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Acceleration of the fermentation of kenkey, an indigenous fermented maize food of Ghana

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Kenkey is a popular staple food of Ghana. It consists of fermented and cooked maize dough, wrapped in leaves. The traditional kenkey-making process is laborious and time consuming (4–6 days). An accelerated option for industrial manufacture of kenkey in sausage casings was developed, which takes approximately 24 h. Hydration of maize to 40% (w/w) moisture content was shortened from 48 to 10 h by pre-cracking the kernels. Fermentation was shortened from 3–4 days to 12 h by incorporating the aflata into the dumpling prior to fermentation, and by using a starter dough. Cooking time and thus energy expenditure was reduced from 2 h to 35 min by changing the dimensions of the kenkey mass from 10–15 cm diameter balls to 6 cm diameter cylinders. Due to the different conditions, yeasts were somewhat more active than in traditional kenkey, resulting in higher ethanol levels. However, these remained low and ethanol had disappeared after cooking. The combination of lactic acid fermentation and cooking resulted in a microbiologically stable product, even after the dumpling had been deliberately contaminated. Copyright © 1996 Canadian Institute of Food Science and Technology. Published by Elsevier Science Ltd.

Keywords: fermented, cereal, maize, Ghana, Africa.

INTRODUCTION

Kenkey, a popular Ghanaian staple food is produced from fermented maize dough. During kenkey production (Muller & Nyarko-Mensah, 1972; Nche *et al.*, 1994*a*) part of the fermented maize dough (usually half) is slurried with water and cooked to gelatinization to give a thick and sticky paste, called the aflata (Figure 1). The aflata serves as a binding agent and moisturizer when it is subsequently mixed with the uncooked remainder of the dough (Nche *et al.*, 1996). When kneaded, the aflata holds the uncooked dough together in a dumpling which can then be shaped, wrapped and boiled to give kenkey.

The traditional process is carried out at an artisanal level. It takes considerable time (4–6 days), physical labour (aflata making, kneading and wrapping of dumplings) and energy (two cooking stages). In view of facilitating convenience in an era characterized by increasing urban populations, it is realistic to assess options for industrial-scale manufacture of kenkey.

It was shown that some parts of the kenkey process can be upgraded by shortening the fermentation period using an accelerated fermentation process (Nche *et al.*, 1994*b*) or by reducing physical labour using pre-cooked dehydrated kenkey mixes (Nche *et al.*, 1996).

The present paper deals with an alternative approach to the kenkey-making process. The general principle is shown in Figure 2. The major difference compared with the traditional process is that the fermentation takes place after the dumpling has been made and filled into a casing material, instead of fermentation prior to dumpling making. In addition, several stages have been optimized (i.e. soaking period, amount of aflata used, fermentation period and cooking time). This would finally result in a 24 h process with reduced energy requirement, yielding a ready-to-eat product.

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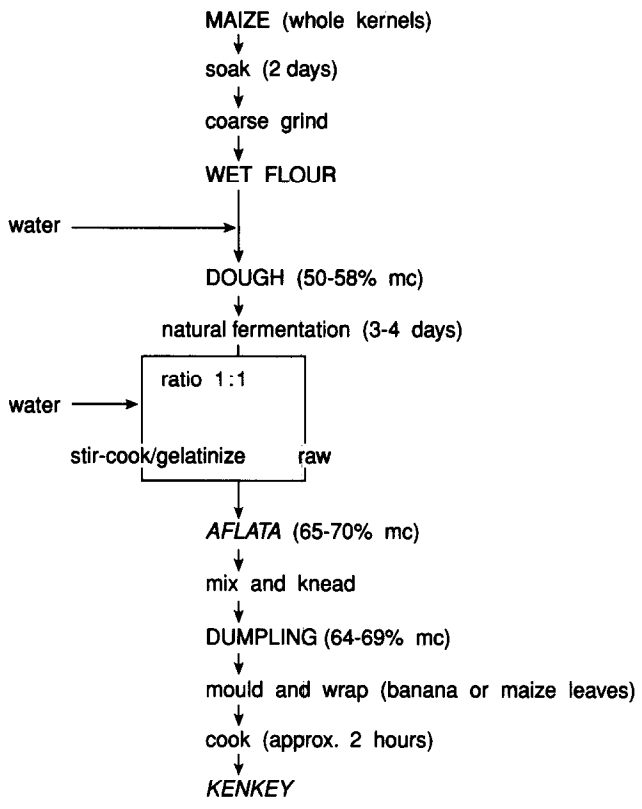

Fig. 1. Traditional kenkey manufacturing process.

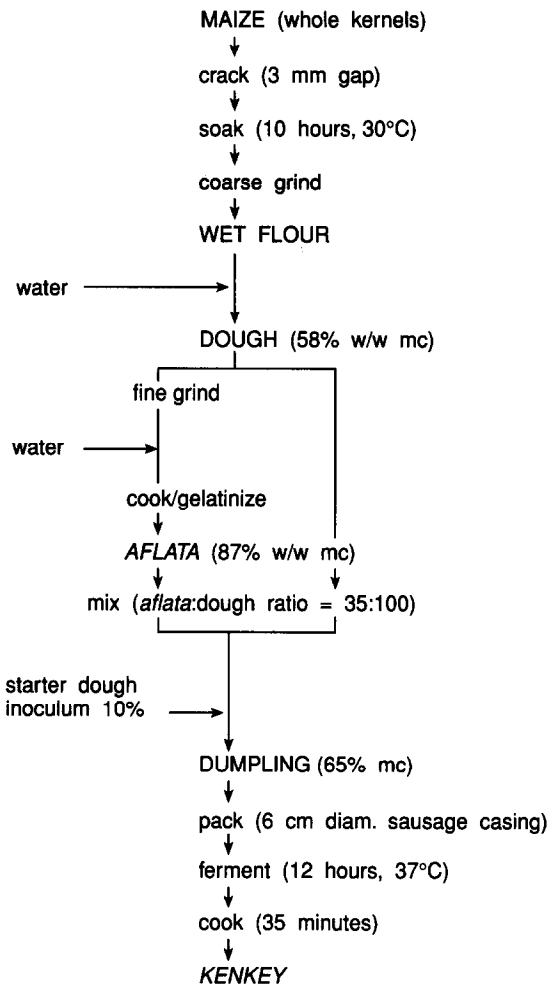

Fig. 2. Accelerated kenkey process in sausage casings.

MATERIALS AND METHODS

Materials

White dent maize (*Zea mays* L.) grown in Zimbabwe was used. For the sausage casing, Nalo Faser I cellulose fibre casing (6 cm diameter) was supplied by Foodpack, Harderwijk, The Netherlands.

Methods

A steel roller mill (Turner, Ipswich, UK) with a 3 mm gap was used to crack the maize. For grinding, a hammer mill (Fritsch Pulverisette type 14.702, Marius Instruments, Utrecht, The Netherlands) with fine rotor and 4 mm sieve (coarse grinding) or 2 mm sieve (fine grinding) was used at Speed 2.

Microbiological

Maize dough (100 g maize flour + 40.5 ml water) was inoculated with 10% (w/w) of previously fermented dough, and incubated for 24 h at 30°C. The resulting starter dough was used as an inoculum at 10% (w/w) level (Nche *et al.*, 1994*a*).

In the microbiological analyses, lactic acid bacteria were enumerated in MRS (deMan, Rogosa and Sharpe) agar with addition of 1 g/l natamycin, yeasts were enumerated in oxytetracycline—yeast extract glucose agar and enterobacteriaceae were enumerated in Violet Red Bile Glucose agar as described by Nout *et al.* (1987). All growth media were obtained from Oxoid, UK. Duplicate samples were made into serial dilution series; appropriate dilutions were plated on duplicate counting plates.

For the contamination experiment, *Escherichia coli* (strain LMM 085) was grown in Brain Heart Infusion Broth overnight at 37°C. Soil suspension was obtained by suspending 1% (w/v) garden soil in tapwater, followed by filtration through filter paper. For challenge testing, kenkey dumpling was contaminated with 1% (v/w) *E. coli* culture and 1% (v/w) soil suspension.

Chemical

Reducing sugars were determined according to Nelson-Somogyi (Kormelink *et al.*, 1991) and related to a glucose calibration curve, measured at 520 nm. Duplicate analyses were made of replicate samples.

The pH and TA [titratable acidity, expressed as percentage (w/w) lactic acid] were determined (single measurements in replicate samples) according to Nout *et al.* (1987).

Table 1. Effect of dough/aflata ratio and of moisture contents of dough on handling and moisture content of dumpling and quality of final kenkey. Traditionally made aflata with 69% w/w moisture content was used (two replicate samples; moisture content analyzed in duplicate)

Dough/aflata ratio	Dough moisture content percentage (w/w)			
	40	50	60	70
1:0				
Handling of dumpling	Dry	Good	Wet	Wet
Moisture content % (w/w) of dumpling	49.0	57.2	59.2	68.7
Quality of final cooked kenkey	Dry	Dry	Dry	Wet
3:1				
Handling of dumpling	Dry	Fair	Good	Wet
Moisture content % (w/w) of dumpling	39.0	60.2	63.4	71.2
Quality of final cooked kenkey	Dry	Fair	Fair	Wet
2:1				
Handling of dumpling		Fair	Good	Wet
Moisture content % (w/w) of dumpling		60.9	64.4	67.5
Quality of final cooked kenkey		Fair	Fair	Wet
1:1				
Handling of dumpling	Dry	Sticky	Fair	
Moisture content % (w/w) of dumpling	55.2	64.2	65.3	
Quality of final cooked kenkey	Dry	Good	Good	
1:2				
Handling of dumpling	Dry	Sticky	Fair	
Moisture content % (w/w) of dumpling	60.8	63.9	68.7	
Quality of final cooked kenkey	Fair	Good	Good	

Lactic acid, acetic acid and ethanol were assayed by high performance liquid chromatography (duplicate analyses in replicate samples) as described previously (De Reu *et al.*, 1995), with butyric acid as an internal standard.

Experimental dumplings

The following compositions were tested (two replicate samples): M (maize dough with 58% moisture content), M + A (100 g M + 35 g aflata with 87% moisture content), M + I (100 g M + 10 g starter dough), M + A + I (M + A + 13 g starter dough).

Statistical analysis

Reported data represent mathematical mean values of four data points. Where applicable, statistical significance was assessed using Student's *t*-tests (Snedecor & Cochran, 1980).

RESULTS AND DISCUSSION

A time saving of 38 h could be achieved during the soaking stage. When soaked in water at 30°C, whole kernels slowly reached a maximum moisture content of 40% (w/w) after 48 h. On the contrary, maize cracked in a 3 mm gap crushing mill took only 10 h to stabilize at its maximum moisture level of 40–42% (w/w).

Uncooked coarsely ground maize flour absorbed water to a maximum of 58.0% (w/w). Attempts to produce kenkey without incorporating aflata were unsuccessful on two accounts: (a) the dough lost its shape without being held together by the cementing effect of aflata; (b) after cooking, the centre was hard and dry. This indicates the two-fold function of aflata as dough binder and supplier of additional moisture. In a bid to reduce energy expenditure associated with aflata making, the quantity of aflata was minimized. Table 1 shows the effect of different dough/aflata ratios, and dough moisture contents, on dumpling handling and properties of the final cooked kenkey. This experiment was carried out with an aflata of 69% (w/w) moisture content made according to the traditional Ghanaian method.

The optimum moisture content of the dumpling was about 65%. At this moisture content, a proper final product was obtained after cooking. When dough of 50 or 60% moisture content was used in a ratio of 1:1 or 1:2 with aflata, a proper final product was obtained. As dough of 50% moisture with these ratios of aflata resulted in a sticky dumpling, it is advantageous to use doughs of approx. 60% mc. In the traditional process, half of the weight of maize needs to be turned into aflata to achieve a final moisture content of 65%. However, we found that maize can absorb considerably more water in aflata after a fine grind. Exploiting the

Table 2. Influence of incorporation of aflata (A) and starter dough (I) on microbial composition and metabolite formation in experimental dumplings fermented in glass jars at 30°C (two replicate samples with duplicate analyses)

	M dumpling[d]				M + A dumpling[e]				M + I dumpling[f]				M + A + I dumpling[g]			
	0 h	12 h	24 h	48 h	0 h	12 h	24 h	48 h	0 h	12 h	24 h	48 h	0 h	12 h	24 h	48 h
Lactic acid bacteria[a]	8.5	8.4	8.5	8.8	8.4	8.5	8.6	8.3	8.3	9.0	9.3*	9.8*	8.2	8.8	9.2*	9.2*
Yeasts[a]	3.8	3.8	4.9	4.9	3.8	3.8	6.1*	6.8*	3.8	3.8	4.9	4.9	3.8	3.9	6.2*	6.0*
Enterobacteriaceae[a]	5.5	3.0	< 2.7	< 2.7	5.5	2.8	< 2.7	< 2.7	5.5	< 2.7	< 2.7	< 2.7	5.5	< 2.7	< 2.7	< 2.7
pH	4.83	4.26*	4.19*	4.02*	4.79	3.92	3.80	3.71	4.80	4.10	4.03	3.82	4.77	3.71	3.58	3.55
TA[b]	0.34	0.58*	0.71*	0.80*	0.30	0.64	0.78	0.90	0.45	0.61	0.73	1.02	0.52	0.86	1.08	1.23
Lactic acid[c]	25	48	60	75	18	40	60	75	36	50	68*	110*	40	50	90*	120*
Acetic acid[c]	8	9	12	14	8	8	8	9	9	10	14	16	7	89	11	
Ethanol[c]	24	58	60	58	13	59	57	78	18	44	62	58	32	63*	75*	100*

[a] $\log_{10}$N (cfu/g).
[b] Titratable acidity, expressed as lactic acid % (w/w).
[c] mM.
[d] Maize dough only.
[e] Maize dough (100 g) + aflata (35 g).
[f] Maize dough (100 g) + starter dough (10 g).
[g] Maize dough (100 g) + aflata (35 g) + starter dough (13 g).
* Significantly ($P < 0.005$) different from corresponding values in the other dumplings.

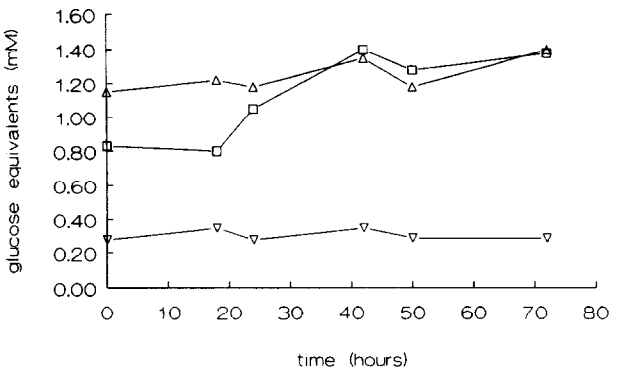

Fig. 3. Effect of aflata and starter dough addition on the evolution of reducing sugars at 4°C in maize dumpling. △ M + A + I dumpling (100 g maize dough + 35 g aflata + 13 g starter dough); □ M + A dumpling (100 g maize dough + 35 g aflata); ▽ M dumpling (maize dough only). (Two replicate samples with duplicate analyses.)

maximum water absorption capacities of both dough (58% w/w) and aflata (87% w/w) we obtained excellent results with a ratio of 100 g dough to 35 g aflata, resulting in a dumpling with 65% (w/w) moisture content.

In order to assess the influence of aflata incorporation prior to fermentation on the amount of fermentable carbohydrates, various dumplings were prepared and kept at 4°C to minimize microbial metabolism. Figure 3 shows that the addition of aflata as mentioned earlier (M + A) significantly ($P < 0.005$) increases the level of reducing sugars (expressed as glucose equivalents) compared with maize dough (M) alone. The reducing sugars are released from the gelatinized starch of the aflata, by the endogenous amylases in the uncooked maize dough. Addition of starter dough (M + A + I) did not result in a significant additional release of reducing sugars. This indicates that the microorganisms in the starter dough do not have amylolytic activities of importance.

Fermentation of experimental dumplings was carried out in sterile glass jars to evaluate the effect of aflata and starter dough on microbial development, acidity and metabolite formation (Table 2). Within a 48 h fermentation period, the level of lactic acid bacteria was higher in dumplings with starter dough addition, as expected. Nevertheless, the endogenous flora of lactic acid bacteria on non-inoculated maize dough is already quite high. Additions of aflata and starter dough to the dumpling appear to have further effects resulting in significant ($P < 0.005$) acceleration of pH decrease and higher levels of titratable acidity, as well as lactic acid in the combination M + A + I. Yeasts were favoured by the incorporation of aflata but not by starter dough. This resulted in higher levels of ethanol in M + A and M + A + I. This could be a disadvantage during processing as it would be accompanied by larger volumes of CO_2 gas which could accumulate in the sausage casings. In all experimental dumplings, the level of acid-sensitive enterobacteriaceae was reduced to below detection level within 24 h, or within 12 h when starter dough was used. Acetic acid was present at relatively low levels and it was not significantly affected by experimental conditions.

When dumpling M + A + I was filled into 6 cm diameter cellulose sausage casings, 15 min were required to achieve a temperature of 85°C at the centre of the sausage, when immersed in boiling water. In order to ensure adequate reduction of vegetative microbial cells, a total cooking time of 35 min was chosen.

Table 3 summarizes the changes of microbial composition and acidity in dumplings with or without deliberate contamination with an *E. coli* culture after 12 h fermentation at 37°C in 6 cm diameter casings followed by 35 min cooking in boiling water. The fermentation period of 12 h was chosen to achieve a pH < 4.0. The data show a drastic reduction in naturally occurring, as well as added, enterobacteriaceae. The cooking period was adequate to kill vegetative cells to

Table 3. Microbial composition and acidity of M + A + I dumplings, fermented with and without added contamination at 37°C, and their respective final products after 35 min cooking (two replicate samples with duplicate analyses)

	Lactic acid bacteria	Yeasts	Enterobacteriaceae	pH
Fresh dumpling[a]	8.7[g]	4.2	5.7	4.78*
Fermented dumpling[b]	8.9	4.2	3.2*	3.91
Cooked kenkey[c]	< 2.7*	< 2.7*	< 2.7*	4.01
Contaminated dumpling[d]	8.8	7.1	7.3	4.76*
Fermented dumpling[e]	8.9	6.0	5.5*	3.90
Cooked kenkey[f]	< 2.7*	< 2.7*	< 2.7*	4.00

[a]100 g maize dough (58% moisture content) + 35 g aflata (87% moisture content) + 13 g starter dough.
[b]Fermented for 12 h at 37°C filled in 6 cm cellulose sausage casings.
[c]Cooked by immersion in boiling water bath for 35 min.
[d]Contaminated with 10^7/g *E. coli* and 1.0% (v/w) soil suspension.
[e]Contaminated dumpling fermented as footnote *b*.
[f]Fermented contaminated dumpling cooked as footnote *c*.
[g]$\log_{10}$N (cfu/g).
*Significance ($P < 0.005$).

below plate count detection level. Some endospore-forming bacteria might have remained. However, these would not be able to germinate at the prevailing pH conditions.

It is concluded that the traditional 4–6 days kenkey manufacturing procedure can be shortened to 24 h by a combination of reducing soaking time of maize, by using a starter dough in a dough–aflata mixture, and by cooking in sausage casings. The latter operation would result in considerable savings on cooking time and thus of thermal energy.

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