Effect of processing method on physico-chemical and functional properties of two fonio (*Digitaria exilis*) landraces

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Abstract In West Africa, landraces or local varieties of fonio are processed into many products by women using small processing units and marketed locally as well as exported to Europe and the United States. The objective of this study was to evaluate the effect of processing methods, namely parboiling, precooking and roasting on the physico-chemical and functional properties of two mainly preferred fonio landraces (*Iporhouwan* and *Namba*) by consumers. Results showed that the physico-chemical characteristics and most functional properties were significantly ($P < 0.0001$) affected by the processing methods. The lowest brightness (L^*) values were obtained for parboiled fonio for the two landraces. However, parboiled fonio presented the best biochemical composition as compared to the dehusked, milled, precooked and roasted fonio samples. The protein

contents of parboiled fonio samples were 6.06 % and 7.24 % for *Iporhouwan* and *Namba* landraces respectively. The values of peak viscosity, trough viscosity, breakdown, final viscosity and setback, were significantly higher for dehusked and milled fonio than for precooked, parboiled and roasted fonio with respect to both landraces. The milled fonio showed highest peak viscosity (2,668.5 cP) which was similar for the both tested landraces.

Keywords Fonio · Landrace · Physico-chemical characteristics · Functional properties · Processing

Introduction

Cereals are raw materials used in the processing of most foods and play an important role in the world economy. Fonio is a cereal which belongs to the Poaceae family, Panicoideae sub-family and the *Digitaria* genus (Adoukonou-Sagbadja et al. 2006, 2007) and it provides a diversity of landraces. *Digitaria exilis* specie is the most grown fonio variety in West Africa, mainly in Guinea, Burkina Faso, Mali, Nigeria, Benin and Senegal, and it is processed for consumption. Fonio, despite its cultural, nutritional and economic importance has occupied a marginal position among cereals because basic processing operations such as dehusking and milling are particularly difficult. Indeed, fonio grain is surrounded by an outer protective covering or husk like rice.

Dehusking and milling is traditionally carried out with a pestle and mortar in an inefficient manner that involved the addition of sand to aid the process with negative consequences for the eventual quality. In order to meet the demands of urban consumers, small processing units are being used to produce a cleaner product for sale in urban markets (Cruz 2004). As a

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result, several fonio-based products mainly the dehusked, milled, precooked, parboiled and roasted fonio are on sale in urban markets in Africa and are even exported overseas. In 2006, Mali exported between 250 tons and 300 tons of fonio to Europe, 80 % of which was precooked fonio (Cruz et al. 2011). Roasted fonio was very scarce while parboiled fonio almost disappeared because it is not appreciated by the consumers. However, the physico-chemical and functional characteristics of processed fonio products are not well known.

Fonio-based products contain nutrients in variable amounts which can be affected by the processing. Therefore, knowledge of the composition of a food is necessary in order to determine the extent of any change in the concentration of the nutrients (Gupta et al. 2003). The methods used during the fonio grain processing were generally mechanical (dehusking, milling) and thermal (precooking, parboiling, and roasting). Fliedel et al. (2004) reported a marked change in nutrient content after the milling of dehusked fonio grains. Parboiling is a process which involves heating of grains in their hull (paddy) in contrast to precooking and roasting which involves heating on dehusking or milling grains. After the parboiling process, the fonio grains are dried and dehusked to remove the first husk and sometimes milling to remove the bran (pericarp and germ) from whole grains. Precooking and parboiling are hydrothermal processing methods. Unlike fonio grains, the effects of thermal treatment on physico-chemical and functional characteristics of other cereals such as rice grains are well studied (Ramesh et al. 2000; Bello et al. 2004; Lamberts et al. 2006a, b; Sareepuang et al. 2008; Mohoric et al. 2009). Changing in physico-chemical and functional properties of the grains varied according to botanical origin and thermal treatment used. Jideani et al. (1994) reported that heating dehusked grain flour at 100–140 °C for 10–40 min resulted in 0–30 % and 45–55 % decreases in fonio and wheat protein solubility, respectively.

Information on characterization of fonio-based food products and the effect of processing on the nutrient composition of fonio grains is still limited. The objective of this study was therefore to evaluate the impact of thermal treatment during the production of parboiled, precooked and roasted fonio on the physico-chemical and functional characteristics of two fonio landraces usually used for processing.

Material and methods

Experimental design

In this study, grains from two fonio landraces (*Iporhouwan* and *Namba*) were considered and each of them subjected to different processing methods: parboiling, precooking and roasting. Two factors (landraces and processing methods) were

thus analyzed in the study. Each combination of landrace and processing methods were replicated three times. The two fonio landraces samples were collected from Boukoumbé (Lat. °N: 8°30' to 11°30', Long. °E: 0°45' to 2°10') municipality in northwest of Benin, West Africa. These fonio landraces were chosen because they were the most preferred by the local women for processing.

Processing methods

Fonio paddy grains were initially cleaned to remove dust and sand particles. The samples were then subjected to three processing methods, parboiling, precooking and roasting. Parboiling was carried out on raw grains (fonio paddy) while samples for precooking and roasting were first dehusked and milled before processing. After processing, all samples were kept in sealed containers at 4 °C.

Parboiling

Fonio paddy grains were soaked in water at 65 °C for between 28 and 32 min for the moisture content of the grains to reach 32–34 % (Cruz et al. 2009, 2011). The paddy grains were drained and steamed for 22 to 33 min according to landrace. Parboiled fonio paddy was dried in the sun under ambient conditions for two days and dehusked with a GMBF huller (Engelberg type, Bamako, Mali). The dehusked grains were washed to remove the dust particles before drying again at room temperature.

Precooking

Fonio paddy grains were dehusked and milled using a GMBF huller, then washed to remove dust and sand particles according to the method described by Rivier and Cruz (2007). After draining, milled grains were steam-cooked for 30 to 48 min. The precooked grains were then sun dried.

Roasting

Milled fonio grains in a GMBF huller were washed to remove dust and sand particles before drying in the sun under ambient conditions. Dried grains are roasted in pot about 300 °C for 30 to 35 min, cooled at room temperature and stored.

Analytical methods

Analyses were performed on parboiled, precooked and roasted fonio as well as on intermediate products (dehusked and milled grains). The samples were ground in a Retsch mill (type ZM 1, Retsch, Haan, Germany) fitted with a 0.5 mm screen and stored at 4 °C until required for analysis.

Biochemical analyses

AACC (1984) methods were used to determine moisture, crude protein ($N \times 6.25$), total ash, crude fat and crude fibre contents. Carbohydrate content was estimated as nitrogen-free extract (NFE) and calculated by difference. Measurements were performed in triplicate and results expressed on dry matter basis.

Iron determination

Approximately 0.5 g of the samples previously mineralized to obtain ash was added to 100 ml of distilled water and homogenized. About 5 ml of this solution were put into a test tube and three drops of reagent Fe-1 (Spectroquant test kits, Merck KGaA, 64271 Darmstadt, Germany) were added and mixed. After incubation for 3 min, Fe concentration was measured using a spectrophotometer (HACH LANGE, DR 5000). Measurements were performed in triplicate.

Zinc determination

Approximately 0.5 g of the samples previously mineralized was added to 100 ml of distilled water and homogenized. 5 ml of this solution was put into a test tube and the reagents of Zn-1, Zn-2, Zn-3, Zn-4 and Zn-5 (Spectroquant test kits, Merck KGaA, 64271 Darmstadt, Germany) were added and mixed respectively. After incubation for 3 min, Zn concentration was measured using a spectrophotometer (HACH LANGE, DR 5000). Measurements were performed in triplicate.

Physical analyses

Colour measurement

Colour of the fonio samples was measured with a Minolta CR-400 Chroma Meter (Konica Minolta Sensing, Inc., Osaka, Japan) standardized with a standard white tile ($Y=88.7$, $x=0.3181$ and $y=0.3353$). The L^* , a^* , b^* values of the colour scales were recorded. L^* expressed the whiteness of the sample with 100 as perfect white and 0 as black. Values of a^* and b^* indicated the red-green and yellow-blue chromaticity, respectively with 0 as gray. Positive a^* and b^* expressed the increased redness and yellowness, respectively.

Particle size distribution

Particle size determination of the fonio samples were performed in a Retsch sieve shaker (AS 200 digit, Haan, Germany). The sieve shaker was fitted with 710 μm , 1,000 μm , 1,250 μm , 2,000 μm and 3,150 μm mesh sizes and agitated for 20 min. The material retained by each sieve was weighed and the percentage of each fraction calculated.

Functional properties

Water absorption capacity

Hydration capacity of the samples was determined according to AACC method 56-20.01. Approximately 2 g flour of each sample were suspended in 40 ml of distilled water, hydrated for 10 min and centrifuged at $1,000 \times$ gravity for 15 min at room temperature. The supernatant was discarded and the residue was weighed. Hydration capacity was calculated and expressed as g water absorbed per g sample.

Swelling power

Swelling power was determined on the different samples according to the method of Flidel et al. (2004). This is the quantity of water absorbed by the grains during steam-cooking. Approximately 60 g of fonio grains were soaked in 18 ml of distilled water and left to stand for about 10 min. The grains were then steamed-cooked in three stages for periods of 10, 12 and 10 min respectively. The steam-cooking was carried out in a steam chamber containing 1.5 l of distilled water placed on a hotplate at 300 °C. Between the steam-cooking stages, the fonio grains were disintegrated and rehydrated with 18 ml of distilled water.

To determine the swelling power of the steamed grains, approximately 3 g of sample was dried in an oven at 100 °C for 24 h. Fonio swelling power was expressed on dry matter basis. Measurements were performed in triplicate.

Pasting properties

The pasting characteristics of the samples were determined using a rapid viscoanalyzer (RVA; Series 4, Newport Scientific Ltd., Sydney, Australia). The values recorded were peak viscosity, trough viscosity, final viscosity, breakdown, setback, pasting temperature and pasting time. The viscosity analysis was done in duplicate.

Statistical analysis

To investigate the variation of each physico-chemical parameter according to landraces and processing methods, a univariate analysis of variance (ANOVA) using the Generalized Linear Model (GLM) procedure of SAS 9 with two factors was conducted. In the model, “landraces” and “processing methods” were considered as fixed with two (*Iporhouwan* and *Namba*) and five (Dehusking, milling, precooking, parboiling and roasting) levels respectively. The interaction of the two factors was also tested. When the interaction was significant, a one-way analysis of variance (processing method as factor) was performed to test the effect of the processing for each landrace on its physico-chemical parameter. Finally, in the

case of significant difference between processing methods, the Student-Newman and Keuls test was applied to separate means. The hypotheses of the tests (normality and homoscedasticity) were checked before. This was done using the Normality test of Ryan and Joiner (1976) and the homoscedasticity test of Levene (1960) respectively.

Results and discussion

Physical characteristics of processed fonio grains

Table 1 shows some physical characteristics (colour and particle size distribution) of the processed (precooked, parboiled and roasted) fonio as well as of their intermediate products (dehusked and milled) grains for the two landraces (*Iporhouwan* and *Namba*) used in this study.

Colour is often regarded as an important criterion of sensory quality, as it is the first parameter that the consumer uses to evaluate a food. It is the first indicator of fonio grain quality (Dury et al. 2007). The colour attributes (L^* , a^* and b^*) of the landraces were significantly different ($P < 0.0001$) from each other. The L^* (brightness or whiteness) values of the *Iporhouwan* landrace grains after dehusking and milling were higher than those of *Namba*. The different treatments also significantly ($P < 0.0001$) affected the colour of fonio grains for two landraces. The L^* values of dehusked fonio (13.78 and 11.05 for *Iporhouwan* and *Namba* respectively) were lower than those obtained for milled fonio (14.77 and 14.07 for *Iporhouwan* and *Namba* respectively). This has resonance with the statement by Lamberts and Delcour (2008) that the brightness (L^*) increased, and redness (a^*) and yellowness (b^*) decreased according to the degree of milling of other cereals such as rice grains because the concentrations of color-

determining components of dehusked rice decreased from the surface to the outer endosperm fractions. Thermal treatments applied to milled fonio during precooking and roasting modified significantly ($P \leq 0.05$) the colour parameters for *Iporhouwan* and *Namba* landraces. The L^* values of pre-cooked and roasted samples decreased as compared to the results of milled fonio while a^* and b^* values increased. The lowest brightness values were obtained with parboiling fonio, a process which involved steaming the paddy fonio before dehusking. The effect of parboiling on the colour parameters of rice has been reported by several authors (Kimura et al. 1993; Bhattacharya 1996; Lamberts et al. 2006a, b; Lamberts and Delcour 2008). Similarly, the decreased brightness and increased red and yellow colour intensities of parboiled of cereal grains are ascribed to Maillard reactions and/or physicochemical changes of different grain components occurring during parboiling (Lamberts and Delcour 2008).

Particle size distribution was significantly ($P < 0.0001$) influenced by both landrace and processing method. The grains of dehusked, milled, parboiled and roasted fonio showed higher percentage of particles with sizes smaller than 710 μm (Table 1). Similar results were reported by Jideani and Akingbala (1993) on fonio grains obtained from Nigeria which had diameters slightly greater than 710 μm . Milling reduced the grain size and the percentage of milled grains (85.82 % and 88.43 % for *Iporhouwan* and *Namba* respectively) retained on the 710 μm sieve was significantly lower than that of dehusked fonio (93.75 % and 92.69 % for *Iporhouwan* and *Namba* respectively). On the other hand, the precooking process increased particle size of milled fonio grains because during precooking, the grains stuck together. Only 32.34 % (*Iporhouwan*) and 29.37 % (*Namba*) of the precooked fonio grains were retained on the 710 μm sieve while the highest percentage was retained on the 1,250 μm sieve.

Table 1 Physical characteristics of the dehusked, milled, precooked, parboiled and roasted fonio obtained from *Iporhouwan* and *Namba* landraces

Landraces	Products	Colour			Granulometry (%)					
		L^*	a^*	b^*	3,150 μm	2,000 μm	1,250 μm	1,000 μm	710 μm	<710 μm
<i>Iporhouwan</i> (I)	(I) dehusked	13.78b	0.19c	3.29e	nd	nd	0.05c	0.27c	93.75a	5.92d
	(I) milled	14.77a	-0.09e	3.36d	nd	nd	0.02d	0.28c	85.82d	13.29a
	(I) precooked	10.77d	0.01d	3.83b	1.19a	10.30a	37.25a	16.98a	32.34e	1.92e
	(I) roasted	12.19c	0.61a	4.27a	nd	nd	0.06c	0.07d	88.17c	6.82c
	(I) parboiling	7.26e	0.57b	3.69c	nd	nd	0.34b	1.39b	89.61b	8.6b
<i>Namba</i> (N)	(N) dehusked	11.05d	0.38b	3.31d	nd	nd	nd	0.31bc	92.69b	6.81c
	(N) milled	14.07a	-0.06e	3.45c	nd	nd	0.02d	0.12c	88.43c	11.18b
	(N) precooked	11.79c	0.04d	4.13a	1.01a	15.68a	38.03a	13.89a	29.37d	1.96e
	(N) roasted	12.57b	0.30c	4.11a	nd	nd	0.06c	0.11c	88.20c	11.61a
	(N) parboiling	6.66e	0.51a	3.62b	nd	nd	0.09b	0.37b	93.79a	5.66d

Mean values of three replicates ($n = 3$) followed by the same letters within the same column for the same landrace are not significantly different ($P \leq 0.05$)

nd not determined

Chemical characteristics of processed fonio grains

The chemical properties of the processed fonio grains are presented in Table 2. The moisture, fibre, ash, lipid, protein, carbohydrate, Fe and Zn contents were determined on the different products.

Moisture contents of the processed fonio samples were significantly different for the two landraces. The lowest moisture contents were obtained with roasted fonio (2.32 % for *Iporhouwan* and 2.33 % for *Namba*) as against the highest milled fonio (13.96 % for *Iporhouwan* and 12.56 % for *Namba*) respectively. The moisture contents of the products were significantly affected by different treatments applied as well as by drying conditions. It is important to store grains with a sufficiently low initial moisture content to prevent mold development and biochemical changes (Richard-Molard and Wrigley 2004). As shown in Table 2, carbohydrates represented the major constituent of fonio grains. The carbohydrate contents of dehusked fonio (91.68 % for *Iporhouwan* and 89.98 % for *Namba*) and milled fonio (93.35 % for *Iporhouwan* and 91.36 % for *Namba*) were higher than results reported in the literature (Temple and Bassa 1991; Jideani and Akingbala 1993; Irving and Jideani 1997; Fliedel et al. 2004; Cruz et al. 2011). The carbohydrate contents of milled samples were higher than the dehusked fonio samples for both landraces. Similar results were obtained on fonio grains by Fliedel et al. (2004). Also, the carbohydrate contents of precooked fonio were higher than that of roasted fonio for both landraces. Protein contents of fonio grains also varied significantly ($P < 0.0001$) according to landrace and product. *Namba* landrace had a higher protein content compared to *Iporhouwan*. The parboiled fonio grains (6.06 % and 7.24 % for *Iporhouwan* and *Namba* respectively) had the highest protein contents followed by dehusked fonio (5.8 % and 7.04 % for *Iporhouwan* and *Namba* respectively) for both landraces. As reported in the literature, during the parboiling process of cereals grains, the

protein molecules are separated and sunk into the compact mass of gelatinized starch, becoming less liable to extraction by mechanical and thermal process (Luh 2001). The protein contents of dehusked fonio decreased significantly ($p \leq 5$ %) after milling. The bran (pericarp and germ) removed during milling is rich in lipid bodies, protein bodies and mineral substances (Juliano 2004). Effect of milling on the nutrient losses such as protein, lipid and mineral elements (iron and zinc) has been reported for fonio (Fliedel et al. 2004; Cruz et al. 2011) and millet (Lestienne et al. 2007) grains. Lipid, fibre and ash contents were very low in fonio grains and significantly ($P < 0.0001$) affected by processing method. The lowest and highest lipid contents were obtained for the precooked fonio and roasted fonio samples respectively for both landraces. The lipid contents of precooked fonio were 0.35 % for *Iporhouwan* and 0.37 % for *Namba* while those of roasted fonio were 1.11 % and 1.97 % respectively for *Iporhouwan* and *Namba*. Therefore, the steaming of milled fonio considerably reduced the lipid content of grains while the roasting increased it. Parboiled fonio had the highest fibre (0.64 % for *Iporhouwan* and 0.67 % for *Namba*) and ash (1 % for *Iporhouwan* and 1.14 % for *Namba*) contents. Among the micronutrient malnutrition situations afflicting human population, iron (Fe) and zinc (Zn) deficiencies are of major concern not only because of the serious health consequences they may cause but also because of the number of people affected worldwide (Frossard et al. 2000; McCall et al. 2000). The highest Fe and Zn contents were obtained with parboiled and dehusked fonio for *Iporhouwan* and *Namba* landraces. Parboiled fonio had a better nutritional composition in comparison to dehusked, milled, precooked and roasted fonio samples. It has been widely reported that the parboiling process improved the nutritional quality of cereal grains especially rice and reduces nutrient losses (Juliano and Hicks 1996; Bhattacharya 2004; Carpenter 2004; Corke 2004; Juliano 2004). However, some consumers do not prefer parboiled

Table 2 Chemical characteristics of the dehusked, milled, precooked, parboiled and roasted fonio obtained from *Iporhouwan* and *Namba* landraces

Landraces	Products	Moisture (%)	Total carbohydrate (%)	Crude protein (%)	Crude lipid (%)	Crude fibre (%)	Total ash (%)	Fe (mg / g)	Zn (mg / g)
<i>Iporhouwan</i> (I)	(I) dehusked	9.29c	91.68c	5.80b	1.29a	0.57ab	0.68b	0.16b	0.17b
	(I) milled	13.96a	93.35a	4.85c	0.91b	0.50abc	0.40c	0.07d	0.12b
	(I) precooked	9.57b	93.28a	5.52b	0.35c	0.37c	0.49bc	0.05e	0.11b
	(I) roasted	2.32e	92.46b	5.63b	1.11ab	0.46bc	0.35c	0.11c	0.08b
	(I) parboiling	5.37d	91.42c	6.06a	0.89b	0.64a	1.00a	0.29a	0.34a
<i>Namba</i> (N)	(N) dehusked	10.17b	89.98d	7.04a	1.35c	0.63a	1.01a	0.35a	0.42a
	(N) milled	12.56a	91.36c	6.21b	1.13d	0.67a	0.64b	0.12d	0.11c
	(N) precooked	7.08c	92.75a	5.97c	0.37e	0.34b	0.58b	0.05e	0.07d
	(N) roasted	2.33e	91.83b	5.63d	1.97a	0.15c	0.43c	0.14c	0.05e
	(N) parboiling	5.15d	89.51e	7.24a	1.45b	0.67a	1.14a	0.23b	0.21b

Mean values of three replicates ($n=3$) followed by the same letters within the same column for the same landrace are not significantly different ($P \leq 0.05$)

Table 3 Functional characteristics of the dehusked, milled, precooked, parboiled and roasted fonio obtained from *Iporhouwan* and *Namba* landraces

Landraces	Products	Swelling power (%)	Water Retention Capacity (g / g)	Peak (cP)	Trough viscosity (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Pasting time (min)	Pasting temperature (°C)
<i>Iporhouwan</i> (I)	(I) dehusked	72.35a	2.51b	2580b	1350.5a	1229.5a	3156a	576a	5.14b	77.28a
	(I) milled	69.54a	2.53b	2668.5a	1369.5a	1299a	3186.5a	518a	5.13b	78.05a
	(I) precooked	67.98a	3.82a	176.5d	176.5c	nd	231c	54.5b	7a	nd
	(I) roasted	66.50a	2.85b	360c	309.5b	50.5b	511b	151b	5.3b	nd
	(I) parboiling	72.18a	3.65a	144e	145.5d	−1.5b	189c	45b	7a	nd
<i>Namba</i> (N)	(N) dehusked	78.83a	2.68d	2548.5a	1527.5a	1021a	3943.5a	1395a	5.44b	79.23c
	(N) milled	77.16a	2.63d	2668.5a	1591.5a	1077a	3711b	1042.5b	5.27b	79.95b
	(N) precooked	73.54a	4.49a	182c	182.5c	−0.5c	240.5d	58.5d	7a	nd
	(N) roasted	74.45a	2.78c	745b	606b	139b	1039c	294c	5.37b	87.13a
	(N) parboiling	70.09a	3.34b	199.5c	201.5c	−2c	252d	52.5d	7a	nd

Mean values of three replicates ($n=3$) followed by the same letters within the same column for the same landrace are not significantly different ($P\leq 0.05$)
 nd not determined

grains of rice and fonio because of the resultant change in grain colour. Juliano and Hicks (1996) reported that parboiled rice is most often used in the industrial and food service markets because of its easy preparation, durability, and stability to overcooking and it was also used in canned and frozen foods, like soups, puddings, and dinners.

Functional properties of processed fonio grains

Swelling power, Water Retention Capacity (WRC) and pasting properties listed in Table 3 were the functional properties determined for the processed fonio grains from *Iporhouwan* and *Namba* landraces.

The swelling power of the different products was significantly ($P=0.0063$) influenced by landrace as against processing methods where the effects were not significantly different ($P=0.1264$). The lowest and highest swelling power was obtained for roasted (66.5 %) and dehusked grains (72.35 %)

respectively for *Iporhouwan* landrace. With respect to *Namba* landrace, swelling power ranged from 78.83 % for dehusked grains to 70.09 % for parboiled grains (Table 3). This table further shows that the grains treated by the heat (precooked, parboiled and roasted fonio) had water retention capacities significantly higher than those treated mechanically (dehusked and milled fonio) for the two landraces. Moreover, the water retention capacities of precooked and parboiled fonio (gelatinized starch by cooked with steam) were higher than those of roasted fonio (dextrinisation of the starch). Majzoobi et al. (2011) reported higher water absorption capacities for pregelatinized starches in comparison to native starches. According to these authors, this observation can be attributed to the destruction of starch granules, reduction of the degree of crystallinity, and degradation of starch molecules during pre-gelatinization. The porous structure of pregelatinized starch can readily absorb more water compared to the native starch. One of the most important industrial measures of starch properties involves the use of the

Fig. 1 Viscosity curves of dehusked, milled, precooked, parboiled and roasted fonio obtained from *Iporhouwan* and *Namba* landraces

Rapid Viscoanalyzer (RVA) to determine the starch's thermal behavior (Jackson 2003). The peak viscosity, trough viscosity, breakdown, final viscosity and setback values reported for the different fonio samples were significantly affected by both landrace and processing method, although the interaction between these two factors was not significant ($P=0.0678$). The values of these different viscosity parameters were significantly higher for dehusked and milled fonio than for precooked, parboiled and roasted samples for *Iporhouwan* and *Namba* landraces. Peak viscosities drastically decreased with heat treatment. The highest Peak viscosity (2,668.5 cP for *Iporhouwan* and *Namba*) was obtained with milled fonio for two landraces (Fig. 1) while the lowest peak viscosities were reported for parboiled fonio (144 cP) for *Iporhouwan* and precooked fonio (182 cP) for *Namba*. Among the heat-treated samples, roasted fonio had the highest peak viscosity, trough viscosity, breakdown, final viscosity and setback for two landraces in contrast to the observation made for water retention capacity. The results showed that *Iporhouwan* landrace was more affected by the roasting process than *Namba*. This may be due to a varietal property. The precooked and parboiled fonio had the highest pasting times (7 min) which were similar both for the both landraces. Pregelatinization of fonio starch increased its pasting time. Milled fonio had the lowest pasting times (5.13 min and 5.27 min for *Iporhouwan* and *Namba*, respectively). The pasting time of fonio grains reported by Jideani et al. (1996) was significantly higher than that obtained in this study for dehusked and milled fonio of the two tested landraces. Pasting temperatures were not detected by the RVA for the precooked and parboiled fonio of both landraces (Table 3).

Conclusion

The different methods of fonio processing, mainly precooking, parboiling and roasting, had significant effects on physical, biochemical and functional characteristics of the two landraces studied. Parboiled fonio had the highest protein, fibre, ash, iron and zinc contents for *Iporhouwan* and *Namba* landraces, although the resultant dark colour is not popular with local fonio consumers who prefer well milled fonio grains i.e. of whitish colour. However, our results showed that nutrient contents of dehusked fonio decreased significantly after milling. Therefore, a compromise should be established between local consumer satisfaction and nutritional quality of fonio-based products in Benin.

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