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Changes in the Physico–Chemical Properties of Maize During Natural Fermentation of Mawè

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The physical and chemical changes that occurred during a 72-h fermentation period were studied in two differently processed maize doughs from Bénin, referred to as home-produced and commercial mawè. The pH decreased from 6.1 to 3.5 in the commercial process and from 6.2 to 3.6 in the home-style process, whereas the titratable acidity increased from 0.2 to 1.7% (w/w, lactic acid) and from 0.3 to 2.3%, respectively. Home-produced mawè had significantly higher levels of crude fat, crude fibre and ash compared with the commercial mawè, as a consequence of the difference in the processing methods. No marked changes in proximate composition occurred during subsequent fermentation. Commercial mawè was whiter than home-produced mawè, and this whiteness increased with increasing fermentation time. Fermentation significantly increased the swelling and thickening capabilities of mawè, which were more pronounced in the commercial than in home-produced samples. Overall, the commercial mawè process appeared to be a technologically more advanced and effective method of mawè manufacture than the home process.

Introduction

Mawè is a sour dough, which has undergone natural fermentation for 1 to 3 days. It is made from dehulled maize, and, on this basis, is different from the whole maize dough used to prepare Ghanaian kenkey¹. Mawè is used for the preparation of a variety of dishes in its area of origin, Bénin and Togo. Depending on its intended use and on individual taste preferences, consumers choose mawè on the basis of its sourness, whiteness and fineness.

An investigation carried out in the Bénin urban area showed that ready-to-use mawè had a titratable acidity of 1.2–1.4% (w/w, as lactic acid), with pH values of approximately 4.2 in home-produced mawè and 3.8 in commercial mawè². These degrees of sourness are generally accepted for the preparation of stiff gels (akassa, agidi, eko)

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and porridge (koko). On the other hand, less sour mawè is preferred for steamed cooked bread (ablo), and more acid mawè is used for the preparation of porridge for sick people. In Bénin, mawè is a substitute for ogi (a fermented maize gruel fermented as a suspension) for akassa and porridge preparation.

The physical and chemical changes during the processing of cereal grains into ogi have been investigated³⁻⁵. As information on the physical and chemical changes during the processing of maize to mawè is lacking, this study was carried out to evaluate these changes.

Experimental

Mawè production

Home-produced mawè and commercial mawè were produced as illustrated in Figs 1 and 2, respectively. The processing was carried out by a local mawè producer, using the maize cultivar Sékou 85 provided by the International Institute of Tropical Agriculture, Bénin. The dough resulting from each process was divided between six plastic buckets with lids. Fermentation was at room temperature (28–32 °C) and was carried out for 72 h. Each process was carried out in duplicate.

Sample treatment, packaging and preservation

After 0, 6, 12, 24, 48 and 72 h fermentation, one bucket of mawè from each process was taken for analysis. Sub-samples (5 g) were used for moisture determination. Portions (100 and 20 g) were used for measurement of colour and determination of pH and titratable acidity, respectively. The remainder of the sample was packed in polyethylene bags, and held at –50 °C for later analysis: frozen samples of mawè were thawed overnight at 5 °C for viscosity measurement or dried in an air-oven at 60 °C for 48 h, ground in a Retsch ZM1 mill and dried further to constant weight at 103 °C. The dried sample was vacuum-sealed in laminated aluminium foil bags until determination of proximate composition.

Chemical analysis

pH and titratable acidity were measured by the method of Nout *et al.*⁶, modified as follows: the sample (10 g) was mixed with distilled water (20 ml) and the pH measured using a Hanna 8417 pH meter (Hanna Instruments, Limena, Italy). Subsequently, this suspension was mixed with distilled water (70 ml) for determination of the titratable acidity. Moisture, crude protein, crude fat and ash contents were determined using AACC⁷ methods 44–15 A, 46–11 A, 30–25 and 08–01, respectively. Crude fibre content was determined as described by Osborne and Voogt⁸. Carbohydrate content was calculated by difference.

Physical analysis

The colour of mawè samples was measured with a Minolta CR-210 portable chromameter, using chromaticity co-ordinates L^* , a^* , b^* and ΔE (illuminant D65, CIE 1976). The instrument was standardized with a standard white tile ($Y = 94.8$, $x = 0.3150$ and $y = 0.3324$). The pasting characteristics were measured using a Brabender Pt 100 Viscograph (Brabender OHG Duisburg, Germany). A 700 cmg sensitivity cartridge was used. Slurries containing 10.0% (w/v) dry matter were analysed. The total weight of slurry in the Viscograph bowl was 450 g. The mixture was heated at 1.5 °C/min from 30 °C up to 92 °C, held at 92 °C for 15 min and then cooled to 50 °C. The Viscograms were interpreted as described by Banigo *et al.*⁹.

^aYields expressed on dry-weight basis

FIGURE 1. Flow diagram for mawè production: home-style process.

Statistical analysis

Samples from different processes and fermentation periods were statistically compared using analysis of variance¹⁰ and Duncan's multiple-range test¹¹.

Results and Discussion

Yield of mawè

The yield of mawè from three replications of each process ranged between 76 and 80% for the home-style process and between 65 and 71% for the commercial process (dry-weight basis). The lower yield in the commercial process was caused mainly by the thorough washing of grits in water to remove hulls and germs, and to the concomitant loss of extractable dry matter in the washing water. In the home-style process, this operation was not applied; the mixture of grits and fines obtained after screening-dehulling was soaked in water without washing (Figs 1 and 2).

A significant ($P < 0.05$) increase in the moisture content of mawè was observed during the fermentation period (Table I). This is caused by the combined effects of dry matter consumption and production of water during aerobic and anaerobic catabolism by yeasts and heterofermentative lactic acid bacteria^{2,12}.

^aYields expressed on dry-weight basis

FIGURE 2. Flow diagram for mawè production: commercial process.

TABLE 1. The influence of fermentation time on the moisture content of mawè^a

Fermentation time (h)	Moisture content (%, w/w, fresh weight)	
	Home-produced mawè	Commercial mawè
0	45.5	46.0
6	45.4	46.0
12	46.1	46.2
24	46.3	46.8
48	47.2	48.4
72	48.3	48.2

^a Mean of two independent determinations. Replicates were within 3 % of the mean.

FIGURE 3. The influence of fermentation time on the pH of mawè. Home-produced mawè ($\square$), commercial mawè ($\blacktriangle$).

FIGURE 4. The influence of fermentation time on the titratable acidity of mawè. Home-produced mawè ($\square$), commercial mawè ($\blacktriangle$).

pH and titratable acidity

The changes in pH and titratable acidity in both types of mawè are shown in Figs 3 and 4, respectively. The titratable acidity of home-produced and commercial mawè increased from 0.3% and 0.2% (w/w, calculated as lactic acid), at the start of the fermentation (t_0), to 2.3% and 1.7%, respectively, after 72 h fermentation (t_{72}). The pH of home-produced mawè still remained the highest.

In the commercial process, water-extractable sugars and proteins are partly lost during the washing of the grits. In the home-style process, the greater availability of fermentable sugars led to enhanced production of organic acids (Fig. 4). But the home-

TABLE II. The proximate compositions of maize raw material, and of mawè at the start (t_0) and after 24 h (t_{24}) and 72 h (t_{72}) of fermentation^a

	Maize (raw material)	Home-produced mawè			Commercial mawè		
		t_0	t_{24}	t_{72}	t_0	t_{24}	t_{72}
(%, dwb) ^b							
Crude protein ^c	11.2	11.3a ^d	11.2a	11.3a	10.3a	10.5a	10.7a
Crude fat	4.9	3.8a	3.8a	3.9a	1.0b	1.1b	1.2b
Crude fibre	1.8	0.9a	0.9a	1.0a	0.5b	0.5b	0.6b
Ash	1.5	1.3a	1.3a	1.3a	0.5b	0.5b	0.5b
Carbohydrate ^e	80.6	82.7a	82.8a	82.5a	87.6b	87.4b	87.0b

^a Mean of two independent determinations.^b dwb = dry-weight basis.^c N $\times$ 6.25.^d a, b. Means with the same letters are not significantly different ($P < 0.05$).^e Calculated by difference.

produced mawè also had a higher protein content and consequently a higher buffering capacity¹³. The latter was responsible for the higher pH compared with the commercial product.

In the commercial product, the lower titratable acidity was, nevertheless, sufficient to create an extracellular pH¹⁴ that limited further growth. The buffering effect of the higher protein content in the home-produced mawè necessitated larger amounts of titratable acidity to reach an inhibitory extracellular pH. In fact, after 72 h fermentation, the home-produced mawè had not yet stabilized. A buffering action by proteins was observed also in ogi³ and Ghanaian maize dough¹⁵.

Our findings confirm that the extent of fermentation of cereal products cannot be evaluated merely on the basis of their pH. Consequently, evaluation of fermentation rates requires monitoring of both pH and titratable acidity. Earlier experiments² showed that at the moment of use, market samples of commercial mawè had a titratable acidity of $1.4 \pm 0.5\%$ (w/w, as lactic acid) and home-produced mawè contained $1.2 \pm 0.2\%$ titratable acidity. These levels of acidity were achieved within 24 h of fermentation in commercial mawè or within 12 h of fermentation in home-produced mawè under the conditions of the present study.

Proximate composition

From Table II, it can be seen that the processing method had only a slight effect on the crude protein content but the crude fat, ash, crude fibre and carbohydrate contents of mawè were influenced significantly ($P < 0.01$). The maize cultivar Sékou 85 sample used contained about 11.2% crude protein, which was reduced to about 10.3% on conversion to unfermented commercial mawè (about 8% loss in t_0 sample) and remained constant on conversion to unfermented home-produced mawè.

A substantial loss of protein (40–50%) was reported during the processing of maize to ogi^{3,16}. Compared with unprocessed maize, the crude fat content was reduced by

TABLE III. The influence of fermentation time on the colour parameters of mawè^a

	Home-produced mawè				Commercial mawè			
	<i>L</i> *	<i>a</i> *	<i>b</i> *	ΔE	<i>L</i> *	<i>a</i> *	<i>b</i> *	ΔE
0 h	78.0	-1.8	11.8	22.6	81.0	-2.2	9.2	18.7
6 h	78.4	-2.0	11.5	22.1	81.1	-2.4	8.8	18.5
12 h	78.9	-2.1	11.4	21.6	81.8	-2.3	8.7	17.9
24 h	79.2	-2.2	11.3	20.9	82.5	-2.4	8.4	16.8
48 h	79.9	-2.3	11.4	20.4	83.4	-2.6	8.1	15.9
72 h	80.8	-2.3	11.3	19.6	83.7	-2.6	8.4	15.7

^a Mean of two independent determinations.

*L**, luminosity parameter. Replicates were within 1.5% of the mean.

*a**, greenness-redness parameter. Replicates were within 9% of the mean.

*b**, blueness-yellowness parameter. Replicates were within 8% of the mean.

ΔE , total colour difference with standard white tile. Replicates were within 5% of the mean.

about 80% in commercial mawè and by 22% in home-produced mawè; the ash content by about 67% in commercial mawè and 13% in home-produced mawè; and the crude fibre content by about 72% in commercial mawè and 50% in home-produced mawè. No marked changes in proximate composition occurred during subsequent fermentation. The only difference between the commercial process and the home process was the washing of the grits before milling, which may explain the difference in proximate composition between both types of mawè.

Changes in colour

Colour parameters recorded during mawè fermentation are given in Table III. The fermentation period and the processing method both affected the colour parameters *L** (luminosity), *a** (greenness-redness) and ΔE (total colour difference with standard white tile) significantly ($P < 0.01$). Commercial mawè was brighter than home-produced mawè, and the *L** values increased with increasing fermentation time, while *a** and ΔE values decreased correspondingly.

The results suggest that the luminosity (whiteness) of the product became more intense during the course of the fermentation. On the other hand, a high correlation ($r \geq 0.96$) was observed between *L** value and the moisture content of the samples obtained at different fermentation times. Furthermore, unfermented samples at different levels of moisture content showed a similar correlation between their respective *L** values and moisture contents (results not included). This would suggest that the increase in the *L** values (or in the luminosity) of the product was due mainly to the increase of the moisture contents during the course of the fermentation.

Viscograph characteristics

The pasting characteristics, which developed during the fermentation of both types of mawè, are listed in Table IV. Fermentation time had no significant effect on the gelatinization temperature (T_g), nor on the time to reach T_g (M_g). On the other hand,

TABLE IV. The influence of fermentation time on the pasting behaviour of mawè^a

	Home-produced mawè				Commercial mawè			
	0 h	24 h	48 h	72 h	0 h	24 h	48 h	72 h
T_g (°C)	72.3	73.2	72	72.8	69.9	70.9	71.3	71
M_g (min)	28.2	28.8	28.6	28.5	26.7	27.3	27.5	27.5
M_n (min)	38.7	40.2	40.1	39.8	36.6	40.5	40.3	39.8
$M_n - M_g$ (min)	10.5	11.4	11.5	11.3	9.9	13.2	12.8	12.3
V_m (BU) ^b	254	344	396	415	233	560	661	681
V_r (BU)	226	293	311	324	148	424	426	426
V_e (BU)	493	630	686	708	392	898	918	983
$V_m - V_r$ (BU)	28	51	85	91	85	136	235	255
$V_e - V_m$ (BU)	239	286	290	293	159	338	257	302
$V_e - V_r$ (BU)	267	337	375	384	244	474	492	557

^a Mean of two independent determinations. T_g , replicates were within 2% of the mean. M_g , M_n , replicates were within 3% of the mean. V_m , V_r , V_e , replicates were within 10% of the mean.^b BU, Brabender unit.

T_g , gelatinization temperature; M_g , time to reach T_g ; M_n , time to reach V_m ; $M_n - M_g$, ease of cooking; V_m , maximum viscosity during heating; V_r , viscosity after 15 min at 92 °C; V_e , viscosity after cooling to 50 °C; $V_m - V_r$, stability of the starch; $V_e - V_m$, setback value; $V_e - V_r$, index of gelatinization.

maximum viscosity (V_m), viscosity after 15 min at 92 °C (V_r), viscosity after cooling to 50 °C (V_e), time to reach V_m (M_n), stability value of the starch ($V_m - V_r$), setback value ($V_e - V_m$) and index of gelatinization ($V_e - V_r$), all increased with fermentation time. The biggest difference was observed between the unfermented sample and the fermented samples. This is in agreement with the report of Banigo *et al.*⁹ that fermentation markedly increased the swelling and thickening characteristics of ogi.

Adeyemi and Beckley⁴ also found that the peak viscosity of soured maize flour was much higher than that of the unsoured maize flour. In contrast, Sefa-Dedeh¹⁷ found that the fermentation of maize dough drastically decreased the viscosity characteristics of Ghanaian-type corn dough. Adeyemi¹⁸ also found that fermentation of sorghum flour samples reduced their peak viscosities. The composition of the fermented substrate, which will be affected by the nature of the raw material used and the processing method, probably affected the behaviour of the paste during the heating, holding and cooling cycles. Adeyemi and Beckley⁴ suggested that the content of damaged starch granules, the α -amylase activity and the pH of the product would be factors having a more important influence than the presence of acetate ions, as suggested by Banigo *et al.*⁹.

There was a significant ($P < 0.01$) increase in the ease of cooking ($M_n - M_g$) of the fermented product, concomitant with the increased time to reach maximum viscosity (M_n). This finding contrasts with previous results on maize ogi⁴, and corroborates the need for more research in order to understand the pasting behaviour of fermented cereal products.

It can be seen also that the processing method affected the gelatinization temperature (T_g) significantly ($P < 0.01$), the time to reach T_g (M_g), the ease of cooking ($M_n - M_g$),

the maximum viscosity (V_m), the viscosity after 15 min at 92 °C (V_r), the viscosity after cooling to 50 °C (V_e), the stability of the starch ($V_m - V_r$) and the index of gelatinization ($V_e - V_r$). The viscosity and the ease of cooking values were higher with mawè obtained by the commercial process, whereas T_g and M_g values were lower.

These results are in accordance with those obtained previously². For Nigerian ogi and Ghanaian maize dough, high gelatinization temperatures have been attributed to greater particle size^{17, 19, 20}, as well as to reduced starch content^{19, 20}; this may explain the behaviour of home-made mawè during heating. The higher crude fibre and crude fat contents of home-made mawè may have reduced the viscosities observed in this product, as reported for ogi obtained from dry milled maize compared with the viscosities of ogi from steeped whole maize²⁰.

Conclusion

The commercial process can be considered a technologically more advanced and more effective method of mawè production, compared with the home process. Its adoption was dictated by the market demand for a product as white and fine as possible, having maximum swelling and thickening characteristics. Considering that the loss of protein is low during commercial mawè processing, and in view of the superior pasting behaviour, commercial mawè may be considered to be of superior quality.

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