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Effect of Different Non-Wheat Bread Making Methods on the Quality of Maize Bread

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Abstract: There is a need in Africa to produce bread from local crops. Maize was used in this work because it is the most important crop produced in Africa. Successes have been reported in the use of sourdough fermentation and pre-gelatinization of gluten-free flour in improving wheat-free breads. Therefore, the effects of 3 non-wheat bread recipes on the quality of bread made from maize were investigated. The 1st was a traditional sourdough method used in Lesotho for making steamed bread. This involved addition of spontaneously fermenting sorghum malt sourdough (equivalent to 15% of the total maize flour) and pre-gelatinization of the starch in the maize flour with boiling water. The 2nd was a food and agriculture organization method which involved pre-gelatinization of the starch in 10% of the maize flour by cooking. The 3rd method was a modern sourdough method which involved spontaneously fermenting 75% of the maize flour. The modern sourdough method produced maize bread with a more open crumb structure and a significant increase in loaf volume compared to the other methods. This is probably primarily due to the high percentage of maize flour fermented leading to a more substantial improvement in bread dough properties which in turn significantly improved maize bread quality.

Key words: Sourdough fermentation, pre-gelatinization, gluten-free flour, maize bread quality, crops

INTRODUCTION

Maize is a potentially suitable alternative to wheat for use in breadmaking in Africa. This is because it is by far the most important crop produced in Africa (about 69.6 million tons) (FAOSTAT, 2012). Bread produced from maize and other wheat-free cereals are not common. The few available in the market are undesirable to consumers due to their low loaf volume, hard and dense crumb structures (Arendt *et al*., 2002). Wheat is the only cereal that its protein (gluten) has the proper functionality to produce high quality breads (Mejia *et al*., 2012). This is attributed to its unique property of forming strong viscoelastic dough when hydrated (Goodall *et al*., 2012). The unique property of gluten is crucial for the water holding capacity of the dough and the gas retention during fermentation (Arendt *et al*., 2008). Gas retention properties in turn determine loaf volume and crumb structure of the resulting bread (Goesaert *et al*., 2005). The challenge however is to produce bread from maize that will imitate closely the desirable qualities (high loaf volume and open crumb structure) that make wheat bread acceptable by consumers.

Few investigations on maize bread have included additives such as egg and maize starch (Sanni *et al*., 1997) improvers containing enzymes such as S500 Acti-plus (Puratos) ascorbic acid (Edema *et al*., 2013) and hydrocolloids such as hydroxyl propyl methyl cellulose (Hera *et al*., 2013) to aid the final quality of maize bread. The use of additives increases the final cost of wheat-free breads (Moroni *et al*., 2009) a critical issue where consumers are food insecure. Sourdough fermentation seems to be a promising alternative since it is a natural process and does not include additional ingredients (Moroni *et al*., 2009). Sourdough is a mixture of flour and water that is fermented by naturally occurring Lactic Acid Bacteria (LAB) and yeasts (Hammes and Ganzle, 1998). Success has been reported in the use of sourdough fermentation on the improvement of the quality of wheat bread and some wheat-free breads (Arendt *et al*., 2007; Edema *et al*., 2013). Also, pre gelatinization of starch in wheat-free flour could be a suitable alternative to hydrocolloids to aid carbon dioxide retention in wheat-free bread making. According to Onyango *et al*. (2009) pre-gelatinized starch, aids in the creation of a viscoelastic batter that can trap and retain carbon dioxide produced during proofing of wheat-free bread dough. This study

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investigated 3 different wheat-free sourdough methods that have been used to produce wheat-free breads from other cereals. This work was carried out to determine which of the 3 wheat-free methods will give maize bread with the most desirable qualities such as high loaf volume and open crumb structure.

MATERIALS AND METHODS

Refined white maize meal (Impala Special Maize Meal, Premier Foods, Isando, South Africa) with a protein content 8.6 g/100 g (db) and a fat content 2.7 g/100 g (db) was milled into a flour using a laboratory hammer grinder (Mikro-Feinmuhle-Culatti MFC grinder, Janke and Kunkel, Staufen, Germany) fitted with a 0.5 mm opening screen. Industrial sorghum malt with a diastatic power of 33.4 SDU g^{-1} was obtained from United National Breweries, Mandini, South Africa.

Production of sourdoughs for maize bread: The sourdoughs used in the 3 wheat-free methods were fermented at 22°C until the pH was below 4 (approx. 72 h). Sorghum malt was used to prepare the sourdough used for maize bread produced using a traditional sourdough method practised in Lesotho. Sorghum malt was mixed with water in a ratio of 1:3 (w v^{-1}). Final pH was 3.7. Maize sourdough used for maize bread produced according to a Food and Agriculture Organization (FAO) method (Satin, 1988) was prepared as above. Final pH was 3.7. Maize sourdough used for maize bread produced using a modern sourdough method was prepared according to Edema *et al*. (2013). Final pH was 3.8.

Production of maize breads: Maize bread was produced using 3 different wheat-free methods. Each method involved addition of sourdough and pre gelatinization. The 1st wheat-free method was a traditional sourdough method practiced in Lesotho according to Nkhabutlane *et al*. (2014) with some modifications (Fig. 1). Baking ingredients (salt, sugar, maize flour) were mixed with boiling water and allowed to cool at ambient temperature (22°C). The maize sourdough and/or pre-gelatinized maize flour and yeast were added. All the treatments were incubated at 25°C for 12 h. The doughs were then either baked or steamed. Baking was for 15-20 min at 210°C and steaming was for 2 h over a pan on an electric hotplate.

The 2nd wheat-free method was a FAO method (Satin, 1988) with some modifications (Fig. 2). This method involved pre-gelatinization of 10% of the maize flour with the total amount of water by cooking for 4 min and then replacing the water that had evaporated. The pre-gelatinized maize flour was allowed to cool before the maize sourdough (equivalent to 10% of total maize flour) and the remaining ingredients (salt, sugar, yeast and remaining maize flour) were added. Mixing was done manually for 10 min. The dough was scooped into aluminum cans (72 mm diam) to half full (200 g dough). Proofing was for 1 h at 22°C. The breads were baked or steamed as above.

The third wheat-free method was performed according to Edema *et al*. (2013) with some modifications (Fig 3). Baking ingredients (sugar, salt, soft margarine and instant dried yeast) were added to maize sourdough (equivalent to 75% of total maize flour). First proofing was at 30°C for 20 min.

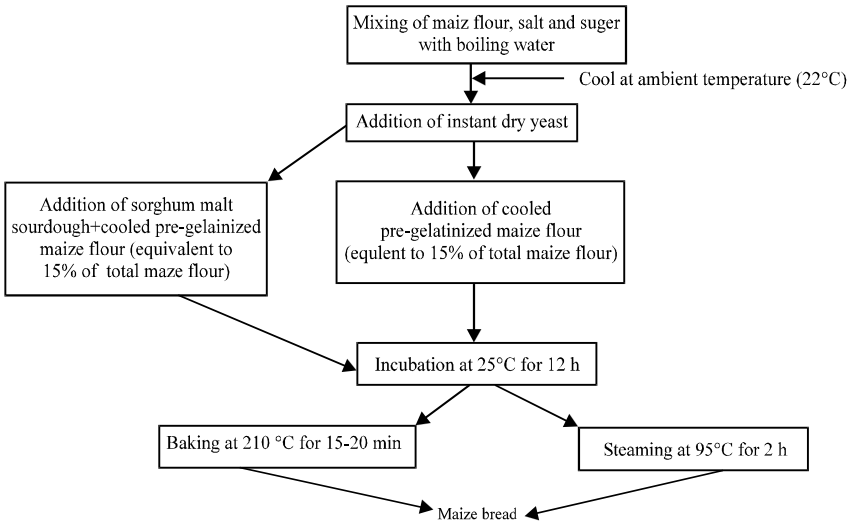

Fig. 1: Procedure for making maize bread using the traditional sourdough method practiced in lesotho according to Nkhabutlane *et al*. (2014)

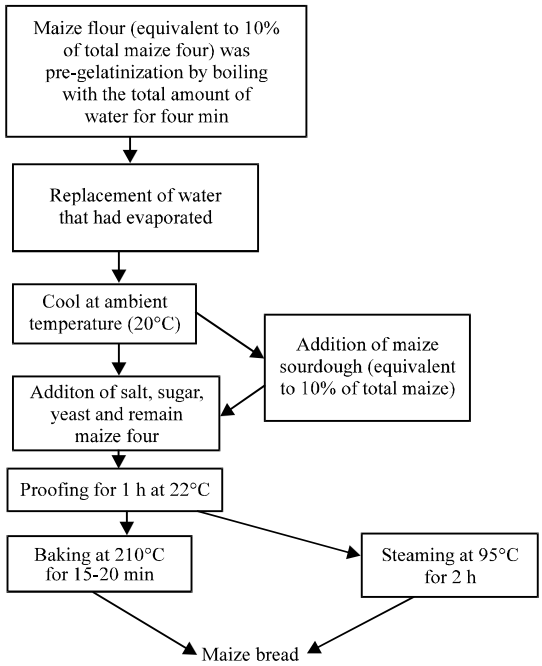

Fig. 2: Procedure for making maize bread using the FAO (Satin 1988)

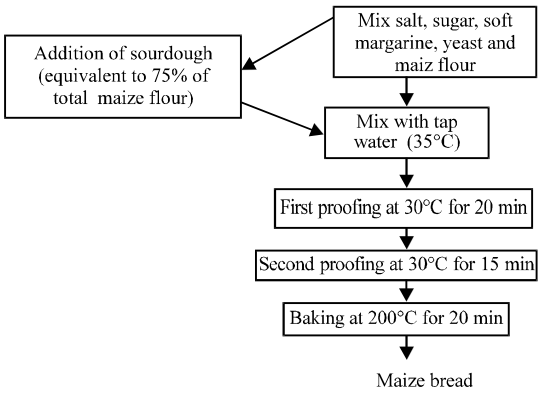

Fig. 3: Procedure for making maize bread using the modern sourdough method according to Edema *et al.* (2013)

The maize bread doug was remixed and scooped into silicone pans (70 mm top diam and 58 mm bottom diam) to half full (47 g dough). The 2nd proof was at 30°C for 15 min. Baking was at 200° C for 20 min.

Analysis: Bread height was measured using a meter rule. Loaf volume and specific volume were calculated. Crumb structure was photographed with a digital camera.

Statistical analyses: All experiments were performed at least twice. Results were analysed using one-way Analysis of Variance (ANOVA). Fisher's Least Significant Difference Test (LSD) was used to determine significant differences between the treatments at $p \leq 0.05$.

RESULTS AND DISCUSSION

Maize bread quality: Maize breads produced by the traditional sourdough method, FAO method and modern sourdough method were all compared with their controls (maize bread without sourdough and pre-gelatinization). Sorghum malt was used to prepare the sourdough used for maize bread produced using a traditional sourdough method. Malted grain when milled produces flour containing starch that is more susceptible to enzymatic hydrolysis than flours from grains that have not been malted (Moroni *et al*., 2009). This in turn is believed to improve the acidification ability of the sourdough. Analyses were not done on the breads made from the traditional sourdough method. This was because steamed breads made using this method were all very soft and looked like a lump of gelatinized starch (Fig. 4). Also baked breads using this same method had cracks and crumbled when sliced. However, bread made with the combination of sourdough and pre-gelatinization showed very slight expansion sideways. Using the FAO method, steamed maize breads generally had a higher loaf volume compared to the baked maize breads (Table 1 and Fig. 5). Baked or steamed maize bread made without pre-gelatinization or sourdough addition had higher loaf volume compared to the breads with sourdough or pre-gelatinization. Loaf volume of baked or steamed maize bread made by addition of maize sourdough and pre-gelatinization of part of the maize flour was not significantly different from the loaf volume of baked or steamed maize bread made by pre-gelatinization of part of the maize meal. Concerning the modern sourdough method, bread with sourdough had a significantly ($p = 0.05$) higher loaf volume (21% increase) and open crumb structure compared to the bread with no sourdough added (Table 2 and Fig. 6). Comparing each wheat-free method with its control, it was only the modern sourdough method that produced bread that had a significantly better quality than its control.

The traditional sourdough method and the FAO method did not improve maize bread loaf volume and crumb structure compared to the modern sourdough method, probably due to pre-gelatinization and also the small proportion of sourdough added (10 or 15% of the total maize flour) compared to the higher proportion of sourdough (75% of the total maize flour) used in the modern sourdough method. Pre-gelatinization probably created an unfavourable environment for gas cell expansion by the yeast provided by the stickiness (high viscosity) of the pre-gelatinized dough. According to

Fig. 4: Effects of sourdough fermentation and pre-gelatinization of part of the maize flour on the loaf volume of baked or steamed maize bread produced using a traditional sourdough method practiced in Lesotho according to Nkhabutlane *et al.* (2014)

Fig. 5: Effects of sourdough fermentation and/or pre-gelatinization of part of the maize flour on the loaf volume and crumb structure of maize bread produced according to a FAO method (Satin, 1988)

Table 1: Effects of sourdough fermentation and pre-gelatinization and baking or steaming on the loaf volume and loaf specific volume of maize bread produced according to a FAO method (Satin, 1988)

Treatments	Weight after baking/steaming (g)	Height after baking/ steaming (mm)	Loaf volume after baking/steaming (cm^3)	Loaf specific volume after baking/steaming (cm^3 g^{-1})
No sourdough or pre-gelatinization				
Loaves baked	158.4^{a}±0.7	59.5^{c}±0.1	242.4^{e}±2.9	1.53^{d}±0.03
Loaves steamed	181.1^{b}±2.8	64.5^{d}±0.2	262.7^{d}±8.6	1.45^{e}±0.03
Part of flour pre-gelatinized				
Loaves baked	154.0^{a}±1.6	51.5^{a}±0.2	209.8^{a}±8.6	1.37^{b}±0.04
Loaves steamed	181.2^{b}±2.7	59.0^{c}±0.3	240.4^{c}±11.5	1.33^{ab}±0.04
Part of flour pre-gelatinized+sourdough				
Loaves baked	153.2^{a}±0.1	52.5^{ab}±0.1	213.9^{ab}±2.9	1.40^{bc}±0.02
Loaves steamed	178.3^{b}±3.6	56.0^{bc}±0.1	228.1^{bc}±5.8	1.24^{a}±0.01

[1]Means and standard deviation n = 2, values followed by different letters are significantly different at $p \leq 0.05$

Table 2: Effect of sourdough fermentation on the loaf volume and specific loaf volume of maize bread produced using the modern sourdough method according to Edema *et al.* (2013)

Treatments	Weight after baking/steaming (g)	Height after baking/ steaming (mm)	Loaf volume after baking/steaming (cm^3)	Loaf specific volume after baking/steaming (cm^3 g^{-1})
Maize bread with no sourdough added	46.5^{a}±0.5[1]	24.7^{a}±0.2	79.5^{a}±6.7	1.7^{a}±0.1
Maize bread with sourdoughadded (75% of total maize flour)	46.0^{a}±0.3	30.0^{b}±0.1	95.8^{b}±2.3	2.1^{b}±0.1

[1]Means and standard deviation n = 2, values in the same column followed by different letters are significantly different at $p \leq 0.05$

Fig. 6: Effect of sourdough fermentation on the loaf volume and crumb structure of maize bread produced using the modern sourdough method according to Edema *et al.* (2013)

Onyango *et al.* (2010) gelatinised starch forms a stiff, inelastic dough that does not favour the expansion of gas cells in the dough. However in apparent contrast, the same authors, Onyango *et al.* (2009) stated that pre-gelatinized starch, aids in the creation of a viscoelastic batter that can trap and retain carbon dioxide produced during proofing of wheat-free bread dough. In line with this, the pre-gelatinisation process in this work probably made the maize flour more of a stiff dough than a batter, thereby preventing the expansion of gas cells. Moroni *et al.* (2011) who worked on the impact of sourdough on the biochemical, rheological and texture of buckwheat flour, batter and bread suggested that the strengthening of the starch gel observed upon acidification of the batter favoured the rupture of gas cells and impaired the textural characteristics of buckwheat bread. In line with this, since the purpose of pre-gelatinization was to provide a soft starch gel-like matrix to trap the CO_2 produced during fermentation, probably the dough viscosity achieved was just high enough to do more damage than good by favouring the rupture of the gas cells resulting in a negative effect on loaf volume and crumb structure of the bread. Also, since the pre-gelatinized dough had to be cooled before other ingredients were added, it is possible that starch retrogradation had occurred, defeating the main aim of pre-gelatinization which was to provide a gel matrix to trap the carbon dioxide produced during fermentation. When gelatinized starch cools down, amylose retrogrades, resulting in an increase in viscosity (Zilic *et al.*, 2010). On cooling, retrogradation occurs, the starch granules in the gelatinized paste associate, leading to the formation of a more ordered structure (Hoover, 1995). Due to this change, the starch granules will not be able to effectively absorb water or trap CO_2 produced in the dough. Also, the small proportion of maize sourdough used (10-15% of the total maize flour) was probably not sufficient to modify the dough properties satisfactorily enough to impact positively on the quality. Clarke suggested that improved volume of sourdough breads is dependent on the nature and intensity of the acidification process.

CONCLUSION

The modern sourdough method produced maize bread with an open crumb structure and a significant increase in loaf volume compared to maize breads produced by the traditional sourdough method practised in lesotho or the food and agriculture organisation method. This is probably due to the absence of pre-gelatinization and the higher proportion of sourdough

used. The high proportion of sourdough probably had a greater impact on bread dough properties which in turn significantly improved maize bread quality.

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