Characterization of the Beninese traditional ogi, a fermented maize slurry: physicochemical and microbiological aspects

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Summary Sixteen commercial samples of ogi, obtained by using traditional 'Goun' methodology, from Cotonou and the surrounding area were characterized and compared with maize raw material. Goun methodology uses floury/friable grains and gives a high yield (84% db) of a very white (L^* value close to 83) and fine (median particle size about 40 μm) slurry. The yield of Beninese ogi, its final water content (58%) and acidity after 3 days of fermentation were slightly higher than for ogi produced using the Nigerian or Ghanaian technology. About 40% of total proteins were lost during the manufacture of ogi, but the digestibility of the residual proteins increased by 20%. At least 50% of both macro- and micromineral elements were lost, with the exception of Fe and Na, whose contents increased. Pasting properties of Beninese ogis were similar to that of mawè, another fermented slurry from Benin. The dominant microflora involved in Beninese ogi was a mixed population of lactic acid bacteria and yeasts, mainly lactobacilli and *Candida*. The difference in microflora composition compared with Nigerian ogi is probably due to the specific hot grain steeping procedure of the Beninese 'Goun' methodology.

Keywords Fermentation, maize, slurry, porridge, quality.

Introduction

Maize-based products constitute the major part of the human diet in most African countries. In the southern region of Benin, in particular, more than 95% of the households consume maize foods every day, and the national annual per capita maize consumption has been estimated at 85 kg (Bertholon *et al*., 1975; CIMMYT, 1991). More than 40 different ways of preparing maize have been recorded in the country, including boiling, baking, granulating and frying (Nago, 1989; Nago, Devautour & Muchnik, 1990). Most of these foods are fermented, deriving from two types of intermediate products, mawè and ogi (Nago, 1989; Hounhouigan *et al*., 1993a). The latter represents 72% of the total fermented intermediate maize production (Nago & Hounhouigan, 1990). In Cotonou, the largest city of Benin (with more than 10% of the national population), about 50 tons of maize are processed daily into ogi, as compared with 9 tons for mawè. Microenterprises produce 86% of the ogi (Nago & Hounhouigan, 1990; Hounhouigan, 1994). Ogi is not marketed in this state, in contrast to mawè, but rather it is found as ready-to-serve foods in markets or at roadsides. The major dishes derived from ogi include (Nago, 1989, 1992; Hounhouigan, 1994) (1) gels of variable stiffness (12–15% dry-matter concentration) having differ-

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ent local names (akassa, kanan, lio, agidi, kafa), which represent 81% of ogi use in Cotonou; (2) porridges (koko) with dry-matter concentration ranging from 7% to 10% (7% of ogi use), which are consumed as breakfast meals or weaning foods; and (3) a semisolid gelatinized mass (akpan), which becomes a thirst-quenching beverage by adding water, ice, sugar and milk.

Ogi (or similar products) is produced in many other African countries such as Nigeria (where it is known as ogi or akamu), Togo, Ghana, Congo (poto-poto), South Africa (mahewu) and Kenya (uji) (Doh, 1970; Muller, 1970; Akinrele, 1970; Banigo & Muller, 1972; Steinkraus *et al.*, 1983; Akingbala *et al.*, 1987; Brauman *et al.*, 1993). The general procedure includes six main steps: grain steeping in water, wet-milling, wet-sieving, decanting and fermentation of the slurry for 1–3 days (Fig. 1). However, some differences exist, particularly in the steeping method (Akinrele, 1970), and three main procedures can be distinguished (Guedegbé, 1986): the cold procedure, in which grain is steeped in cold water for 3 days (steeping liquor is changed every day); the 'Fon' method, in which maize grains are steeped in water at 85 °C for 24 h; and the 'Goun' procedure, mostly used in Benin, in which grains are cooked in boiling water for about 10 min then steeped at ambient temperature for 12–48 h (Fig. 1). Variations in steeping conditions lead to

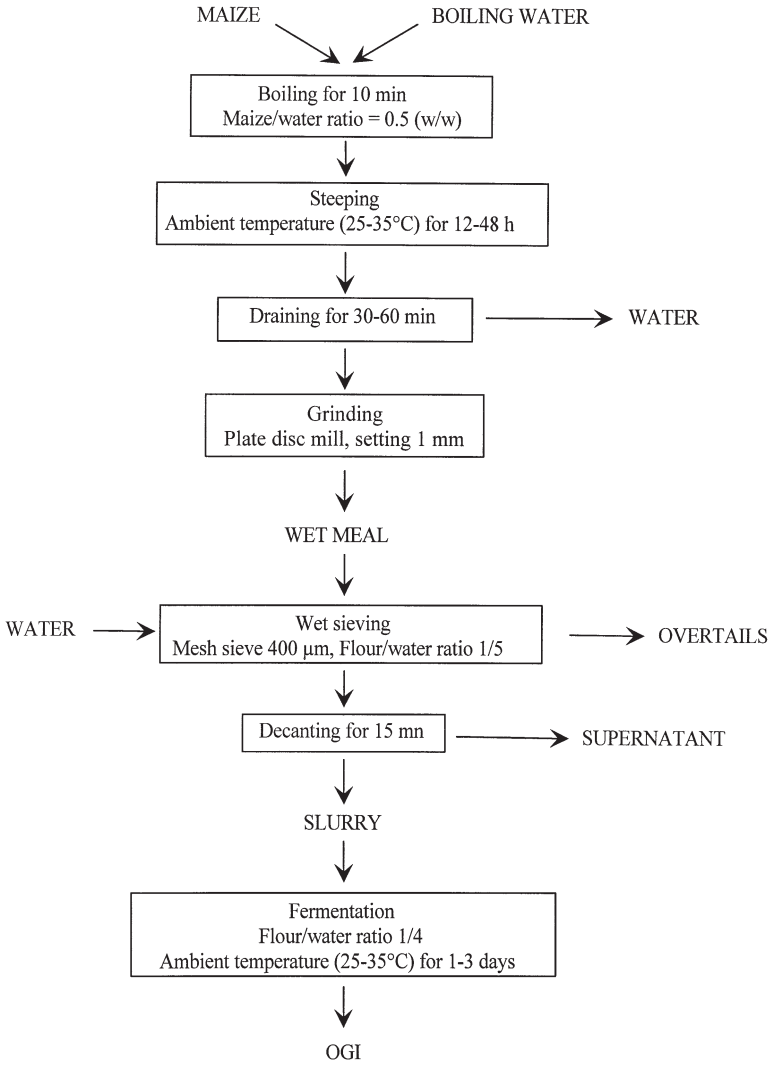

Figure 1 Schematic flow-sheet for producing ogi using the Goun methodology.

important differences in the fermenting microflora and subsequently in the quality of intermediate and final products (Akinrele, 1970; Obiri-Danso, 1994; Adeyemi & Beckley, 1986).

In contrast to ogi, Beninese mawè has been extensively investigated (Hounhouigan *et al.*, 1993a,b,c,d). Workers in Nigeria and Ghana have reported on the technological aspects of local ogi production and its material and protein balances (Akinrele, 1970; Banigo & Muller, 1972; Adeyemi, 1983; Makinde & Lachance, 1976; Akingbala *et al.*, 1987). Others have investigated the physicochemical and microbiological characteristics of the product and the effects induced by cultivar and processing (Akinrele, 1970; Umoh & Fields, 1981; Akingbala, Rooney & Faubion, 1981a; Adeyemi & Beckley, 1986; Adeyemi *et al.*, 1987).

These results cannot be directly extrapolated to the Beninese 'Goun' ogi, owing to the differences in its processing method. Consequently, it is necessary to investigate the Beninese traditional ogi processing for further product quality improvement. The present study was carried out to characterize the procedure and the product in terms of material balance and microbiological and physicochemical properties.

Materials and methods

Commercial ogi samples

Sixteen ogi samples were collected from different commercial producers in Cotonou and its surroundings. Ogi samples were placed in separate sterile bags, put in an ice-box containing ice and brought to the laboratory. Subsamples were immediately taken for microbial culture, pH, titratable acidity and colour measurements. The remainder was packed in bags and stored at −20 °C.

Maize

Commercial ogis were prepared with maize lots purchased from markets in the area. According to the producers, maize lots could be arranged in six classes, among which two were identified as the local varieties Gnonli and Gbogboué. Maize samples of these six classes were collected for analysis.

As gnonli, a local white ecotype, is a well known variety in Benin, and because it was recognized as one of the maizes used by ogi producers, it was used in technological experiments for determining material balance. It was provided by the Applied Research in Rural Environment Programme in Lokossa (Benin) from crops harvested in the main growing season (March–July) of 1993. The sample was air-dried at ambient temperature (25–35 °C) to less than 15% water content (wet basis) and stored at 4 °C until used.

Ogi production

Ogi was prepared from Gnonli grains by a local producer, using the traditional 'Goun' process (Fig. 1). Ten kilograms of grains were cleaned, boiled for 10 min, steeped for 1 day, wet-milled and wet-sieved using tap water in the ratio (water–ground product) of 5. After settling for 15 min, the starchy sediment was recovered and allowed to ferment. The process was triplicated.

Chemical analyses

Protein, fat and ash contents were determined using the 46–11A, 30–25 and 08–01 AACC methods respectively (AACC, 1984). Dry-matter content of dried grains was determined using the 44–15A AACC method (AACC, 1984). Predrying in an oven at 70 °C and grinding was followed by oven-drying at 130 °C for 2 h for wet grains and overtails (bran and germ) (Anonymous, 1976). In the case of ogi and souring water (ogi supernatant), a predrying was performed on a hot plate (at 150 °C) for 2 h. Starch content was determined by a polarimetric method after hydrolysis of starch by hydrochloric acid, deproteinization and filtration (Godon & Loisel, 1984). For the measurement of the pH of ogi, 10 g of sample was mixed with 20 mL of distilled water, and the measurement was taken with a Hanna 8417 pH-meter (Hanna Instruments, Limena, Italy). Titratable acidity of ogi (2 g of ogi homogenized with 8 mL of distilled water) was determined by titration with 0.01 N NaOH; phenolphthalein (1% w/v) was used as indicator (1 mL per titration). Results were expressed as mg of lactic acid per g of ogi (dry basis). Mineral contents were deter-

mined using an atomic absorption spectrometer for Ca, K, Na, Mg, Fe, Zn, Mn and Cu (Pinta, 1969) and by colorimetry for phosphorus (Stuffins, 1967). Pepsin digestibility of proteins was determined as described by Mertz *et al.* (1984). The procedure consists of *in vitro* digestion by pepsin and titration of indigestible proteins using the Kjeldahl method.

Physical analyses

Thousand-kernel weight was determined on 30-g samples and calculated on a dry basis. Dent kernel percentage was evaluated by visual examination of 50 kernels (Mestres *et al.*, 1991). The endosperm vitreousness was determined as the relative ratio of the vitreous endosperm area of 100 kernel cross-sections (Louis-Alexandre *et al.*, 1991).

The colour of the ogi samples was measured with a Minolta CR-210b portable chromometer, using chromaticity coordinates L^*, a^*, b^* and ΔE (illuminant D65; Hounhouigan *et al.*, 1993a). The instrument was standardized with a standard white tile ($Y = 94.8$, $x = 0.3150$ and $y = 0.3324$). The particle size was determined as described by Sefa-Dedeh (1989): a 100-g ogi sample was shaken for 30 min through 250, 180, 125, 90 and 45 μm screen sieves, on an Endecotts test sieve shaker (Endecotts, London, UK). A continuous jet of water was sprayed onto the sample. The solid content of the sample on each sieve was determined by drying, and the corresponding percentage of the sample (dry weight basis) was calculated. The solid content of the throughs from the bottom sieve (45 μm) was determined by difference.

The pasting characteristics were measured using a Brabender Pt 100 viscograph (Brabender OHG, Duisburg, Germany). Slurries containing 10.0% (w/v) dry matter were analysed using a 700-cmg sensitivity cartridge. The total weight of slurry in the viscograph bowl was 450 g. The mixture was heated at 1.5 °C min^{-1} from 30 °C up to 92 °C, held at 92 °C for 15 min and then cooled to 50 °C at 15 °C min^{-1}. The following parameters were measured: pasting temperature (*T*p, temperature at which viscosity starts to increase), maximum viscosity during heating (*V*m), viscosity after 15 min at 92 °C (*V*r) and viscosity after cooling at 50 °C (*V*e).

Microbiological analyses

Duplicate subsamples (10 g) from ogi sample were homogenized with 90 mL of sterile peptone–physiological salt solution (5 g of peptone, 8.5 g of NaCl, 1000 mL of distilled water, pH 7.0 ± 0.2) and decimal diluted. All cultures were in pour plates. Total aerobic mesophilic bacteria, lactic acid bacteria, lactobacilli, yeasts and Enterobacteriaceae were enumerated after incubation respectively on Plate Count Agar (PCA), MRS agar (Oxoid CM 361), Rogosa agar (Oxoid CM 627), Yeast Extract Glucose Agar (Oxoid CM 545) with addition of 0.01% sterile oxytretracyclin after autoclaving) and Violet Red Bile Glucose Agar (VRBG, Oxoid, CM 485), as described by Hounhouigan *et al.* (1993a). All media were prepared according to the manufacturer's directions. Lactic acid bacteria and yeasts were randomly isolated from selected plates, and the isolates were purified by successive subculturing on MRS agar and yeast extract glucose agar respectively as described by Hounhouigan *et al.* (1993c,d). After microscopic examination, purified cultures were grown on slants of the same specific media and stored at +5 °C before identification. Identification was performed according to Harrigan & McCance (1976) and Hounhouigan *et al.* (1993c,d), using successively various preliminary tests and then API 50 CHL (for lactic acid bacteria) and ID 32 C (for yeasts) kits obtained from API system SA (La Balme-les-Grottes, Montalieu, Vercieu, France).

Results and discussion

Characterization of commercial maize lots

The physicochemical characteristics of the six classes of commercial maize grains identified by and collected at ogi producers were fairly similar with low thousand-kernel weights, typical of local ecotypes (Table 1). However, two types of grains could be distinguished. The first type, including those recognized as Gnonli by ogi producers, had a very low vitreousness, intermediate dent kernel percentage and fairly high starch content, which are typical characteristics of Gnonli kernels (Nago *et al.*, 1997). The second type, called Gbogbouè, according to ogi producers, had low dent kernel percentage and low vitreousness typi-

Table 1 Physicochemical characteristics of commercial maize lots used for preparing ogi

Characteristic	Gnonli-like	Gbogboué-like
Thousand kernels weight (g, db)	183	182–186
Dent kernel percentage	23–27	9–15
Vitreousness (%)	24–26	48–53
Starch content (%, db)	77	75
Protein content (%, db)	9.8	10.0–10.6
Lipid content (%, db)	4.0–4.1	3.9–4.4
Ash content (%, db)	1.35–1.38	1.22–1.47

cal of Gbogbouè kernels. This showed that ogi producers prefer small and floury kernels that are friable (Nago *et al.*, 1997).

Material balance in traditional ogi processing in Benin

Using the 'Goun' processing method, ogi yielded between 84% and 86% (db) of Gnonli kernels; overtails represented the major part of dry-matter losses (13–15%), whereas less than 2% were lost within discarded water (overtails and supernatant). Beninese ogi yield was slightly higher than those observed in Ghana (80–82%; Andah & Muller, 1972; Banigo & Muller, 1972) and Nigeria (70–77%; Adewusi *et al.*, 1991) using the cold grain steeping procedure. This difference may be due to a better softening of maize kernels using the 'Goun' methodolgy as we measured a water content of steeped grain at 42% (wb) against 38% in the case of the cold steeping procedure (Akinrele, 1970; Banigo & Muller, 1972). However, these differences may also be linked to variation in maize quality, although these studies were carried out using commercial local maize samples that appeared quite homogeneous. The yield of Beninese traditional ogi was much higher than that of commercial mawè (65–71%; Hounhouigan *et al.*, 1993b), which is obtained after two successive purification processes: grains are roughly ground and dry-sieved (pericarp is discarded); obtained grits are extensively washed and floating particles (germs) discarded.

Chemical characteristics of the Beninese ogi

Commercial ogis collected in Cotonou and its surroundings were all prepared using 'Goun' procedure with grain steeping for 12–48 h. Their chemical characteristics were very similar (Table 2), with coefficients of variation between samples lower than 7%, and were very close to those of Gnonli ogi. The moisture content (58%) of Beninese ogi was higher than that of Nigerian and Ghanian ogis (around 50%; Banigo & Muller, 1972; Sefa-Dedeh, 1989). The protein content of Beninese ogi was about 3% lower than that of raw grains; this represented a loss of protein of 38% in the case of Gnonli ogi. This was in the range of protein losses (22–39%; Andah &

Table 2 Chemical characteristics of Beninese commercial ogi (16 samples analysed) and of ogi produced from Gnonli

Characteristics	Commercial ogi		Gnonli ogi
	Mean	SD*	Range
Dry-matter content (%, wb)	42	3	40–44
Starch content (%, db)	77	2	76–80
Crude protein (%, db)	7.2	0.5	6.7–7.9
Free lipids (%, db)	3.6	0.1	3.0–3.5
Ash (%, db)	0.5	0.1	0.4–0.6
pH	3.4	0.2	3.3–3.7
Titratable acidity (mg lactic acid g^{-1}, db)	13.8	0.4	13.8–16.0
Pepsin digestibility (% initial protein)	95	3	ND

*Standard deviation.
ND, not determined.

Table 3 Physical characteristics of Beninese commercial ogi (16 samples analysed) and of ogi prepared from Gnonli

Characteristics	Commercial ogi		Gnonli ogi
	Mean	SD*	Range
Particle size distribution			
$x <$ 45 μm	53	3	55–60
$x <$ 90 μm	80	3	80–86
$x <$ 125 μm	88	2	87–93
$x <$ 180 μm	91	3	89–96
$x <$ 250 μm	94	3	92–98
Colour parameters			
L^*	83	0.6	80–84
a^*	−1.9	0.3	−1.4/−1.2
b^*	9.5	0.6	9.0–9.8
ΔE	16.9	0.9	16.2–18.6

*Standard deviation.

Muller, 1972; Banigo & Muller, 1972; Adewusi *et al*., 1991) obtained for ogi processing using the cold steeping procedure and close to the losses measured in the case of commercial mawè (37%, Hounhouigan *et al*., 1993b). In addition, 'Goun' ogi had lower lipid and ash contents than raw grains (Table 1), indicating that a partial degerming occurred during processing. Degerming was more efficient in the Goun process than using the cold steeping ogi process, which gives ogi with a residual lipid content of 3.9–4.2% (Muller, 1970; Andah & Muller, 1972; Banigo & Muller, 1972). This might be due to the better grain softening observed with the 'Goun' procedure, which should facilitate kernel fractionation during processing. Nevertheless, degerming was much less efficient than with the two-step purification procedure of mawè whose residual lipid content was of 1% (db; Hounhouigan *et al*., 1993a).

Mineral content of the various commercial ogis was quite similar with a coefficient of variation beween samples ranging from 3% to 9%. With mean values of 85 and 123 mg 100 g^{-1} (db), respectively, K and Mg contents of ogi were about one-quarter of that of whole grains of Beninese local ecotypes (Nago *et al*., 1997). Similarly, mean values for Ca and Zn (5.3 and 1.1 mg 100 g^{-1}, db) and for P, Mn and Cu (123, 0.5 and 0.08 mg 100 g^{-1}, db) were one-third and one-half, respectively, of those of whole grains. On the contrary, ogi Fe and Na contents (3.6 and 2.8 mg 100 g^{-1}, db) were higher than for whole grains. These minerals are likely to arise from water (for Na) and small particles extracted from the grinder (made of iron disc plates).

Beninese ogis (Table 2) were slightly sourer than Nigerian and Ghanaian ogis, whose pH ranged from 3.5 to 4.5 (Akinrele, 1970; Banigo & Muller, 1972; Umoh & Fields, 1981; Adeyemi *et al*., 1987; Akingbala *et al*., 1987). The Beninese ogi titratable acidity was similar to that of commercial Beninese mawè (14 mg g^{-1} db; Hounhouigan *et al*., 1993a).

In vitro protein digestibility of ogi was very high (Table 2), and about 20% higher than that of whole kernels of Beninese local ecotypes (Nago *et al*., 1997). This might be due to the action of proteolytic enzymes either present in the grain (Nche *et al*., 1996) and/or produced by proteolytic bacteria (Tongnual *et al*., 1981). This improvment of protein digestibility could partly balance the nutitional loss of proteins during the extraction process.

Physical characteristics of the Beninese ogi

Beninese ogi has a fine texture, with a median particle size around 40 μm (Table 3) and about 80% of particles under 90 μm. Beninese ogi particle size distribution was close to those of commercial mawè (Hounhouigan *et al*., 1993a) and Ghanaian ogi (Sefa-Dedeh, 1989).

Beninese ogi had a high luminosity (L^*) and a low ΔE (total colour difference with standard white tile), which are good indices of quality as consumers look for whiteness of ogi and derived products (Akingbala *et al*., 1981b). Beninese ogi

Table 4 Pasting behaviour of Beninese commercial ogi (16 samples analysed) and of ogi prepared from Gnonli measured using the viscoamylograph on 10% (db) slurries

Characteristics	Commercial ogi		Gnonli ogi
	Mean	SD*	Range
T_p (°C) †	71.6	0.8	71–73
V_m (BU) ‡	936	94	882–996
V_r (BU)	542	57	485–620
V_e (BU)	1002	130	922–1058

*Standard deviation.
†Pasting temperature.
‡Brabender unit.
V_m, maximum viscosity during heating; V_r, viscosity after 15 min at 92 °C; V_e, viscosity after cooling to 50 °C.

colour parameters were similar to those of commercial mawè (Hounhouigan *et al.*, 1993a).

Pasting behaviour of the Beninese ogi

Brabender viscosity profiles of Beninese traditional ogis were similar to those obtained in previous works for maize or sorghum ogis and for mawè (Banigo *et al.*, 1974; Adeyemi, 1983; Adeyemi *et al.*, 1987; Hounhouigan *et al.*, 1993a). However, we could only compare Beninese ogi pasting parameters with those observed for mawè (Table 4) because no other study on ogi has been made with 10% dry-matter pastes. Great variations were observed in commercial and Gnonli ogi paste viscosities. They were however in the same range and similar to the values observed for 3 days' fermented commercial mawè that had for example a V_e of 983 (Brabender units; Hounhouigan *et al.*, 1993b). Beninese ogi and mawè had also similar pasting temperatures.

Microbiological characteristics of the Beninese ogi

The dominant microorganisms of ogi were lactic acid bacteria (109 CFU g^{-1}) and yeasts (107 CFU g^{-1}). The association of these two categories of organisms has been noticed in the spontaneous fermentation of ogi and many other cereal foods (Akinrele, 1970; Nout, 1980; Adegoke & Babalola, 1988; Hounhouigan *et al.*, 1993a,c). Moreover, as already observed for ogi and similar products, Enterobacteriaceae were absent from the Beninese product; this is presumably a result of the low pH.

A total of 65 strains of lactic acid bacteria were isolated from the product. They were mostly heterofermentative lactobacilli. Three main *Lactobacillus* species (*L. fermentum,* biotype *cellobiosus*, *L. brevis* and *L. fermentum*) accounted for 90% of the lactic acid bacteria isolates, whereas *L. curvatus* and *L. buchneri* accounted for 6%. These findings are quite similar to those reported by Hounhouigan *et al.* (1993d) for mawè, by Adegoke & Babalola (1988) for Nigerian ogi, and by Mbugua (1984) for uji, a spontaneously fermented maize product from Kenya. However, Akinrele (1970) isolated from Nigerian ogi, obtained with the cold steeping procedure, three other bacteria, namely *L. plantarum*, *Corynebacterium* sp. and *Aerobacter cloacae*, and found the first to be the predominant species. Failure to find *L. plantarum* in this work could be a result of difference in processing and particularly in the steeping procedure. Indeed, steeping duration and temperature can induce dramatic changes in the microbial population of ogi (Akinrele, 1970).

Fifty-four strains of yeasts were isolated from Beninese ogi. *Candida* species represented 41% of the isolates, including mainly *C. humicola* and *C. krusei. Geotrichum* spp. accounted for 26% of the yeast isolates. Other isolates were identified as *Cryptococcus* and *Trichosporon* species. Some of these yeasts were detected in Nigerian ogi (e.g. *C. krusei*, *Rhodotorula* spp.) by Akinrele (1970) and in mawè (e.g. *C. krusei*, *C. kefyr*) by Hounhouigan *et al.* (1993c). Other yeasts have been also reported from ogi, namely *Saccharomyces cerevisiae* and *Candida mycoderma* (Akinrele, 1970).

Conclusion

Beninese ogi producers use small, floury/friable grains as raw material. Commercial ogi is very similar to that made from Gnonli using the traditional Beninese 'Goun' methodology in controlled conditions. In this case, the ogi yield was 84% (db). Beninese ogi, partly degermed, was a very white, fine and watery mash. It appeared slighly sourer and more watery than Nigerian ogi. This difference might be due to the specific hot steeping procedure used in Benin and/or to the use of floury/friable grains.

The dominant microorganisms involved in the fermentation of Beninese ogi were lactobacilli (mainly *L. cellobiosus*, *L. brevis* and *L. fermentum*) and yeasts (*Candida humicola*, *C. krusei*, *Geotrichum* spp.). Differences in microflora composition compared with Nigerian ogi may due to the hot steeping procedure used in Benin.

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