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Rheological properties of corn-wheat composite bread after common and separated hydration: from raw material to final product properties

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Abstract

Background: The war in Ukraine has led to a sharp rise in the cost of food imports, including wheat. In response to this situation, the FAO has encouraged African countries to make greater use of their local grains in breadmaking. Thus, this study aims to optimize the formulation of composite bread made from wheat and corn flour.

Materials and Methods: Two corn varieties were used in the study: FBC6 and Massongo. The Minitab 19 software was used to generate the experimental design. Three levels (10%, 12.5%, and 15%) of maize flour were mixed with wheat flour for the bread production tests. These tests were conducted using both combined and separate hydration methods to compare the rheological and technological properties of the composite flours and the physical and sensory properties of the composite breads.

Results: Substituting wheat flour with corn flour resulted in a gradual decrease in protein content from 11.25% to 10.6%, whereas ash content and absorption rate increased. The incorporation levels tested resulted in a decrease in extensibility, swelling index, baking strength, and dough elasticity index, and an increase in dough tenacity. Separate hydration increased the weight and length of the loaves.

Keywords: Maize; Common Hydration; Separate Hydration; Composite Bread; Physical Pro and Sensory Properties

1. Introduction

Bread is a food whose consumption is steadily increasing. In Burkina Faso, the population is entirely dependent on wheat imports. Whereas maize production is growing. For this reason, using local flours to partially replace soft wheat flour in bread making is becoming the best solution for reducing wheat imports and promoting the use of local grains. In recent years, the FAO has launched a broad program to promote the use of local grains in Africa. Since then, numerous studies tohave aimed at incorporate local flours into bread production. However, only one country, Burkina Faso, has mandated the incorporation of 5 to 10% corn flour into wheat flour. In the face of the global health crisis and the Russia-Ukraine war, the world is facing a major wheat import crisis. Ukraine exports 18 million tons of wheat and Russia 34 million (compared to 20 million tons for France). These two countries account for 23% of global exports (Gourdji, Pandey and Peiris, 2025).

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Maize (*Zea mays L*) is the most widely cultivated plant in the world and the leading cereal crop, ahead of wheat. In Burkina Faso, maize is grown in all regions (Waongo Laux, & Kunstmann, 2015). Maize is the second most produced cereal in Burkina Faso, with production reaching 1,710,898 tonnes in 2019, making it one of the country's main cereal crops (Somda et al., 2023). Maize forms the basis of the rural population's diet. It is used for human and animal consumption (poultry, pigs, cattle) and serves as a raw material in certain industries (breweries, soap factories, and oil mills) (Ogidi, & Hung, 2025). It is the most energy-rich cereal (Adesanmi, Malomo, & Fagbemi, 2020) due to its nutritional advantages like high starch content, protein and mineral content and the most economical in terms of production (Kaushal et al., 2023). Maize kernels contain two fat-soluble vitamins: provitamin A, or carotenoids, and vitamin E. Carotenoids are found primarily in yellow maize (6.4 to 11.3 µg/g) at levels that can be genetically controlled, while white maize contains little or no carotenoids (Violeta et al., 2018). Beta-carotene is an important source of vitamin A, but unfortunately, yellow maize is used much less for human consumption than white maize. To promote the use of local cereals, and especially in response to the soaring cost of wheat, this study was conducted to test the incorporation of two maize varieties produced locally in Burkina Faso: yellow maize (FBC6) and white maize (Massongo). The principal objective of this study was to evaluate "The Effect of the hydration technique on the rheological properties of composite flours and on the physical and sensory properties of composite breads: case of corn - wheat".

2. Materials and Methods

2.1. Study Setting

The study was conducted at the Grand Moulin de Mê laboratory and the Wend Konta bakery, part of the Burkinabé Society of Commerce and Industry (FBCI) in Bobo Dioulasso, from June to September 2025.

2.2. Maize flour processing

Maize flour processing has been performed in four steps to obtain a very fine grind (Figure 1):

- *Sorting*: This is the first step, which involves sorting the maize to remove defective kernels and impurities such as pebbles, pieces of wood, and other debris.
- *Washing*: During this step, the kernels are washed with cold water to remove dust and other impurities.
- *Soaking*: In the third step, the selected kernels are soaked in water and left to rest for 24 hours, according to F1 formula

With

$$Xg = \frac{15.5 - \text{Mc (Maize)}}{100 - 15.5} \quad \text{(F1)}$$

Xg: quantity of wet corn;

15.5: desired moisture content;

Mc: moisture content of the corn to be wetted.

Milling: In the last step, the wet corn is passed through an industrial mill several times to obtain a very fine grind.

Figure 1 Corn flour produced after applying common and separate hydration

3. Experimental Design

The experimental design was carried out following the Methodology for Designing Mixtures generated in Minitab. A two-factor centred mixture design was used. The quantities of flours used (**Table 1**) were chosen based on data available in the literature (with corn flour ranging from 10 to 15% of the total composite flour, the remainder being wheat flour). Two types of hydrations were performed: common hydration and separate.

Table 1 Experimental design applied during this work

Samples	Corn flour	Quantity (g)	Wheat flour quantity (g)	Hydration technic
E0	Massongo	0	2000	Common
E1		200	1800	
E2	FBC6	300	1700	
E3		200	1800	
E4	Massongo	300	1700	
E5		200	1800	Separated
E6	FBC6	300	1700	
E7		200	1800	
E8	Massongo	300	1700	
E9		250	1750	Common
E10	FBC6	250	1750	
E11	Massongo	250	1750	Separated
E12	FBC6	250	1750	

3.1. Common Hydration bread processing

3.1.1. Description of the Unit Operations for Bread Production from Blended Flour (Wheat/Corn).

After mixing the blended flours (wheat/corn) in the lab using an MR2L mixer (KPM Analytics) according to the experimental design, the ingredients were measured using an analytical balance: yeast (10%), salt (15%), improver (0.5% flour), and water, which varies between 60% and 65% depending on the blended flour and was added gradually until the desired dough consistency was achieved. In a spiral mixer, the dough was kneaded for 3-5 minutes at a speed of 45-55 rpm, followed by a second kneading at 75-85 rpm for 10 minutes. The dough was then left to rest for 10 to 15 minutes. After being divided into portions, these were rounded into balls, left to rest, then shaped and placed in a proofing chamber for one hour. The dough balls were then baked at 250°C for 25 minutes in a rotary oven equipped with a steam injection system (Balla et al., 1999; Hébrard et al., 2001).

3.1.2. Separate hydration bread processing

Hydration of Corn Flour: Using an analytical balance, the quantity of corn flour to be incorporated into the wheat flour is measured for each percentage (10%, 12.5%, 15%). Water is heated in an electric water heater, and the temperature is measured with a thermometer by immersing the thermometer in the water. The temperature should not exceed 80°C. The dough is kneaded by hand with a whisk for a few minutes. The surface of the dough is covered with plastic wrap to prevent a hardened layer from forming. The dough is allowed to cool to room temperature. After the hydrated corn dough has cooled, it is added to the other ingredients in the mixer, and the mixer is started. The other bread-making steps are then followed, like those used in standard hydration bread-making (Balla et al., 1999).

3.2. Physicochemical Analysis

3.2.1. Extraction rate

Determining the extraction rate on a small scale allows us to know the yield on a large scale and thus estimate the quantity of flour that can be produced. To do this, 2 kg of pre-cleaned wheat were soaked for 24 hours. The wheat was then ground and the flour and bran were collected and weighed. The value was then obtained using the formula F1:

(F1)

$$\text{Extraction rate (\%)} = \frac{\text{Wheat weight}}{flour\ \text{weight}}$$

3.2.2. Moisture Content

The ash content and moisture content can be determined using the official method. For this, the baskets for moisture content and the crucibles for ash content are sterilized in an oven at 130°C for 2 hours, then left to cool in a desiccator for approximately 30 minutes. The baskets and crucibles are weighed empty, and this weight is recorded (m1). Next, 5g of flour is added, and this weight is recorded (m2). The baskets are placed in the moisture-content oven at 130°C for two hours, and the crucibles in the ash-content oven at 900°C for four hours. At the end of the test, the baskets and crucibles are removed and placed in the desiccator for approximately 30 minutes to cool. The new mass is recorded (m3). The moisture content of flour is calculated using the following formula F2. Then ash content was evaluated (F3).

The ash content was evaluated using formula F3.

3.3. Analysis of Technological Properties

Falling Time (Hagberg Test)

$$\text{Ash content (\%)} = (m3 - m2) \times \frac{100}{m1} \times \frac{100}{(100-\text{Mc})}(\text{Mc}) \qquad \text{(F3)}$$

The falling time was measured using the Amylab FN from Chopin Technology, France. This test determines the alpha-amylase enzyme activity of wheat and flour according to ISO 5725/1986 using the Hagberg method (1951). The HTT value must be between 248 and 394 seconds. The Hagberg method measures the time it takes for a stirrer to pass through a sample of starch, formed by the gelatinization of a liquid flour suspension under its own weight.

$$\text{Mc (\%)} = \frac{m1+m2-m3\ \mathbf{100}}{\boldsymbol{m}} \qquad \text{(F2)}$$

The shorter, the time required for the stirrer to fall, the higher the alpha-amylase level. To measure the TCH, the procedure is as follows: using a wash bottle, 25 ml of distilled water is taken from a graduated measuring cup and measured using an analytical balance. A quantity of flour, determined by its moisture content, is also measured on an analytical balance and added to the test tube through a funnel. The mixture is then thoroughly shaken, and the tube is placed in the instrument (ISO 5529 : 2007).

3.4. Damaged starch content

This is determined using the SDmatic device (Chopin Technology, France) in accordance with standard 5529:2007 and must be between 19 and 24. The device measures the capacity and rate of iodine absorption by a flour solution in an acidic medium; indeed, iodine has the particularity of binding rapidly to damaged starch granules. The result is displayed as a percentage of iodine absorbed and in units corresponding to the international standard UCD. The procedure involves measuring 120 ml of distilled water using a wash bottle and weighing it with an analytical balance after switching on the instrument. Then, 1.5 g of citric acid and 3 g of potassium iodate are measured using the analytical balance and added to the water, along with a drop of sodium thiosulfate. The bottle is then closed and shaken to homogenise the solution. The solution is then poured into a reaction beaker placed under the instrument. Next, 1 g of flour (plus or minus 0.1 g) is weighed onto a flour spoon, which is inserted directly into the metal slot under the screen. Using a test pen, the "test" button is pressed, and the flour's weight and protein content are recorded. The "test" button is pressed a second time, and the instrument will start. The value is displayed after a few minutes. After the test, a cleaning procedure using distilled water is mandatory for the device.

3.5. Hydration Rate

This is the amount of water needed to hydrate 100 kg of flour. The average hydration rate for a bastard dough is 60%, but it is common to hydrate around 64% to 66% to obtain a soft dough. Water is one of the three essential elements for making dough. Within the dough, water is present as bound water (0.4-0.5%). Bound water contributes, like other molecules, to the supramolecular organisation of the dough; free water is responsible for fluidity. The hydration rate is determined using infrared spectroscopy. And it can be determined by the following relationship:

$$CH = ((GH - GS) / GH) \times 100,$$

where:

CH%: hydration capacity,

GH: wet gluten,

GS: dry gluten.

The amount of water added must be adjusted to the characteristics of the flours (protein content, degree of starch damage), as a water deficit or excess will alter the pasta's properties.

3.6. Rheological Properties of the Pasta

The rheological properties were determined using the AlvéoPC (Chopin, France), according to ISO 27971 (2009). The method is based on the swelling of a pasta sample under air pressure. The evolution of the pressure within the bubble is measured and plotted as a curve called an alveogram. The AlvéoPC consists of two inseparable parts: For preparing dough samples and the Alvéograph itself, where the dough disc is deformed into a bubble until it ruptures. Furthermore, the AlvéoPC comes with all the necessary accessories for dough handling:

- **P:** maximum pressure reached during the test, expressed in mm; it reflects the dough's tenacity and its resistance to deformation. It must be between 61 and 85.
- **L:** dough extensibility index (the property of a dough to deform easily), expressed in mm, which indicates the capacity for porosity (air pockets) in a loaf. The desired value should be between 68 and 108.
- **W:** incorrectly called the strength index, it is actually a measure of energy. It is expressed in joules and is the energy required to inflate a dough bubble until it bursts. It is proportional to the area under the alveogram curve (Figure 4). The higher its value, the higher the protein network of a flour. It should be between 174 and 234.
- **G:** swelling index given by the square root of the volume of air (ml) injected until the bubble bursts; it indicates the extensibility of the dough. It should be between 18.3 and 23.3.
- **P/L**: The P/L ratio of the pressure P at the abscissa L before rupture indicates the overall equilibrium of the alveogram. It should be between 0.8 and 1.8. A high ratio indicates a tenacious flour (the dough's ability to resist deformation).
- **IE:** The elasticity index is the ratio IE = P200 / Pmax (where P200 and Pmax are respectively equal to the pressure measured for a bubble volume of 200 mL, i.e., L = 40 mm, and the maximum pressure). This index reflects the elasticity of the dough; the higher the IE, the greater the dough's elasticity.

3.7. Sensory Analysis

3.7.1. Selection of the Sample Tasting Panel

In my trials, the tasters consisted of bakery managers (sales manager), bakers and bakery employers, professors and students, and bakery customers.

3.7.2. Sensory characteristics

After baking and storing the bread samples, they were presented to consumer for sensory analysis using a code. This does not allow consumers to know the bread content in composite flour and the hydration level for each sample. Some whole loaves were presented to allow for observing the bread's external appearance (size, colour, crust), while other loaves were cut into small slices with a bread slicer to facilitate tasting and allow for the presentation of the texture, description of the air pockets, and crumb colour. A tasting sheet was provided to the taster for each sample, containing sensory characteristics (color, aroma, flavor, texture, overall acceptability), to allow the tasters to record their assessments.

3.7.3. Technological characteristics of bread

After storing the loaves on open wooden shelves, we begin our test. Cooling the loaves is essential to prevent warping. We use five baguettes for each criterion to be measured. *Bread circumference*, *length*, *height, and weight* were measured.

3.8. Statistical data analysis

The collected data were entered and organised using Excel 2016, which was also used to calculate means and standard deviations. For data analysis and comparison, MINITAB 19 (2020) was used.

4. Results

4.1. Physicochemical Properties of the Blended Flours

Table 2 presents the baking characteristics of French wheat flour, Massongo corn flour, and FBC6. Analysis of this table shows that wheat flour is richer in protein (11.25%) than the two corn flours used in the study. Furthermore, the protein content of FBC6 corn (9.05%) is significantly different from that of Massongo corn flour, which contains 8% protein. The moisture content, wet gluten content, and zeleny index are higher for wheat flour than for the other flours. However, the corn samples have higher water absorption and ash content. No significant difference was noted in the whiteness of the flours.

Table 2 Characteristics of flours used during all experiments

Samples	Proteins (% MS)	Moisture (% MS)	Ash (% MS)	Water absorption (%)	Gluten (%)	Zeleny index (ml)	Whiteness
Wheat	11.25±0.07^{a}	13.70±0.28^{a}	0.61±0.01^{a}	58.80±1.13^{a}	25.50±0.07^{a}	48.50±0.70a	55.50±0.70^{a}
Maize FBC6	9.05±0.21^{b}	10.80±0.14^{b}	1.92±0.06^{b}	74.50±1.13^{b}	10.25±0.6^{b}	30.50±2.12b	43.50±0.70^{a}
Maize Massongo	8.0±0.14^{c}	10.25±0.07^{b}	1.80±0.02^{b}	74.30±0.42^{b}	8.10±1.41^{b}	24.50±3.54b	52.50±9.19^{a}

Legend: Means ± SD, represent the average values obtained after two replicates. The standard deviation was calculated from these replicates. The values a, b, and c accompanying the means are obtained by comparing the means pairwise using Fisher's exact test. Means with no shared letter are considered significantly different.

4.2. Rheological Properties of Composite Doughs

Table 3 shows the rheological characteristics of composite doughs.

Table 3 Rheological Characteristics of Composite Doughs

Rhéological parameters	Wheat (%)	Corn FBC6 (%)			Corn Massongo (%)		
	100	10.00	12.5	15	10	12.5	15
P	114	122	128	124	114	132	116
L	63	44	41	37	46	33	35
G	17.6	14.7	14.2	13.5	15.1	12.8	13.1
W	280	222	218	190	213	193	173
P/L	1.81	2.77	3.12	3.35	2.48	4	3.31
I.E. (%)	5.6	51.6	48.8	0	51.8	0	0

P: Dough tenacity index (mm H2O), standard (61-85); L: Dough extensibility index (mm), standard (68-108); G: Swelling index, given by the square root of the area required to burst a dough bubble, standard (18.3-23.3); W: Baking strength index, energy required to inflate a dough bubble until it bursts (in J), (174-234); P/L: Dough tenacity-to-extensibility ratio, standard (0.8-1.8); IE: Dough elasticity index (%), standard (45-55)

The alveograph test of the composite flours showed that substituting (10%, 12.5%, 15%) wheat flour with Massongo and FBC6 maize flours led to a decrease in extensibility, swelling index, baking strength, and dough elasticity index, and an increase in dough tenacity and the tenacity-to-extensibility ratio.

4.3. Baking Characteristics of Composite Doughs

The Zeleny index, which measures the percentage of damaged starch, shows no significant variation except for the 15% Massongo flour, whose decreased (Balla et al., 1999).

4.3.1. Sensory Properties of Composite Breads

Table 4 presents the sensory properties of the composite breads. An analysis of this table shows that the tasters observed no significant difference between the bread samples. Both corn varieties produced breads of similar quality to the control bread (100% wheat). Despite substitution rates of 10%, 12.5%, and 15%, and variations in hydration techniques, the products obtained at the end of the experiments exhibited good colour, flavour, crumb texture, and aroma. Based on the assessment of these sensory properties, a score of 9 out of 10 was awarded as the overall acceptability score for the breads produced.

Table 4 Sensory characteristics of composite breads

Experiments	Colour	Flavour	Texture	Aroma	Acceptability
E0	9.2 ± 1.03[a]	8.4 ± 1.58[a]	8.6 ± 0.97[a]	8 ± 0.94[a]	9.8 ± 0.63[ab]
E1	9.6 ± 0.84[a]	7.6 ± 1.84[a]	7.78 ± 1.86[a]	8.8 ± 1.03[a]	9.4 ± 1.35[ab]
E2	8.4 ± 1.57[a]	8.2 ± 1.66[a]	8.2 ± 1.07[a]	8.4 ± 0.8[a]	8.4 ± 1.74[ab]
E3	9.2 ± 1.03[a]	9.4 ± 0.96[a]	8.8 ± 1.03[a]	8.6 ± 0.96[a]	9.8 ± 0.63[ab]
E4	9.6 ± 0.84[a]	9.2 ± 1.03[a]	8.8 ± 1.03[a]	8.6 ± 1.34[a]	10 ± 0[a]
E5	9.4 ± 1.34[a]	9.2 ± 1.39[a]	9 ± 1.41[a]	8.8 ± 1.03[a]	9.2 ± 1.68[ab]
E6	9 ± 1.69[a]	8.8 ± 1.68[a]	8.4 ± 1.26[a]	8 ± 1.33[a]	9 ± 1.69[ab]
E7	9.4 ± 1.34[a]	9.4 ± 1.34[a]	9.2 ± 1.03[a]	8.8 ± 1.39[a]	9.4 ± 1.34[ab]
E8	8 ± 1.88[a]	7.8 ± 1.75[a]	8.2 ± 1.47[a]	8.6 ± 0.96[a]	8 ± 1.63[b]
E9	8.8 ± 1.39[a]	8.2 ± 1.47[a]	8.8 ± 1.03[a]	8.4 ± 0.84[a]	9.4 ± 1.34[ab]
E10	9 ± 1.41[a]	8.8 ± 1.03[a]	8.4 ± 0.84[a]	8.4 ± 1.26[a]	9.6 ± 0.84[ab]
E11	8 ± 1.33[a]	8.4 ± 1.83[a]	7.8 ± 1.47[a]	8.4 ± 1.26[a]	9.2 ± 1.03[ab]
E12	8 ± 1.63[a]	8.2 ± 1.75[a]	8.4 ± 0.84[a]	8.2 ± 1.13[a]	9 ± 1.05[ab]

E0: 100% wheat (Control); E1: 90% wheat + 10% Massongo corn, common hydration; E2: 85% wheat + 15% but Massongo, common hydration; E3: 90% wheat + 10% corn FBC6, common hydration; E4: 85% wheat + 15% but FBC6; common hydration, E5: 90% wheat + 10% Massongo corn, separate hydration; E6: 85% wheat + 15% but Massongo, separate hydration; E7: 90% wheat + 10% corn FBC6, separate hydration; E8: 85% wheat + 15% but FBC6, separate hydration; E9: 87.5% wheat + 12.5% but Massongo, common hydration; E10: 87.5% wheat + 12.5% but FBC6, common hydration; E11: 87.5% wheat + 12.5% but Massongo, separate hydration; E12: 87.5% wheat + 12.5% but FBC6, separate hydration

4.4. Effect of Hydration Type on Composite Breads

Experiments showed that separate hydration resulted in a crumb with more air pockets compared to the crumb of breads hydrated using the same method for the FBC6 maize variety and for incorporation rates of 10% and 15%. The same observation was made for the Massongo variety in experiments. **Figure 2** shows cross-sections of composite breads from experiments E9 to E12. Observations from experiments E10 and E12 show that separate hydration resulted in more air pockets in the crumb of the FBC6 variety of bread compared to combined hydration of the same variety. Air pockets were also observed in the Massongo variety. However, the difference in air pockets between separate and combined hydration was less pronounced with the Massongo variety.

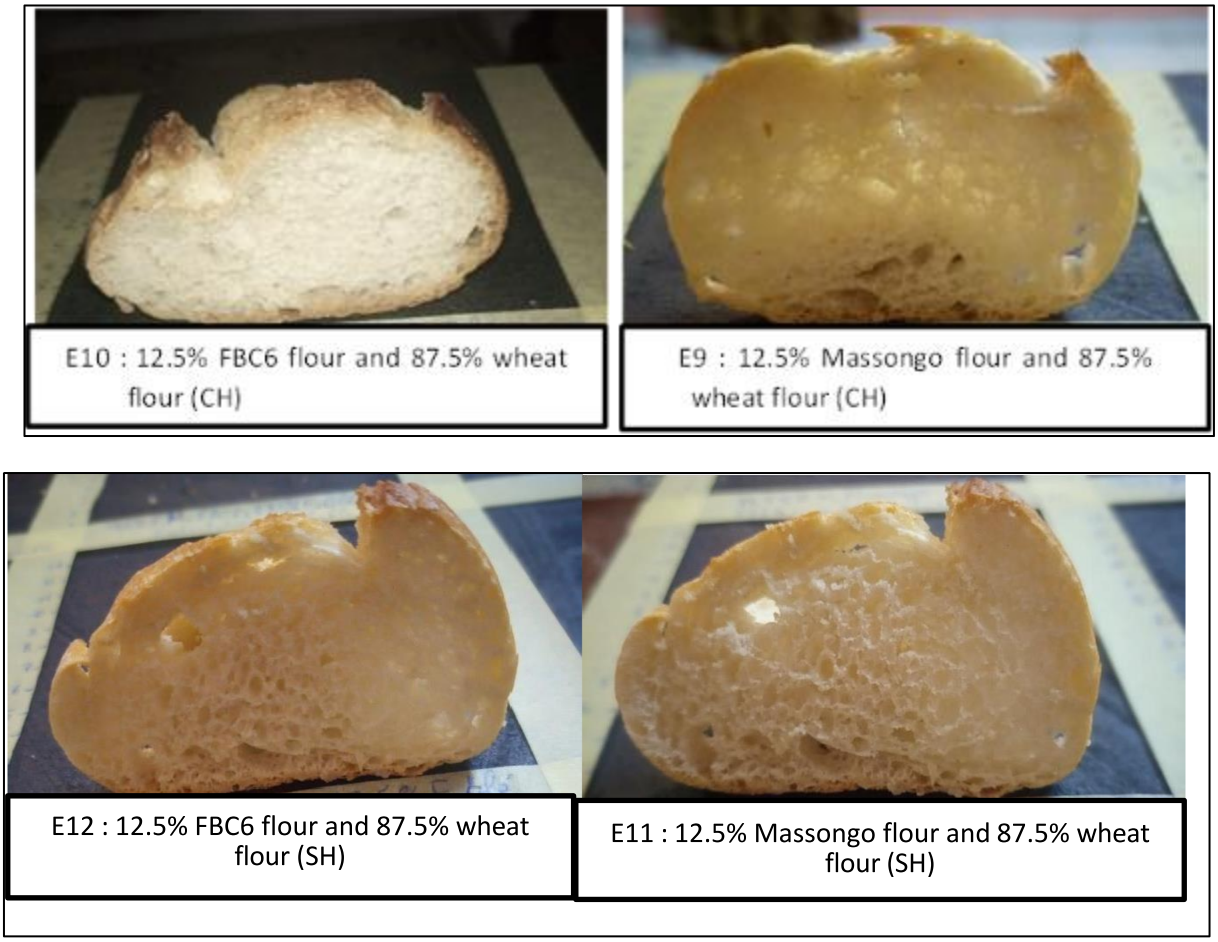

Figure 2 Composite breads made from two different varieties of corn that have undergone the same hydration

5. Discussion

Analyses of the physicochemical and baking characteristics of composite flours (wheat/maize) showed that substituting wheat flour with Massongo and FBC6 maize flour (10%, 12.5%, 15%) resulted in a progressive decrease in protein content followed by a slight decrease in moisture content, while the ash content and absorption rate increased. This variation is thought to be associated with an increase in the level of damaged starch. Indeed, damaged starch is highly hygroscopic and absorbs between two and four times its weight in water (Feuillet, 2000). However, this water will be released again to create a sticky dough, resulting in a denser loaf with a high weight and small volume. This explains the high weight of the composite (wheat/corn) breads, especially with separate hydration levels (FBC6, 12.5%, and 15%), and their smaller circumference compared to 100% wheat bread.

On the other hand, high hydration improves the bread's shelf life by delaying rancidity and makes the crumb soft and finely aerated (Feuillet, 2000). The Zeleny index, which measures the proteins' ability to swell in a lactic environment, was low. This value is influenced by the protein content, which is low in corn flour. These low values may be associated with the absence of gluten in corn and the flour's particle size (Feuillet, 2000). Substituting 10%, 12.5%, and 15% Massongo and FBC6 maize flour for wheat flour increased falling time, resulting in a slight decrease in amylase activity (Sambe et al., 2017). Indeed, during periods of high humidity, an amylase (alpha-amylase) develops in the flour, contributing to the degradation of starch into sugars. This starch degradation and the breaking of chains cause liquefaction. The consequences for the baker include a risk of stringy dough, flat loaves, and a sticky, heavily colored crumb (Sambe et al., 2017). Significant problems arise with falling times below 120-130 seconds (formation of sticky dough, excessive browning of the crust). This means that the flours used show no indication of germination (Sambe et al., 2017).

There is no established relationship between falling number and grain protein content, the Zeleny index is unaffected or only slightly affected, and the alveogram parameters are not affected in all cases. The results of the alveogram analyses also showed that substituting 10%, 12.5%, and 15% of wheat flour with sorghum flour led to decreased flour strength and extensibility and increased the balance between tenacity and extensibility (Khating et al., 2014). This is a consequence of low hydration in the composite flours, which resulted in poor dough-raising and extensibility properties (Sambe et al., 2017).

Separate hydration increased the crumb structure, bread weight, and overall length because starch gelatinization increased the viscosity of the medium and further enhanced starch gelation (Feuillet, 2000). The resulting dough is more extensible and rises better during fermentation. Bread produced using this hydration method is larger and contains more air pockets. (Balla et al., 1999).

6. Conclusion

In conclusion, breadmaking trials showed that incorporating FBC6 or Massongo maize flour at rates of 10%, 12.5%, or 15% into wheat flour produced breads acceptable to consumers without significant degradation of sensory characteristics. Separate hydration improves the loaves' weight and texture and enhances their taste by eliminating the aftertaste of maize flour. The potential for valorising maize flour is interesting for several reasons. On the one hand, it aligns with policies promoting local cereals in Burkina Faso to reduce soft wheat imports. On the other hand, from a nutritional standpoint, the quality of white bread is improved thanks to the addition of vitamins A and E and minerals. The taste, highly appreciated by the tasters, was due to the corn's distinctive flavour. Using composite corn flour enabled the production of the best bread with a 15% incorporation rate into wheat flour, regardless of the hydration method.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared that they have no conflicts of interest.

Disclaimer (Artificial intelligence)

The authors hereby declare that they did not use any generative AI technologies, such as Large Language Models (e.g., ChatGPT, Copilot) or text-to-image generators, for writing or editing this manuscript.

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