Available online at http://www.ifgdg.org

Int. J. Biol. Chem. Sci. 17(2): 392-399, February 2023

ISSN 1997-342X (Online), ISSN 1991-8631 (Print)

International Journal of Biological and Chemical Sciences

Original Paper http://ajol.info/index.php/ijbcs http://indexmedicus.afro.who.int

Parboiling effect on the rheological characteristics of Sahel 108, 328 and 329 rice varieties grown in Senegal River Valley

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Received: 29-11-2022 Accepted: 26-02-2023 Published: 28-02-2023

ABSTRACT

In order to help State to ensure food security of the populations, technologies for substituting wheat flour with flour from local food resources such as rice are used in bread making. The aim of this study was to determine the rheological behavior of pastes obtained by incorporating parboiled and non-parboiled rice flour in the bread-making process. The results obtained revealed that parboiling improves the tenacity of the mixed wheat (85%) and rice (15%) paste. Indeed, the parboiled Sahel 328 and Sahel 329 rice varieties would give a tougher mixed paste (P/L = 1.24±0.030; 1.28±0.020 respectively) and closer to that of 100% wheat (P/L= 1.13±0.050). The incorporation of parboiled Sahel 329 rice flour resulted in a paste with a swelling index closest to that of the control (WS). The results also indicated that all the parboiled rice studied composite flours had satisfactory baking strength. Of all studied varieties, Sahel 329 when parboiled, gave the closest rheological properties to the control (100% wheat). In addition, we can consider from this study, the alternative use of rice in bread-making supports the idea that rice would be a better vehicle than the soft wheat flour used for iron and folic acid fortification in Senegal.

Keywords: Senegal River Valley, Parboiled rice, bread making, rheological characteristics.

INTRODUCTION

In most people's diets, consumption of flour products in general, and bread in particular, occupies an important place. As a result, non-wheat producing countries are becoming increasingly dependent on imports, particularly during international crisis. Senegal, like many African countries, is not spared from this situation because of its heavy dependence on the international market. From a composition point of view, wheat flour is constituted by approximately 90% of starch and 10% of gluten (Dobraszczyk and Morgenstern, 2003). Thus, starch is the most

DOI : https://dx.doi.org/10.4314/ijbcs.v17i2.8

important part of wheat flour. Although, the pastes quality of flours used in bread-making depends on the wheat gluten, the quality of the starch plays an essential role.

Indeed, when perfectly dispersed, starch gives fresh bread its characteristic soft texture. Also, for its two main forms, amylose, which is unbranched, and amylopectin, which is branched, the starch content is fundamental for cooked products preservation (Anonyme, 2019). Most wheats have a very similar amylose-amylopectin ratio (26-28% amylose for 72-74% amylopectin in soft wheat) making this aspect often forgotten in the wheat-bread chain (Anonyme, 2019). This point is, however, a focus of interest and some actors in the sector are proposing flours that guarantee less natural ageing of bread. These flours are simply derived from particular varieties that are richer in amylopectin and therefore have a lower staling capacity.

Rice naturally has very different levels of amylose and amylopectin depending on the variety. Indica rice (basmati, Thai...) is naturally rich in amylose. These are "hard" rice that shrink quickly after cooking. Contrary, Japonica rice contain more amylopectin than the former and their retrogradation is therefore slower. After cooking, Japonica rice stays soft longer. At extreme, glutinous rice contains almost only amylopectin and therefore does not retrograde at all. They can retain their consistency for up to several weeks without going stale (Anonyme, 2019).

In view of this importance of rice, it occurs another technological process generally used to improve its nutritional quality which is parboiling. Studies have already shown that parboiling rice preserves the minerals and B vitamins that migrate into the grain during soaking. Due to their intolerance of gluten, many people find themselves deprived of wheat-based bread. Thus, faced with a gradual increase in the price of wheat from 240 €/tone to 270 €, then to 300 € and 325€ between June and August 2021, Senegal has put in place a mechanism to support the price of flour in order to avoid its increase. For example, the Value Added Tax (VAT) on flour was reduced from 18 to 6% from January to August 2021, then customs duty on wheat and the VAT on flour were cancelled simultaneously from September 2021. But wheat prices have continued to rise steadily, reaching 340 € and more per ton in October, making the support measures insufficient (MCPME, 2021). This situation and many others, therefore, push researchers to look at alternatives in order to help the government ensure the food security of the populations. Technologies to replace partially wheat flour with flours from local food resources are increasingly being developed. Generally, reconstituted bread flours are mixtures of wheat flour incorporated with local cereal flours (millet, maize, rice, sorghum, etc.) or others in various proportions (AGRIINFOS, 2015; Balla et al., 1999). Thus, the aim of this study was to determine the rheological behavior of pastes obtained by incorporating parboiled and non-parboiled rice flour in the bread-making process.

MATERIALS AND METHODS

Plant material

The plant material used in this study consisted of a wheat flour as a control and three local rice varieties as samples, all locally purchased. The control was a type 55 wheat flour. The rice varieties were Sahel 108, Sahel 328 and Sahel 329 which were taken from test plots at the Centre de Recherches Agricoles de Saint Louis located at Mbagam in the Senegal river valley.

Laboratory material

The laboratory material used in this study was mainly a CHOPIN alveograph. In addition, for sample treatments of rice, a parboiler machine was used.

Parboiling

For each of the rice varieties studied, one (1) kg of paddy was taken, cleaned, soaked at 80°C for 16 hours and parboiled. It was sun–dried for 30 min and shade–dried to an average moisture content of 14% and finally dehusked using an Engelberg machine.

Sample preparation for analysis

The samples consisted of 100% type 55 wheat flour, which was the control (WS), 85% type 55 wheat flour, mixed with 15% of none parboiled (NE) or parboiled (E) rice flour of each variety.

Alveographic test

The value of a paste is determined by number of properties that are useful in the manufacture of baked goods such as bread, rusks, biscuits, etc. An alveograph makes it possible to study the main parameters by subjecting a paste piece to a biaxial deformation. The alveograhic test was performed according to (ISO 5530-4, 2002).

The method consisted of swelling of a paste sample which is subjected to air pressure. The pressure curve, called alveogram in the bubble, was used to study toughness (P), extensibility (L), swelling (W) and the balance between toughness and extensibility (P/L) of the paste. The procedure consisted firstly of preparing 1 liter of a 2.5% NaCl solution and then determining the moisture content of flour. A burette was then filled with this salt solution to the sample moisture level. After word a 250g mass of flour was introduced into a mixer, keeping constant the kneading time and the water content of the paste. After kneading, the paste was rolled and cut into 5 small circular tubes. After a break of 15 min, the bubble was inflated until it bursts and the deformation diagram was drawn on a recorder. The alveographic curve was therefore the image of certain paste physical properties, 30 min after the beginning of its elaboration.

Statistical analysis

Results obtained from alveographic analyses of the pastes were subjected to a variance (ANOVA) analysis with XLSAT software version 6.3.1. Significance of statistical tests was determined at the 5% level. Means were compared with the Tukey test.

RESULTS

Effect of parboiling on tenacity

Table 1 shows the paste resistance to deformation or its toughness which was expressed by the maximum pressure parameter (P), the extensibility (L) and the configuration ratio (P/L)

The results in Table 1 showed that the 100% wheat paste had a significantly higher-pressure resistance than the mixed wheat (85%) and parboiled or non-parboiled rice (15%).

For mixed wheat (85%) and rice (15%) pastes, parboiling significantly (95%) increased the pressure resistance for the Sahel 108 and Sahel 328 varieties. However, for Sahel 329 variety, parboiling had no significant effect.

The 100% wheat paste was significantly more extensible (92.65±0.58 mm) than the mixed wheat - parboiled or non-parboiled rice paste (74.97±0.17mm), at most.

Effect of parboiling on swelling index

In Table 2, are presented results on paste swelling capacity expressed by the swelling parameter G. The swelling index G is a quality criterion for flours (Colas A., 1997). It represents the extensibility of the paste and allows to assess the ability of the glutinous network to retain carbon dioxide **(**Boudreau and Menard, 1992).

Figure 1 illustrates the behavior of the different pastes studied. The results analysis showed that there was variability in the swelling index G regardless of the formulation. The 100% wheat paste (control) had a significantly higher swelling index (21.75±0.380) than all the mixture of wheat (85%) and rice (15%) studied.

Effect of parboiling on baking strength

Table 3 presents results on the baking strength W of pastes obtained with 100% wheat or mixture of wheat (85%) and non – parboiled or parboiled rice (15%).

It is considered that the paste deforming work or baking strength (W), necessary for the creation of a bubble, can be considered as a model of what happens in the bakery during the formation of cells under the action of the carbon dioxide released during bread fermentation (Boudreau and Menard, 1992).

Figure 2 shows the variation in baking strength of the different studied pastes.

The pastes obtained with the parboiled Sahel varieties 108, 328 and 329 had a higher baking strength (256.67±1.53; 265.33±1.53 and 274.33±1.53 respectively) than the same varieties without parboiling and closer to the control (357±20).

Table 1: Effect of parboiling on P, L and P/L of different pastes obtained by 100% wheat flour or 85% wheat flour mixed with 15% of rice flour.

Samples	P (mmH2O)	L (mm)	P/L
WS-NE108	81,00^{a}±1	54,39^{a}±0,48	1,49^{d}±0,026
WS-NE328	85,33^{b}±0,58	61,72^{b}±0,76	1,38^{c}±0,026
WS-NE329	96,00^{d}±1	65,06^{c}±0,27	1,48^{d}±0,020
WS-E108	88,00^{c}±1	68,30^{d}±1,03	1,29^{b}±0,025
WS-E328	90,33^{c}±0,58	72,64^{e}±1,29	1,24^{b}±0,030
WS-E329	96,00^{d}±1	74,97^{f}±0,17	1,28^{b}±0,020
WS	105,00^{e}±1	92,65^{g}±0,58	1,13^{a}±0,050

Values with the same letters in the same column are not significantly different at 5%.

Table 2: Effect of parboiling on swelling index of different pastes obtained by 100% wheat flour or 85% wheat flour mixed with 15% of rice flour.

Samples	G
WS-NE108	16,35^{a}±0,150
WS-NE328	17,12^{b}±0,060
WS-NE329	18,59^{d}±0,080
WS-E108	17,79^{c}±0,030
WS-E328	18,89^{d}±0,070
WS-E329	19,66^{e}±0,110
WS	21,75^{f}±0,380

Values with the same letters in a column are not significantly different at 5%.

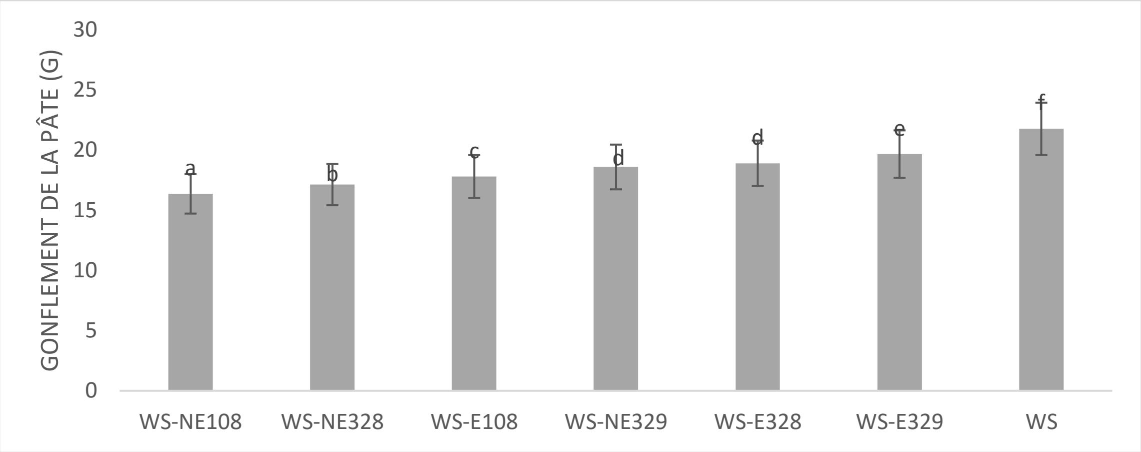

Figure 1: Comparative effect of parboiling on swelling index of 100% wheat flour or mixture of 85% wheat flour and 15% of rice flour.

Table 3: Effect of parboiling on baking strength W of pastes make with 100% wheat or mixture of wheat (85%) and non–parboiled or parboiled rice (15%).

Samples	**W**
WS-NE108	205,00[a]±1,00
WS-NE328	210,00[b]±1,00
WS-NE329	228,33[c]±1,53
WS-E108	256,67[d]±1,53
WS-E328	265,33[e]±1,53
WS-E329	274,33[f]±1,53
WS	357,00[g]±2,00

Values with the same letters in same column are not significantly different at 5%.

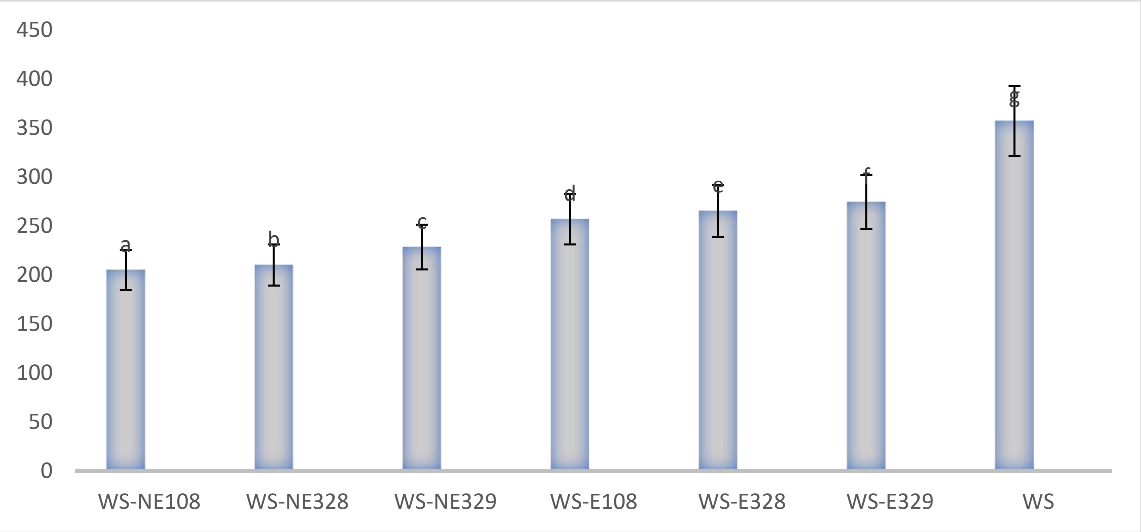

Figure 2: Variation of the baking strength for different types studied pastes.

DISCUSSION

It can be seen that for mixed wheat-rice pastes, the extensibility was significantly higher for all studied rice varieties, when parboiled. As for the configuration ratio (P/L), 100% wheat paste had the lowest value significantly (1.13±0.050). Indeed, according to Bouttet and Streiff (2020)**,** this pressure extensibility ratio (P/L) is used to assess the balance of flour. The results showed that all the studied pastes had a P/L ratio higher than 0.7. These pastes were therefore acceptable according to ISO 5530 – 4 (2002). Among wheat-rice mixed pastes, P/L decreased significantly when the rice sample was parboiled regardless of variety.

The analysis of all parameters considered (P, L and P/L) showed that parboiling improved the said parameters by making them tend towards a value closer to that of 100% wheat. From these results, parboiled rice varieties were more likely to produce more extensible pastes than non-parboiled, especially Sahel 329 (L = 74.97±0.17 mm and P/L = 28±0.020). According to Martin (1998), extensibility was linked to the hydration capacity of proteins, but high levels of damaged starch and pentosan cause competition for water and limited their absorption by the reserve proteins. In Autran's (1996) view, it is the gliadin fraction that explains the extensibility of paste. According to Anonymous (1995), a P/L value of 1.50 corresponds to a very strong and moderately stretchy paste. It should be noted that in French milling a wheat with a P/L higher than 2 is not bread making **(**Anonymous, 1995).

It was also noted that all samples consisting of 85% wheat and 15% parboiled rice had improved tenacity and are closer to the control sample (100% wheat or WS). This showed that bread similar to 100% wheat bread could be obtained with a 15% incorporation of parboiled rice flour using one of the three rice varieties Sahel 108, Sahel 328 and Sahel 329.

In conclusion, it can be said that parboiling improves the tenacity of the mixed wheat (85%) and rice (15%) paste. Indeed, the parboiled Sahel 328 and Sahel 329 rice varieties would give a tougher mixed paste (P/L = 1.24±0.030; 1.28±0.020 respectively) and closer to that of 100% wheat (P/L= 1.13±0.050).

For all studied varieties, parboiling significantly increased the swelling index. For incorporation of rice flour in bread making, the Sahel 329 variety improved the swelling index of mixed wheat-rice pastes better (18.59±0.080), especially when parboiled (19.66±0.110); bringing it closer to that of the control (WS). Thus, the use of the parboiled Sahel 329 variety could be recommended to improve the swelling index of the composite flour (85% wheat flour and 15% rice flour) in bread making.

Of all the varieties studied, the incorporation of parboiled Sahel 329 rice flour resulted in a paste with a swelling index closest to that of the control (WS).

The baking strength varied significantly regardless to the sample composition. The variability of W may depend on the variety of cereals used and in particular on the harvest which differs from one year to another (Bartolucci and Launay, 1997; Dubois, 1994). However, the paste obtained by incorporating parboiled Sahel 329 rice flour has the closest baking strength to 100% wheat paste (WS).

According to El Yamlahi et al. (2013), The W value for standard quality wheat is in the range 160-200, while for good quality wheat the W value is between 220 and 300. This indicated that all the parboiled rice studied composite flours had satisfactory baking strength. The observed deviations in relation to the control flour would be due to the rice starches which could influence the rheological characteristics of the flours. Indeed, during the parboiling process, the starch becomes gelatinized. Also, the work results of Petrofsky and Hoseney (1995) and Uthayakumaran et al. (2002) revealed that starches isolated from different varieties of wheat and mixed with different varieties of gluten had different rheological characteristics.

Conclusion

The present study showed that Sahel 108, Sahel 328 and Sahel 329 rice flours could be used in incorporation of local cereal flours in bread-making. Also, the study showed that parboiling rice significantly improved the rheological properties (P/L, G and W, among others) of pastes make by a mixture of wheat (85%) and rice (15%). Of all studied varieties, Sahel 329 when parboiled, gave the closest rheological properties to the control (100% wheat). This alternative use of rice (bread-making in addition to cooked dishes such as rice cooked in water or oil) supports the idea that rice would be a better vehicle than the soft wheat flour used for iron and folic acid fortification in Senegal. In the future, studies on organoleptic and nutritional characteristics of bread products obtained are envisaged.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

FS : main author who carried out the activities; AD : Assistant who supervised the work in the laboratory; ONF : Technical assistance and scientific contribution; SEATM: Technical assistant on parboiling; MF: oversaw data management and analysis; MS : bread-making laboratory supervisor (proofreader and correction); ATG : thesis director of the main author and general supervisor of the work (proofreading and scientific contribution).

ACKNOWLEDGEMENTS

To USAID Feed the Future Sustainable Intensification Innovation Lab (SIIL) for supporting this work.

REFERENCES

AGRIINFOS mensuel d'infoRmationS agRicoleS et RuRaleS - 9e année - N° 85 - SEPTEMBRE 2015.< https://www.inter-reseaux.org/wp-content/uploads/agriinfos_85.pdf >

Anonyme. 2019. Le rôle de l'amidon dans la conservation du pain. <https://www.interforum.fr/images/EAD/art/doc/4/408036317631353632373634353039353430313835NONPUBLIE.pdf>.

Anonyme. 1995. Contrôle de la qualité des céréales et protéagineux, guide pratique. Publication ITCF/ONIC, Paris, France, 254p.

Autran JC. 1996. La qualité culinaire : de quoi est-elle faite. Coll. Perspectives blé dur. Toulouse, France : 57-71.

Balla A, Blecker C, Oumarou M, Paquot M, Deroanne C. 1999. Mise au point de pains composites à base de mélanges de farines de sorgho-blé et analyse texturale. *Biotechnol. Agron. Soc. Environ.*, **3**(2): 69–77. URL: https://popups.uliege.be/1780-4507/index.php?id=15630.

Bartolucci JC, Launay B. 1997. Stress relaxation of wheat flout doughs following bibble inflation or lubricated squeezing flow and its relation to wheat flour quality. In *Wheat Structure, Biochemistry and Functionality*. Ed. J D Schofield.

Boudreau A, Menard G. 1992. *Le Blé, Eléments Fondamentaux et Transformation*. Presses Université Laval ; 439 p.

Bouttet D, Streiff A. 2020. Le W et le P/L, deux critères majeurs pour la panification. ARVALIS - Institut du végétal. https://www.arvalis-infos.fr/le-w-et-le-p/l-deux-criteres-majeurs-pour-la-panification-@/view-32871-arvarticle.html . Consulté le 25/02/2022.

Dobraszczyk BJ, Morgenstern MP. 2003. Review: rheology and the bread making process. *J. Cereal Sci.*, **38** : 229-245. DOI: 10.1016/S0733-5210(03)00059-6

Dubois M. 1994. Rendement en pâte en boulangerie et en industrie de la cuisson. Industrie des Céréales. No 89, p. 39-43.

El Yamlahi A, Berny E, Hammoumi A, Ouhssine M. 2013. Effect of barley (*Hordeum vulgare* L.) flour incorporation on the baking quality of wheat (*Triticum aestivum* L.) flour. *Journal of Chemical and Pharmaceutical Research,* **5**(2): 162-170.

Godon B. Loisel W. 1997. *Guide Pratique d'Analyses dans les Industries des Céréales* (2ème édn). Collection Science et Techniques Agroalimentaires. Lavoisier Tec et Doc. Paris.819 p.

ISO 5530 – 4. 2002. Specifies a method, using an alveograph, for determining certain rheological properties of doughs obtained from soft or hard wheat flours *Triticum aestivum* L.

Martin G. 1998. Quantité et qualité : les enseignements de la champagne. Industriesdes céréales, No 110, P 5-9.

MCPME (Ministère du commerce et des petites et moyennes entreprises). 2021. Conseil national de la consommation sur la farine et le pain. <https://commerce.gouv.sn/2021/12/17/conseil-national-de-la-consommation-sur-la-farine-et-le-pain >.

Petrovsky KE, Hoseney RC. 1995. Rheological properties of dough made with starch and gluten from several cereal sources. *Cereal Chem.*, **72**: 53-58.

Uthayakumaran S, Newberry M, Phan-Thien N, Tanner R. 2002. Small and large strain rheology of wheat gluten. *Rheologica Acta,* **41**(1-2): 162-172.