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Applications of Hydrocolloids and Its Effects on Physicochemical Characteristics of Gluten-free Bread from Corn and Rice Flour

(Pengaplikasian Hidrokoloid dan Kesannya terhadap Ciri Fizikokimia Roti Tanpa Gluten daripada Jagung dan Tepung Beras)

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ABSTRACT

Rice and corn flour can be used for gluten-free bread using a number of food hydrocolloids to improve the physicochemical properties closer to wheat products. This research aims to observe the effect of different types of food hydrocolloids, namely *xanthan gum, glucomannan, carrageenan and CMC* (Carboxymethyl Cellulose) on the physicochemical characteristics of gluten-free bread made from rice and corn flour. This research used a completely randomized design with two replications. This research observed the application of hydrocolloids to the formulation of gluten-free bread. The optimal increase in hydrocolloid concentration was determined to be 1 g for both CMC and carrageenan in both corn and rice flour. The highest addition of 1 g CMC in gluten-free bread made from corn flour, resulted in a specific volume of 3.422 cm^3/g. The best gluten-free corn bread after drying contains a composition of 5.73% moisture content, 1.89% ash content, 17.34% fat content, 9.37% protein content, 65.67% carbohydrate content, and energy of 456.22 Kcal.

Keywords: Bread; corn; gluten-free; hydrocolloid; rice; technology

ABSTRAK

Beras dan tepung jagung boleh digunakan untuk roti bebas gluten menggunakan beberapa hidrokoloid makanan untuk meningkatkan sifat fizikokimia lebih dekat dengan produk gandum. Penyelidikan ini bertujuan untuk melihat kesan pelbagai jenis dan kepekatan hidrokoloid makanan terhadap ciri fizikokimia roti bebas gluten yang diperbuat daripada beras dan tepung jagung. Penyelidikan ini menggunakan reka bentuk rawak sepenuhnya dengan dua replikasi dan analisis menggunakan perisian SPSS 24. Penyelidikan ini memerhatikan penggunaan hidrokoloid kepada perumusan roti bebas gluten. Peningkatan optimum dalam kepekatan hidrokoloid ditentukan sebagai 1 g untuk kedua-dua CMC (Karboksimetil Selulosa) dan karagenan dalam kedua-dua jagung dan tepung beras. Penambahan tertinggi 1 g CMC dalam roti bebas gluten yang diperbuat daripada tepung jagung, menghasilkan isi padu tertentu 3.422 cm^3/g. Roti jagung bebas gluten terbaik selepas pengeringan mengandungi komposisi 5.73% kandungan lembapan, 1.89% kandungan abu, 17.34% kandungan lemak, 9.37% kandungan protein, 65.67% kandungan karbohidrat dan tenaga 456.22 Kcal.

Kata kunci: Bebas gluten; beras; hidrokoloid; jagung; roti; teknologi

INTRODUCTION

Research and development for gluten-free products are growing. This is related to the development of an allergic disease to gluten or Celiac Disease (CD) which is also expanding. Approximately 1% of the world's population is affected by inflammatory disorders such as diarrhea, constipation, bloating, nausea, and vomiting (Aljada, Zohni & El-Matary 2021; Caio et al. 2019; Gujral 2012; Moreno et al. 2017). Nowadays, there has been a substantial increase in the prevalence of CD over the last 50 years and the number of CD patients is undiagnosed (Al-Toma et al. 2019). Several processed food products can be developed for the commercialization of gluten-free products, one of which has quite the potential is bread.

Bread is generally prepared using wheat flour as raw material which contains gluten. A gluten-free diet can be prepared using non-wheat raw materials, such as corn cereals, rice, sorghum, and millet (Gabrovska et al. 2015). Another alternative as the main raw material for processing gluten-free bread is to use other carbohydrate sources as raw materials. Potential raw materials that can be used to process bread products are corn flour and rice flour. Both flours have quite high protein levels. The protein content of corn flour is 8.41% (Herawati & Kamsiati 2021). The use of different protein isolates will improve the characteristics of gluten-free products (Skendi, Papageorgiou & Varzakas 2021).

Bread items will be challenging to produce or experience stalling, which is one of the limits of gluten-free product. Toth, Vatai and Koris (2020) stated that 70.8% of consumers were not satisfied with gluten-free bread due to texture and sensory taste parameters. According to Smidova and Rysova (2022), gluten-free bread has a crumb that is less flexible, harden quickly, and is easily crushed. Incorporating a hydrocolloid ingredient is one technique to enhance the properties of gluten-free bread.

Some potential hydrocolloids that can be added include glucomannan, carrageenan, Carboxymethyl cellulose (CMC), and xanthan gum. Research on adding CMC to bread (Harsono et al. 2021); CMC for gluten free cakes (Ameer 2019); xanthan gum and CMC on rice bread (Wongklom et al. 2016); Hydroxyprophyl Methylcellulose (HPMC) and xanthan gum (Belorio & Gomez 2020). Cellulose derivatives, such as CMC and HPMC, are the hydrocolloid components most widely used for making gluten-free product dough. Cellulose derivatives can interact with ingredients and form a matrix. These components are often combined with other ingredients such as thickeners, proteins, and other emulsifiers (Bender & Schoenlechner 2020). It is very important to research the potential type and concentration of the right hydrocolloid according to the raw materials used as well as the characterization of the gluten-free bread products produced.

Numerous criteria relating to physicochemical features, microstructural profiles with a Scanning Electron Microscope, and sensory evaluation can be used to analyze the qualities of gluten-free bread. Sensory analysis can be used to evaluate the consumer acceptability of the product using gluten-free bread. Research and development regarding textural properties and good sensory elements for gluten-free bread is urgently needed (Bourekoua et al. 2017). This research aims to examine how various hydrocolloid types and concentrations affect the product quality and attributes of gluten-free bread.

MATERIALS AND METHODS

The materials used in this research activity are: rice flour (Rose Brand), corn flour (Mugo), Vivaneta psyllium husk, margarine (Blue Band Brand), eggs, sugar, salt, baking powder, yeast powder (Fermipan Brand), xanthan gum (PT. Indogel), glucomannan (PT. Indogel), Carrageenan (PT. Sarana Mitra Anugrah), CMC (PT. Indogel) and chemicals for analyzing proximate levels. The equipment used includes mixer, oven, chromameter CR 410 Konika Minolta INC, Texture Analyzer TATX, Ion Sputter tool (Hitachi E-1045), SEM Jeol JSM-IT200 at 15 kV, and Std. PC 40, RVA Perten, XRD cobalt Bruker.

GFB (GLUTEN FREE BREAD) PROCESSING

Gluten-free bread was made with two types of non-gluten flour, namely corn flour and rice flour. The bread was added with hydrocolloid. The types of hydrocolloid that used in this research were xanthan gum (XG), glucomannan (G), carrageenan (K) and carboxymethyl cellulose (CMC). There were 8 types of gluten free bread produced in this research: gluten free bread with corn flour and was made without additional hydrocolloid as a control (C), added hydrocolloids in the form of xanthan gum (XG), glucomannan (G), carrageenan (Cr), and carboxymethyl cellulose (CMC). The aim of making this bread was to determine the effect of hydrocolloids on gluten-free bread made from corn flour. Next, the optimal treatment of the bread can be determined to produce the best formulation.

Materials were weighed using an analytical balance. The ingredients for making white bread are corn flour or rice flour (103 g), psyllium husk (12 g), sugar (10 g), oil (20 mL), salt (0.95 g), eggs (35 g), baking powder (1.6 g), yeast powder (3 g), water (138 mL), and hydrocolloid (0.5 g). Then, the ingredients are mixed using a mixer and fermented at room temperature for 40 min. During fermentation, the bread dough is covered with a wet cloth to maintain temperature and humidity. The next stage was using oven for baking the dough at 175 °C for 40 min. For the subsequent stages, the selection was based on the parameter of high specific volume for the addition of hydrocolloids representing the treatment of using corn and rice flour. To analyze the characteristics of gluten-free bread, it is carried out on the outside or often called the crust and on the inside of the bread or often called the crumb.

The selection of the best sample based on the analysis of specific volume characteristics in the previous stage, the addition of CMC to gluten-free corn bread compared to the addition of carrageenan to gluten-free corn bread. This is done to compare the same type of hydrocolloid that exhibits a high specific volume in rice bread. To determine the optimal point for increasing specific volume, concentrations of 0, 0.5, 1, 2, and 4 g are utilized. The optimal point is determined based on the highest specific volume point from the addition of the selected hydrocolloid concentration in the previous stages.

ANALYSIS DESIGN

The analysis design was carried out by modifying the types of hydrocolloids in the form of xanthan gum, glucomannan, carrageenan, and CMC using a concentration of 0.5 g. This treatment was compared with a control without the addition of hydrocolloids for each rice flour and corn flour. The research design used a completely randomized design with two replications. The analysis was carried out in the form of colour, sensory evaluation (sensory test), texture, and density analysis. The collected data was then carried out by ANOVA with a confidence interval of 95%. Different tests were carried out using Duncan. Statistical analysis was performed using SPSS 24 software.

The three best samples were chosen to represent corn flour and rice flour based on the results of the lowest density, and they were then further analyzed for the specific volume of gluten-free bread. The best samples were then subjected to additional analysis using proximate, RVA, XRD, and microstructural profiles with SEM after being compared to the control for each sample of corn and rice flour.

COLOUR ANALYSIS

The colour parameter is divided into two categories in order to distinguish distinct components of gluten-free bread products. The crust of gluten-free bread is visible on its surface, whereas the interior is commonly referred to as the crumb. Colour measurement used the Chromameter CR 410 Konika Minolta Inc. on the parameters Lightness (L), redness (a), and yellowness (b) with calculations as Selimovic et al. (2014). The calibration process is carried out using black and white standards before the instrument is used for measurement. Sample is placed in a sample holder and covers the entire Croma Meter lens. The analysis was carried out by identifying the values of L, a, and B. The values of L (white/black), a (red/green), and b (yellow/blue). The degree of whiteness of the values L, a, and b is calculated according to the formula as shown herewith.

$$WI = 100 - [(100 - L)^2 + a^2 + b^2]^{1/2}$$

SENSORY ANALYSIS

The bread samples that had been prepared according to the formula were then cut into squares with dimensions of 5 × 5 × 5 cm representing the crust and crumb parts and placed on a small plate for sensory analysis. Drinking water was prepared to rinse the mouth before the panelists carried out analysis between samples. Sensory analysis was conducted using a panel of semi-trained assessors, involving students and researchers within the scope of the Food Testing Laboratory at Laptiab, KST Serpong, Indonesia. The analysis method followed the modified procedures outlined in Moni et al. (2023). A total of twenty-five semi-trained panelists participated in the sensory tests. The evaluation utilized a seven-point preference scale, ranging from 1 for 'very dislike' to 7 for 'extremely like'. Panelists were provided with mineral water to neutralize their palates and were given intervals to refresh their palates. The panelists were instructed to analyze the samples and provide assessments based on colour, aroma, flavour, texture, and overall acceptance for both the crust and crumb of gluten-free bread.

TEXTURE ANALYSIS

Texture analysis was performed using the Stable Micro Systems TA.XT Plus Texture Analyzer. Analysis was carried out according to the tool analysis guide for bread samples with pre vtest 1.00 mm/s, test speed 1.70 mm/s, post-test 10.00 mm/s with TA variable No 5.00 g with a distance of 5.00 mm with a height of 3.6 cm, strain 40.0% and trigger force 5.0 g. The probe used is P/36R of 36 mm DIA Aluminium. The sample that has been prepared is then placed in the sample holder and further analysed to determine the firmness level of the gluten free bread.

PROXIMATE ANALYSIS

Proximate analysis was carried out according to the AOAC Method (2005). The analysis includes moisture content, ash content, fat content, protein content. Based on the results of the analysis of the four parameters, then an analysis of carbohydrate levels by different was carried out.

RVA ANALYSIS

RVA analysis was carried out using the modified Herawati, Kamsiati and Sunarmani (2021) method. RVA analysis was performed using the Tecmaster Perten RVA tool. RVA analysis includes weighing samples of dried bread flour that has been mashed to a size of 100 mesh and 3.5 g into the tube. The sample is then added to a tube with 25 mL distilled water into the tube. The stirring rod is inserted into the tube and installed RVA device. The tool rotation is set from 0 to 10 s, with a speed of 960 rpm. The temperature from 0 s to 1 min is set at 50 °C. Rotate the stirrer on the 10th-s set at 160 rpm. The temperature starts to rise in the first min up to 4 min 42 s, from 50 °C to 95 °C. The temperature was held for 2 min 30 s at 93 °C. The temperature is then lowered from 93 °C to 50 °C until the 11th min. The profile ends at 13 min.

CRYSTALLINE PROFILE ANALYSIS

XRD analysis was carried out using the modified Herawati, Kamsiati and Sunarmani (2021) method. Analysis using XRD Type Cobalt Bruker was carried out to determine the Gluten-free dry bread crystallinity profile. The bread is dried and smoothed first with a size of 100 mesh. The tool was switched on during sample preparation. Gluten-free dry bread flour samples (1-2 g) are taken and put in a holder or a certain sample holder XRD tool. Samples are analyzed at the desired angle of 2Θ in the range 10° to 130°. The peak profile can be seen from the analysis results, and the calculation results of the composition of the amorphous and crystalline phases can be seen based on the results of the analysis on tools. Crystallinity concentration is the ratio of crystals area to area under a smooth X-ray diffraction curve (amount between crystals and amorphous regions).

MICROSTRUCTURE ANALYSIS

The sample was previously prepared and coated with Au with an Ion Sputter tool (Hitachi E-1045) with I=30 mA and t=10s. Then the samples were tested using SEM Jeol JSM-IT200 at 15 kV and Std. PC 40.

RESULTS AND DISCUSSION

GLUTEN-FREE BREAD COLOUR

Colour is a crucial parameter in food products. It is the first physical parameter observed, making food products easily accepted by consumers visually. The colour parameter is differentiated into two for identifying parts of gluten-free bread products. On the surface of gluten-free bread, it can be observed in the crust, while the interior is often identified as the crumb. Bread is classified as a solid food foam because it contains gas within its solid structure, which is a result of either yeast fermentation or the application of artificial leavening agents (Zhou et al. 2014). According to Scanlon, Sapirstein and Fahloul (2001), a breadcrumb is an open-cell foam consisting of highly connected pores. The surface and interior of gluten-free

TABLE 1. Crumb and crust colour analysis of gluten-free bread

Sample	Crust				Crumb			
	L	a	b	WI	L	a	b	WI
BC-C	57.540^{a}	8.370^{a}	23.930^{c}	50.840^{a}	67.685^{a}	3.815^{ab}	29.985^{b}	55.705^{a}
BC-XG	57.540^{a}	8.490^{a}	22.030^{abc}	51.015^{a}	67.700^{a}	3.740^{ab}	29.740^{b}	55.830^{a}
BC-G	61.055^{a}	7.655^{a}	25.125^{c}	52.880^{bc}	67.445^{a}	3.555^{ab}	29.570^{b}	55.705^{a}
BC-Cr	58.200^{a}	8.445^{a}	22.655^{bc}	51.555^{ab}	66.215^{a}	4.185^{b}	27.790^{b}	56.040^{a}
BC-CMC	58.190^{a}	8.450^{a}	21.925^{abc}	52.035^{ab}	66.895^{a}	3.795^{ab}	26.935^{b}	57.155^{a}
BR-C	62.015^{a}	6.935^{a}	15.555^{a}	58.365^{c}	64.550^{a}	2.960^{a}	10.630^{a}	62.870^{bc}
BR-XG	59.630^{a}	6.720^{a}	16.515^{ab}	55.820^{abc}	67.175^{a}	3.075^{a}	11.315^{a}	65.140^{d}
BR-G	63.280^{a}	6.890^{a}	16.230^{ab}	59.265^{c}	67.125^{a}	3.390^{ab}	12.170^{a}	64.785^{cd}
BR-Cr	60.785^{a}	7.995^{a}	16.990^{ab}	56.520^{bc}	63.855^{a}	3.080^{a}	11.995^{a}	61.795^{b}
BR-CMC	63.025^{a}	6.675^{a}	17.080^{ab}	58.725^{c}	65.075^{a}	3.020^{a}	13.040^{a}	62.585^{b}

Numbers followed by different letters in the same column are significantly different at the 95% level
BC: Bread with Corn Flour; BR: Bread with Rice Flour; C: Control; XG: Xamthan Gum; G: Glucomannan; Cr: Carragenan; CMC: Carboxymethyl Cellulose

bread exhibit distinct colour characteristics due to the proofing and baking processes. Based on the results of colour analysis for parameters L, a, b, and WI (Whiteness Index), the results obtained are shown in Table 1.

Crust and Crumb colour analysis was carried out on gluten-free bread. The L, a value of crust and the L value of crumb gluten-free bread showed statistical results that were not significantly different between treatments. Meanwhile, other parameters showed significant differences between treatments. This difference is possible because the colour of the flour as the main raw material used is different, corn flour is yellow, while rice flour is white. The colour formation during the cooking of the dough results from chemical reactions such as pyrolysis, caramelization, and the Maillard reaction, or a combination of these reactions, depending on the specific formulation. It can be inferred that a lower sugar content or a higher starch content in the formulation contributes to the lighter color of the crust observed in these products (Esteller & Lannes 2005). According to Nasir et al. (2020), the values of L, a and b depend on the type and concentration of the raw materials used. Apart from that, the color value is influenced by the gradual reduction in moisture content and the oxidation of lipids (Sanz-Panella et al. 2013).

Whiteness index (WI) is a parameter value for the degree of whiteness in the crust and crumb of gluten-free bread. The WI values of corn and rice gluten-free bread with the addition of hydrocolloids result in significantly different WI values. The raw materials of gluten-free bread show higher WI values in both crust and crumb compared to gluten-free bread made from corn flour. This is attributed to rice flour having a white colour, while corn flour is yellow as its primary raw material. Meanwhile, hydrocolloids generally have a white colour as additives.

The WI (Whiteness Index) value of the crust portion of gluten-free bread is generally lower than the WI value of the crumb portion. This is because the crust is directly exposed to surface heat and undergoes browning due to the Maillard reaction. Selimovic et al. (2014) stated that baking temperature had bigger influence on formation of products of Maillard's reaction in wheat bread. The occurrence of the Maillard reaction process during the baking process in making gluten-free bread can affect the colour quality of the L, a, b, and WI values produced.

SENSORY PROFILE OF GLUTEN FREE BREAD

Good textural characteristics and sensory elements in gluten-free bread are very necessary to determine product acceptability (Bourekoua et al. 2017). Sensory analysis of gluten-free bread was carried out on the crust and crumb of the bread produced. These two parts represent the characteristics of the physical properties of bread on the outside and inside. The sensory characteristics observed included colour, aroma, taste, texture, and general acceptability of the bread served to the panelists. Based on both the crust and crumb parts of the bread, the sensory analysis results were obtained as shown in Table 2.

The results of sensory analysis of the crust and crumb of gluten-free bread showed significant differences between treatments. Significant differences between treatments include parameters of colour, aroma, taste, texture, and general acceptability. This shows that the type of hydrocolloid and corn flour or rice flour influenced the panelists' acceptance of the gluten-free bread produced. The colour is one of the most important indicators of gluten-free bread quality (Monteiro et al. 2021).

The highest general acceptance was found in gluten-free corn bread with the addition of carrageenan, followed by CMC corn bread and gluten-free rice bread with the addition of carrageenan. Sensory parameters exhibit significant variability and can be subjective, requiring additional analyses to complement the analytical parameters. This forms the basis for selecting subsequent samples to optimize the concentration increase of hydrocolloid addition in gluten-free bread. The sensory profile of the use of corn flour on average is still higher compared to the use of rice flour. As part of the considerations for selecting the addition of carrageenan, it is used for enhancement in both corn and rice flour for the production of gluten-free bread, in addition to specific volume considerations and other analysis parameters.

Based on the overall acceptability results for both gluten-free crust and crumb, the addition of CMC to corn flour yielded high scores. Texture parameters from sensory analysis also play a crucial role in considering the subsequent selection of hydrocolloid usage. Crockett et al. (2011) provided the following information based on evaluations by 28 taste testers: the mean score in acceptability testing was 4.0 ± 2.0; texture was described as excessively dry, coarse, reminiscent of a sponge, sandy, foamy, with a beany flavor, chemical aftertaste, and an unappealing shiny appearance.

TEXTURE AND SPECIFIC VOLUME OF GLUTEN-FREE BREAD

One of the important parameters is the specific volume of bread used for the determination and assessment of bread quality (Matos & Rosell 2012). Mir et al. (2016) stated that hydrocolloids could improve the texture of gluten-free bread. The textural characteristics of the gluten-free bread were observed using the TAXT tool and the results were obtained as shown in Table 3. The specific volume to determine the swelling power of the bread is due to the addition of hydrocolloid types as shown in Table 3.

The specific volume of a bread loaf serves as a reliable

TABLE 2. Results of sensory analysis of crumb and crust gluten-free bread

Sample	Crust					Crumb				
	Colour	Aroma	Taste	Texture	General Acceptance	Colour	Aroma	Taste	Texture	General Acceptance
BC-C	4.760^{abc}	4.080^{ab}	4.040^{ab}	3.840^{a}	4.120^{a}	5.160^{b}	3.960^{ab}	3.680^{a}	4.120^{a}	4.240^{a}
BC-XG	4.440^{a}	3.640^{a}	4.000^{a}	4.280^{abc}	4.280^{a}	4.760^{ab}	3.680^{a}	4.360^{abc}	4.360^{ab}	4.440^{ab}
BC-G	5.120^{abc}	4.880^{c}	4.920^{cd}	4.720^{bc}	5.040^{b}	5.040^{b}	4.880^{c}	4.320^{abc}	4.480^{ab}	4.720^{ab}
BC-Cr	5.520^{c}	5.040^{c}	5.040^{d}	5.000^{bc}	5.240^{b}	5.200^{b}	4.880^{c}	4.880^{c}	5.480^{c}	5.440^{c}
BC-CMC	5.360^{bc}	5.080^{c}	4.800^{bcd}	5.080^{c}	5.040^{b}	5.160^{b}	4.600b^{c}	4.920^{c}	5.040^{bc}	5.080^{bc}
BR-C	5.000^{abc}	4.800^{bc}	4.360^{abcd}	4.520^{abc}	4.760^{ab}	5.160^{b}	4.160^{abc}	3.920^{ab}	4.960^{bc}	4.640^{ab}
BR-XG	4.800^{abc}	4.640^{bc}	4.440^{abcd}	4.200^{ab}	4.600^{ab}	4.880^{ab}	4.320^{abc}	4.480^{abc}	4.720^{abc}	4.800^{abc}
BR-G	4.600^{ab}	4.640^{bc}	4.360^{abcd}	4.400^{abc}	4.600^{ab}	4.600^{ab}	4.280^{abc}	4.280^{abc}	4.440^{ab}	4.360^{ab}
BR-Cr	4.760^{abc}	4.680^{bc}	4.160^{abcd}	4.560^{abc}	4.600^{ab}	4.200^{a}	4.840^{c}	4.840^{c}	4.560^{ab}	4.760^{abc}
BR-CMC	4.960^{abc}	4.880^{c}	4.640^{abcd}	4.760^{bc}	5.040^{b}	4.800^{ab}	4.400^{abc}	4.600^{bc}	4.920^{abc}	5.000^{bc}

Numbers followed by different letters in the same column are significantly different at the 95% level
BC: Bread with Corn Flour; BR: Bread with Rice Flour; C: Control; XG: Xamthan Gum; G: Glucomannan; Cr: Carragenan; CMC: Carboxymethyl Cellulose

TABLE 3. Results of texture analysis of gluten-free bread

No	Sample	Texture (Firmness)	Specific volume (cm3/gram)
1	BC-C	554.541abcd	1.425abc
2	BC-XG	1072.923cd	1.560bc
3	BC-G	1182.356d	1.435abc
4	BC-Cr	554.172abcd	1.485abc
5	BC-CMC	385.656ab	1.705c
6	BR-C	968.472bcd	1.255abc
7	BR-XG	414.902abc	1.040ab
8	BR-G	302.372ab	0.955a
9	BR-Cr	848.057abcd	1.305abc
10	BR-CMC	201.364a	1.010ab

Numbers followed by different letters in the same column are significantly different at the 95% level
BC: Bread with Corn Flour; BR: Bread with Rice Flour; C: Control; XG: Xanthan Gum; G: Glucomannan; Cr: Carragenan; CMC: Carboxymethyl Cellulose

metric for assessing bread quality and is intricately linked to the water content retained within the gluten network. It effectively reflects volume fluctuations in bread produced through diverse formulations and methods, signifying the capacity of gluten strands to retain the gas generated during fermentation and dough proofing. This attribute is an objective measure, and when coupled with density, it elucidates the correlation between the solid content and the proportion of air in the baked dough (Monteiro et al. 2021).

According to the findings of the texture quality examination, it differs significantly from the results of the use of the hydrocolloid and flour types. For further research, the specific volume parameters will be further considered. Based on the results of statistical analysis of specific volume which can represent capacity development, three types of treatment were selected for comparison, Gluten Free Bread from Corn-CMC, Corn-Carrageenan, and Rice-Carrageenan.

The specific volume serves as a crucial parameter for selecting the formulation to enhance the concentration of hydrocolloid addition. It is a measure of the expansion capability of the resulting gluten-free bread. This parameter is significant because gluten-free bread typically exhibits limited expansion due to the absence of gluten in the raw materials. Gluten is responsible for the leavening process in bread making. Therefore, the selection of the best samples is based on the highest specific volume, representing gluten-free bread made from corn flour and rice flour raw materials. To further investigate, the optimization of hydrocolloid concentration was based on the highest specific volume observed in gluten-free bread with the addition of CMC and carrageenan to corn flour compared to the addition of carrageenan to rice flour.

The firmness or hardness of bread is associated with the force required to induce deformation or breakage of the product, and this is contingent on the formulation employed. Texture profile data is primarily linked to factors such as increased air incorporation in the dough, greater specific volume of the bread, resilience, crumb porosity, and external characteristics of the bread, including its shape and symmetry (Monteiro et al. 2021). Khalil (1998) noted a rise in hardness with the substitution of low-fat cake with a carbohydrate fat replacer. Dadkhah, Hashemiravan and Seyedain-Ardebili (2012) similarly observed an elevation in hardness when shortening was substituted with oat bran in a shortened cake. The reduction in springiness may be linked to a decrease in the quantity of crumb cells, as evident in the analysis of the cellular structure of cake crumb (Marina et al. 2016).

OPTIMIZATION OF THE SPECIFIC VOLUME CONCENTRATION OF GLUTEN-FREE BREAD

Several sensory and specific volume analysis parameters showed that gluten-free bread samples from carrageenan corn flour, CMC corn flour and carrageenan rice flour showed higher results compared to other treatments. Based on these results, optimization was carried out to increase the concentration of food additives in the form of added hydrocolloids. Optimization treatment was carried out using an additional concentration of 0.5; 1; 2 and 4 grams. Optimization results as shown in Figure 1.

The three samples were then optimized for variations in the addition of hydrocolloid concentrations to specific volume parameters. The increase in the concentration of the addition of hydrocolloids was modified by adding the concentrations of 0.5, 1, 2, and 4 (g) to the flour base. Based on the results of the analysis, it was obtained that the concentration of 1 g was the optimal concentration for the addition of the hydrocolloid. The addition of hydrocolloid concentration can entrap more water components, thereby reducing the potential increase in the specific volume of the resulting gluten-free bread. Optimization of increasing the hydrocolloid amount resulted in an optimal concentration of 1 g addition, with the same base formula for other components resulting in the optimal specific volume with a 1 g addition of hydrocolloid concentrate.

The optimal increase in hydrocolloid concentration was observed with the highest addition of 1 g of CMC in gluten-free bread made from corn flour, resulting in a specific volume of 3.422 cm^3/g. With larger additions of hydrocolloids, the specific volume of gluten-free bread decreased. This concentration increase pattern is consistent for carrageenan in gluten-free corn bread, with a specific volume of 2.575 cm^3/g, and carrageenan in rice bread at 2.701 cm^3/g.

As stated by Katina et al. (2006), incorporating fiber into baked goods is considered advantageous to reduce volume and crumb elasticity in bread quality technology. Rocha and Santiago (2009) reported similar findings when assessing wheat bread with the addition of 25%, 50%, and 75% baru fruit peel and pulp to enhance fiber content. The outcomes of these authors ranged from 1.76 to 2.5 mL/g specific volume.

PROXIMATE ANALYSIS

The proximate analysis includes moisture content, ash content, protein content, fat content, and carbohydrates by different. Proximate analysis of gluten-free bread was carried out by preparing bread samples which were first dried at 60 °C for 3 h. This was done to prevent sample damage during the delay in analyzing the proximate levels of gluten-free bread samples. The proximate analysis was carried out to determine the composition of the main chemical components found in gluten-free bread resulting from the addition of hydrocolloids compared to controls. The results of the proximate analysis of gluten-free bread is as shown in Table 4.

The proximate content of gluten-free bread samples made from rice and corn flour raw materials resulted in statistically significant differences in water, ash, fat, protein, and carbohydrate content among treatments. The variation in hydrocolloid types also influenced the proximate composition of the resulting gluten-free bread,

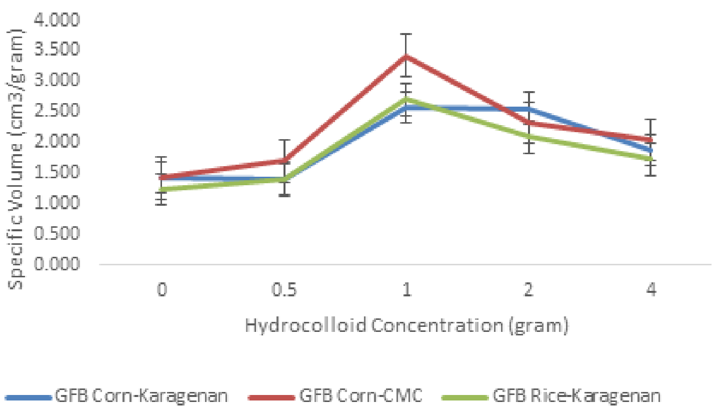

FIGURE 1. Optimization of the addition of hydrocolloid concentration to the specific volume of gluten-free bread

leading to differences in energy content as well. In gluten-free rice control bread, the moisture content is quite high. This can be caused by the absence of the addition of hydrocolloids, the dough absorbs more water and results in a higher water content of gluten-free rice bread compared to other treatments.

The ash content from proximate analysis ranged between 1.67% and 1.90%. Differences in formulas and types of flour resulted in statistically significant variations in ash content. Therefore, it can be concluded that the ash content of gluten-free rice bread is influenced by the quantity of rice flour in the bread formulations (Ronie et al. 2023). A similar outcome was reported by Silva et al. (2020), where the authors observed that the ash content in gluten-free rice bread made from a composite of red rice flour and cassava flour ranged from 1.11% to 1.34%.

The fat content of gluten-free bread varies depending on the type of flour and hydrocolloid used. Variations in fat content may occur due to potential interactions between the components of the flour type and hydrocolloid used. The relatively high protein content in gluten-free bread can be attributed to the use of raw materials such as corn flour and rice flour, which inherently possess a high protein content. The protein content of corn flour is 8.41% (Herawati & Kamsiati 2021). The accumulation of water, ash, fat, and protein content influences the carbohydrate content, calculated by different methods.

RVA PROFILE

Pasting properties are stages of absorption of water by the starch granules and cause the granules to lose their crystal structure after well-swelling (Ruiz et al. 2023). Rapid Visco Analysis (RVA) is a step to analyze the effect of the bread flour produced in relation to the pasting profile and viscosity on rotation and temperature treatment. Based on the results of the RVA analysis of the sample, the results obtained are shown in Table 5.

Based on the RVA Table, it can be seen that the type of flour and the use of hydrocolloids affect the peak viscosity of the resulting gluten-free bread. The addition of hydrochloric acid shifts the peak viscosity pattern of gluten-free bread. The resulting peak viscosity is also different. Based on is table, it shows that there is an upward trend in the final viscosity pattern for all types of gluten-free bread samples.

Ruiz et al. (2023) conducted a study on gluten-free rice bread, which appeared to have a significant effect on the use of mixed flour peak viscosity, as well as trough, breakdown, and final viscosity, compared to single flours. A higher protein could lead to lower peak viscosity, affecting peak time, trough, and breakdown viscosities by lowering the water-holding capacity of the starch during gelatinization (Ohizua et al. 2017).

CRYSTALLINE PROFILE ANALYSIS

Crystalline profile analysis was carried out on samples of control gluten-free bread and gluten-free bread with the addition of hydrocolloids. The amorphous and crystalline phases of the gluten free bread can be observed from the results of the XRD pattern analysis as shown in the Figure 2.

The crystallinity profile of gluten-free bread is relatively similar to the peak around 17° and 23°. This peak is possible because the components of the ingredients used are relatively almost the same with the only difference being corn and rice flour and the type of hydrocolloid of around 1%. The high level of crystallinity can cause starch granules to become stable and more resistant structures during the gelatinization process.

An elevation in hydration (plasticization) of the constituents will prompt, under room temperature conditions, a transition from a glassy to a rubbery state in the macromolecules (proteins and polysaccharides) found

TABLE 4. Results of proximate analysis of corn and rice gluten-free bread

Sample	Moisture content (%)	Ash content (%)	Fat content (%)	Protein content (%)	Carbohydrate content (%)	Energy (kcal)
BC-Control	6.17c	1.77b	13.47b	7.76a	70.84d	435.59c
BC- CMC 1%	5.73a	1.89cd	17.34e	9.39c	65.67b	456.22e
BC- Carrageenan 1%	6.08b	1.90d	12.67a	7.92b	71.44e	431.41a
BR-Carrageenan 1%	10.65e	1.83c	16.54d	7.75a	63.24a	432.78b
BR-C	6.73d	1.67a	14.62c	9.47c	67.51c	439.50d

Numbers followed by different letters in the same column are significantly different at the 95% level
BC: Bread with Corn Flour; BR: Bread with Rice Flour

TABLE 5. Profile pasting properties roti gluten-free

Sample	Peak viscosity (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Pasting temperature (°C)
GFBC-Control	579.00d	112.00c	2719.00c	2252.00a	85.48ab
GFBC- CMC 1%	1041.00c	359.00bc	2183.00d	1501.00b	93.85a
GFBC- Carrageenan 1%	469.50d	151.00bc	2415.50d	2097.00a	91.90a
GFBR-Control	3657.50a	1010.00a	3839.50a	1192.00b	71.48b
GFBR-Carrageenan 1%	2418.00b	587.50b	3352.00b	1421.50b	85.95ab

Numbers followed by different letters in the same column are significantly different at the 95% level
GFBC: Gluten Free Bread with Corn Flour; GFBR: Gluten Free Bread with Rice Flour

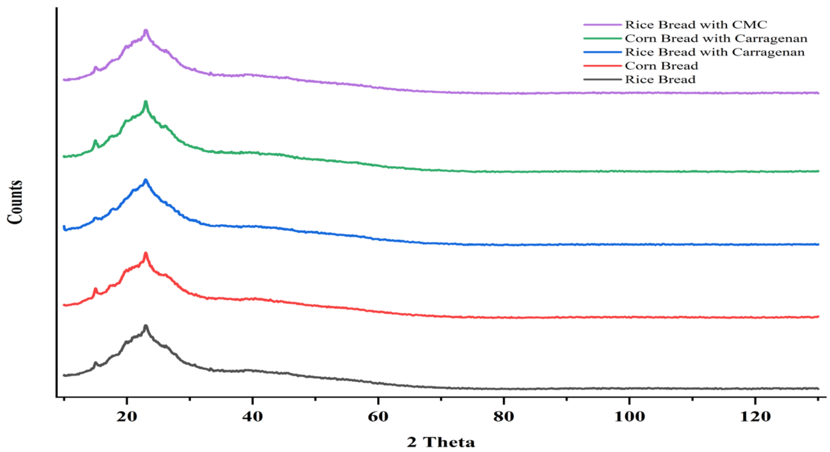

FIGURE 2. Crystallinity profile of gluten-free bread with hydrocolloid addition

in the amorphous regions. The absorption of water by starch will be contingent upon its condition. The degree of starch crystallinity post-baking is expected to impact the crust staling kinetics, consequently influencing the reduction in crispness (Primo-Martin et al. 2007).

MICROSTRUCTURE PROFILE

The microstructural profile of glute-free bread porosity can be analyzed using SEM (Scanning Electron Microscope). Based on the results of the microstructural profile analysis, it can be seen that the difference in the use of flour type and hydrocolloid type affects the microstructural profile of the gluten-free bread produced as shown in Figure 3.

Based on the results of the microstructural profile, it can be seen that the pore distribution of the bread is quite different between the control and the bread added with hydrocolloid food additive. The porosity of the control bread was coarser than the gluten-free bread with the addition of hydrocolloids. The amount of porosity is also influenced by the type of flour and the type of hydrocolloid added. Based on the microstructure profile, starch granules are no longer visible, and gelatinization has begun, with merging among granules and other components. Gelatinization alters the initial configuration of starch granules, causing them to become wrinkled, diminished, and deformed (Ashwini, Jyotsna & Indrani 2009; Sowmya et al. 2009). The extent of starch gelatinization emerges as

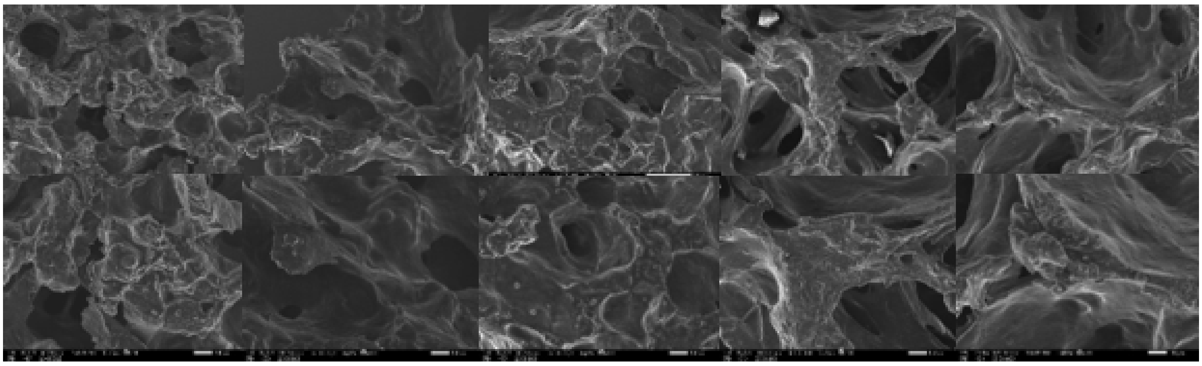

FIGURE 3. Microstructural profile of gluten free bread with the addition of hydrocolloids (Top part magnification 50x; bottom part magnification 100x; From left to right: GFBC-Control, GFBC-1% CMC, GFBC- 1% Carrageenan, GFBR-Control and GFBR-Carragenan)

a crucial element influencing the internal texture of baked goods and their longevity (Blaszczak et al. 2004).

The baking process above its gelatinization point causes starch granules to undergo gelatinization and fuse with each other and other components. The formation of porosity is also evident, with porous regions observed among the gluten-free bread dough. Differences in flour types and hydrocolloids result in varying degrees of porosity, as illustrated in Figure 3. Hesso et al. (2015) elucidated that in the preparation phase when flour and water were combined resulted in a network structure of proteins and soluble solutes influenced forming a matrix with starch granules embedded within. The formulation could potentially impact the network between gluten and starch (Thani et al. 2021).

The control loaf has a porous structure with empty internal pores. The inner surface of the pores of the control bread was rough and uneven compared to the smooth surface of the bread treated with arabic gum as a hydrocolloid component used as a food additive (Bourekoua et al. 2017). Furthermore, Bourekoua et al. (2017) stated that the swollen starch structure visible on the rough surface was present in the control samples compared to the compact structure in the bread with the addition of hydrocolloids which looks more amorphous and homogeneous.

CONCLUSIONS

The use of types of flour as raw materials and the addition of food additives affects the characteristics of colour, sensory elements, texture, and specific volume of gluten-free bread. The important parameter indicating the highest level of expansion is the specific volume at 3.422 cm^3/g, which is observed in gluten-free bread with the addition of CMC in corn flour. Based on the results of the proximate analysis, the addition of types and use of different flour raw materials affects the moisture, ash, fat, protein, and carbohydrate content produced from gluten-free bread. The microstructural profile of gluten-free bread is influenced by the addition of the type of hydrocolloid used. Future studies should focus on maximizing the utilization of several hydrocolloid types in combination to achieve more ideal physicochemical properties.

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