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Improvement of the rate of substitution of wheat by rice in bread making by the use of xanthan gum: Technological and sensory properties

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Abstract

The aim of this study was to explore the possibilities of producing composite breads from blends of rice and wheat flours, with the addition of xanthan gum. The aim is to provide an effective and considerable substitute for wheat in bread making. Six formulations of rice (R) and wheat (B) flour blends were prepared in different proportions: 100%B, 50%R/50%B, 60%R/40%B, 65%R/35%B, 70%R/30%B, 85%R/15%B. The functional and rheological characteristics of the composite breads were evaluated and compared with those of 100% wheat bread, used as a reference. A constant percentage of xanthan gum (0.25%) was added to each mix. Samples containing 50%, 65% and 70% rice flour, in combination with xanthan gum, showed promising results in terms of volume, water loss, color and sensory acceptability. The 50%R/50%B bread gave the best rheological results, with a volume of 1.7933cm3/g, closest to that of the control bread with a specific volume of 3.448cm3/g of wheat; its water loss was 8.9%, lower than that of the control bread (10%); and its color and honeycomb structure were similar to those of wheat. Sensory evaluation revealed that the 50%R/50%B bread was the most appreciated by panellists, achieving an acceptability rate of 80%. This study demonstrates the feasibility of replacing wheat with other cereals, such as rice, using xanthan gum to maintain excellent technological and sensory properties. These results suggest that rice could be appropriately incorporated into wheat flour, up to a substitution rate of 70%.

Keywords: Xanthan gum; Rice flour; Wheat flour; Composite breads; Technological properties; Sensory acceptability

1. Introduction

In Senegal, bread is a highly prized foodstuff, defined as the bakery product obtained by baking a kneaded and fermented dough prepared from bread-making cereal flour, drinking water, sourdough yeast and salt (François and Michels, 2021). The country depends entirely on wheat imports to meet an estimated demand of 745,000 tonnes per year, representing a value of 149.3 billion FCFA (ANSD, 2022).

However, global wheat production is facing challenges, with forecasts indicating a potential drop in the harvest. The FAO estimates that wheat production is set to fall below its five-year average. Indeed, it is predicted that at least 20% of winter-planted areas will not be harvested, due to direct destruction, difficulties of access or lack of resources to harvest (FAO, 2022).

This situation highlights the need to diversify food sources and promote sustainable solutions to guarantee food sovereignty, based on local resources.

For this reason, research has turned to composite flours, defined as a blend of several flours obtained from roots, tubers, cereals and legumes, with or without the addition of wheat flour (Shittu et al, 2007). The technology of bread making with composite flours, in which imported wheat flour is partially or entirely replaced, is well mastered.

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Composite flour has advantages for developing countries, as it reduces the need to import wheat flour and encourages the use of domestic agricultural products as flour (Hugo, 2000).

The gluten present in wheat flour plays a fundamental role in bread-making, as it is an essential structuring protein that gives the dough viscoelasticity, good gas-holding capacity and good crumb structure to the resulting baked product (Gallagher et al, 2003). Rice is one of the most suitable cereals for gluten-free preparations, thanks to its hypoallergenic proteins, high-energy content and excellent digestibility, neutral flavor and white color (Gujraj et al, 2003).

The addition of hydrocolloids such as xanthan gum is an important approach developed to mimic the properties of gluten in gluten-free bakery products (Alvarenga et al, 2011).

The aim of this study is to improve the substitution rate of wheat by rice in bread making by adding xanthan gum by analyzing the effects of incorporating rice flour and xanthan gum on rheological and functional characteristics.

2. Material and methods

2.1. Plant material

Rice grains of a variety named R in this study and produced in the Senegal River valley were meticulously processed into flour in the laboratory using a grain mill to obtain a grain size <200 µm. The soft wheat flour was purchased from stores in Dakar. The xanthan gum used as a gluten substitute was produced by the Biotechnologies laboratory of the Institut de Technologie Alimentaire. A quantity of 0.25% xanthan gum was added to all bread samples.

2.2. Sample preparations

Rice grains of a variety named R in this study and produced in the Senegal River valley were meticulously processed into flour in the laboratory using a grain mill to obtain a grain size <200 µm. The soft wheat flour was purchased from stores in Dakar. The xanthan gum used as a gluten substitute was produced by the Biotechnologies laboratory of Institute of Food Technology. A quantity of 0.25% xanthan gum was added to all bread samples.

Table 1 The different flours obtained, and the substitution rates used.

Composite Flours	Wheat flour (%)	Rice flour (%)
100B	100	0
50R/50B	50	50
60R/40B	60	40
65R /35B	65	35
70R /30B	70	30
85R /15B	85	15

2.3. Rheological characterization

An F4 rheofermentometer (Chopin Technologies France) was used to study the release of gas when rice flours were added to dough samples. Measurements included parameters such as maximum dough height, total volume of gas produced, volume of carbon dioxide (CO2) lost during leavening, and volume of CO2 retained at the end of the test. The method complies with AACC 89-01 for the measurement of yeast activity and gas production.

2.4. Breadmaking Test

After determining the optimum level of xanthan gum, 500 g flour blends were prepared with wheat-rice substitution rates ranging from 50% to 85%. The aim was to compare the results of breadmaking using a fixed xanthan gum rate, while substituting wheat flour with rice flour. The process involved mixing the flours, adding improvers, dough rising, shaping, fermentation, baking at 200°C for 25 minutes, followed by evaluation of technological and sensory properties.

2.5. Characterization of the bread obtained (physical properties)

2.5.1. Specific volume

Specific volume, which is the ratio of bread volume to weight, has been generally adopted in the literature as a more reliable measure of bread size (Shittu, 2007).bread specific volume was determined by modifying the rapeseed replacement method according to AACC 10-05.01 (ACC, 2000), using millet seeds instead of rapeseed. The specific volume (Vsp) of bread, expressed in cm3/g, is the quotient of bread volume (V) and mass (M).

$$Vsp(cm3/g) = V/M \ldots\ldots\ldots (1)$$

2.6. Water losted

The percentage of weight loss is calculated by taking the ratio of the difference between the initial weight of the dough before fermentation and the weight of the bread after baking to the initial weight of the dough. It is calculated just after cooking according to the Keskin formula (2004). An initial weight of 250g before fermentation was used.

$$\text{Water lossed (\%)} = ((\text{dough weight-bread weight}))/(\text{ dough weight})*100 \ldots\ldots..(2)$$

2.7. Hydration rate (HR)

Water helps hydrate the ingredients and form the dough during the frasing process. It promotes biochemical reactions and also acts as a plasticizing agent, allowing proteins and starch to change from a solid, rigid state to a more malleable one. In general, the hydration rate of a dough is maintained between 45 and 50 grams of water for every 100 grams of wet dough. To calculate it, you need to take into account the water from the flour and other ingredients. This makes it possible to adjust the amount of water to be poured into the mixer (Buche, 2011).

$$HR = ((\text{water mass+ water mass of flour+ water mass of ingredients})) /(\text{ mass of the wet dough})*100 \;..(3)$$

2.7.1. Color

Using a colorimeter (model CR-410, Konica Minolta Sensing, Inc. Japan), measurements were taken on various bread samples according to AACC method 14-22.01. Light absorption intensities were recorded on a white background with the scales L* (brightness), a* (redness), and b* (yellowing). Each sample was measured three times.

2.7.2. Honeycomb structure

Numerous studies have adapted digital image analysis for quantitative assessments of the alveolar structure of cereal products. 2D image-acquisition devices such as cameras, scanners and video cameras can be used to obtain high-contrast images (Sapirstein, 1994). Most image analyses cited in the literature use binary (black and white) or grayscale images, although most acquisition techniques produce color images. Binarization distinguishes alveoli (black) from walls (white), while a grayscale image represents the spatial distribution of gray intensities for each pixel (Lassoued, 2005).

To quantify the honeycomb structure of bread samples, the phone is positioned on a laboratory stand inside an enclosure controlled to maintain stable brightness. Images are cropped to uniform dimensions of 600 by 600 pixels, simplifying processing and making it easier to assess the number of cells per square centimeter. Each image undergoes the following steps: grayscale conversion, honeycomb detection (black) and counting to provide data on the number of honeycombs per square centimeter.

2.7.3. Sensory analyzes.

Prepared breads were evaluated for color, odor, taste, texture and overall acceptability, both unaccompanied and with the addition of chocolate. The samples were judged by 35 panelists made up of staff from the Institut Technologie Alimentaire (ITA) on a hedonistic scale of 9. The acceptability index (AI) was calculated using Fernandes and Salas Mellado's formula (Fernandes and Salas-Mellado (2017)

$$AI(\%) = (\text{score*Hedonic scale})/100 \ldots\ldots\ldots\ldots..(4)$$

2.8. Statistical analyzes

All measurements were carried out in triplicate, and the data were subjected to an analysis of variance to test the effects of the various experimental factors on the properties measured. The Fisher test was used to classify treatments in the event of a significant difference. All analyses were performed using XLSTAT software version 6.1.9. Statistical significance was defined at 0.05.

3. Results and discussion

3.1. Rheological characterization of the paste

Table 2 highlights the measurements of the rheo fermentometer analyzes of the different formulations

Table 2 Results of measurements of rheo fermentometer analyzes of the different samples

Samples	Development of the dough			Gas behavior		
	Hm (mm)	T1(h)	H'm (mm)	VtCO2 (ml)	VrCO2(ml)	RCO2 (%)
Witness	37.7	3:00;00	53.8	1147	1024	89
50R/50B	21.6	2:57:00	30.2	745	733	98
60R/40B	13.7	3:00:00	29	738	693	94
65R/35B	12.2	3:00:00	24.1	726	697	96
70R/30B	9.4	2:57:00	13.4	725	657	91
85R/15B	5.7	1:58:00	17.6	334	328	98

Hm : maximum height of the dough, T1: maximum development time of the dough, H´m: maximum height of gas release, VtCO2: total volume of CO2, VRCO2: volume of CO2 retained, RCO2: CO2 retention coefficient

3.2. Gas production during fermentation

Analysis of Table 2 shows that the control sample produces more CO2 with a total CO2 volume (VtCO2) of 1147ml. This CO2 production decreases progressively with increasing rice flour until it reaches the value of 334ml corresponding to the highest rice incorporation rate (85R/15B). However, the composite pasta samples have a higher retention coefficient than the control sample.

Pasta containing 50% rice flour has the highest CO2 retention capacity, followed by the other composite bread samples. The increased addition of rice flour could explain the reduced amylase activity of wheat, essential for the transformation of starch into sugars. This reduction in sugars available for fermentation by yeast could, in turn, impact gas production, thus influencing the dough rising process.

Carbon dioxide production is a very important quality criterion, as good gas production and retention affect the final qualitý of the bread. Martinez (2014).

From the fermentable carbohydrates from flour and those released by wheat amylases, yeasts produce carbon dioxide and ethanol as well as organic acids by fermentation (Roussel and Chiron, 2002). This observation was corroborated by the work of Morteza Jafari et al (2018) on composite breads based on cassava and xanthan gum.

3.3. Dough development during fermentation

3.4. Characterization of the bread obtained

The data in Table 2 show that the maximum heights of the pulp samples range from 5.7 mm for sample 85R/15B to 37.7 mm for the control. Similarly, maximum gaseous fermentation heights ranged from 17.6 mm for sample 85R/15B to 21.6 mm for the control sample. A reduction in maximum dough height (Hm) and maximum gaseous fermentation height (H'm) was observed with increasing rice flour content in the composite dough samples. A decrease in maximum dough height could be due to low matrix development, thus minimizing the amount of retained gas that prevents dough extension (Gómez et al., 2011). These observations were confirmed by the work of Mohammed Dahir et al, (2015) on the fermentation of sorghum-wheat composite doughs. According to Gandikota and MacRitchie (2005), the H'm parameter was closely related to bread volume, a good attribute for predicting the final product.

The time required for maximum dough development (T1) varied between samples, with some interesting observations. Samples with a higher rice content have a shorter fermentation time. This observation was confirmed by Muzaffar et al(2021), who reported that the time taken for these stages - kneading, fermentation and baking - is shorter in gluten-free bread-making than in conventional wheat flour-based bread-making.

Generally speaking, the most favorable performances are observed in the following order of samples: 50% rice dough comes out on top, followed by 60% rice dough, then 65%, 70% and finally 85% rice doughs.

3.4.1. Physical properties

Table 3 shows the results of physical properties (specific volume, water loss, hydration) of the different bread samples.

Table 3 Results of physical properties of the different samples

Samples	Specific volume (cm3/g)	Water loss (%)	Hydration (%)
100B	3.448[a] ±0.024	10[a]±0.01	60[a]±0.01
50R/50B	1.793[b]±0.025	8.9[b]±0.02	63[b]±0.02
60R/40B	1.311[c]±0.026	7.5[c]±0.11	63[b]±0.13
65R/35B	0.931[d]±0.064	7.5[c]±0.11	63[b]±0.01
70R/30B	0.706 [e] ±0.050	6.9[d]±0.11	66[c]±0.01
85R/15B	0.6[f]±0.026	6.8[d]±0.11	71[d]±0.02

Values represent mean ± standard deviation, n =3

3.4.2. Volume

The control sample has a higher specific volume with a value of 3.448 cm3/g than the 85R/15B sample with a value of 0.6 cm3/g. Significant differences ($p < 0.05$) are noted on the specific volumes of the different samples. . Thus, as the incorporation rate of rice flour increases, the specific volume decreases. This would be due to the reduction in the quantity and quality of proteins in the composite bread samples. This hypothesis is confirmed by the work of Ragaee and Abdel-Aal (2006). The same trend was observed by Elisa Julianti et al , (2015) on the work of breads based on composite flour of sweet potato, corn, soy and xanthan gum . The decrease in specific volume was already predictable with the increase in the incorporation of rice, as observed previously with the maximum height of gas release (H'm) . According to Gandikota and MacRitchie (2005) , the parameter H'm is closely linked to the volume of bread, it is a good attribute to predict the final product. Since these parameters are closely related, reducing the gassing height results in a decrease in volume. . The results show that the highest specific volume is obtained with the 50% rice sample; followed respectively by 60%, 65%, 70% and 85% rice. The incorporation of gum plays a crucial role in these results.

3.4.3. Hydration rate

The bread samples present a range of hydration levels varying from 60 to 71%, with significant differences ($p<0.05$) between them. The control bread had the lowest hydration level, while the 85R/15B bread had the highest level. It is observed that the hydration rate increases with the increasing incorporation of rice flour in the formulation. This result could be attributed to the superior ability of rice flour to retain water because of its lower humidity than that of wheat.

3.4.4. Water loss

A reduction in water loss during cooking was demonstrated with the increase in the incorporation rate of rice flour. The 85R/15B rice bread showed the lowest water loss at 6.8%, while the wheat-based control bread showed the highest water loss at 10%. This reduction can be explained by the high water content maintained in the crumb due to the ability of the starch to retain large quantities of water, favoring the gelatinization of the starch during cooking and thus trapping the water inside. inside the bread. (Kamela, 2016). These results were also confirmed in Kamela's work on gluten-free breads, where 100% wheat bread showed the greatest water loss (12.394%), while the lowest loss (7.40%)) was observed in the case of 100% rice bread.

Table 4 shows the results of colorimetric tests of different bread samples

Table 4 Results of colorimetric tests of crust and crumb

Samples	Crust Color			Mime color		
	L*	a*	b*	L*	a*	b*
100B	68.293[a] ± 0.01	4.197[b] ± 0.005	27.643[b] ± 0.02	84.360[a] ± 0.07	0.537[f] ± 0.006	19.58[a] ± 0.01
50R/50B	64.703[d] ± 0.09	6.990[a] ± 0.06	27.797[b] ± 0.015	67,560[e] ± 0.01	0.023[e] - ± 0.015	14.39[b] ± 0.02
60R/40B	65.330[c] ± 0.16	7.030 [a] ± 0.015	30.020[a] ± 0.001 -	71.440[d] ± 0.07	0.080[a] ± 0.001	14.72[b] ± 0.023
65R/35B	65.230[c] ± 0.72	1.270[c] ± 0.01	15,837[e] ± 0.012	74.093[b] ± 0.55	0.457[c] ± 0.12	13.13[c] ± 0.023
70R/30B	66.260[b] ± 0.05	2.443[d] ± 0.012	17.477[d] ± 0.02	76.200[a] ± 0.46	0.36[d] ± 0.02	14.79[b] ± 0.11
85R/15B	66.747[b] ± 0.11	2.377[d] ± 0.02	18.857[c] ± 0.006	76.297[a] ± 0.12	0.697[b] ± 0.46	13.68[c] ± 0.31

3.4.5. Crust color

Figure 1 Image of the different bread samples

The results of the colorimetric tests of the crusts, illustrated in Table 2 and in Figure 2, show that the control bread has a high luminance (L* = 68.293) with a much more golden crust than the other composite bread samples. The 65R/35B bread has a lower luminance (L* = 63.472). Colorimetric tests indicate that all bread samples have a good golden color due to enzymatic browning linked to the Maillard reaction (Muriel jackot et al, 2012). For composite breads, tests show an increase in crust luminance as the rate of rice flour incorporation increases.

3.4.6. Crumb color

The results of the colorimetric tests of the crumbs, illustrated in Table 2 and in Figure 2, reveal that the crumb of the 85R/15B bread has a high luminance (L* = 75.580), thus explaining its lighter shade compared to the crumb of the control bread, which has a lower luminance (L* = 63.472). Colorimetric tests indicate that the color of the crumb becomes more pronounced with increasing the proportion of rice flour. This could be due to the influence of the high incorporation of rice in the formulation. This trend was confirmed by the work of Kamela (2016) showing that bread made entirely of rice (100%) had the highest luminance (L*) for both the crust and the crumb.

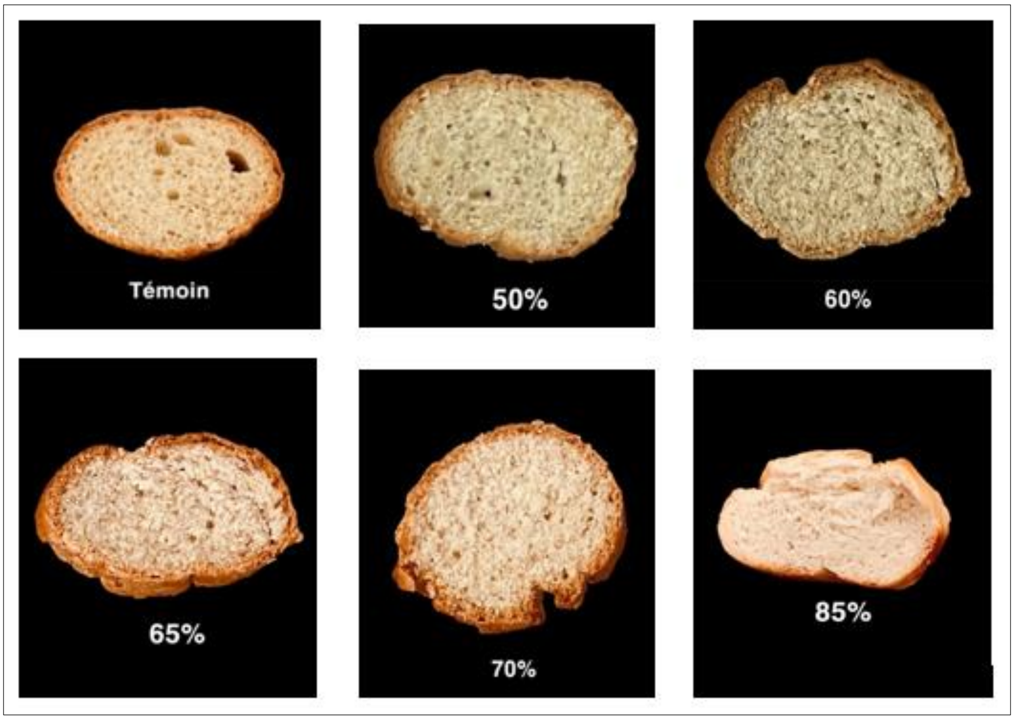


Figure 2 Crumbs of the different samples

3.4.7. Cells

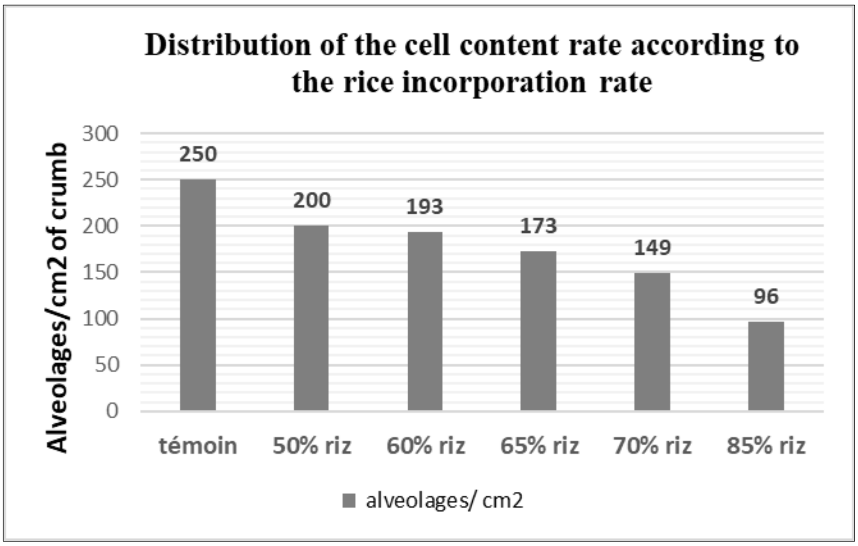


Figure 3 Distribution of the alveolation rate according to the incorporation rate of the different samples

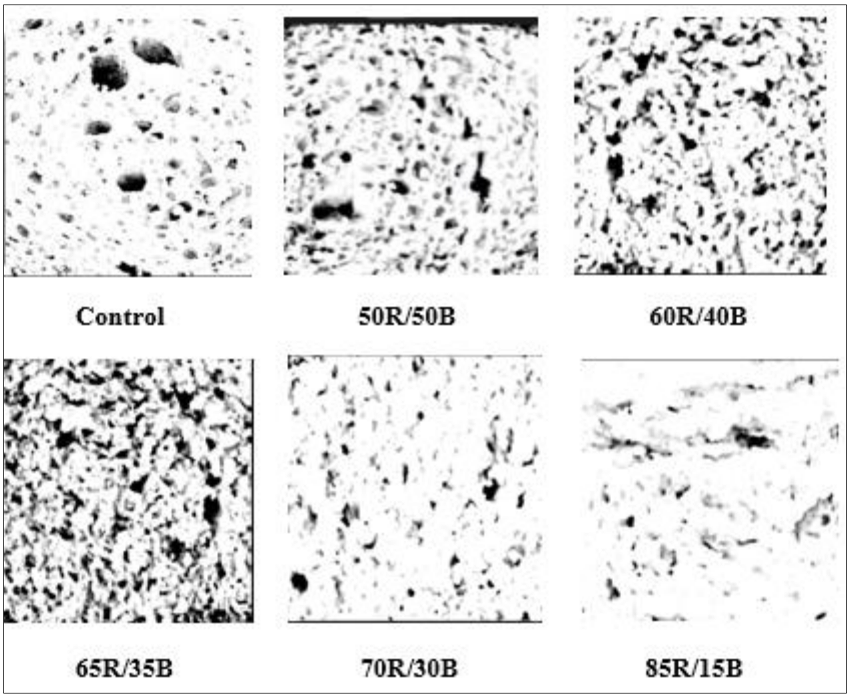


Figure 4 Photos of the crumbs of the different samples after image processing

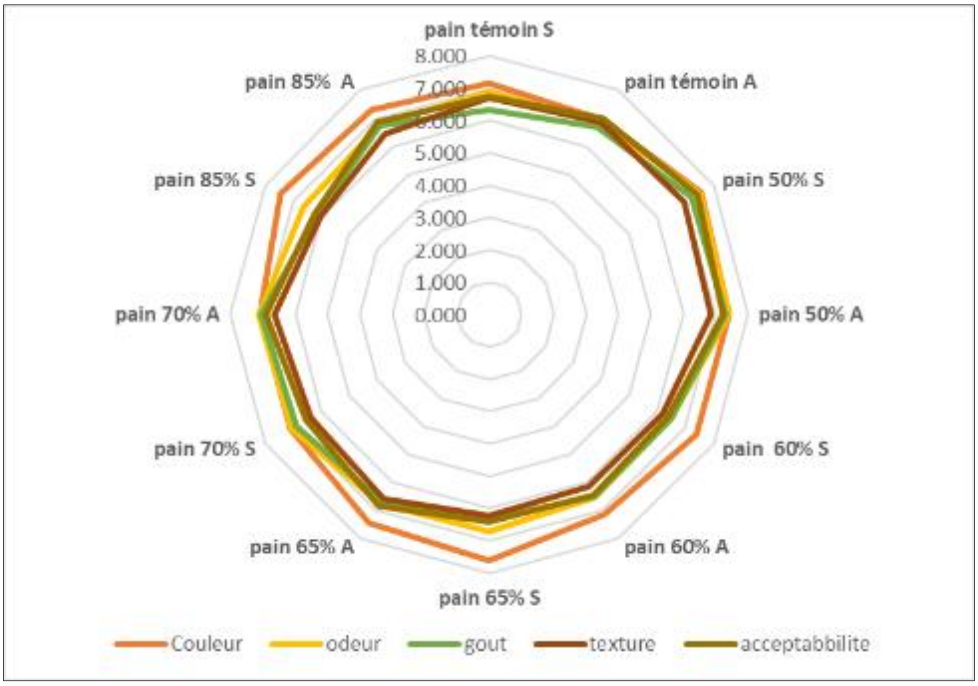
The reference bread is distinguished by a particularly airy crumb, with a cell density reaching 250 cells/cm^2. On the other hand, bread (85R/15B) has a denser texture, marked by a lower density of cells, at only 96 cells/cm^2. When the rice incorporation rate increases in the different samples, the number of cells decreases, leading to a denser crumb. The reduction in the number of cells in bread, observed with the increase in the proportion of rice, could be attributed to the absence of gluten in rice. This could compromise the formation of the gluten network essential for carbon dioxide retention, resulting in a denser crumb. The bread with 50R/50B has the best cellular structure among the composite breads, approaching the control bread.

3.4.8. Sensory analysis

Table 5 shows the results of sensory test of the different bread samples.

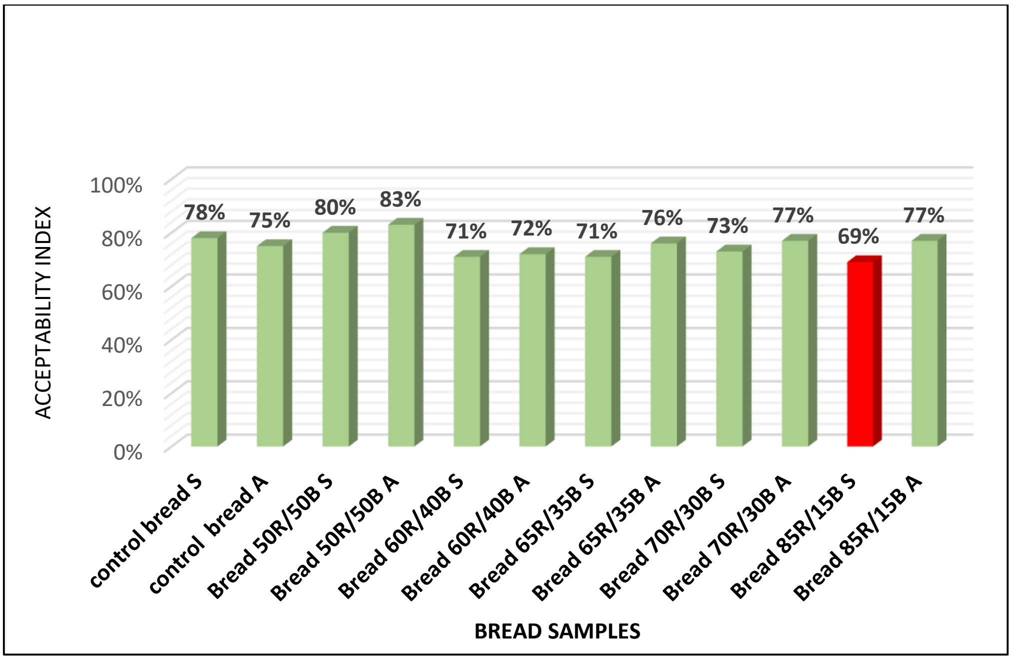
Table 5 Results of the sensory test of the different bread samples

		Samples					
		Witness	**50% rice**	**60% rice**	**65% rice**	**70% rice**	**85% rice**
Color	Unaccompanied bread	7.143^{a}	7.571^{bc}	7.4^{abc}	7.629^{c}	7.086^{ab}	7.457^{abc}
	Bread with side dishes	6.943^{abc}	7.4^{abc}	7.143^{abc}	7.457^{abc}	7.086^{ab}	7.286^{abc}
Smell	Unaccompanied bread	6.886^{abc}	7.429^{bc}	6.486^{a}	6.714^{abc}	7.057^{abc}	6.629^{abc}
	Bread with side dish	6.886^{abc}	7.514^{c}	6.543^{ab}	6.771^{abc}	7.143^{abc}	6.771^{abc}
Taste	Unaccompanied bread	7.086^{cd}	7.314^{d}	6.257^{ab}	6.343^{ab}	6.886^{cd}	6.143^{a}
	Bread with side dish	7.086^{cd}	7.229^{d}	6.486^{abc}	6.686^{abcd}	6.057^{cd}	6.743^{abcd}
Texture	Unaccompanied bread	6.69^{bc}	6.97^{c}	6.17^{ab}	6.37^{abc}	6.4^{ab}	6.02^{a}
	Bread with side dish	6.89^{c}	6.85^{c}	6.14^{ab}	6.66^{bc}	6.829^{cd}	6.45^{abc}
Acceptability	Unaccompanied bread	6.74^{abcd}	7.42^{dc}	6.37^{ab}	6.54^{abc}	6.4^{ab}	6.22^{f}
	Bread with side dish	7^{c}	7.22^{nd}	6.45^{abc}	6.88^{bcde}	6.82^{bcd}	6.88^{bcde}



Pain = bread (English); S: without accompaniment P: with accompaniment

Figure 5 Sensory profile of the different bread samples



S : without accompaniment P **:** with accompaniment

Figure 6 Acceptability index of different bread samples depending on the incorporation rate

The results of the sensory test, illustrated in Figure 5, indicate the existence of significant differences ($p<0.05$) with regard to color, odor, taste and texture between the mixed bread samples and the control bread (100% Wheat). The results show that the 50R/50B composite bread obtained the highest sensory score, with an acceptability rate of 80% while that of 85R/15B obtained the lowest acceptability rate at 69%. As for the overall acceptability of breads without accompaniments, the 85R/15B bread was less appreciated. For breads with accompaniment, all samples were deemed acceptable exceeding the threshold of 70% (Fernandes and Salas-Mellado, 2017).

4. Conclusion

The study found that the addition of xanthan gum was essential for achieving high substitution rates, and its influence on improving bread quality.

Bread-making tests have shown that rice flour could replace wheat flour by up to 70% without any significant depreciation in the physical and organoleptic characteristics of the breads. Among the composite bread samples studied, the one containing 50% rice flour stood out by presenting the best rheological, baking and sensory characteristics.

In view of the positive results obtained, it is recommended to explore the substitution of wheat by other local cereals and tubers and to study the synergies of hydrocolloids for a total substitution of wheat, thus opening the way to promising alternatives in research. .

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] ACC. (2000) . American Association of Cereal Chemists. Approved methods of the AACC. St Paul, Minnesota: The Association,.

[2] Alvarenga et al, FL (2011). Characterization of gluten-free bread prepared from maize, rice and tapioca flours using hydrocolloid seamed agar–agar. Canada: Rec. Res. Sci. Tech.,.

[3] ANSD. (2022). Agence Nationale de la Statitistiaue et de la Demographie.

[4] Buche, F. (2011). Influence of the formulation of wheat flour doughs on their oxygen consumption and carbon dioxide production during kneading and fermentation: Biochemical and rheological consequences. Food and Nutrition. AgroParisTech,.

[5] Effect of extrusion wheat bran on dough rheology and bread quality. Food Science and Technology, 2011.

[6] Elisa Julianti et al, HR (2015). Functional and rheological properties of sweet potato, corn, soy and xanthan gum composite flours. Journal of the Saudi Society of Agricultural Sciences , 171-177.

[7] FAO (1996). . Codex Alimentarius: Cereals, pulses, legumes, derived products and vegetable proteins. (Vol. Vol 7. 2nd edition.). Rome.: FAO.

[8] FAO. (2022). isra.sn. _ Retrieved from Isra.sn: https://isra.sn/2022/05/07/webinarfoncier/

[9] Fernandes and Salas-Mellado. (2017). Added chia seed mucilage to reduce fat content in breads and cakes.

[10] Gallagher et al, AK (2003). The effect of dairy and rice powder addition on loaf and crumb characteristics, and on shelf life (intermediate and long-term) of gluten-free breads stored in a modified atmosphere. Eur. Food Res. Technol.

[11] Gandikota, S., & MacRitchie, F. (2005,). Dough expansion capacity: methodology and applications. J. Cereals Sci. , 157-163.

[12] Gujraj et al, GI (2003). Effect of cyclidextrin glycosyl transferase on dough rheology and bread quality from rice flour. Agricultural J.

[13] Hugo, L.R. (2000). Malted sorghum as a functional ingredient in composite bread. Grain saw.

[14] ICC. (1996). Standard methods of the international association for cereal science and technology. Vienna, Austria.: International Association for Cereal Chemistry.

[15] Kamela, S. (2016). Incorporation of canola proteins into gluten-free bread: technological impact and modeling of the baking process. Quebec: Laval University.

[16] Lassoued, N. (2005). Alveolar structure of cooking cereal products in relation to the rheological and thermal properties of the dough: Effect of composition. ENSIA.

[17] Martinez, M.D. (2014). Effect of different microstructural characteristics of soluble and insoluble fibers on gluten-free dough rheology and bread-making. Journal of Food Engineering , 49-56.

[18] Mohammed Dahir et al, K.-XZ-N. (2015). Incorporation of different additives into sorghum-wheat composite flour: effect on. Journal of Academia and Industrial Research .

[19] Morteza Jafari et al, AK (2018). Functional effects of xanthan gum on quality attributes and microstructure of extruded sorghum-wheat composite dough and bread. elsevier.

[20] Muriel jackot et al, PF (2012). Food color from theory to practice. Paris: Lavoisier.

[21] Muzaffar et al, KS (2021). Technological Aspects of Gluten Free Bread. In: Mir, SA, Shah, MA, Hamdani, AM Gluten-free bread technology. Retrieved from cham. https://doi.org/10.1007/978-3-030-73898-3_3.

[22] Okaka and Potter. (1977).

[23] Ragaee and Abdel-Aal. (2006). Sticky properties of starch and proteins of selected cereals and quality of their products. Food chemistry.

[24] Sapirstein, H. e. (1994). Instrumental measurement of bread crumb grain by digital image analysis. Cereal Chemistry.

[25] Shittu et al, AR (2007). Effect of baking time on certain physical properties of bread. Power Res Int.

[26] Shittu, A.R. (2007). Effect of baking time on some physical properties of bread loaf. Food Res Int.