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Influence of Mechanical Shelling on the Microbiological and Physico-Chemical Quality of *Souna* Millet (*Pennisetum glaucum*) and its Derivatived

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Abstract : *Souna* millet (*Pennisetum glaucum*) is used in Senegal for human consumption after primary processing to obtain flour and semolina. Mechanical shelling and dry milling of local cereals results in processed products with a long shelf life. The objective of this work is to study the influence of mechanical shelling on the microbiological and physico-chemical qualities of *Souna* millet and primary products, flour and semolina. The results of the physico-chemical analyses revealed a reduction in the content of the various parameters studied. However, the greatest losses were obtained on flour fatty acidity with 50% and on millet ash with 55% while the reduction in protein content only varied from 12% to 15% for millet and flour respectively with 14% for semolina. The percentages of reduction of calcium (14.6%), zinc (23.3%) and potassium (18.4%) contents obtained after shelling, were more important on millet, while the highest losses of iron and magnesium composition were noted respectively in flour with 18.1% and in semolina with 15.3%. At the same time, the results of microbiological analyses showed a decrease in the level of contamination of husked millet and derived products by aerobic mesophilic flora at 30°C, by yeasts and molds and by thermotolerant coliforms. An absence of Salmonella was also noted in all samples as well as Bacillus cereus, Staphylococcus aureus and E. coli were not enumerated.

Keywords : *Souna* Millet, Mechanical Shelling, Flour, Semolina, Microbiological and Physicochemical Quality

Introduction

Souna millet (*Pennisetum glaucum*) is considered to be one of the most important crops in semi-arid zones (HADIMANI and *al*., 2001) and forms the basis of the human diet in the Sahelian zones of West Africa. In Senegal, millet not only represents one of the main cereals grown, but it occupies first place with more than 60% of the area set aside for the last few years and also accounts for 35% of national cereal production (NASD, 2018).

Like all other local cereals, millet seeds are used for human consumption after primary processing by crushing or grinding to obtain flours and semolinas. These constitute the raw materials for secondary processing products (arraw, couscous, thiacry, etc.) which have become essential in the diet of Senegalese urban populations (BROUTIN and *al*., 2000). Mechanical shelling and dry milling of local cereals are examples of this, which make it possible to obtain processed products with a minimum shelf life of six months (BROUTIN and *al*., 2003).

Efforts are being made in research level in the field of local cereal processing to design competitive products of better quality and meeting consumer expectations in terms of taste, ease of preparation, etc. (BLEIN and *al*., 2012). However, it is important to enhance and improve the quality of food in order to develop dry processed products that can have a longer shelf life ensuring the protection of consumers who are more demanding and aware of the health quality of foodstuffs. For this, it is necessary to make available to the consumer products with guarantees of health quality or compliance with manufacturing and storage standards (FAO/WHO, 2005).

It is in this context that this study aims to investigate the influence of mechanical shelling on the microbiological and physico-chemical qualities of *Souna* millet, flour and semolina from its primary processing.

Materials and Methods

Plant material

Souna millet (*Pennisetum glaucum*) purchased at the "Castors" market in Dakar (Senegal), was used in this study.

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Technological material

The technological equipment consisted mainly of a scale, an abrasive disc sheller, a hammer mill, a SWECO brand vibro-sifter and plastic basins.

Laboratory equipment

This equipment is usually used in chemistry and microbiology laboratories for quality control analysis of foodstuffs.

Methodology

The methodology is centered on the one hand on the experimentation of the technologies for the primary processing of Souna millet into flour and semolina obtained after milling and on the other hand on the microbiological and physico-chemical analyses of these various products.

Primary processing of millet

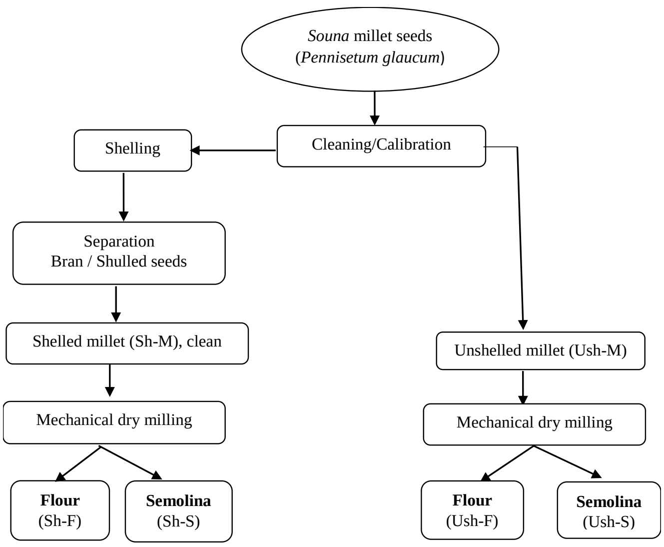

Figure 1: Diagram of the process of transformation of *Souna* millet into flour and semolina

Analysis methods

Physico-chemical analyses

To evaluate the influence of shelling on the physico-chemical quality of *Souna* millet (*Pennisetum glaucum*) and flour and semolina from its primary processing, the following parameters were analyzed : fatty acidity, ash, protein, calcium (Ca), iron (Fe), zinc (Zn), magnesium (Mg) and potassium (K).

Fatty acidity was determined according to ISO 7305 method, after titration of the supernatant obtained after centrifugation of a solution prepared from 5±0.001g of sample in 30 mL of 95° alcohol.

After dry cleaning the raw Souna millet seeds to remove impurities, they were then graded using a SWECO brand vibro-sifter.

The study was carried out on 40 kg of Souna millet (Pennisetum glaucum) that had been dry-cleaned to remove impurities and then graded using a SWECO brand vibro-sifter. The clean millet was then divided into two equal batches: one to be hulled and the other not hulled.

Shelling: it was done mechanically by the dry process using an abrasive disc shelling machine (manufactured by the company SISMAR in Senegal) which allowed the bran to be separated from the shelled seed.

Milling: it consisted of reducing the *Souna* millet seeds using a hammer mill into flour (sieve mesh diameter is 0.5 mm) and semolina (sieve mesh diameter is 1 mm).

Figure 1 below summarizes the different technological operations.

Ash was determined from 4±0.001g of finely ground sample then incinerated in a furnace at 550°C according to AOAC: 923.03 (32.1.05).

Protein content was determined from total nitrogen determination by the Kjeldahl method described in AOAC International 18th Ed.2005, Rev.2007 2001.11.

The minerals Ca, Fe, Zn, Mg and K were determined according to the AOAC method: 968.08 (4.8.02) with hydrochloric acid by Atomic Absorption Spectrophotometry (AAS) after incineration of the samples and dissolution of the ashes.

Microbiological analyses

In order to control the manufacturing process and the microbiological quality of the finished products, the microbiological analyses were directed towards the search for Salmonella (NF EN ISO 6579-1) and towards the enumeration of the aerobic mesophilic flora at 30°C (ISO 4833-1), yeasts and molds (NF V08 059), thermotolerant coliforms (NF V 08-060), *E. coli* (NF ISO 16649-1), *Bacillus cereus* (NF EN ISO 7932), and *Staphylococcus aureus* (NF EN ISO 6888-1). The results obtained were expressed in colony forming units per gram (CFU/g) according to the formulas of the NF EN ISO 7218 standard of 2007.

Results and Discussion

The results of physicochemical and microbiological analyses were represented by the averages of three separate tests performed on each sample (Tables 1 and 2).

Little information has been found in the literature on the study of the impact of shelling on the physico-chemical characteristics of millet. Similarly, to our knowledge, no research has yet been directed towards the physico-chemical and microbiological characterization of flours and semolinas obtained after milling shelled or unshelled millet. To this end, the physico-chemical results of this study obtained on whole millet and shelled millet were compared with those found by some authors (SOW, 2014 ; BEKOYE, 2014 ; SONGRE-OUATTARA, 2015). In addition, the HACCP microbiological limits for dry foods (BROUTIN, 2005) were used as references for the interpretation of the results.

However, from the analysis of the results in Table 1, it appears that the values of the physico-chemical parameters, although they varied between the different samples, were in accordance with the nutritional quality criteria of the Codex standard (CXS 170-1989).

Acidity, ash, and protein (Table 1) levels were lower for shelled millet (Sh-M) as well as for semolina (Sh-S) and flour (Sh-F). Looking at curve 2, it was found that the more advanced the technology, the higher the rate of acidity reduction with 50% for flour, 20% for semolina and 19% for millet.

Figure 2 also showed that the percentage reduction in ash content was higher after shelling for millet with a loss of 55%. A loss of 4% and 7% was also noted for semolina and flour respectively. This effect of hulling on millet ash levels was observed with the results obtained by SOW (2014) who found a reduction of 32.12%. Nevertheless, these results do not corroborate with those of BEKOYE (2014) who revealed higher ash percentages after shelling with 1.40% for unshelled *Souna* millet versus 1.89% for shelled millet. By comparing the rates of reduction of acidity and ash, the loss of protein content is lower for products after shelling with a decrease of 12% for millet, 14% for semolina and 15% for flour.

With regard to mineral contents, the same reduction effect due to shelling was observed. However, the results presented in Table 3 showed that calcium (Ca), zinc (Zn) and potassium (K) suffered the greatest losses after shelling on millet with 14.6%, 23.3% and 18.4% respectively. In contrast, the highest percentages of reduction in iron (Fe) and magnesium (Mg) were observed respectively on flour with 18.1% and on semolina with 15.3%.

Variations were noted between the results of this study and those of different authors who performed physico-chemical analyses on the same variety of *Pennisetum glaucum* millet. According to SONGRE-OUATTARA and *al*. (2015), these variations may be due to an influence of ecological conditions of the growing area, genetic factors, or analytical techniques.

Regarding the microbiological analyses, the results in Table 2 revealed that *Salmonella* were absent, *Bacillus cereus*, *Staphylococcus aureus* and *E. coli* were not enumerated in any of the samples. These analytical results complied with the health safety criteria for dry foodstuffs.

However, aerobic mesophilic flora, yeasts and molds, and thermotolerant coliforms were found in all samples, with a higher level of contamination in unshelled millet (Ush-M). Although ADJILE and *al*, (2015) ; HOUSSOU and *al*, (2016b) showed in their study that milling was a critical step, the results in Table 2 showed a decrease in this microbial load on Sh-F flours and Sh-S semolinas. These results, which are lower than the microbiological criteria, may indicate compliance with good hygienic practices in the processing process and effective cleaning of the equipment used to process shelled millet into semolina and flour.

Yeasts and moulds were present in all samples in lower quantities and below the limit of acceptability (BROUTIN, 2005) in shelled millet as well as semolina and flour obtained after milling with $3.9.10^3$ cfu/g, $4.7.10^3$ cfu/g and $4.1.10^3$ cfu/g for Sh-M, Sh-S and Sh-F samples respectively.

Thermotolerant coliforms, very widespread in the environment and saprophytic of humans and animals, were also found in all samples of millet, flour and semolina in lower quantities for the products obtained after shelling, with $3.4.\ 10^3$ cfu/g for Sh-M, $6.3.10^3$ cfu/g for Sh-S and $1.2.10^3$ cfu/g for Sh-F against respectively $5.3.10^4$ cfu/g for Ush-M, $1.8.10^4$ cfu/g for Ush-S and $3.3.10^4$ cfu/g for Ush-F. The presence of these thermotolerant coliforms in processed products may be justified by their ubiquitous nature according to N'GORAN-AW (2018) who showed that they can be found in flour during processing.

However, these germs counted in *Souna* millet and its primary products (aerobic mesophilic flora at 30°C, yeasts and molds and thermotolerant coliforms) were considered by BIROLLO and *al*, (2001) as indicators of hygiene in the food manufacturing process. Thus, compliance with good hygiene and manufacturing practices and/or a better selection of raw materials is necessary in the processing to obtain products of better microbiological quality.

Table 1 : Physico-chemical quality of raw materials and derived products

Parameters	Samples					
	Ush-M	**Sh-M**	**Ush-S**	**Sh-S**	**Ush-F**	**Sh-F**
Acidity (% H2SO4)	0,21 ±0,01	0,17 ±0,01	0,05 ±0,00	0,04 ±0,00	0,04 ±0,01	0,02 ±0,00
Ash (%)	1,93±0,01	0,87±0,01	0,90 ±0,02	0,86±0,05	0,96±0,02	0,89±0,02
Proteins (%)	10,83±0,05	9,57±0,07	8,63±0,04	7,38±0,07	8,14±0,04	6,91±0,05
Ca (mg/100g)	9,97±0,24	8,51±0,11	10,42±0,17	10,22±0,17	10,75±0,65	10,50±0,54
Fe (mg/100g)	3,56±0,15	2,97±0,13	6,08±0,17	5,08±0,13	7,07±0,21	5,79±0,17
Zn (mg/100g)	2,62±0,07	2,01±0,04	1,72±0,05	1,53±0,05	1,68±0,07	1,49±0,05
Mg (mg/100g)	71,42±1,08	63,74±1,05	70,67±4,92	59,84±3,57	65,33±3,64	56,41±2,75
K (mg/100g)	291,37±1,48	237,67±1,04	242,58±12,82	236,63±10,87	250,01±10,14	247,66±9,81

Ush-M : Unshelled Millet ; **Sh-M** : Shelled Millet ; **Ush-F** : Unshelled Millet Flour ; **Sh-F** : Shelled Millet Flour ; **Ush-S** : Unshelled Millet Semolina ; **Sh-S** : Shelled Millet Semolina.

Table 2 : Microbiological quality of raw materials and derived products

Parameters	Nature of the samples					
	Ush-M	**Sh-M**	**Ush-S**	**Sh-S**	**Ush-F**	**Sh-F**
AMF at 30°C (cfu/g)	$5,2.10^{6}$	$2,1.10^{5}$	$7,1.10^{5}$	$8,8.10^{4}$	$9,7.10^{4}$	$4,9.10^{4}$
Y & M (cfu/g)	$8,5.10^{4}$	$3,9.10^{3}$	$3,6.10^{4}$	$4,7.10^{3}$	$3,3.10^{4}$	$4,1.10^{3}$
Therm. colif. (cfu/g)	$5,3.10^{4}$	$3,4.10^{3}$	$1,8.10^{4}$	$6,3.10^{3}$	$1,5.10^{3}$	$1,2.10^{3}$
E. coli (cfu/g)	< 10	< 10	< 10	< 10	< 10	< 10
Bac. cereus (cfu/g)	< 100	< 100	< 100	< 100	< 100	< 100
Staph. aureus (cfu/g)	< 100	< 100	< 100	< 100	< 100	< 100
Salmonella /25g	absence	absence	absence	absence	absence	absence

AMP : Aerobic Mesophilic flora ; Y & M : Yeast and moulds ; Therm. colif. : Thermotolerant coliforms; *Bac. cereus ; Staph. aureus* : *Staphylococcus aureus*.

Table 3 : **Percentage of mineral reduction after shelling**

Minerals	Samples		
	Millet	**Semolina**	**Flour**
Ca	14,6 %	1,9 %	2,3 %
Fe	16,6 %	16,5 %	18,1 %
Zn	23,3 %	11,1 %	11,3 %
Mg	10,8 %	15,3 %	13,7 %
K	18,4 %	2,5 %	0,9 %

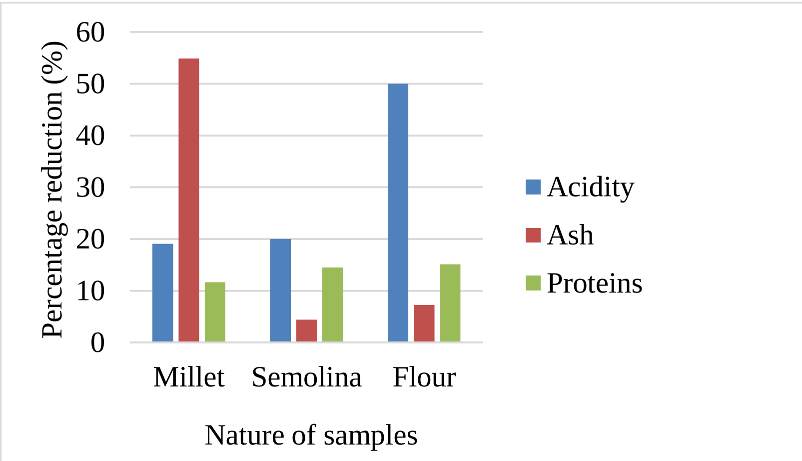

Figure 2 : Reduction rate of fatty acidity, ash and protein levels after shelling

Conclusion

Laboratory experiments on the mechanical shelling and processing of *Souna* millet (*Pennisetum glaucum*) into flour and semolina made it possible to assess the influence of shelling on the microbiological and physico-chemical qualities of different millet samples and its primary products resulting from milling. The results of the analyses showed a negative effect of shelling on the physico-chemical parameters with reductions noted in fatty acidity, ash levels, protein contents and mineral content (calcium, zinc, potassium, iron, magnesium). Furthermore, a positive effect of shelling resulting in a significant reduction in the flora studied was observed on the microbiological quality of the different samples. The aerobic mesophilic flora at 30°C, yeast and moulds, thermotolerant coliforms that could be counted before treatment were reduced after shelling. Microbiological results were marked by the absence of *Salmonella*, similarly *Bacillus cereus*, *Staphylococcus aureus* and *E. coli* were not counted in any of the samples. However, good hygiene and manufacturing practices and/or a better selection of raw materials are required in processing to obtain better microbiological quality products. In perspective, studies could focus on the characterization of shelling technology and on a diagnosis of the quality of millet and its by-products sold on local markets.

Conflict of interest

The authors declare no conflict of interest.

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