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Full Length Research Paper

Small scale production and storage quality of dry-milled degermed maize products for tropical countries

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The present study aims to propose a comprehensive appropriate technological package for small-scale processing of maize flour, which meets consumer demand for quality and achieves extended shelf life. One traditional soft cultivar was processed by the conventional method (direct grinding with disc mill) and was compared with flours obtained under various degerming and grinding intensities; two types of grinder (disc mill and hammer mill, already present on the market) were tested in parallel. Consumer satisfaction scores were registered for the different products after increasing storage duration (0 to 6 months). It was shown that combining degerming and hammer milling produce high quality flour from hard grains, which can be stored up to 6 months without significant deterioration. In parallel, physicochemical and rheological characterizations showed that the main reaction occurring during storage is lipid degradation, which slightly increased fat acidity, hence decreasing taste and elasticity acceptability of the paste.

Key words: Maize, degermination, grinding, shelf life, rancidity, pasting behaviour, sensorial analysis, taste, texture.

INTRODUCTION

In West Africa, maize is mainly used for human consumption, particularly as a thick dough prepared by boiling maize flour (Nago et al., 1997). Maize flour is generally home-made using a pestle and a mortar or a hired small motor-driven grinder. Due to time constraints for urban households, maize flour is now becoming an important ready-to-cook marketed product in many African countries. In West Africa, ready-to-cook maize flours are generally produced on a very small scale either as whole maize flour (Nago et al., 1997) or after abrasive dehulling (Somda, 1988; Ndiaye, 1995; Goïta, 1995). However, these products do not meet the consumer demand in terms of texture and taste attributes. This is due in particular to residual lipids originating from the germ, which leads to a rapid increase in fat acidity during storage of the flour, and imparting an undesirable flavour (Andah, 1976) and a dramatic change in the paste texture (Nago et al., 1997).

Recently, a cheap dry degerminator has been successfully tested for the production of long-life degermed maize flours. It enables production of maize flours with low fat content (less than 1%), and a yield of over 50% when applied to dry hard grains (Mestres et al., 2003). The flour can be stored up to 3 months without excessive fat acidity. The limitation of this technology, however, is that it can only be used for hard or semi-hard grains, whereas consumers are used to and prefer eating a thick paste prepared from soft grains (Nago et al., 1997). Hard grains are also more difficult and more expensive to convert to the very fine flour necessary for preparing the thick paste (Nago et al., 1997; Hounhouigan et al., 1999).

Based on this experience, the present study aims to propose a comprehensive appropriate technological package for processors combining a choice of maize grain types, degerminator and grinding conditions. One traditional soft cultivar wias processed by the conventionnal method (direct grinding with disc mill), and compared with flours obtained under various degerming and grinding intensities; two types of grinder (disc mill and hammer mill, already present on the market) were tested in parallel. Consumer satisfaction scores was registered for the different products after increasing storage duration (0 to 6 months). Various physicochemical and rheological characterizations were performed in parallel to monitor

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the changes occurring during storage and to help select the technological package.

MATERIALS AND METHODS

Materials

Two maize cultivars (Gnonli and Gbogboué) used in Benin were obtained from the International Institute of Tropical Agriculture (Calavi, Benin). They were winnowed and manually sorted to eliminate foreign materials and damaged grains, and then stored in hermetic containers at ambient temperature.

Maize processing

Degerming was performed using a dry degerminator from Maquina d'Andrea (Sao Paulo, Brazil). Eleven kg of maize grains were poured in the degerming chamber, which has 36 metallic blades mounted on a horizontal shaft rotating at 850 rpm. After 8, 11 or 14 min, the product was successively sieved on a perforated plate with circular apertures 6 mm in diameter and a metallic grid with 4 x 4 mm square sieve apertures (Mestres et al., 2003). Three fractions were separated (the overs - whole or broken grains, the grits and the bran meal), but only the grits fraction was collected for analysis.

The grinding was performed using a hammer mill (Songhaï, Porto Novo, Bénin) with 1 mm sieve aperture, or a disc mill (Amuda 1A, India). The material (whole grain or grits) was milled three or four times consecutively to obtain the flour. The flours were stored in closed plastic containers at ambient temperature (25-35°C) for 6 months.

Physico-chemical analyses

Particle size distribution was evaluated by sieving 30 g of flour through a 250 µm sieve on a shaking siever (Endecotts, London). Colour was measured with a chromameter (Minolta). Pasting behaviour was evaluated using a Rapid Visco Analyzer (RVA) model 3D (Newport Scientific, Narrabeen, Australia) with 12.5% slurries heated to 95°C at 6°C/min, kept at this temperature for 5 min and then cooled down to 50°C at 6°C/min (Mestres et al., 1997). Pasting temperature, viscosity at the beginning of the 95°C plateau (V95b) and at the end of the plateau (V95f) and final viscosity (Vfin) were determined. For swelling and solubility determination, 8% slurries were heated with the RVA to 95°C at the same heating rate, kept for one min at 95°C, and then were rapidly centrifuged at 5,000 g for 5 min. The supernatant and the sediment were collected and weighed fresh and after drying to calculate the swelling power and solubility (Mestres et al., 1997).

Moisture, ash and free lipid contents were determined by oven-drying for 72 h at 105°C, incineration for 24 h at 550°C, and petroleum ether extraction followed by evaporation and drying at 100°C for 30 min, respectively. Fat acidity was determined in duplicate after extraction with 95% ethanol (ISO, 1986) and expressed as mg KOH necessary to neutralise 100 g dry matter. Titratable acidity was determined by titration with 0.01 M NaOH and expressed as percentage lactic acid equivalent. Glucose content was determined by HPLC; sugars were extracted in 5 mM sulphuric acid and separated using an HPX87H column (Biorad, Hercules, USA) with 5 mM sulphuric acid. Glucose level was quantified by refractometric detection (Mestres and Rouau, 1997).

All physicochemical analyses were performed in duplicate. Mean values were calculated and reported: the coefficient of variation was between 2 and 4% for all analyses.

Sensorial analyses

Maize flours and freshly prepared thick pastes were assessed by 20 assessors, who were regular consumers of thick maize paste. During each session, five samples (flours first, then thick pastes) were evaluated. The samples were letter coded and presented on one dish for the flours and another one for the pastes. Assessors were invited to score each sample from 1 (really dislike) to 5 (really like) for four and six attributes for the flour and the paste, respectively. The attributes were chosen by the assessors after one pre-test, in which three samples were presented. They are colour, fineness, aroma and taste for the flour and colour, homogeneity, aroma, taste, firmness and cohesiveness for the paste.

The pastes were prepared just before the test in a procedure similar to the conventional one. One hundred grams of flour were dispersed in 300 ml of cold water. The dispersion was heated and boiled for 5 min. Two hundred grams of flours were then added to the thin paste, which was mixed vigorously. The obtained thick paste was allowed to cook for 11 min, and then poured out into an isothermal container until the beginning of the test.

Experimental design and statistical analysis

The experimental apparatus comprised two sets of samples. On the one hand, whole grains of both cultivars were ground using the two grinders (disc mill, DM, and hammer mill, HM), with either 3 or 4 successive passes. On the other hand, three different durations of degerming were tested with Gbogboué grains, which were HM ground with 3 or 4 passes. Each sample set was analyzed monthly and ANOVA was performed independently on both sample sets (including whole Gbogboué ground with HM for the second one, as 0 degerming point) using Statistica 7.0 (StatSoft, Tulsa, USA).

RESULTS

All the samples (8 whole maize flours, 6 degermed maize flours) were analyzed monthly for a period of 3 months, and then were partly characterized after 6 months of storage. Some interactions between the processing factors and the storage factor were in evidence, but the effect of the main factors is largely predominant for most variables. The effect of processing and storage are presented separately.

Physico-chemical characteristics of the fresh maize flours

The effect of the varietal and processing factors is similar throughout the storage period. We present the results obtained for the fresh maize flours. Proximate composition of fresh maize flour (Table 1) was not influenced by the type of grinder, nor by the number of grinder passes. Gnonli whole maize flour had a higher fat degerming dramatically decreased the level of the bran and germ related components (fat and ash), but also the titratable acidity and the glucose content. A degerming of more than 11 min leads to a flour with fat content lower than 2% (dry basis, db). Grits recovery was 53-58% based on initial grain, but the effective recovery was 68-70% considering that overs (mainly consisting of non-processed

Table 1. Chemical characterization of fresh maize flours (mean values for three and four successive grinder passes).

Variety	Grinding	Degerming	Dry Matter (% wb)	Fat (% db)	Ash (% db)	FA[1] (g KOH/ 100 g db)	TA[2] (lactic acid equiv., % db)	pH	Glucose (mg/g db)
Gnonli	Disc mill	0	87.7	4.3	1.5	28.7	0.8	6.0	12.4
	Hammer mill	0	87.7	4.4	1.5	29.7	0.9	6.0	12.9
Gbogboué	Disc mill	0	88.1	4.9	1.4	20.2	0.7	6.1	12.5
	Hammer mill	0	90.1	5.0 c	1.6 b	20.3	0.9 c	6.2	14.8 b
	Hammer mill	8	90.0	2.5 b	0.8 a	14.1	0.6 b	6.0	6.8 a
	Hammer mill	11	90.1	1.5 a	0.7 a	12.5	0.4 a	6.0	6.2 a
	Hammer mill	14	89.7	1.3 a	0.5 a	13.9	0.4 a	5.8	5.6 a
SDR[3]			0.8 0.7	0.2 0.1	0.1 0.1	3.2 3.6	0.06 0.02	0.05 0.1	1.3 1.1

[1]Fat acidity.
[2]Titratable acidity.
[3]Standard deviation of the residual from the ANOVA tests: left, with the first set of samples (effect of the cultivar, grinder type and number of passes), right, with the second set of samples (effect of the level of degerming and number of passes); different letters in the same column indicate significantly different mean values for the degerming level.

grain) can be recycled. Nor were flour physical properties (particle size and colour) influenced by the processing parameters. Surprisingly, the flour particle size did not significantly change with the type of grinder or the number of passes. In any case, Gbogboué gave whole flour with larger particle size and higher b value (yellow index, Table 2). Its particle size decreased with degerming, and intensively degermed (for 11 or 14 min) Gbogboué had a similar level of particles passing through 250 µm sieve as whole Gnonli flour.

Considering the pasting behaviour of the maize flours, it was revealed that the processing parameter significantly affected the solubility and the apparent viscosity measured with the RVA at the beginning of the 95°C plateau (V95b): solubility was higher with disc milling (35.8% as opposed to 32.1% with HM), and V95b was lower (158 RVU as opposed to 190 RVU). In addition, solubility increased with the number of grinder passes (from 32.4 for 3 passes to 35.4 for 4 passes) and V95b decreased (from 188 to 161). The pasting behaviour of Gnonli was significantly different to that of Gbogboué (Table 3): swelling power was higher whereas solubility was lower, thereby giving a paste with higher viscosity at a lower pasting temperature. The degerming of Gbogboué tended to reconcile its pasting behaviour with that of Gnonli: swelling power and solubility increased, thereby giving a degermed Gbogboué flour paste with viscosity and pasting temperature close to those of the paste obtained from whole Gnonli flour. acidity but lower fat and glucose contents. As expected,

Evolution of the physico-chemical characteristics with storage

Among the proximate characteristics, only fat acidity dramatically changed with storage. Fat acidity increased almost linearly for the whole maize flours throughout the storage time (Figure 1) yielding a value around 135 mg KOH/ 100 g (db) for both cultivars after 6 months' storage. It increased sharply during the first month of storage for the degermed flours, and then steadily but slowly increased after, yielding a value around 40 mg KOH/ 100g (db) after 3 to 6 months' storage. In parallel, a slight increase in titratable acidity was observed for Gnonli whole flour, 1.28 (% lactic acid/g db) after 3 months, as opposed to 0.83 for the fresh flour. Titratable acidity of Gbogboué whole and degermed flours did not significantly change with storage.

Swelling power, particularly of whole flours, slightly decreased with storage, whereas the solubility index did not change: swelling power of Gnonli and Gbogboué whole flours decreased from 0.82 and 0.70 to 0.76 and 0.66, respectively tively, after three months' storage. Pasting temperature steadily increased both for whole and degermed maize flours (Figure 2a). The increase

Table 2. Physical characteristics of fresh maize flours (mean values for three and four successive grinder passes).

Variety	Grinding	Degerming	Fines[1]	L*	a*	b*
Gnonli	Disc mill	0	48.4	86.6	-0.6	8.0
	Hammer mill	0	55.2	86.2	-0.7	8.3
Gbogboué	Disc mill	0	25.6	84.1	-0.4	11.7
	Hammer mill	0	24.8 a	84.8 a	-0.4 c	11.3
	Hammer mill	8	43.3 b	87.2 b	-0.9 b	11.1
	Hammer mill	11	49.9 b	88.0 b	-1.0 ab	10.9
	Hammer mill	14	53.1 b	88.1 b	-1.3 a	10.9
SDR[2]			2.8 3.4	0.42 0.42	0.1 0.1	0.3 0.3

[1]Percentage of particles passing through the 250 µm sieve.
[2]Standard deviation of the residual from the ANOVA tests: left, with the first set of samples (effect of the cultivar, grinder type and number of passes), right, with the second set of samples (effect of the level of degerming and number of passes); different letters in the same column indicate significantly different mean values for the degerming level.

Table 3. Pasting behaviour of fresh maize flours (mean values for three and four successive grinder passes).

Variety	Grinding	Degerming	Swelling power (g/g)	Solubility (% db)	Pasting temperature (°C)	V95b (RVU)	V95f (RVU)	Vfin (RVU)
Gnonli	Disc mill	0	9.4	33.8	76.4	206	153	427
	Hammer mill	0	9.4	30.9	77.3	252	196	569
Gbogboué	Disc mill	0	8.6	37.7	81.7	111	128	358
	Hammer mill	0	8.7	33.2 a	81.0 b	130 a	121 a	383
	Hammer mill	8	9.2	37.3 a	77.7 a	150 ab	162 b	385
	Hammer mill	11	9.5	36.3 a	76.1 a	173 c	183 b	431
	Hammer mill	14	9.1	44.5 b	76.1 a	159 b	180 b	409
SDR[1]			0.4 0.3	0.8 1.6	1.5 0.9	15 7	19 11	48 33

[1]Standard deviation of the residual from the ANOVA tests: left, with the first set of samples (effect of the cultivar, grinder type and number of passes), right, with the second set of samples (effect of the level of degerming and number of passes); different letters in the same column indicate significantly different mean values for the degerming level.

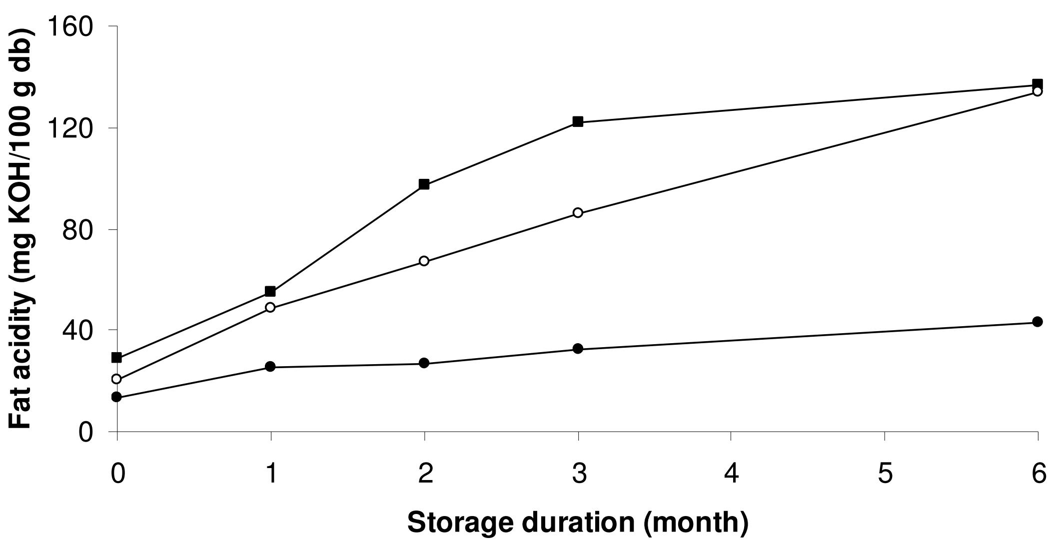

Figure 1. Evolution of fat acidity with flour storage time. (●), degermed Gbogboué; (o), whole Gbogboué; (■), whole Gnonli.

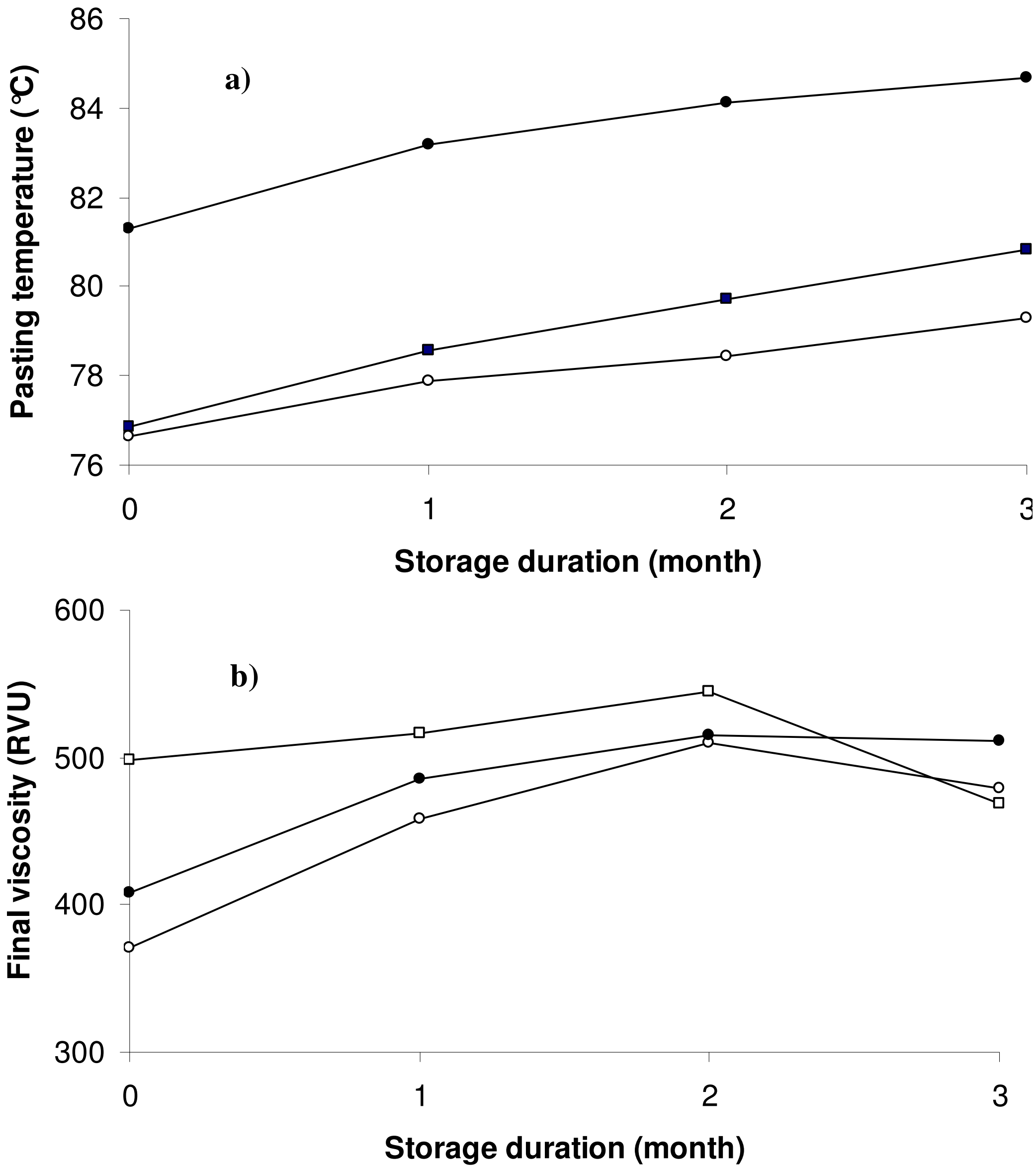

Figure 2. Evolution of pasting temperature **(a)** and final viscosity **(b)** with flour storage time. (●), degermed Gbogboué; (o), whole Gbogboué; (■), whole Gnonli.

months' storage. At the same time, the final viscosity measured with the RVA increased during the first two months' storage, and then became almost stable (Figure 2b).

Sensorial attributes of fresh maize flours and the derived paste

As for the physico-chemical characteristics, the effect of the varietal and processing factors is quite similar throughout storage period, and the results for fresh maize flours are presented. The precision of sensorial attributes was quite satisfactory, with a standard deviation of the residual ranging between 0.8 and 1.5 (Tables 4 - 5), which represented a standard deviation of the mean value for the 20 panellists of 0.18-0.34 for the various attributes. The cultivar effect was significant for three flour attributes: whole Gnonli flours were preferred by consumers (higher satisfaction scores) according to their fineness, colour and aroma.

Degerming, however, improved the scores of Gbogboué flours for colour and aroma, and intensively degermed flours were equivalent or even preferred to whole Gnonli flour. The grinding conditions (grinder type and number of passes) did not greatly affect the flour attributes; in particular, no effect of the number of grinder passes could be revealed, even on the fineness. The use

Table 4. Sensorial analysis of fresh maize flours (mean values for three and four successive grinder passes).

Variety	Grinding (min)	Degerming	Fineness	Colour	Aroma	Taste
Gnonli	Disc mill	0	3.3	3.5	3.1	2.9
	Hammer mill	0	4.0	3.5	3.3	3.2
Gbogboué	Disc mill	0	2.1	2.6	2.8	3.0
	Hammer mill	0	3.9	2.7 a	2.9 a	3.2
	Hammer mill	8	3.8	4.4 b	3.5 b	3.7
	Hammer mill	11	3.8	4.3 b	3.5 b	3.4
	Hammer mill	14	4.1	4.5 b	3.8 b	3.5
SDR[1]			1.2 0.9	1.2 0.8	1.1 1.0	1.3 0.9

[1]Standard deviation of the residual from the ANOVA tests: left, with the first set of samples (effect of the cultivar, grinder type and number of passes), right, with the second set of samples (effect of the level of degerming and number of passes); different letters in the same column indicate significantly different mean values for the degerming level.

Table 5. Sensorial analysis of fresh maize flour pastes (mean values for three and four successive grinder passes).

Variety	Grinding	Degerming (min)	Colour	Smoothness	Aroma	Taste	Cohesiveness	Firmness
Gnonli	Disc mill	0	2.7	3.1	2.4	3.2	2.9	3.1
	Hammer mill	0	3.6	3.1	3.8	3.2	2.8	3.4
Gbogboué	Disc mill	0	2.2	2.5	1.7	3.2	2.6	2.3
	Hammer mill	0	2.6 a	3.3 a	2.9 a	3.4 a	3.0 a	3.2
	Hammer mill	8	4.6 b	4.3 b	4.6 c	4.2 b	4.1 c	3.6
	Hammer mill	11	4.5 b	3.2 a	3.9 b	3.7 a	3.4 ab	3.0
	Hammer mill	14	4.6 b	3.6 a	4.3 bc	3.8 ab	3.9 bc	3.2
SDR[1]			1.4 1.0	1.4 1.3	1.2 1.0	1.3 1.3	1.5 1.4	1.5 1.5

[1]Standard deviation of the residual from the ANOVA tests: left, with the first set of samples (effect of the cultivar, grinder type and number of passes), right, with the second set of samples (effect of the level of degerming and number of passes); different letters in the same column indicate significantly different mean values for the degerming level.

of hammer mill, however, significantly improved the fineness attributes for both varieties.

Concerning the paste attributes, the cultivar effect was highly significant for colour, aroma and firmness: as expected, Gnonli was preferred for preparing a paste from whole maize flour. In addition, it gave a smoother paste than Gbogboué when the grinder was the hammer mill. The type of grinder indeed significantly affected paste quality; consumers preferred paste prepared from hammer mill flours, according to their higher scores of aroma and firmness registered for both varieties. The number of passes, however, did not show any significant effect on paste attributes. Degerming greatly improved sensorial scores; pastes prepared with degermed Gbogboué therefore had higher scores than those prepared with whole Gnonli, with the exception of firmness, which was in the same range for degermed Gbogboué and whole Gnonli. It should be observed that most degermed Gbogboué scores were near or over 4, i.e. close to the highest hedonic score (5).

Evolution of sensorial attributes with flour storage

Flour storage for 3 to 6 months did not greatly affect flour attributes. Only aroma showed a significant change with storage, decreasing by 0.3 after 3 months' storage for all flours.

On the contrary, all paste attributes (except colour) were affected by flour storage. Aroma was improved for whole flour pastes but decreased for degermed ones (Figure 3a). At the end of storage, aroma from whole maize flours was equivalent to that of degermed ones. Taste, cohesiveness and firmness all decreased with flour storage (Figure 3b, 3c), falling to a value of below 2.5 (minimum acceptable score) after 3 months' storage for whole Gnonli and Gbogboué maize pastes. Scores of degermed Gbogboué pastes, however, stabilized around 3 after 3 to 6 months' storage. Strangely, paste smoothness for whole maize flours decreased with storage: from a mean value of 3.0 for fresh flours to 2.55 after 3 months' storage.

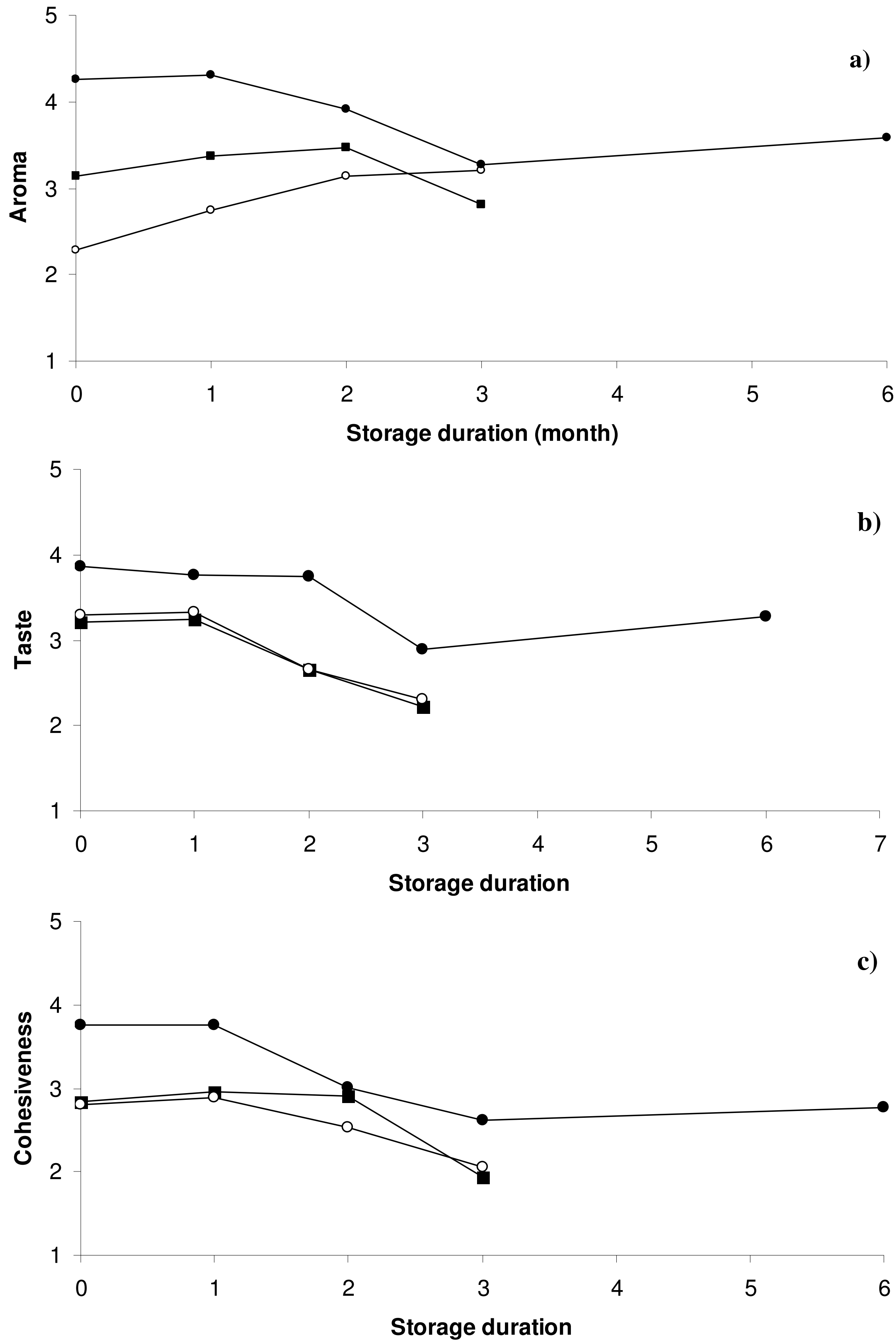

Figure 3. Evolution of paste aroma **(a)**, taste **(b)** and cohesiveness (**c**) with flour storage time. (●), degermed Gbogboué; (o), whole Gbogboué; (■), whole Gnonli.

Table 6. Correlations between sensorial attributes and the physico-chemical and pasting properties of the flours.

Parameter	Flour attributes				Paste attributes					
	Fineness	Colour	Aroma	Taste	Colour	Smoothness	Aroma	Taste	Cohesiveness	Firmness
Fat	-0.52 **	-0.79 **	-0.63 **	-0.63 **	-0.84 **	-0.64 **	-0.63 **	-0.54 **	-0.54 **	-0.37 *
Titratable acidity	-0.37 *	-0.59 **	-0.49 **	-0.63 **	-0.64 **	-0.51 **	-0.37 *	-0.61 **	-0.49 **	-0.32
pH	0.16	-0.17	-0.03	0.12	-0.13	-0.02	-0.16	0.13	0.09	0.08
Fat acidity	-0.29	-0.43 **	-0.42 *	-0.44 **	-0.49 **	-0.54 **	-0.30	-0.77 **	-0.62 **	-0.47 **
Glucose	-0.41 *	-0.71 **	-0.61 **	-0.59 **	-0.75**	-0.57 **	-0.50 **	-0.45 **	-0.42 *	-0.26
Fines (<250 µm)	0.46 **	0.67 **	0.52 **	0.41 *	0.59 **	0.39 *	0.46 **	0.28	0.30	0.23
L*	0.48 **	0.73 **	0.66 **	0.51 **	0.75 **	0.57 **	0.62 **	0.50 **	0.52 **	0.39 *
a*	-0.20	-0.44 **	-0.19	-0.30	-0.48 **	-0.42 *	-0.31	-0.21	-0.15	-0.19
b*	-0.16	-0.10	-0.32	0.07	0.02	0.05	-0.07	-0.09	-0.17	-0.08
Swelling power	0.26	0.27	0.26	-0.01	0.09	0.21	0.06	0.13	0.15	0.18
Solubility	0.09	0.48 **	0.34	0.33	0.42 *	0.30	0.31	0.33	0.35 *	0.17
Pasting temperature	-0.54 **	-0.68 **	-0.65 **	-0.35 *	-0.59 **	-0.51 **	-0.49 **	-0.54 **	-0.59 **	-0.45 **
V95b	0.60 **	0.43 **	0.48 **	0.16	0.38	0.38 *	0.38 *	0.22	0.27	0.34
V95f	0.59 **	0.63 **	0.58 **	0.41 *	0.67 **	0.54 *	0.54 **	0.31	0.33	0.34
Vfin	0.48 **	0.05	0.12	0.09	0.13	0.11	0.16	-0.14	-0.09	0.07

*Significant at 1 % level.
**Significant at 0.1 % level.

DISCUSSION

As expected, Gnonli was largely preferred to Gbogboué for the conventional products (whole maize flour and paste). Gnonli is indeed a floury and friable grain (Nago et al., 1997) compared to Gbogboué, which is a semi-vitreous and semi-friable grain, thus giving flour with lower particle size. This directly affects the sensorial fineness of the flour and the paste smoothness; consumers indeed look for very fine flour making for a smooth and cohesive paste (Hounhouigan et al., 1999). Degerming dramatically improved the sensorial scores of Gbogboué products, which can be even higher than those of Gnonli. This appears mainly due to a reduction of the flour particle size; the mechanical fragmentation occurring during degerming thus facilitates size reduction during grinding. In addition, the hammer mill appears much more efficient than the disc mill, giving flour with higher fineness and paste with higher smoothness and cohesiveness. The effect of hammer milling could not however be shown by measuring the particle passing through 250 µm sieve; the difference may be due to the distribution of finer particles, which was not measured. The correlation between flour fineness (percentage of particle passing through 250 µm sieve) and paste smoothness indeed was not very high (Table 6), but the impact of size reduction could be more clearly revealed by increase in paste viscosity (V95b and V95f). Finer flour indeed gives higher paste viscosities due to facilitated swelling for smaller particles (Mestres et al., 1997).

The number of grinder passes did not affect the flour particle size, the flour fineness or the paste smoothness. Processors in Benin, however, increase the number of grinder passes in order to reduce flour particle size, up to 6 or 7 times for hard and cohesive grains (Hounhouigan et al., 1999). It may be inferred that three passes were sufficient in our case as Gbogboué is not a hard grain but a semi-friable grain.

We observed overall deterioration of paste quality when the flour has been stored: taste and cohesiveness of whole maize flour paste fell to unacceptable levels after three months' storage (Figure 3). This was clearly correlated with the degradation of the lipids (increase of fat acidity, Table 6, Figures 4a, 4b). Lipid hydrolysis indeed leads to free fatty acids formation, which imparts a rancid, off flavour to the product (Andah, 1976). They can also form complexes with amylose, thus decreasing solubility and increasing paste viscosity (Mestres et al., 1997). The formation of complexes between amylose and free fatty acid generated during storage may also explain the decrease in swelling power, the increase in pasting temperature and the drop in paste cohesiveness. This phenomenon was much less pronounced for degermed flours; the fat acidity level of which remains quite low even after 6 months' storage, and which gives acceptable pastes even after 6 months' storage. Strangely, the aroma of whole maize flour paste increased at the beginning of storage, but slightly decreased for degermed flours; the aroma score of degermed flour, however, remains higher than that of whole flours.

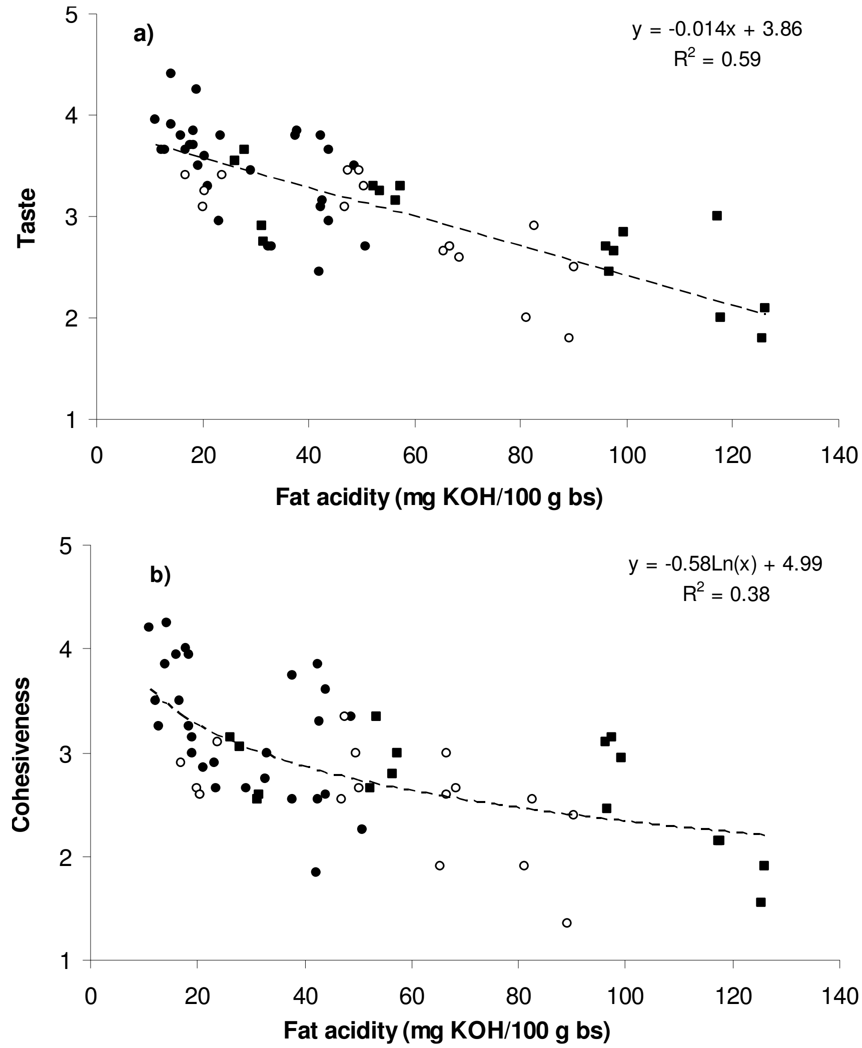

Figure 4. Relationship between fat acidity of the flour and taste **(a)** or paste cohesiveness **(b)**. (●), degermed Gbogboué; (o), whole Gbogboué; (■), whole Gnonli.

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