African Journal of Biotechnology Vol. 12(15), pp. 1836-1844, 10 April, 2013
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.765
ISSN 1684–5315 ©2013 Academic Journals

*Full Length Research Paper*

# Sensory diversity of fonio landraces from West Africa

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Accepted 24 August, 2011

**This study aims to establish if there is some sensory variability among fonio landraces. Fonio, the oldest indigenous and very tasty cereal growing in West Africa, is usually consumed as a couscous. Group interviews of consumers were conducted in Bamako, Mali to identify the main quality criteria of a cooked grain. Fonio grain must be swollen, not sticky with a soft consistency, pale and containing low impurities. Sensory properties of 20 fonio landraces from Mali, Guinea and Burkina Faso were established using a descriptive sensory analysis. Five sensory descriptors were chosen among the quality criteria. Each landrace was tasted and scored in triplicate by a group of 18 trained panellists. Principal component analysis and hierarchical cluster analysis were used. The 20 landraces clustered into four sensory classes. Sensory criteria of variability were first visual characteristics (colour and impurities) and then the consistency of cooked grains. Landraces from Guinea and Mali were variable for both visual and textural characteristics; those from Burkina Faso appeared to be more homogenous. The sensory variability of fonio offers to processors, who intend to promote this tiny cereal both in the sub-region and beyond, the possibility to choose adapted landraces to develop new products.**

**Key words:** ***Digitaria*** *exilis*, fonio, landraces, cooked grain, sensory variability, Mali.

## INTRODUCTION

Fonio (*Digitaria exilis*), also called acha or hungry rice, is the oldest indigenous African cereal. West African populations have cultivated fonio across the dry savannas for thousands of years (National Research Council, 1996). Nowadays, fonio grows in non-wooded regions from Cape Verde to Lake Chad. Because of its short growing cycle, fonio supplies food to several millions of people during the critical period of shortage (Portères, 1976). It is grown on approximately 450,000 ha with yields of 450 to 1400 kg/ha despite the poor soils and low rainfall (FAOSTAT, 2008). The production of fonio declined sharply in the 1960s but began to recover 20 years later (Cruz, 2004). Since then, it has been increasing regularly and represents approximately 500,000 tons per year (FAO STAT, 2008).

Although, considered to be a minor species of millet, fonio is described as one of the best tasting West African cereals with high nutritional potentiality due to its particular richness in methionine and cystine (de Lumen et al., 1993). Fonio is usually consumed as a couscous, after a long and tedious process comprising dehusking, milling, washing and three steam cookings. A precooked fonio is obtained after only one steam cooking followed by drying and packaging (Fliedel et al., 2004). Fonio is also prepared using different traditional or non-traditional recipes (Jideani, 1999; Nnam and Nwokocha, 2003; Jideani et al., 2007). Knowledge of sensory variability of fonio landraces is needed for processors who develop new products and intend to promote this tiny cereal both in the sub-region and beyond to Diaspora in Europe and United States.

The sensory properties of several cereals have been widely described through quantitative descriptive analyses

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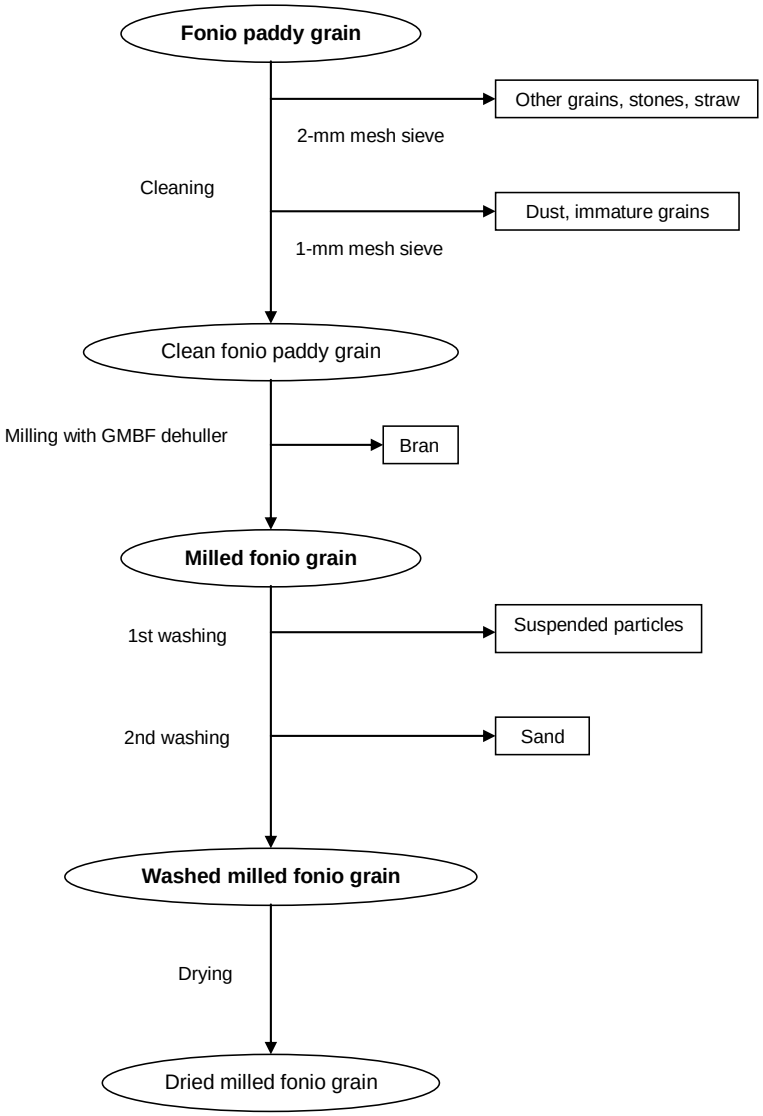


**Figure 1.** Flow chart of milling and washing of fonio paddy grains.

(Murray, 2001; Kebakile et al., 2008) or through the description of consumer preferences using hedonic tests (Linhardt et al., 2008; Toma et al., 2008). However, to our knowledge, no studies have been published on sensory analysis of cooked fonio grain comparable to those reporting on cooked rice grain (Meullenet et al., 2000; Champagne et al., 2004; Tomlins et al., 2005). Sensory studies on fonio have mainly concerned bakery products (McWatters et al., 2003; Ayo and Nkama, 2004; Jideani et al., 2008). One sensory study has concerned a traditional beverage “kunun zaki” (Ayo, 2004). The ways fonio is consumed have already been studied through several surveys conducted in the capitals of three West African countries (Guinea, Mali and Burkina Faso) (Konkobo-Yaméogo et al., 2003). In these surveys, inter-viewees were asked to prioritise criteria for the purchase of raw fonio grain. However, quality criteria concerning cooked fonio grain were not included.

The overall aim of this study was to establish the sensory variability of fonio landraces.

## MATERIALS AND METHODS

20 fonio landraces were collected from farmers in villages situated in different agroecological regions in three West African countries: 11 landraces from Mali, five from Guinea and four from Burkina Faso. All the landraces were cultivated and harvested in September 2006.

### Preparation of samples

Fonio landraces were processed in the Laboratory of Food Technology, Institute of Rural Economics (IER), Bamako, Mali (Figure 1). Paddy grain of each landrace was cleaned then milled with a GMBF

**Table 1.** Guideline for panellists on how to score cooked fonio landraces

| Criteria | Descriptor | Definition of descriptor | Protocol |
|---|---|---|---|
| Visual | Grain colour | Colour of cooked grain:<br>10: Paler grain colour<br>0: Darker grain colour | Put the white bowl containing a sample of cooked fonio on a dark support (e.g. a black mat). With a spoon, place a small quantity of product on the black mat to judge grain colour more easily if necessary, then give a sensory value (scale from 0 to 10). |
| Visual | Grain size | Size of cooked grain:<br>10: Smaller grain<br>0: Larger grain | Observe the whole sample of fonio in the white bowl, and then if necessary, place a few grains in the spoon for better assessment of grain size. |
| Visual | Grain cohesiveness | Texture of cooked grain<br>10: The grains remain separate<br>0: The grains form a compact mass | Remove some cooked fonio grains with the spoon and let them fall into the bowl. Note if the texture is light with separate grains or, on the contrary, if the grains are sticky and form a compact heavy mass. |
| In mouth | Grain consistency | Consistency of cooked grain:<br>10: Soft<br>0: Firm, stiff | Put a teaspoon of fonio into your mouth. After chewing a few times, estimate the consistency of the product, is it harder rather than softer or the reverse. If necessary, take a small quantity of product between your fingers to confirm the feeling in your mouth and give a sensory mark. |
| Visual | Presence of impurities | Presence of black foreign seeds and/or fonio paddy grains:<br>8-10: Very few impurities<br>6-8: Few impurities<br>4-6: Average number of impurities<br>2-4: Too many impurities<br>0-2: Far too many impurities | With the back of the spoon, spread a sample of fonio over the inside of the white bowl. Observe the product as a whole and estimate the quantity of impurities present (whole or paddy fonio grains and black foreign seeds). |

dehuller, an Engelberg type huller adapted for fonio (Marouze et al., 2008). It removes the husks and bran in two stages and produces grain of good technological quality (Fliedel et al., 2004). Milled fonio was washed in two steps according to traditional processing which has been standardized in the laboratory. The first step removes any remaining particles of bran and dust, and the second, particles of sand using the principle of density difference. Water was drained and the grain was dried in a Hoheheim type solar dryer until its moisture content did not exceed 10% (wet basis w.b.). The grain was stored at ambient temperature until sensory analysis.

For each sensory evaluation session, fonio grain was cooked using a standardized protocol developed for this study and based on traditional processing: 250 g of dried milled grain was cooked four times for 10 min in a traditional steam cooker containing 1.5 l of water. Before each steam cooking, the grain was rehydrated with successively 150, 180, 100 and 70 ml of water, a total of 500 ml (water/fonio ratio = 2 volume/weight).

### Survey to establish quality criteria for cooked fonio

Qualitative surveys were conducted in Bamako, Mali, prior to sensory descriptive analysis in order to improve our perception of consumer preferences and to identify quality criteria for cooked fonio. Five focus groups were organized. Each focus group contained six people recruited from one type of stakeholder: consumers of precooked fonio, consumers of traditionally milled and cooked fonio, cooks in restaurants, large-scale processors and small-scale processors, making a total of 30 stakeholders. Each interviewee was asked to answer the question: “What are the grain characteristics that make fonio good to eat”.

### Descriptive sensory analysis of fonio landraces

A group of 18 trained panellists scored the intensity value of 5 descriptors chosen among those mentioned during qualitative interviews. Four visual descriptors (colour, size, cohesiveness, and presence of impurities) and one “mouth-feel” descriptor (consistency) were used (Table 1). Each landrace was coded using three random digit numbers, then cooked and rapidly served to the panellists. Three sessions were organized per week. In each session, three landraces were tasted one by one by panellists individually. A glass of water was provided to each of them to rinse their mouth between samples. The 20 fonio landraces were tasted in triplicate. A discontinuous numerical scale from 0 to 10 was used to assess the intensity value of descriptors. Details on the definitions of descriptors, scale of intensity value, order of perception and protocol for scoring each descriptor were fixed (Table 1).

### Statistical analysis

All sensory data analyses were performed using XLSTAT Pro system software (version 2009.4.03, Addinsoft™, Paris, France). Two-way variance analysis was used to evaluate the variability among

landraces and the performance of the panel. The coefficient of reliability for each descriptor was calculated as the ratio between the mean square of the product (MSp) and the mean square error (MSe). R = 1 – MSe/MSp (Bianchi et al., 2009). Principal component analysis (PCA) was used on the least square mean values across panellists to explore the relationship between descriptors and to explore the variability of the sensory characteristics of fonio landraces (Bower, 2009). PCA was conducted using a correlation matrix (Borgognone et al., 2001). Hierarchical cluster analysis (HCA) was performed to classify fonio landraces. Cluster analysis is a classification method which forms subgroups of similar objects based on assessment of the distance between measured variables (Bower, 2009). Sample dissimilarities were calculated using the scared Euclidian distance and the Ward hierarchical method was used to form clusters (Ward, 1963). One way variance analysis was used to determine for which descriptor there were significant differences between classes. If ANOVA detected significant differences, Newman-Keuls mean multiple comparison test was performed to detect significant pairwise differences between landraces per descriptor with a confidence interval of 95%. This test was also used to determine differences between classes (Mestres et al., 2011)

## RESULTS AND DISCUSSION

### Quality criteria of cooked fonio

Results of the interviews in five separate groups showed that a good cooked fonio is swollen, not sticky, with a soft consistency, and contains no sand (for 30 stakeholders out of 30, 30/30). The grains must be smooth (28/30), individual (27/30), and not rough (25/30). Besides these textural criteria, some other criteria such as colour and flavour were mentioned. The colour of the cooked grains must be pale (20/30), with a small amount of paddy, herbs and other impurities (26/30). A sweet flavour and an indigenous flavour of cooked fonio are appreciated according to 23 and 10 stakeholders out of 30 respec-tively while a dusty and old smell must be avoided in the opinion of nine stakeholders.

The texture of cooked fonio appeared as one of the main quality criteria for Malian consumers. Studies on rice have also underlined that the most discriminatory sensory attributes were appearance and texture charac-teristics of cooked rice (Okabe, 1979; Rousset et al., 1999).

### Relevance of sensory analysis of fonio

#### *The five descriptors were relevant*

The five descriptors were not redundant. Correlations between mean panel scores for each sensory descriptor ranged from -0.5 to 0.7. No correlation close to 1.0 was found, indicating that the five descriptors were not redundant.

The descriptors discriminated the landraces efficiently. Two - way variance analysis of the overall panel data sho-wed a highly significant landrace effect for all the five descriptors.

#### *The panel was reliable and efficient*

The coefficient of reliability was above 0.80 for all descriptors. It reached 0.99 for colour and impurities. Bianchi et al. (2009) found that a coefficient of reliability above 0.75 indicated good repeatability and discrimination by the panel. The reliability of our panel was thus good for the five descriptors and very good for colour and impurities descriptors.

#### *Variability in sensory characteristics of the 20 fonio landraces*

The fonio landraces were described in average as clear (7.4) with relatively small (6.8) and individualized (6.7) grains. Their texture was described as rather soft (6.8) with few impurities (6.9) (Table 2). We demonstrated significant differences between the 20 landraces. Péazo1, Fungban, Finiba/Kassangara and Dalaman showed darker colour than all the other landraces (score of 4.9, 5.5, 6.0 and 6.3, respectively). The clearest landrace was Fonibagbè (8.8). The differences in grain size were lower and all landraces had rather small grains (score between 6.3 and 7.3). The landraces with smaller grains were Pétama, Tamabè and Tioi, the one with bigger grains was Foniba. All the landraces had a score of cohesiveness showing grains rather individualized after cooking (mean score between 6.0 for Souloukou Mania, the stickier landrace after cooking, and 7.3 for Tamabè, the landrace with better separated cooked grains). Fonibagbè had a softer consistency (8.1) than all of the other landraces. Péazo1 had the firmer cooked grain (5.9). Fonibagbè and Tamatioi grains contained very few impurities (scores of 8.5 and 8.4, respectively) while Péazo1 contained much more impurities (4.5). Colour and impurities were the descriptors which better differentiated the 20 fonio landraces. The differences between landraces for size and cohesiveness were smaller.

The two first axes (F1 and F2) in the principal component analysis (PCA) of sensory data explained 86% of the variance; the first and second axes accounting for 57 and 29%, respectively (Figure 2). Descriptors contributing mainly to axis 1 were colour, impurities, and size with respectively 31, 27 and 22% of global inertia of the axis. Axis 2 was strongly influenced by cohesiveness which contributed for 60% of variance while consistency contributed for 33%. A significant and negative correlation between panel mean scores for consistency and cohesiveness (-0.5) may explain the opposite relation between these two sensory characteristics. Most variability was located on the two axes, indicating that sensory data are rather bidimensional. Variability between the 20 fonio landraces was based mainly on one physical axis and one textural axis.

The 20 landraces were distributed over the entire sensory PCA plan (Figure 3) indicating that it is possible to find one fonio landrace with one specific sensory characteristic regarding textural or visual aspect. The right part of the projection plan (F1, F2) grouped all the fonio landraces associated with higher intensity values for the descriptors. The 20 fonio landraces were clustered in four

**Table 2.** Sensory characteristics of 20 fonio landraces from three West African countries.

| Landrace | Country | Colour | Size | Cohesiveness | Consistency | Impurities | Sensory class |
|---|---|---|---|---|---|---|---|
| Dalaman | Guinea | 6.3$^{f}$ | 6.4$^{ef}$ | 6.1$^{def}$ | 7.0$^{bcd}$ | 5.2$^{h}$ | 2 |
| Finiba | Mali | 7.9$^{c}$ | 7.0$^{abcd}$ | 6.6$^{bcde}$ | 7.3$^{bc}$ | 7.8$^{bc}$ | 3 |
| Finiba/Kassangara | Mali | 6.0$^{g}$ | 6.5$^{cdef}$ | 6.9$^{abc}$ | 6.1$^{fg}$ | 5.7$^{g}$ | 1 |
| Foniba | Burkina Faso | 7.3$^{d}$ | 6.3$^{f}$ | 6.2$^{def}$ | 6.6$^{cde}$ | 6.6$^{ef}$ | 2 |
| Fonibagbè | Guinea | 8.8$^{a}$ | 6.9$^{abcde}$ | 6.1$^{ef}$ | 8.1$^{a}$ | 8.5$^{a}$ | 3 |
| Fungban | Burkina Faso | 5.5$^{h}$ | 6.6$^{bcdef}$ | 6.8$^{abcd}$ | 6.3$^{efg}$ | 7.3$^{d}$ | 1 |
| Kassangara | Mali | 8.1$^{bc}$ | 7.1$^{abc}$ | 6.7$^{abc}$ | 7.1$^{bcd}$ | 8.2$^{ab}$ | 3 |
| Kélianingbè | Guinea | 8.3$^{bc}$ | 6.9$^{abcde}$ | 6.6$^{abcde}$ | 7.1$^{bcd}$ | 7.0$^{de}$ | 3 |
| Kökounin | Guinea | 8.1$^{bc}$ | 7.1$^{ab}$ | 7.1$^{ab}$ | 6.8$^{bcde}$ | 7.8$^{bc}$ | 4 |
| Péazo1 | Mali | 4.9$^{i}$ | 6.6$^{bcdef}$ | 6.7$^{abcde}$ | 5.9$^{g}$ | 4.5$^{i}$ | 1 |
| Péazo2 | Mali | 8.2$^{bc}$ | 6.9$^{abcdef}$ | 7.1$^{ab}$ | 6.7$^{cde}$ | 8.2$^{ab}$ | 4 |
| Pémousso | Burkina Faso | 7.4$^{d}$ | 6.5$^{def}$ | 6.4$^{cdef}$ | 7.1$^{bcd}$ | 7.1$^{de}$ | 2 |
| Pétama | Mali | 8.6$^{ab}$ | 7.3$^{a}$ | 7.2$^{ab}$ | 6.6$^{def}$ | 7.5$^{cd}$ | 4 |
| Pêyè | Mali | 7.3$^{d}$ | 6.8$^{abcdef}$ | 6.7$^{bcde}$ | 6.6$^{cde}$ | 6.7$^{ef}$ | 3 |
| Souloukou Mania | Guinea | 6.7$^{e}$ | 6.8$^{abcdef}$ | 6.0$^{f}$ | 6.8$^{bcde}$ | 5.1$^{h}$ | 2 |
| Tama | Mali | 7.2$^{d}$ | 6.5$^{def}$ | 6.6$^{bcde}$ | 7.1$^{bcd}$ | 6.3$^{f}$ | 2 |
| Tamabè | Mali | 8.3$^{bc}$ | 7.2$^{a}$ | 7.3$^{a}$ | 6.6$^{def}$ | 6.8$^{ef}$ | 4 |
| Tamatioi | Mali | 8.3$^{bc}$ | 7.0$^{abcde}$ | 6.8$^{abc}$ | 7.4$^{b}$ | 8.4$^{a}$ | 3 |
| Tioi | Mali | 7.9$^{c}$ | 7.2$^{ab}$ | 6.4$^{cdef}$ | 7.1$^{bcd}$ | 6.3$^{f}$ | 3 |
| Warr | Burkina Faso | 7.0$^{de}$ | 6.5$^{def}$ | 7.0$^{abc}$ | 6.3$^{efg}$ | 6.6$^{ef}$ | 1 |
| Mean value | | 7.4 | 6.8 | 6.7 | 6.8 | 6.9 | |
| Landrace effect | | * | * | * | * | * | |

[4] a, b, c, d, e, f in a column, means with the same letter were not significantly different at $p<0.05$ level based on Newman-Keuls test. * significant at $p > 0.05$ level in a two way variance analysis.

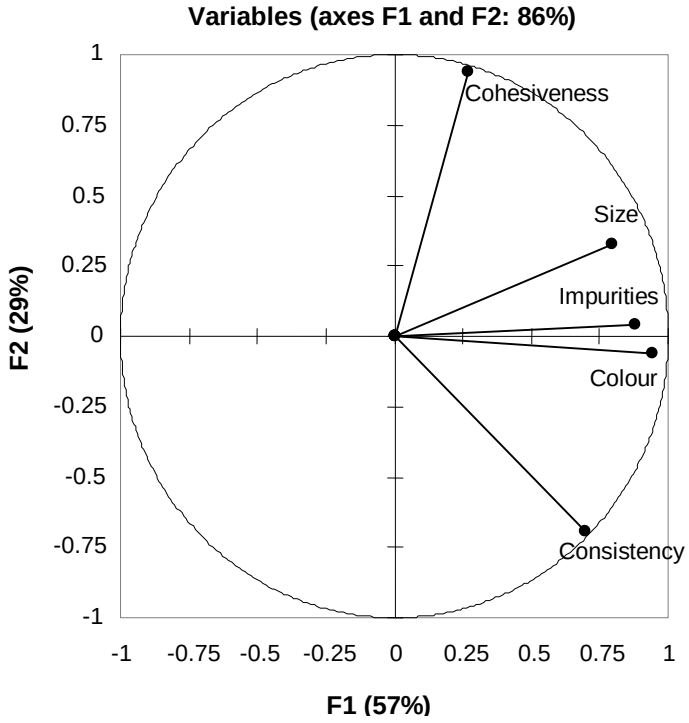


**Figure 2.** Principal component analysis (PCA) of sensory data: projection of sensory descriptors.

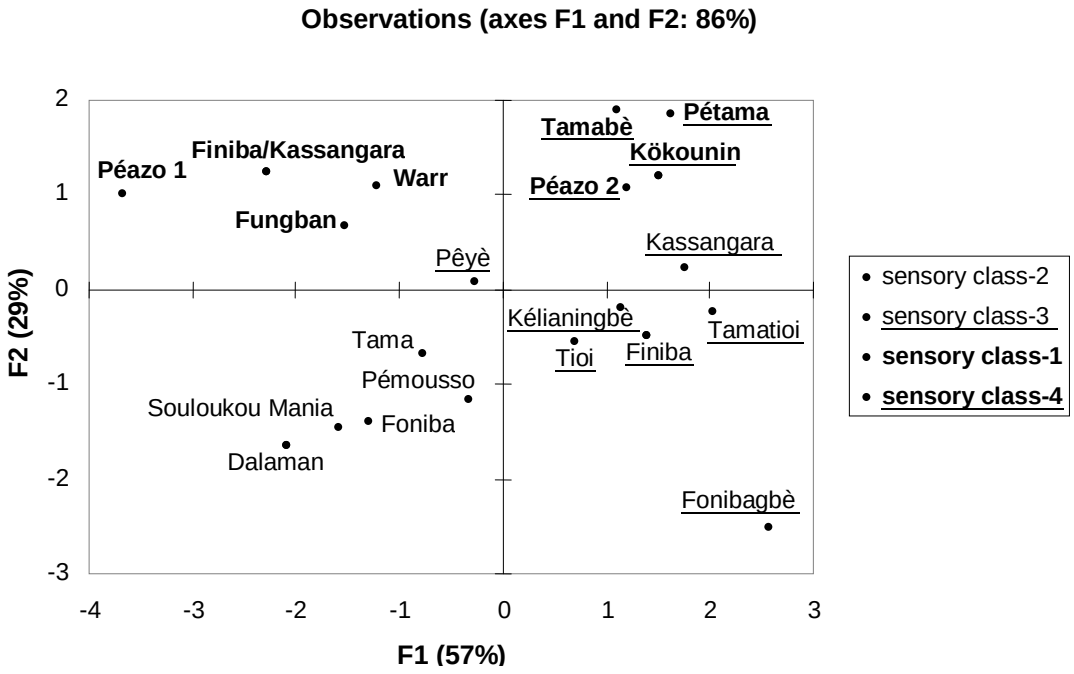


**Figure 3**. Principal component analysis (PCA) of sensory data: projection of fonio landraces.

sensory classes by hierarchical cluster analysis (Figure 4). The classes were relatively homogeneous as shown by the projection of classes on the PCA plan (F1, F2) (Figure 3). Class 1 was scored lower for visual aspect (larger grains with many impurities and darker colour) and lower for consistency (firmer cooked grains). Class 2 was scored lower for visual aspect and lower for cohesiveness (sticky grains). Class 3 was scored higher for visual aspect (smaller and paler grains containing few impurities) and higher for consistency (soft grains). Class 4 was scored higher for visual aspect and higher for cohesiveness (individualized grains).

Multiple comparison tests showed that the four landraces belonging to class 1 were scored among the lowest for all descriptors (Table 3). Five landraces belonged to class 2 and had bigger and rather stickier grains with more impurities. Seven landraces belonged to class 3 and were among those that scored higher for all descriptors, except cohesiveness for which they got a medium score. Four landraces belonged to Class 4 and were among those scored higher for all descriptors, except consistency for which they got a medium score. Classes 3 and 4 had smaller and paler grains with fewer impurities. They had softer but less separated grains or the reverse.

There were no significant differences between the 3 countries. The projection of the countries of origin on the PCA plan (F1, F2) showed that the fonio landraces on the right part of the plan came from Guinea and Mali (Figure 5). These landraces belonged to Class 3: Kélianingbè and Fonibagbè from Guinea, Tioi, Finiba, Tamatioi, Pêyè and Kassangara from Mali, and to Class 4: Tamabè, Pétama, and Péazo 2 from Mali and Kökounin from Guinea (Figure 3). Fonibagbè was separated from the others mainly because of its softer cooked grain. Pêyè had average scores for all descriptors. Landraces from Guinea and Mali were scored higher or lower and were scattered over the sensory plan. All landraces from Burkina were scored lower for visual characteristics and were grouped in the left part of the PCA plan. They appeared to be more homogeneous, even though there were only four. Our results on the sensory variability of fonio landraces from Mali, Guinea and Burkina Faso showed some similarity with results in genetic diversity (Adoukonou-Sagbadja et al., 2007). These authors analyzed 118 accessions of *Digitaria exilis* from five countries (Benin, Burkina Faso, Guinea, Mali and Togo) by amplified fragment length polymorphism (AFLP) and found that all fonio accessions of the same geographic origin clustered in one and the same group, except for the Guinean and Malian accessions, which split into two different groups. These results could explain the differen-ces of variability encountered on sensory properties of Burkinabe landraces compared to that of Malian and Guinean ones. However, the number of landraces we used to establish a sensory analysis of fonio was intentionally limited and not representative of each country. Further investigation on landraces collected from farmers in the entire growing area of each country would be necessary to conclude on the effect of geographic origin on the sensory properties of fonio. Other factors of variability should be studied such as farming methods or post-harvest treatment, as already demonstrated in rice grain

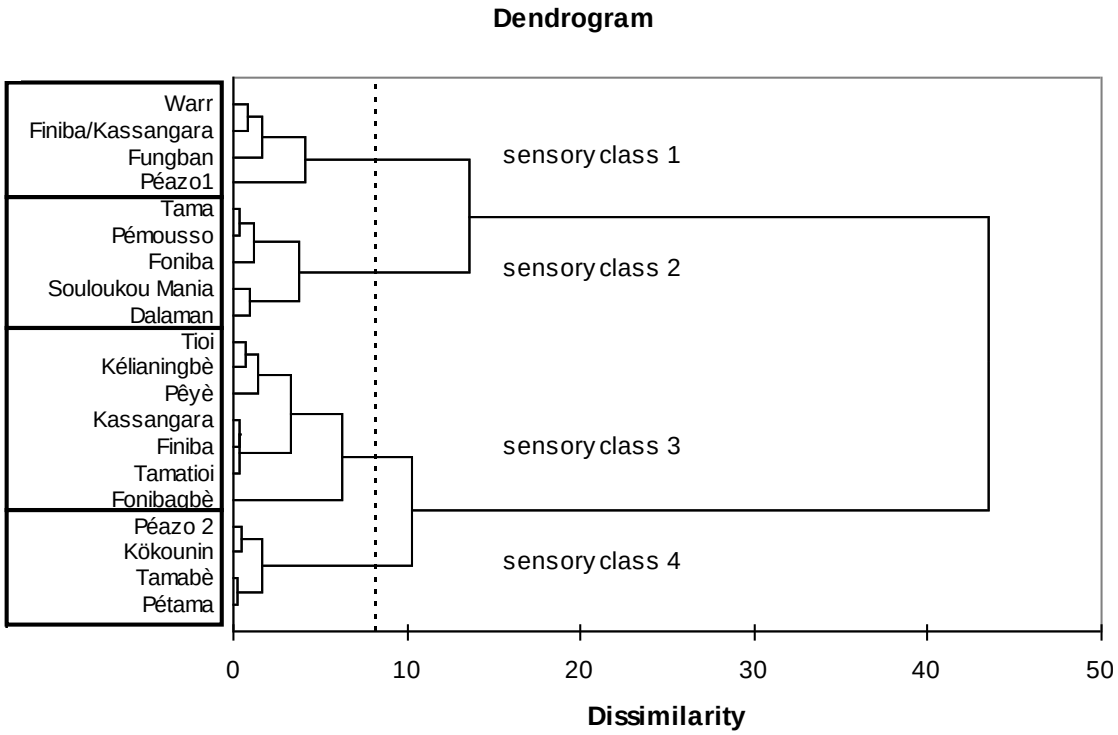


**Figure 4.** Hierarchical clustering of the 20 fonio landraces.

**Table 3.** Multiple pair-wise comparisons between landraces in sensory classes for each descriptor.

| Descriptor | Class 1 | Class 2 | Class 3 | Class 4 |
|---|---|---|---|---|
| Colour | 5.8$^{c}$ | 7.0$^{b}$ | 8.1$^{a}$ | 8.3$^{a}$ |
| Size | 6.6$^{b}$ | 6.5$^{b}$ | 7.0$^{a}$ | 7.1$^{a}$ |
| Cohesiveness | 6.8$^{b}$ | 6.3$^{c}$ | 6.6$^{b}$ | 7.2$^{a}$ |
| Consistency | 6.2$^{c}$ | 7.0$^{ab}$ | 7.3$^{a}$ | 6.7$^{b}$ |
| Impurities | 6.0$^{b}$ | 6.1$^{b}$ | 7.6$^{a}$ | 7.6$^{a}$ |

In a line, means with the same letter (a or b or c) were not significantly different at $p < 0.05$ based on Newman-Keuls test

(Meullenet et al., 2000; Champagne et al., 2004).

## Conclusions

Variability of sensory characteristics of fonio landraces was demonstrated. The first sensory criteria of variability of cooked fonio grain were the visual characteristics (mainly colour and impurities). They appeared as important criteria of selection of fonio grain to develop new products. The second criterion of sensory variability was a textural characteristic, the consistency of cooked grain. Precooked fonio should be developed from a landrace selected for its whiter and softer grains after cooking. The visual and textural variability of fonio offers to processors the possibility to choose landraces adapted to their new processes.

The variability in sensory characteristics of fonio landraces in relation to the country of origin should be confirmed. Some link between sensory variability and genetic diversity seemed possible and should be investigated. The relationship between sensory characteristics of cooked fonio grain and its chemical and physical characteristics needs to be investigated.

## ACKNOWLEDGEMENTS

The research activities presented in this paper were funded by the European INCO-DEV-2 FONIO project “Upgrading quality and competitiveness of fonio for improved livelihoods in West Africa” within the sixth framework programme FP6 of the European Commission (2006-2009). We are grateful to Sandrine Dury, UMR Moisa Cirad, for

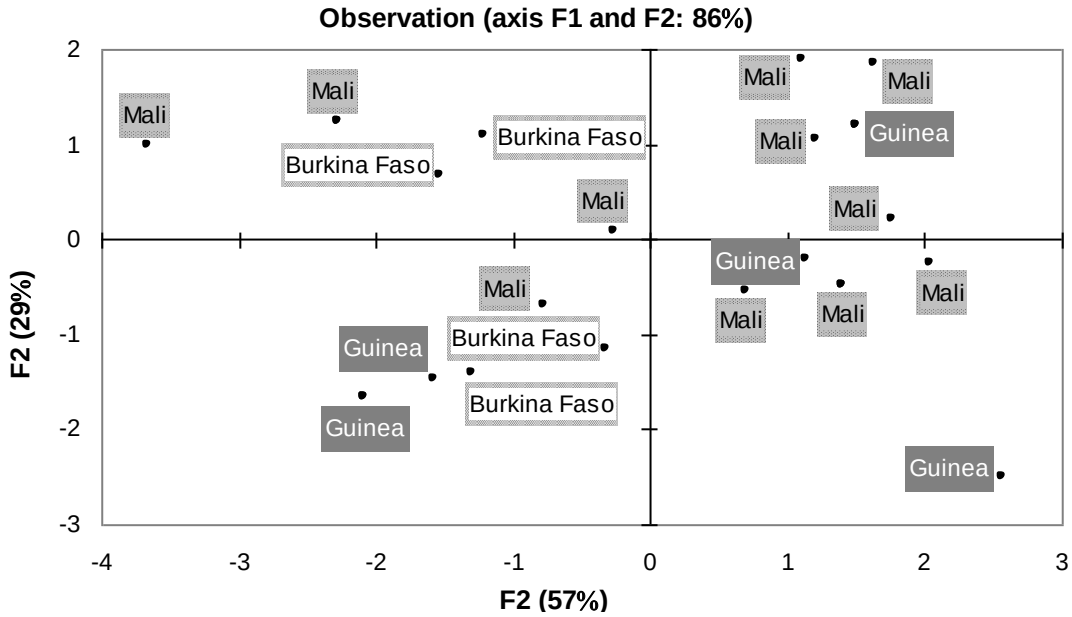


**Figure 5.** Principal component analysis (PCA) of sensory data: projection of countries of origin of fonio landraces.

her assistance in implementing the group interviews in Bamako, and Christian Mestres, UMR Qualisud Cirad, for his constructive criticism of the manuscript. We would like also to thank Sandy Blancher, student at Cirad (2006-2007), for her active participation in the group interviews, all the technicians in the Laboratory of Food Technology and all the panelists at IER, Bamako.

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