proteins found in cereals (Rai et al., 2018). Toxic prolamin proteins specific to celiacs include gliadin in wheat, hordein in barley, secalin in rye, and avenin in oats (Schalk et al., 2017). As a result of the consumption of gluten-containing foods by celiac patients, immunological reactions occur in the mucosa of the small intestine, resulting in the flattening of villi, which are responsible for absorption on the inner surface of the small intestine (Aljada et al., 2021). This reduction in absorption surface area makes nutrient absorption challenging, leading to deficiencies in essential nutrients such as calcium, iron, folic acid, and fat-soluble vitamins (Turabi et al., 2009). The most common symptoms in celiac individuals include developmental disorders, short stature, abdominal pain, swelling, weight loss, vomiting, chronic diarrhea, and chronic fatigue in children. Additionally, osteoporosis (bone loss) as a result of insufficient mineral density of bones, and immune system disorders may occur in adults (Di Nardo et al., 2019). The only treatment for this disease is a lifelong gluten-free diet (Vici et al., 2016). When individuals adhere to this diet, the intestinal issues decrease or completely disappear. On the other hand, symptoms reappear upon the consumption of gluten-containing foods (Parzanese et al., 2017). Today, some companies produce various commercial products such as; gluten-free bread, pasta, cakes, biscuits, wafers, and puddings for celiac patients. Nevertheless, the high prices of these products often make the purchasing process tough by the consumers (Turabi et al., 2009; Nicolae et al., 2016). Therefore, in the rapidly expanding market for gluten-free products, consumers have the option to purchase final products such as; bread and cake or they can make various products by using gluten-free starch mixtures at home. Celiac patients can create fresh bread primarily based on starch using gluten-free mixtures (Jnawali et al., 2016). Although the production of bread and other bakery products from gluten-free mixtures requires several pieces of equipment, including a household mixer and an oven, and, most importantly, time and effort, bread can be economically, conveniently, and swiftly made at home using bread-making machines, which are widely available today (Kawamura-Konishi et al., 2013). These machines only require placing the flour and liquid ingredients into the kneading bowl. All essential kneading, resting, aeration, shaping, fermentation, and baking processes are automatically executed by the machine. It is considerably challenging to produce gluten-free bread using commercial mixtures with bread-making machines that exhibit excellent results with gluten-containing flours. The production method and components utilized in gluten-free bread production are as crucial as the method itself. Especially in bakery products, various ingredients including hydrocolloids, enzymes, emulsifiers, certain polysaccharides functioning as dietary fiber, and additives like milk and dairy products are incorporated into the formulation to achieve the desired textural structure. Hydrocolloids, primarily soluble in water, elevate viscosity by binding free water. It create a gel-like structure in conjunction with protein molecules, thereby augmenting stability and yield, resulting in a consistent structure and enhancing overall quality and sensory acceptability. Conversely, based on the literature review, there is a limited number of studies on gluten-free bread production utilizing household-type bread making machines (Kadan et al., 2001; Kawamura-Konishi et al., 2013; Purhagen et al., 2012; Yano, 2010).

Based upon all the information, the objective of this study was to develop gluten-free bread formulations that can easily be produced and enjoyed fresh by celiac patients using household-type bread making machines. To achieve this, gluten-free bread was prepared with the incorporation of xanthan gum (XG), hydroxypropyl methyl cellulose (HPMC), carboxymethyl cellulose (CMC), and methyl cellulose (MC) at two different concentrations (3% and 5%). Subsequently, various quality attributes of the gluten-free breads such as moisture content, baking loss, specific volume, color, texture, and sensory properties were evaluated by analysis.

2. Materials and Methods

2.1. Materials

Rice flour (Basak Gıda Inc., Konya, Turkey) (moisture 9.95%, ash 0.56%, protein 6.77%, fat 0.25%), corn starch(Sunar Mısır Inc., Adana, Turkey) (moisture 10.65%, ash 0.12%, protein 0.4%, fat 0.18%), potato starch (Basak Gıda Inc., Konya, Turkey) (moisture 9.32%, ash 0.37%, protein 0.12%, fat 0.32%), powdered sugar, fresh baker's yeast, sunflower oil, and salt were the materials used in the experiments. Xanthan gum (Ashland, Belgium), hydroxypropyl methylcellulose (Ashland, Belgium), carboxymethyl cellulose (Ashland, Belgium), and methylcellulose (Ashland, Belgium) were supplied from distributors in Turkey. Gluten-free bread-making trials were conducted at Çukurova University, Faculty of Agriculture, Department of Food Engineering, Cereal Processing Technology Laboratory. In the research, Tefal (B13-A, Pain Dore, Turkey) bread-making machine was utilized.

2.2. Gluten-Free Bread Production

Preliminary experiments were carried out to determine the starch mixture and water ratio to be used in the gluten-free bread formulation. In the experiments, samples were evaluated in terms of volume, crust collapse, pore structure and textural properties (crumb softness) and it was determined that a starch mixture consisting of 50% corn starch, 20% potato starch, and 30% rice flour, with water ratios of 100% and 102%, was suitable for the main experiments.

Bread was prepared following the method of Skara et al. (2013), with some modifications. Table 1 outlines the ingredients used in gluten-free bread production. Gluten-free bread was produced using two different concentrations (3% and 5%) of four different hydrocolloids (XG, HPMC, CMC, MC) either individually or in combination, totaling 31 different applications with three repetitions each (Table 2). In addition, gluten-free bread was prepared without the use of hydrocolloids (control), and a commercially available gluten-free starch mixture (commercial product) was also utilized.

Table 1. Composition of gluten-free bread dough

Ingredients	Amount (%)
Starch mixture$^{(1)}$	100.0
Sugar	4.0
Oil	5.0
Milk powder	4.0
Salt	1.5
Yeast	4.0
Hydrocolloids^{2}	3.0-5.0
Water	100.0-102.0

$^{(1)}$ Rice flour (%30), Corn starch (%50), Potato starch(%20)
$^{(2)}$ Total Hydrocolloid concentration

The machine automatically conducts all operations without requiring additional external interventions. When producing gluten-free bread using the bread maker, the yeast and liquid ingredients (water and oil) were initially placed in the bowl of the bread baking machine, followed by the addition of the dry ingredients. The prepared mixture underwent mixing, fermentation, and baking processes within the 6th program of the bread maker, encompassing 13 minutes of mixing, 35 minutes of fermentation, and 30 minutes of baking. These relevant processes were completed in a total of 98 minutes, comprising 13, 35, and 50 minutes consecutively. The gluten-free bread crumb was not fully baked and textural quality defects were detected during production, so an additional 20 minutes beyond the program's baking time were accounted for. The baked breads were kept in polyethylene packages after cooling.

Table 2. Hydrocolloid compositions (%)

Sample Code	Concentration(%)	Hydrocolloid ratio(%)			
		XG	HPMC	CMC	MC
Control	0	0	0	0	0
Commercial product	0	0	0	0	0
F1	3-5	100	0	0	0
F2	3-5	0	100	0	0
F3	3-5	0	0	100	0
F4	3-5	0	0	0	100
F5	3-5	50	50	0	0
F6	3-5	50	0	50	0
F7	3-5	50	0	0	50
F8	3-5	0	50	50	0
F9	3-5	0	50	0	50
F10	3-5	0	0	50	50
F11	3-5	33.3	33.3	33.3	0
F12	3-5	33.3	33.3	0	33.3
F13	3-5	33.3	0	33.3	33.3
F14	3-5	0	33.3	33.3	33.3
F15	3-5	25	25	25	25

F: Formulation

2.3. Gluten-Free Bread Analysis

Gluten-free bread samples cooled for 2 hours on wire racks in closed cabinets; specific volume (g/cm^3) (Moore et al., 2006) and baking loss (Aguilar et al., 2015) were determined. Moisture content were determined by keeping the gluten-free breads in the oven at 130-135 °C for 4 hours, 6 hours after baking (Moore et al., 2006). Analyzes were carried out with 3 replications.

2.3.1. Color Analysis

Gluten-free bread color intensity measurements were determined by Konica Minolta CM-5 (Japan) calorimeter. This instrument makes the three-dimensional color measurement, L (lightness) on the Y axis; 0=black to 100=white, for example light-darkness, a on the X-axis; green (-a), red (+a), b on the Z axis; yellow (+b), blue (-b) indicate color size or location (Ozkoc and Seyhun, 2015). Color analyzes were performed on control, commercial product and bread formulations using 3% hydrocolloid. However, at 5% hydrocolloid usage, color analyses could not be performed due to the observed collapses in the bread crust and the lack of uniformity.

2.3.2. Texture Analysis

The textural properties of the gluten-free breads were determined using the TA.XT- plus Texture Analyzer (Stable Micro Systems, UK). Two slices of 12.5 mm thick bread that did not contain the crust were analyzed by stacking them on top of each other. The slices were pressed down at a speed of 1 mm/s using a 50 mm cylindrical probe and pressed until 50% deformation was applied to the breads, and the load was kept on the breads for 30 seconds. Hardness, elasticity, cohesiveness and chewiness values were measured (Skara et al., 2013).

2.3.3. Sensory Analysis

Sensory analysis was performed on four different gluten-free breads: HPMC+CMC; XG+HPMC+CMC; XG+CMC+MC, and all hydrocolloids were identified. Samples, coded with three-digit random numbers, were evaluated by 14 non-celiac, trained and semi-trained panelists using a hedonic scale ranging from 1 (very bad) to 5 (very good). The samples were evaluated based on porosity, taste, aroma, softness, appearance, and general acceptability (Mudgil et al., 2016).

2.4. Statistical Analysis

The data obtained in the experiments were evaluated using the SPSS 20 (SPSS Inc., USA) statistical program, ANOVA analysis of variance ($p<0.05$). Significant differences were determined according to the Duncan multiple comparison test (Efe et al., 2000).

3. Findings and Discussion

The effects of different concentration of hydrocolloids on external appearance and internal structure of gluten-free breads are showed in Figure1.

3.1. Physicochemical Properties of Gluten-Free Breads

Specific volume of gluten-free bread produced in household-type bread machine with different hydrocolloid combinations are given in Table 3. As can be seen in table, the lowest specific volume in gluten-free breads was determined in the control sample with a value of 2.00 g/cm^3, while the highest specific volume was determined in the F4 (5% MC) sample with a value of 3.76 g/cm^3. Whilst the increase in hydrocolloid concentration generally caused a significant increase ($p\leq0.05$) in the specific volume of gluten-free breads, the use of XG and CMC caused a significant decrease ($p \leq 0.05$) in samples where been used single and in combination equal proportions. On the other hand, with the increase in the use of HPMC and MC, the specific volume increases and it has the highest specific volume among the samples ($p \leq 0.05$). In addition, the specific volume of the hydrocolloid-added samples were found to be significantly higher compared to the control and commercial bread ($p \leq 0.05$). Due to the gluten-like behavior of hydrocolloids in the resulting dough, the specific volume increase in gluten-free breads occurred due to the retention of CO_2 during fermentation. Liu et al. (2017) found that HPMC (2.22 g/cm^3) in potato starch-based breads gave lower specific volume than wheat bread (3.08 g/cm^3) and higher specific volume compared to potato starch control bread (1.45 g/cm3) without hydrocolloid use. It is reported that HPMC has a beneficial effect on gas cells in fermentation. Calle et al. (2020) in their study examining the effects of HPMC, XG and guar in taro and potato starch-based breads, found that HPMC (1.70 mL/g); Liu et al. (2017) found that the specific volume varied between 1.23-2.03 mL/g in the increasing use of HPMC, XG and CMC in potato flour-based gluten-free breads (0-0.5-1-2%), and the highest value was 2% HPMC (2.03 mL/g); Horstmann et al. (2018) reported that increasing (0.25-1.5%) HPMC and XG addition to potato starch-based breads reduced the specific volume of XG and increased HPMC, but this change was statistically insignificant ($p > 0.05$). In our study, the specific volume increased as the HPMC usage rate increased, and the use of XG and CMC negatively affected the specific volume of the samples. It is thought that this difference for XG and CMC is due to the potato starch used as raw material and the amount of water (Figure 1).

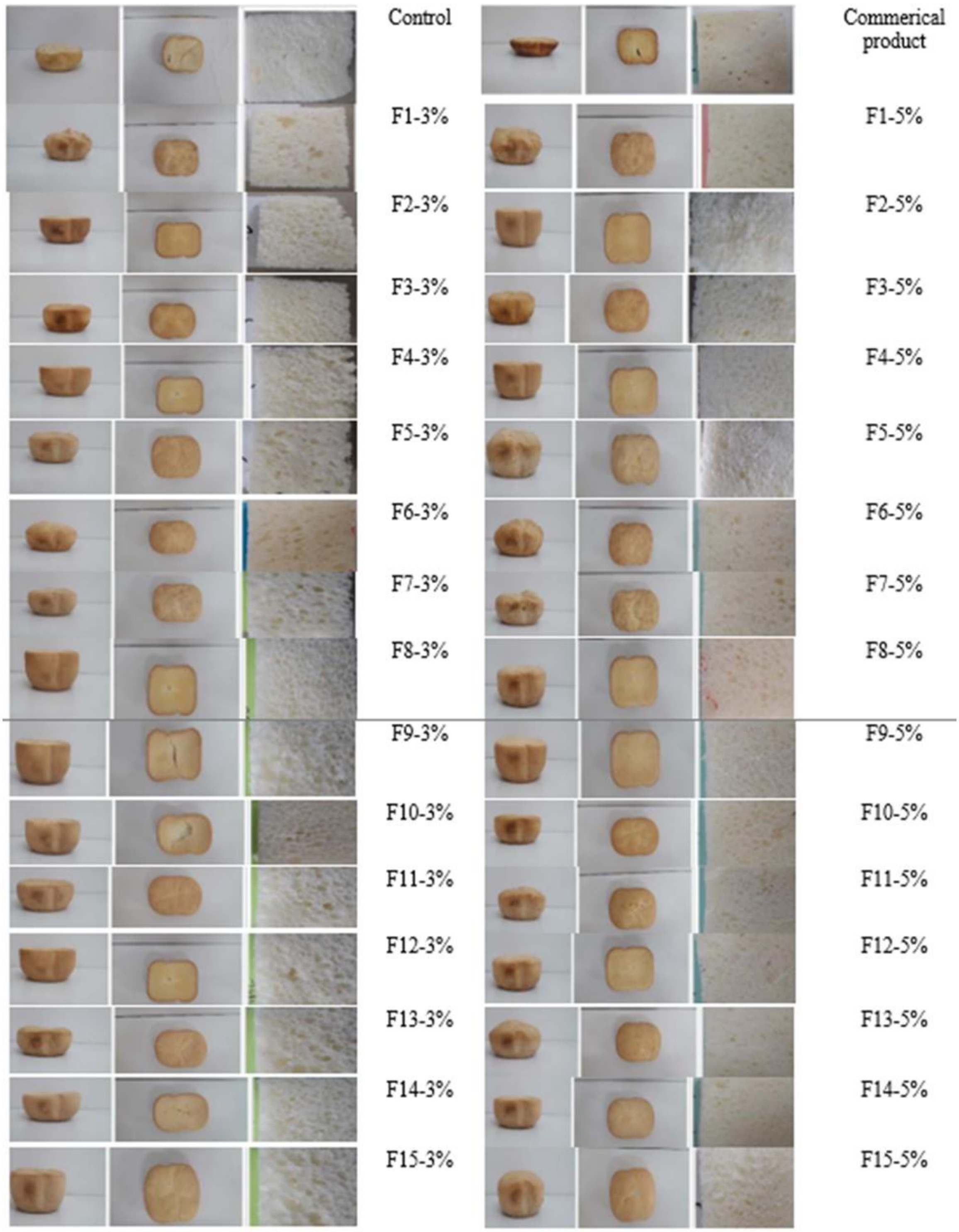

Figure 1. The effects of different concentration of hydrocolloids on external appearance and internal structure of gluten-free breads

Table 3. Physicochemical properties of gluten-free breads

Sample Code	Specific volume (g/cm^3)	Moisture(%)	Baking loss
Control (0%)	2.00^{m}	44.37^{a}	24.22^{a}
Commercial product (0%)	2.71^{l}	41.75^{b}	20.45^{c}
F1 (3%)	$3.34^{\text{ghı}}$	28.58^{o}	18.82^{efgh}
F1 (5%)	2.88^{k}	$31.89^{\text{j-m}}$	$16.84^{\text{ıj}}$
F2 (3%)	$3.57^{\text{b-e}}$	$33.43^{\text{e-k}}$	22.70^{b}
F2 (5%)	3.72^{ab}	$34.20^{\text{d-h}}$	20.63^{c}
F3 (3%)	$3.37^{\text{f-ı}}$	29.56^{no}	19.70^{cde}
F3 (5%)	2.82^{kl}	35.07^{cde}	$17.76^{\text{hı}}$
F4 (3%)	$3.63^{\text{a-d}}$	$33.80^{\text{d-j}}$	22.59^{b}
F4 (5%)	3.76^{a}	36.53^{c}	20.64^{c}
F5 (3%)	3.13^{j}	30.93^{mn}	19.04^{efg}
F5 (5%)	$3.53^{\text{b-f}}$	$32.15^{\text{ı-m}}$	$17.71^{\text{hı}}$
F6 (3%)	3.15^{j}	31.09^{mn}	$18.14^{\text{e-h}}$
F6 (5%)	2.90^{k}	$32.05^{\text{j-m}}$	16.54^{j}
F7 (3%)	3.14^{j}	31.65^{klm}	$18.17^{\text{e-h}}$
F7 (5%)	$3.48^{\text{d-h}}$	$32.73^{\text{g-m}}$	$16.79^{\text{ıj}}$
F8 (3%)	$3.24^{\text{ıj}}$	30.98^{mn}	20.72^{c}
F8 (5%)	$3.47^{\text{d-h}}$	$33.15^{\text{f-l}}$	$18.09^{\text{e-h}}$
F9 (3%)	$3.63^{\text{a-d}}$	34.66^{def}	23.36^{ab}
F9 (5%)	3.67^{abc}	35.68^{cd}	19.67^{cde}
F10 (3%)	$3.26^{\text{ıj}}$	31.45^{lm}	20.73^{c}
F10 (5%)	$3.51^{\text{c-g}}$	$34.54^{\text{d-g}}$	19.14^{def}
F11 (3%)	$3.37^{\text{f-ı}}$	31.01^{mn}	19.06^{efg}
F11 (5%)	$3.51^{\text{c-g}}$	35.08^{cde}	$17.63^{\text{hıj}}$
F12 (3%)	$3.37^{\text{ghı}}$	$32.22^{\text{ı-m}}$	19.80^{cde}
F12 (5%)	$3.62^{\text{a-d}}$	34.62^{def}	$18.08^{\text{e-h}}$
F13 (3%)	$3.33^{\text{hıj}}$	30.87^{mn}	19.26^{def}
F13 (5%)	$3.57^{\text{b-e}}$	$35.04^{\text{c-f}}$	$17.83^{\text{hı}}$
F14 (3%)	$3.21^{\text{ıj}}$	$32.30^{\text{ı-m}}$	20.28^{cd}
F14 (5%)	$3.55^{\text{b-f}}$	$33.99^{\text{d-ı}}$	$17.89^{\text{ghı}}$
F15 (3%)	$3.44^{\text{e-h}}$	$32.48^{\text{h-m}}$	19.82^{cde}
F15 (5%)	$3.62^{\text{a-d}}$	35.14^{cde}	$17.68^{\text{hı}}$

F:Formulation
Differences between values shown with the same letter for the same feature in the table are insignificant according to the 0.05 confidence limit

As seen in Table 3, it was determined that the moisture content of gluten-free breads varied between 28.58% (F1-3%) and 44.37% (control). When hydrocolloids were used single, the highest and lowest moisture contents were determined in samples F4 (MC) and F1(XG), respectively. The reason for this difference is that MC has a strong water binding property and the water in the dough remains in the bread during baking. Since XG can release the water during the baking process thus the water evaporates and goes away from the structure. In the use of combined hydrocolloids, it was determined that gluten-free breads in which XG and CMC were used together at 3% (F6) had the lowest moisture content, and gluten-free breads in which HPMC and MC were used at 5% (F9) had the highest moisture content. Mohammadi et al. (2014) reported that the moisture content of gluten-free bread obtained as a result of the combined use of XG and CMC in corn starch and rice flour-based gluten-free breads was lower than in the samples produced as a result of single use of XG ($p \leq 0.05$). Akin et al. (2019) declared that the moisture of the final products obtained by adding HPMC to tapioca starch has lower moisture content compared to rice flour and potato starch-based gluten-free breads with XG addition. That was explained by the fact that XG binds more water than HPMC. With the increase of XG and CMC in the concentration, it was determined that the single and combined usage affected the moisture values in gluten-free breads obtained ($p \leq 0.05$).

Baking loss values of gluten-free bread produced in household-type bread machine with different hydrocolloid combinations are given in Table 3. Compared to the control group, a significant decrease was observed in the baking loss value of gluten-free breads produced using different types, combinations and concentrations of hydrocolloids ($p \leq 0.05$). In addition, there is a decrease in the baking loss value of gluten-free breads in parallel with the increase in the total hydrocolloid rate. This can be explained by obtaining final products with higher moisture content due to the increase in the concentration of hydrocolloids with high water binding capacity under the same baking conditions. Similarly, Lazaridou et al. (2007) and Mohammadi et al. (2014) reported that as a result of the amount of hydrocolloid and its combined use, the water binding capacity increased and the baking loss decreased. As can be seen in Table 3, it was determined that the lowest baking loss value in the samples was 16.54% (F6-5%), the highest value was 24.22% (control). Among the breads using hydrocolloids, the highest baking loss value (23.26%) was detected in the samples coded F9, in which HPMC and MC were used together at 3% total hydrocolloid concentration. As a result, when the baking loss values of gluten-free breads were examined, it was determined that among all formulations, the baking loss value of gluten-free breads produced using XG and CMC was lower than gluten-free breads using HPMC and MC. Tamilselvan et al. (2022) and Di Renzo et al. (2024) reported that the use of HPMC and XG, as in our study, reduced baking loss compared to the control, and this was associated with the water retention capacity of hydrocolloids, which is likely due to the decreased rate of water evaporation as a result of the retention of gelatinized starch granules by hydrocolloids during the baking process (Vidaurre-Ruiz et al., 2019)

3.1.1. Color Properties of Gluten-Free Breads

Color, aroma and texture are important in consumer preferences for bakery products (Challacombe et al., 2011). Gluten-free bread color is affected by the physicochemical properties of the dough such as water content, amino acid content, pH, amount of reducing sugar, and baking conditions such as oven temperature-baking time, relative humidity and heat transfer properties during baking (Alifakı, 2013). The effects of different hydrocolloids on the crust color parameters (L, a, b) of gluten-free bread samples are given in Figure 2. Crust L value in gluten-free breads was found between 68.42 (F2-3%) and 75.49 (F15-3%) ($p \leq 0.05$). When the hydrocolloid ratio was increased from 3% to 5% within the same combinations, it was observed that the L value of the bread crust decreased, indicating a darker color ($p \leq 0.05$). Gluten-free breads characterized by a lighter crust color are not preferred by consumers and it is desirable for the crust to darken in bread production (Paciulli et al., 2016). Crust a values of gluten-free bread samples were determined between 0.41 (control) and 4.80 (F6-3%) ($p \leq 0.05$). In the current study, a values of gluten-free bread samples were found to be higher than the control sample ($p \leq 0.05$). In our study, it was determined that the a values of control and commercial bread were low. This situation is thought to be related to the fact that cracks occur on the upper surface of the bread during the baking process and a complete bread crust does not form. Crust b values of bread samples were determined between 15.99 (commercial bread) and 24.75 (F1-3%) ($p \leq 0.05$). The color parameters of bread crust are affected by Maillard and caramelization reactions and the color of the raw material used in the product formulation (Barışık and Tavman, 2018). In our study, the use of low amounts of sugar and protein sources such as milk and dairy products used in the gluten-free bread composition and the Maillard reaction occurring during the baking process affected the color parameters of the samples. Similar to our study, Mohammadi et al. (2014), Paciulli et al. (2016), Belorio and Gomez (2020), Sahin et al. (2020), Oncel and Özer (2024), Salem et al. (2024) stated that the single-combined use of hydrocolloids in gluten-free bread formulation improved the color properties of the final product (compared to the control group).

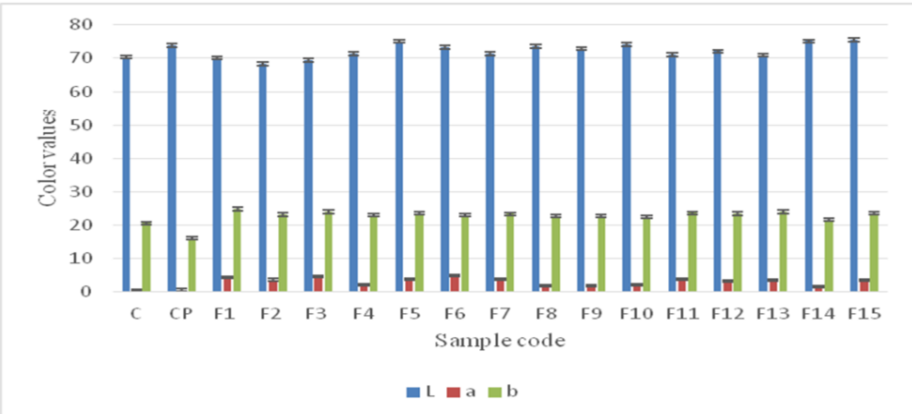

Figure 2. Crust color properties of gluten-free breads

The effects of different hydrocolloid types and combinations on the textural properties (hardness, chewiness, cohesiveness, elasticity) of gluten-free bread produced using a household-type bread machine are given in Table 4. The hardness of the samples vary between 541.79 g (F9-5%) and 21403.05 g (control) ($p \leq 0.05$). Our study reveals that the increase in total hydrocolloid concentration and hardness values, except for samples coded F1, F3 and F6, is effective in water binding and porosity in gluten-free breads (Sabanis and Tzia, 2010). For this reason, it was determined that the increase in hydrocolloid concentration in the dough composition also caused an increase in the hardness value of gluten-free breads ($p \leq 0.05$). On the other hand, a negative correlation was detected between the specific volume and hardness values of the samples. Particularly, the stated correlation was observed in the single use of HPMC and MC (specific volume-hardness). As seen in Table 4, the crust softness of gluten-free breads were obtained as HPMC>MC>XG>CMC. While the softness showed a negative correlation with the specific volume, it showed a positive correlation with the chewiness data. Vidaurre-Ruiz et al. (2019) usage 5% XG and 5% tara gum in a corn-potato starch based gluten-free bread formulation and found the lowest hardness with XG. The researchers attributed this to agglomeration caused by crumb collapse. Similar results reported by Akin et al. (2019), Alsaiqali et al. (2023), Lazaridou et al. (2007), Liu et al. (2018), Mohammadi et al. (2014), Oncel and Özer (2024).

As seen in Table 4, when the hydrocolloid ratio increased (from 3% to 5%), the highest decrease in hardness was detected in the HPMC-added samples. This decrease is associated with the ability of hydroxypropyl methyl cellulose, which is described as non-ionic modified cellulose, to reduce the hardness and increase the specific volume, cohesiveness and dough consistency in gluten-free bread (Encina-Zeleda et al., 2019). The chewiness of samples varied between 309.12 (F9) and 10164.61 (control) ($p \leq 0.05$). When the hydrocolloid ratio in the formulation was increased from 3% to 5%, chewiness decreased except for samples coded F1, F3 and F6. Gluten-free breads are required to have low chewiness. In our study, it was determined that the chewiness values of gluten-free breads had a negative relationship with specific volume and a positive relationship with hardness. Breads with low specific volume have high hardness and chewiness was determined to be low ($p \leq 0.05$).

Table 4. Textural properties gluten-free breads

Sample Code	Hardness	Chewiness	Elasticity	Cohesiveness
Control (0%)	21403.05^{a}	10164.61^{a}	0.882^{fg}	0.88^{fg}
Commercial product (0%)	2455.76^{b}	1349.69^{b}	1.000^{b}	1.00^{b}
F1 (3%)	1135.97^{g}	877.09^{g}	0.94^{c}	0.94^{c}
F1 (5%)	1228.96^{ef}	962.16^{e}	0.92^{cd}	0.75^{c}
F2 (3%)	1149.29^{fg}	547.18^{op}	0.92^{cd}	0.92^{cd}
F2 (5%)	550.25^{p}	334.00^{s}	0.80^{ı}	0.66^{kl}
F3 (3%)	1237.64^{ef}	1051.93^{d}	0.99^{b}	1.00^{b}
F3 (5%)	1663.46^{c}	1171.23^{c}	0.83^{h}	0.82^{a}
F4 (3%)	817.59^{lm}	816.85^{h}	0.92^{cd}	0.93^{cd}
F4 (5%)	634.76^{o}	385.68^{r}	0.90^{de}	0.67^{jk}
F5 (3%)	1265.79^{e}	811.04^{h}	0.99^{b}	1.00^{b}
F5 (5%)	763.67^{mn}	446.33^{q}	0.94^{c}	0.73^{e}
F6 (3%)	1149.19^{fg}	863.82^{g}	0.92^{cd}	0.93^{cd}
F6 (5%)	1350.61^{d}	1078.44^{d}	0.82^{hı}	0.77^{b}
F7 (3%)	1230.33^{ef}	932.14^{f}	0.94^{c}	0.94^{c}
F7 (5%)	712.40^{no}	462.88^{q}	0.80^{ı}	0.75^{cd}
F8 (3%)	1221.71^{efg}	746.17^{ı}	0.996^{b}	1.00^{b}

F8 (5%)	879.96^{jkl}	571.00^{no}	0.87^{g}	0.74^{d}
F9 (3%)	643.69^{o}	373.34^{r}	0.94^{c}	0.95^{c}
F9 (5%)	541.79^{p}	309.12^{s}	0.90^{ef}	0.63^{m}
F10 (3%)	976.98^{hi}	651.72^{jk}	1.04^{a}	1.04^{a}
F10 (5%)	735.57^{mn}	622.73^{kl}	1.00^{b}	0.71^{h}
F11 (3%)	935.57^{hij}	668.99^{j}	0.99^{b}	1.00^{b}
F11 (5%)	867.98^{jkl}	621.21^{kl}	0.99^{b}	0.72^{ef}
F12 (3%)	1165.01^{fg}	668.82^{j}	1.00^{b}	1.01^{b}
F12 (5%)	680.74^{no}	543.02^{op}	0.94^{c}	0.73^{ef}
F13 (3%)	956.32^{hij}	672.94^{j}	1.01^{b}	1.01^{b}
F13 (5%)	909.77^{ijk}	628.23^{kl}	0.99^{b}	0.71^{gh}
F14 (3%)	932.07^{hij}	600.97^{lm}	1.00^{b}	1.00^{b}
F14 (5%)	822.78^{klm}	527.76^{p}	0.99^{b}	0.69^{i}
F15 (3%)	1017.67^{h}	604.22^{lm}	1.00^{b}	1.00^{b}
F15 (5%)	733.68^{mn}	585.00^{mn}	0.99^{b}	0.73^{ef}

F:Formulation
Differences between values shown with the same letter for the same feature in the table are insignificant according to the 0.05 confidence limit.

Horstmann et al. (2018) emphasized that the use of HPMC in potato starch-based gluten-free bread increased hardness and decreased chewiness compared to the control. The elasticity of the samples varied between 0.804 (F7) and 1.040 (F10) ($p \leq 0.05$). Mohammadi et al. (2014) study stated that as the amount of XG-CMC increases in rice flour-based gluten-free breads, the elasticity value decreases. Similarly, in our study, a decrease in the elasticity value was observed as the hydrocolloid (from 3% to 5%) concentration increased. As a result of our study, it was observed that the gluten-free breads had a more spongy, non-crumbling and non-crushable texture. The cohesiveness of samples varied between 0.63 (F9) and 1.04 (F10) ($p<0.05$). It was determined that as the hydrocolloid concentration increased, the cohesiveness of the samples decreased. Liu et al. [29] reported that decreased cohesiveness in gluten-free breads would cause the samples to have a crumbly structure and negatively affect sensory acceptability. Calle et al. (2020) emphasized that the use of HPMC+XG+Guar gum in gluten-free breads reduced cohesiveness compared to the control and that this decrease was associated with the high water retention capacity of hydrocolloids.

3.1.3. Sensory Properties

In our study, the quality characteristics of gluten-free bread were evaluated by panelists and samples coded F8, F11, F12, F15 (at 5% usage rate) were subjected to sensory analysis. The gluten-free breads were presented to panelists and they were asked to evaluate the bread in terms of appearance, crumb structure, taste, aroma, color and general acceptability. As a result of the evaluation, it was determined that especially the samples coded F15 received the highest score from the panelists (Figure 3). As known; the most important factor in choosing bakery products is appearance and this situation affects the consumer's preferability positively or negatively and this also has the impact on the consumer's decisions regarding other sensory qualities of the food (Stantiall and Serventi, 2018). General appearance values of gluten-free bread samples varied between 3.37 (F8) and 4.62 (F15). Gluten-free bread, which is appreciated for its external structure, was found to have F15 at 5% concentration ($p \leq 0.05$). In our study, although there was no statistically significant difference ($p > 0.05$) between the samples in terms of bread crumb structure, taste, aroma, color and general acceptability, there were significant differences in terms of appearance properties. Thus, as seen the external structure is a determinant on sensory quality and this parameter depends on the bread formulation.

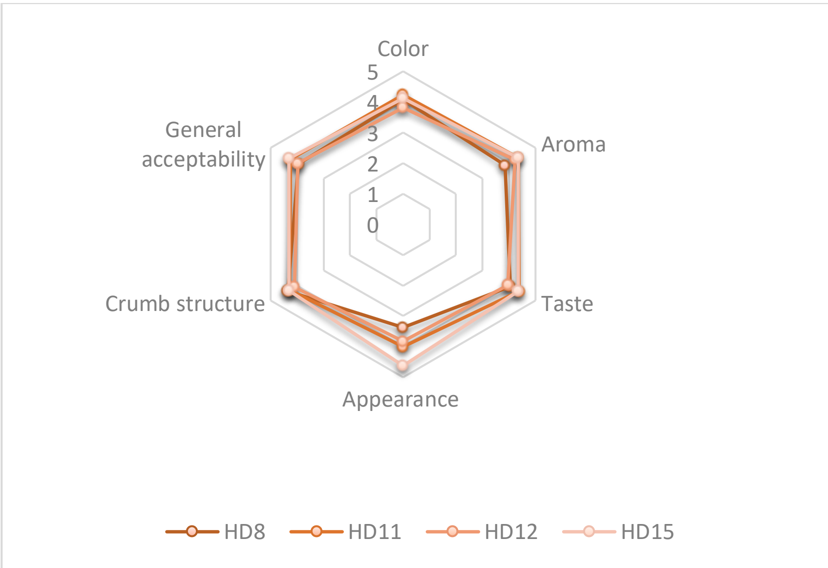

Figure 3. Sensory properties of gluten-free breads

4. Conclusions and Recommendations

In the production of gluten-free bread, the process method is as important as the type, accessibility and qualities of the raw materials used in the product formulation. In our study, the household-type bread machine was used to produce gluten-free bread quickly and easily. Our study revealed that the bread produced is superior to the commercial product sold in the market in terms of physicochemical, textural and sensory qualities. Based on the usage rate, it was determined that the use of 5% hydrocolloid in the dough formulation positively affected the consumable qualities of the final product. As a result of the data, MC used single at 5% concentration had the highest value in terms of specific volume, 5% HPMC+MC had the lowest value in terms of hardness, and F15 obtained from the combination of 5% XG+HPMC+CMC+MC had the highest value in terms of sensory evaluation. And consequently, it has been determined that these are the breads (F15) which had the preferred features in the market. Literature studies examine the possible effects of single use of hydrocolloids in gluten-free bread production. However, in our study, the results of the combined interactions of different hydrocolloids were discussed and it was determined that equal usage ratio of each hydrocolloid was preferred in terms of consumability (XG+HPMC+CMC+MC). In the perspective of our study, it has been thought that the use of the household-type bread machine, the hydrocolloid type and concentration will guide gluten-free bread formulations planned to be developed in the future.

Acknowledgements

Authors are grateful for financial support from Cukurova University Scientific Research Unit (Project No: FYL-2018-10597).

Authors' Contributions

The authors contributed equally to the study.

Statement of Conflicts of Interest

No conflict of interest or common interest has been declared by the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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