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Optimization of Parboiling Process Pearl Millet (*Pennisetum Glaucum* [L.]R.Br.) GB 87-35 Variety

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Abstract

The present study was conducted to optimize parboiling millet process in a local variety GB 87-35 of pearl millet in Senegal. Parboiling millet process was realized: Whole millet grain was soaked at different temperatures of 60, 70, 80 and 90°C for 4 h, followed by steaming and drying before milling. The conditions were standardized by analyzing milling quality milling and effect of parboiling on physicochemical composition of grain millet. The results were submitted to analysis of variance (ANOVA), with Fisher's post test to compare the difference between the samples. The confidence interval was 95%. The results showed that the soaking temperature of 60, 70 and 80°C for 4 h are optimum conditions for improving the milling quality of pearl millet variety GB 87-35 for obtaining the better milling millet yield with 88.21, 89.79 and 89.55% respectively and the lower percentage of broken millet with 1.81; 1.79 and 1.82% respectively. The physicochemical composition of the samples indicated that parboiling pearl millet decrease nutrients losses during milling. Thus, parboiling millet at 60 or 70°C for 4 hours of soaking and 15 minutes of steaming, improved milling efficiency by increasing milling milllet yield and reduced broken percentage and nutrients losses during milling.

Keywords: Parboiling; Pearl millet; Milling quality; Physicochemical composition

Introduction

Food security remains a major challenge in Africa and around the world. Agriculture is the predominant economic sector in sub-Saharan Africa [1]. It occupied 70% of rural populations who depend on it for their livelihood. The diets of the African peoples are mainly based on vegetable resources, in particular cereals. Among the latter, we may cite pearl millet (*Pennisetum glaucum* [L.]R. Br.), one of the most significant cereals crops that grown in the tropical and developed countries [2]. According to Reddy et al. [3] pearl millet is cultivated on about 27 million ha in some of the harsh tropical environments of sub-Saharan Africa and Asia. It is a versatile crop, used for food, fuel and feed [4].

In Senegal, cereals constitute generally the staple food; they represent 65% of energy sources and 61% of protein intakes [5]. Pearl millet constitutes more than 60% of the production of cereals in Senegal [6].

Nutritionally, pearl millet is characterized by high micronutrients content, particularly with regard to calcium and iron, and high dietary fiber. Their pearl millet grains are richer in proteins and essential amino acids than all other cereals. The nutraceutical value of these grains, by virtue of their high dietary fiber, phytochemicals and low glycemic index, has received increasing attention [7-9].

Pearl millet is generally used in the feed after decorticage, a unitary processing operation which reduces the nutrients content linked to the low yield of milling and the high rate of breakage. The Percentage broken is one of the important factors in assessing the ability to dehulling. Parboiling is one of the processing technologies applied to milling of paddy to improve the milling efficiency and to reduce the breakage [10-15]. It is a hydrothermal treatment given to paddy to improve its qualities and it involves the three basic processes of soaking to absorb water, steaming to gelatinize the starch in the endosperm and drying before milling [16]. So the starch structure from amorphous form and hardens the endosperm, making it translucent. The hardening process makes the grains tough and increases its resistance to breakage during milling operation, improving the milling yield and reducing the nutrients losses during milling and cooking [17]. It also increases grain resistance to insect attacks and improves its nutritional quality. The information on the parboiling millet is limited and reported only for finger millet [18] and little millet grains [19]. The objective of this study was to optimize parboiling process millet in a Senegalese variety of pearl millet.

Material and Methods

Millet material

A local variety, GB 87-35 was used in this study. GB 87-35 millet is one of the most common varieties in Senegal. It was obtained from the National Center for Agronomic Research (CNRA) in Bambey, Senegal. The grains were cleaned to remove stones and other impurities in vibrating screen, packed in barrel and stored in ambient conditions for further studies. The tests of parboiling millet were carried out at the «Atelier Céréales et Légumineuses» and physicochemical analysis at the « laboratoire de Chimie » of the «Institut de Technologie Alimentaire (ITA)».

Millet parboiling process

Parboiling process was carried out in 4 steps and all treatments were done in triplicates.

Soaking: For each test, 7 kg of whole millet grains were initially soaked in 10.5 liters of water using a kettle for 4 hours with increasing temperatures of 60, 70, 80°C and 90°C. After soaking, the grains were cooled to room temperature in covered kettle.

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Pre-drying: The steamed paddy was dried in the sun about for 1 hour to reduce the amount of water to speed up the process of gelatinization during the steaming step.

Steaming: The soaked grains were steamed using the parboiling system, consisting of a container in form of a bucket, bottom and bottom quarter of the perimeter of which are perforated and surmounted by a kettle made of cast aluminum. The steaming time was fifteen (15) minutes.

Drying: The steamed paddy was firstly dried in the sun about for 1 hour. Drying was completed in the shade for 3 days before the husking process. Moisture was determined using the moisture meter and residual moisture between 10 and 12% was obtained.

Milling/Decortication: This operation was carried out with the huller. The abrasive grinding wheels, by rotating at 1300 rpm, produce an abrasion of the outer layers by the friction against the mass of the moving grains. The residence time of the millet grains in the husking chamber of the decorticator was 3 minutes; necessary time to obtain sufficiently husked grains. The latter were separated from bran with a chamber.

After decortication, whole millet grains were separated from broken in vibrating screen. The milling millet yield and the percentage of broken grains were calculated.

The milling millet yield expressed as a percentage represents the ratio of the weight of the husked grains on the weight of unhusked grains.

$$\text{Milling millet yield (\%)} = \frac{\text{weight of the husked grains (g)}}{\text{weight of the unhulled grains (g)}} \times 100$$

The broken percentage is the ratio of the weight of broken grains on the weight of husked grains.

$$\text{Broken percentage (\%)} = \frac{\text{weight of the brokens grains (g)}}{\text{weight of the husked grains (g)}} \times 100$$

Physicochemical analysis:" The millet were analyzed for moisture, protein, fat, ash, fibre and mineral elements content following the classics methods of AOAC [20].

The determination of water content consists in drying the sample in a GENEQ-inc brand incubator at 105 ± 2°C until constant weight AOAC [20].

The total protein content is determined according to the Kjeldahl method (n x 6.25) described [20]. The ash is assimilated to the residue obtained after incineration for 4 hours at 550°C in a muffle furnace of the Heraeus brand (NF 03-720) according to AOAC [20]. The crude fiber content was determined by the segmental hot digestion of the defatted sample with two acidic and basic hydrolyses followed by EDTA complexation. [20].

The mineral elements (Fe, Zn, and Mg) were determined from the ash obtained by incineration. The residue was dissolved in HCl and the mineral constituents (Fe, Zn and Mg) were determined by Atomic Absorption Spectrometry (AAS) according to AOAC [20] method (Hitachi Z6100, Tokyo, Japan).

Statistical analyzes: The differences of mean values among millet samples were determined by one-way analysis of variance (ANOVA). This ANOVA was applied to compare the impact of parboiling on milling millet yield, percentage of broken millet and physico-chemical composition. The analyses of nutritional values were carried out using the AOAC [20] guidelines for determining nutritional parameters. The Fisher tester was used to determine whether or not there was a significant difference between the samples once the different parameters studied during millet parboiling process. The confidence interval was 95%.

Results and Discussion

Millet parboiling was optimized by considering the milling quality by focus on the milling millet yield, the percentage of broken and the physico-chemical composition of millet grains. The milling millet yield and broken percentage of parboiled and unparboiled grains millet during milling is presented in figure 1 and the physico-chemical composition in Table 1.

Milling millet yield

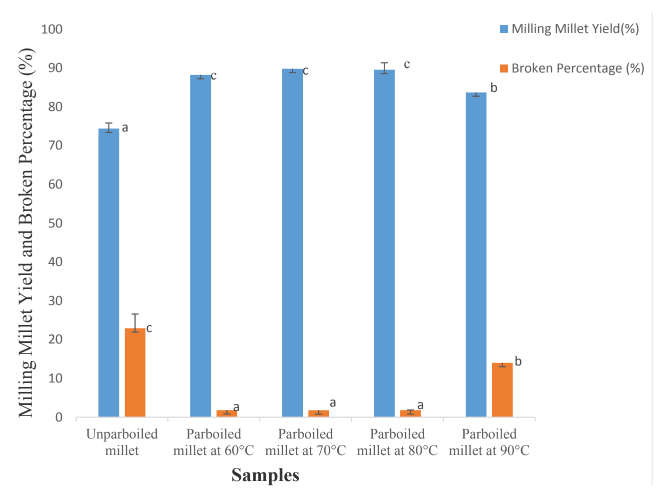
The milling millet yield in unparboiled sample was 74. 37 %. The milling millet yield of the parboiled samples was higher than those of the unparboiled millet. The yields were of 88.21; 89.79 and 89.55 %, respectively for 60, 70 and 80°C. These rates were not different between them and were considerably higher than those of the milling millet yield of parboiled millet at 90°C which represented 83.69 %.

Consequently, it may be considered that parboiling millet would lead to increase the milling millet yield, in particular for 60, 70, and 80°C.

The milling yield obtained with the unparboiled millet corroborates to those reported by Fliedel [21] which varied from 65 to 75%.

During the steaming, the essentially almond starch is gelatinized at temperatures below 90°C applied for 4 hours. Under 80°C, the gelatinization carried out and followed by a progressive drying leads to a compaction of the starch and a hardening of the almond thus allowing the parboiled millet to better resist the abrasion during the milling [17]. According to Bhattacharya [20] and Parnsakhorn and Noomhorm [14] the improvement of milling millet yield may be due to the increased binding effect of starch with gelatinization and melted protein bodies from the steaming process seal the fissures.

Furthermore, the temperature of 90°C could be considered as being higher than the gelatinization temperature with respect to the



Values with different superscript letters within the same parameter are significantly different (p<0.05, mean ± SD)

Figure 1: Milling millet yield and broken percentage of the different samples.

Samples \ Parameters	Untreated millet	Unparboiled decorticated millet	Parboiled decorticated millet at 60°C	Parboiled decorticated millet at 70°C	Parboiled decorticated millet at 80°C
Moisture content(%)	10,57^{c} ± 0,03	11,08^{d} ± 0,05	9,31^{a} ± 0,06	9,43^{ab} ± 0,22	9,55^{b} ± 0,10
Proteins (%)	13,45^{d} ± 0,05	11,85^{a} ± 0,07	12,55^{c} ± 0,13	12,3^{b} ± 0,07	12,36^{b} ± 0,07
Ash (%)	1,47^{d} ± 0,04	0,92^{a} ± 0,00	0,99^{bc} ± 0,02	1,02^{c} ± 0,02	0,97^{b} ± 0,01
Fiber %	1,47^{c} ± 0,12	0,72^{a} ± 0,04	1,02^{b} ± 0,06	0,97^{b} ± 0,03	0,94 ± 0,05^{b}
Iron (mg/100 g)	6,54^{c} ± 0,20	5,11^{a} ± 0,19	5,76^{b} ± 0,11	5,69^{b} ± 0,11	5,65^{b} ± 0,03
Zinc (mg/100 g)	2,87^{c} ± 0,06	2,24^{a} ± 0,09	2,62^{b} ± 0,13	2,66^{b} ± 0,04	2,68^{b} ± 0,03
Magnesium (mg/100 g)	114,83^{c} ± 1,03	67,55^{a} ± 4,03	93,05^{b} ± 0,56	94,50^{b} ± 0,48	95,14^{b} ± 1,25
Values with different superscript letters within the same parameter are significantly different (p<0.05, mean ± SD)					

Table 1: Physico-chemical composition of the different samples.

temperature of 80°C. For cereals in general, the starch gelatinization temperature varies between 60 and 75°C; then rarely greater than 80°C [23]. The reduced milling yield may be due to excessive absorption of moisture and severe deformation of the grain where grain loses exuded part of the endosperm and the resultant cooking changes the structure of the starch and reduces the resistance of the grains to crushing due to dehulling [14].

From this analysis, it can be seen that from the 4 temperatures studied, 60, 70 et 80°C would be the most suitable for millet parboiling by considering the best milling millet yield.

Percentage of broken millet grains

The statistical study revealed that the percentage of broken grains was significantly lower in the parboiled millet (14% maximum at 90°C) than in the untreated millet (23.34%). Considering all the parboiled millets, it is observed that the soaking temperature influences the broken millet rate. At the temperatures of 60, 70 and 80°C, the corresponding broken proportions were 1.81; 1.79 and 1.82% respectively and showed no significant difference between them. These percentages were significantly lower than those obtained at 90°C which was equal to 14%.

For samples parboiled, the broken percentage is akin to those found by Mannuramath [19].

Thus, it can be seen that for the soaking temperatures comparable to those of the gelatinization of the starch, the broken is a function of the temperature. Beyond the gelatinization temperature (above 80°C), it is observed that the percentage of the broken millet increases again, even if it remains lower than those of the unparboiled millet.

From this analysis, it appears that parboiling millet decreases broken grains. Moreover the broken percentage is a function of soaking temperature. In fact, during the soaking phase, the starch of the almond gelatinizes for temperatures between 60 and 75°C [23]. This chemical phenomenon allows to the millet after drying having a moisture content that varies between 10 and 13%; a compaction of the grain allows it to withstand the shocks suffered during the milling. This impact resistance results in a reduction in the breaking percentage.

Beyond the gelatinization temperature, there is an extended cooking (this is the case at 90°C.) which gives a pasty appearance to the almond and causes, after drying, zones of weakness of the grain, decreasing the impact resistance during milling and increasing the broken proportion [14].

It can be noted that the soaking temperatures, 60, 70 or 80°C could be considered as the most suitable in the study for the parboiling of GB 87-35 the millet variety. Thus, in the study of parboiling effect on the physico-chemical composition, only parboiled millet at 60, 70 and 80 will be considered.

Effect of parboiling on physicochemical composition

The results obtained for moisture content for all millets were well below the maximum moisture limit (13%) recommended by FAO/WHO [24] for pearl millet. The moisture content for parboiled decorticated millet samples is lower than the moisture content of unparboiled decorticated. Our result conformed that found by Adeyemi et al. [25] who said that the gradual increase of the soaking temperature and the subsequent drying causes a decrease in the moisture content of the rice.

The parboiled decorticated millet samples have higher proteins content than the un-parboiled decorticated millet. The improvement of the milling yield by the parboiling also favors this preservation of the proteins. The protein-rich aleurone layer binds more to the crystallized albumen and avoids being dragged into the sound with its proteins as a result of parboiling. This would reduce the abrasive effect of dehulling [17].

Bernard [26] said that the decrease in the protein content beyond the soaking temperature at 60°C is certainly due to the increase in the soaking temperature, which is explained by the denaturation of the proteins. Then 60°C is the most appropriate soaking temperature considering the protein content.

The parboiled millets samples also have higher fiber content than the nonparboiled millet sample. After steaming, the enhanced protection of the albumen due to the gelatinization and crystallization and compacting of the starch millet grain obtained after drying thus makes the grain harder and resistant to abrasive shelling of the shelling and this resistance to shocks causes a decrease in the breaking rate [27], therefore a reduction of losses in cellulosic elements during dehulling. There is no significant difference on the fibre content of parboiled millets samples. This result shows a constant and stable value for crude fibre as the temperature increases. Thus, it can be considered that millet can be parboiled at 60, 70 or 80°C because the latter have no effect on the cellulose content of millet GB 87-35.

Ash of the parboiled samples was higher than those of the unparboiled millet but there is no significant difference on the fiber content of parboiled millet samples. Raghavendra and Juliano [17], reported that the gelatinization and compacting of the millet grain obtained after parboiling reduces the negative effect of dehulling on the ash content of millet. The temperatures 60 and 70°C are the best soaking temperatures to obtain much higher ash content.

The statistical study revealed that the mineral composition (Fe, Zn and Mg) was significantly lower in the unparboiled decorticated millet than all the parboiled millets. On the other hand, between parboiled millet samples, the soaking temperature has no effect on the mineral element content. Thus millet can be considered to be parboiled at the initial soaking temperatures 60, 70 and 80°C considering the mineral element content of millet.

According to Raghavendra et Juliano [17], gelatinization and compacting of the millet grain obtained after parboiling reduces the negative effect of dehulling on the mineral elements of pearl millet.

Overall, the results obtained on the physicochemical composition show that the parboiling of millet at the initial soaking temperatures of 60,70 and 80°C makes it possible to attenuate the nutrient losses due to the dehulling of millet grains and that 60 and 70°C are the best soaking temperatures.

Conclusion

Parboiling is commonly considered to improve the milling quality and the nutritional quality of millet. Based on the results of studies carried out, we can observe that it is true only if the pearl millet *(Pennisetum glaucum)* GB 87-35 is soaked, first dried, steamed and dried, under carefully controlled conditions: initial soaking temperatures at 60, 70 or 80°C for 4 hours. The milling millet yield is improved and the broken millet grains are decreased. The results obtained on the physicochemical composition show that parboiling of millet makes it possible to attenuate nutrient losses due to milling of millet grains. Thus, in order to carry out the parboiling of millet GB 87-35, the soaking temperature of 60 or 70°C, a soaking time of 4 hours and steaming 15 minutes are optimum conditions.

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