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The Effect of Cowpea Supplementation on the Quality of Kenkey, a Traditional Ghanaian Fermented Maize Food

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ABSTRACT

The effects were evaluated of cowpea-mediated protein enrichment on factors relating to kenkey acceptability. Kenkey was prepared on a laboratory scale from a 4:1 mixture of maize (*Zea mays*) and red or white cowpea (*Vigna unguiculata*) and compared with an all-maize product in terms of parameters such as the fermentation profile of doughs, colour and fracture profiles. There was no significant difference between the fermentation profiles after 4 days' fermentation at 30 °C, with final dough pH values reaching 4.07 and 4.08 for all-maize and maize/cowpea mixtures, respectively. Addition of wholegrain cowpeas resulted in an increase in the crude protein content to 12.99% (w/w) and 13.89% (w/w; dry weight basis) for kenkey supplemented with 20% white and 20% red cowpea, respectively, compared with 10.80% (w/w) for unsupplemented kenkey. Addition of cowpea reduced the whiteness (Hunter L value) of the kenkey by 12% (using white cowpeas) and by 27% (using red cowpeas). The use of dehulled red cowpeas improved the whiteness only slightly. Cowpea-supplemented kenkey was more homogeneous and less prone to fracture than all-maize kenkey. The force required to fracture cowpea-supplemented kenkey was higher than for traditional kenkey, and increased with increasing cowpea concentrations. Kenkey stored for 24 hours required over twice as much force to fracture than freshly prepared kenkey. A group of native Ghanaians familiar with the traditional maize kenkey sampled the new product and confirmed that kenkey made from a mixture of wholegrain white cowpea or dehulled red cowpea and maize compared very well with the traditional kenkey.

INTRODUCTION

Kenkey, a dumpling made from fermented maize dough, is a popular staple amongst the people of Ghana. There are several types of kenkey (ga, fanti), but the processing methods are largely similar. In the traditional kenkey process^{1,2}, maize is cleaned and then steeped for 1 to 2 days. The steep water is drained and the grain coarsely milled and made into a dough by adding water (1:3; v/w). The dough is then left to ferment naturally in a heaped mass or in covered containers for 2 to 3 days. The fermented dough is then divided into two equal parts, one of which is slurried and cooked to gelatinisation. This gives a sticky paste which is then mixed with the

uncooked part to give a kneadable dough called the aflata. Balls of appropriate size (≈ 500 g) are shaped, wrapped (in corn sheaths for ga kenkey or banana leaves for fanti kenkey). Salt is also added to dough for ga kenkey before shaping and wrapping. The wrapped dumplings are immersed in water and boiled in a drum or large iron pot for 2 to 3 hours.

Since maize is the basic raw material, such products are rich in carbohydrate, relatively low in protein and deficient in some essential amino acids, particularly lysine. In a region where animal sources of protein are often in short supply, plant sources such as legumes may be of immense importance. Attempts have been made, with some success, at improving the protein quality and quantity of traditional maize-based fermented products of Ghana³ and Nigeria⁴ by supplement-

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tation with soya beans. Soya beans are rather expensive, however, and are not well known in West African households. Being relatively cheaper and more readily available, cowpeas may provide a suitable alternative to the more expensive soya beans⁵. In this work, cowpeas were used as a protein supplement to the traditional all-maize Ghanaian kenkey. This improves both protein quantity and protein quality since the methionine-containing maize is complemented by the lysine-containing cowpeas⁶ providing a better balance of amino acids, especially essential amino acids.

In this research, the rate of fermentation, the colour and textural properties, as well as the overall acceptability, of cowpea-supplemented kenkey were compared with the conventional all-maize formula.

EXPERIMENTAL

Maize (*Zea mays* cv. Obaatanba) and red and white cowpeas (*Vigna unguiculata* cvs Benpla and Asontem, respectively) were obtained from the Crops Research Institute, CSIR, Kwadaso, Ghana. Whole grain and dehulled cowpeas were used. Dehulling was done by hand following 48 h of soaking in excess water.

The laboratory kenkey process

In the laboratory process (Fig. 1), maize or a 4:1 mixture of maize and cowpea (0.5–1.0 kg) was soaked for 48 h in tap water (approx. 3 l). The soak water was drained and the grain coarsely ground in a hammer mill (Fritsch Pulverisette, Type 14.702, Marius Instruments, Utrecht, The Netherlands) with rotor and sieve no. 4 and made into a dough, M_0 , Mw_0 or Mr_0 , from maize, maize/white cowpea or maize/red cowpea, respectively, by adding water (1:3; v/w). The dough was then placed in a 1-l beaker, covered with polyethylene film and allowed to ferment naturally for a standard 4 days at 30 °C. The fermented dough, M_4 , Mw_4 or Mr_4 , was then divided into two equal portions, one of which was slurried with water (3:1; v/w; dry weight basis) and stir-cooked to gelatinization to give the aflata. The cooked and uncooked portions were mixed, kneaded and dumplings were made and wrapped, first in polyethylene film followed by aluminium foil, as direct contact with aluminium foil resulted in darkening of the foil

during cooking, imparting a black colour to the outside of the dumpling. The wrapped dumplings were immersed in boiling water to cook. Dumplings were smaller (250–300 g) than in the traditional household process, hence the cooking time (under constant heat in a covered saucepan) was reduced to 1 h. The resulting products were all-maize (M_4C_1), white cowpea-supplemented (Mw_4C_1) and red cowpea-supplemented (Mr_4C_1) kenkeys.

Fermentation profile

During the 4 days of fermentation, the microbial count, pH, and titratable acidity (per cent lactic acid) were determined⁷ on a daily basis. Counts were made of the functional groups of microorganisms in the product, namely lactic acid bacteria (LAB) and yeasts. In addition, *Enterobacteriaceae* were monitored for public health reasons. Lactic acid bacteria were counted in MRS agar (Merck 10661) pour plates containing 0.1% (w/v) Natamycin ('Delvocid', Gist-brocades, Delft, The Netherlands) overlaid with MRS agar without Delvocid, the yeasts in Oxytetracycline Glucose Yeast Extract agar (Oxoid CM 545) containing 0.01% (w/v) oxytetracycline (Oxoid SR 073A), and the *Enterobacteriaceae* in Violet Red Bile Glucose agar, VRBG (Merck 10275), with a VRBG overlay.

Characterisation of isolated lactic acid bacteria

Isolates were made daily from appropriate MRS counting plates. Five representative colonies of LAB were isolated and subsequently purified on MRS agar. These were then stored at –80 °C in cryotubes containing 15% (w/v) glycerol in MRS broth for later characterisation. Characterisation tests included Gram stain, morphology (by microscopic observations), catalase reaction, growth at 15 °C and/or 45 °C, homo/heterofermentation and arginine hydrolysis. Confirmation of isolated lactic acid bacteria was obtained from established descriptions of non-sporing Gram-positive rods⁸ based on the utilisation of relevant carbohydrates on the API 50 CHL test strips (API System SA, Montalieu Vercieu, France).

Crude protein content

The crude protein content was determined using

Figure 1 Laboratory method for kenkey production.

a semi-automated version of the micro-Kjeldahl method for nitrogen determination⁹. Experiments were done twice and all samples run in duplicate. The values for nitrogen concentration were converted to crude protein content by multiplying by 5.26 for the maize¹⁰ and 5.46 for maize-cowpea blends ($5.26 \times 80\% + 5.46 \times 20\%$).

Colour

Colour parameters L , a and b , representing whiteness, redness and yellowness, respectively, were measured using a DR LANGE Tricolor LFM3 Colorimeter (Hunterlab, 9529 Lee Highway, Fairfax, Virginia), calibrated with a standard

white tile ($L=88.20$; $a=-0.96$; $b=-1.69$). Two measurements were made of the surface of each sample.

Fracture stress

Fracture stress was measured using an Overload Dynamics instrument (Marius Instruments, Utrecht, The Netherlands) having two plates, between which samples of standard cylindrical dimensions (length 3 cm; diameter 2 cm) were placed vertically and compressed at constant speed until fracture, and the fracture stress was calculated¹¹. Dehulled cowpeas were used in supplemented kenkeys.

Table I Fermentation profiles of all-maize and cowpea-supplemented maize doughs

Dough ^a	pH	Titrateable acidity (%) ^b	Lactic acid bacteria (log ₁₀ cfu/g)	Yeasts (log ₁₀ cfu/g)	<i>Enterobacteriaceae</i> (log ₁₀ cfu/g)
M ₀	6.02 ^a	0.49	6.72	4.36	6.53
M ₁	4.00	0.97	8.09	<1.70	<1.70
M ₂	3.86 ^b	1.11	8.01	<1.70	<1.70
M ₃	4.05 ^c	1.15	7.97	<1.70	<1.70
M ₄	4.07 ^c	1.12 ^a	7.93 ^a	<1.70	<1.70
Mw ₀	5.87 ^a	0.49	6.05	4.79	8.86
Mw ₁	4.19	1.31	8.17	<1.70	<1.70
Mw ₂	4.11	1.46	8.00	<1.70	<1.70
Mw ₃	4.07 ^c	1.55	7.94	<1.70	<1.70
Mw ₄	4.08 ^c	1.57 ^b	7.93 ^a	<1.70	<1.70
Mr ₀	6.65 ^d	0.32	7.86	4.61	8.62
Mr ₁	4.31	1.32	8.34	<1.70	<1.70
Mr ₂	4.11	1.58	8.52	<1.70	<1.70
Mr ₃	4.07 ^c	1.67	8.13	<1.70	<1.70
Mr ₄	4.08 ^c	1.73 ^c	8.07 ^a	<1.70	<1.70

^a Sample codes: M = 100% maize; Mw = 80% maize + 20% white cowpea; Mr = 80% maize + 20% red cowpea; subscripts (0, 1, 2, 3, 4) indicate fermentation time (days).

^b Expressed as per cent lactic acid (w/w).

^{a, b, c, d} Values in the same column, with the same letter, are not significantly different ($P < 0.05$).

Product evaluation

An untrained five-member panel of native Ghanaians (three males and two females, aged between 28 and 40 years) familiar with traditional kenkey was asked to evaluate the control and supplemented products on the basis of their sourness (taste), smell, texture, colour, doneness (degree of cooking) and hardness. This was done by individual structured interview, followed by group discussion. Each panellist was asked to sample the product and formulate how the supplemented kenkey compared with the all-maize traditional kenkey with respect to the above criteria. Each panellist was advised to draw from his or her experience as a traditional kenkey consumer. Individual comments were compared and the group discussion that followed was aimed at reaching a general consensus on the potential acceptability of the new product and recommendations on the possible improvement of the less-acceptable parameters.

RESULTS AND DISCUSSION

In our experiments to study lactic acid fermentation in kenkey doughs (Table I), the pH decreased and the titratable acidity increased as the lactic acid bacteria (LAB) count increased. LAB

counts exceeded 10^8 /ml after only 24-h fermentation. Further incubation led to a slight fall in LAB counts. Where yeasts occurred, lower counts ($<10^5$) than LAB were often noticed. Yeast counts declined sharply with the rapid decrease in pH. The *Enterobacteriaceae* counts also fell rapidly to below detection level as a result of acid production by the LAB¹². Some authors¹³ believe that other substances (e.g. bacteriocins) produced by the dominating LAB may contribute to the disappearance of *Enterobacteriaceae*.

Table I confirms the trend observed by previous authors¹⁴ investigating the changes in pH and titratable acidity during the natural fermentation of cereals and legumes. They reported an optimum fermentation period of 2 and 3–4 days at 30 °C for cereals and legumes, respectively. The pH of all-maize dough (M₀) fell from 6.02 to 3.86 in just 2 days, whereas that of supplemented doughs (Mw₀ and Mr₀) required a further day to reach its lowest value of 4.07. After 4 days of incubation, the pH of all three doughs stabilised at 4.08. The higher titratable acidity values obtained for supplemented doughs could be attributed to the high buffering capacity of the medium due to the higher content of proteins and amino acids^{15,16}. The addition of 20% cowpeas, therefore, did not hinder proper dough fermentation, although a longer time was required for

Table II Crude protein contents of doughs of maize and maize-cowpea blends

Dough ^a	Crude protein content (%; w/w; dry matter) ^b
M ₀	10.41 ± 0.49
M ₄	10.80 ± 0.32
Mw ₀	12.57 ± 0.21
Mw ₄	12.99 ± 0.21
Mr ₀	13.51 ± 0.20
Mr ₄	13.89 ± 0.24

^a See Table I for meaning of sample codes.^b Mean ± s.d.; *n* = 4.

acidification to stabilise. Two and 3 days of fermentation were sufficient to lower the pH of all-maize and cowpea-supplemented doughs, respectively, to the inhibitory pH range (3.6–4.1) for food poisoning bacteria reported by Hamad and Fields¹⁷. These authors did not specify lactic acid as responsible for lowering the pH to this inhibitory range, however.

Tests identified *Lactobacillus plantarum*, *L. confusus*, *L. brevis* and *Pediococcus pentosaceus* as the main lactic acid bacteria present in the fermenting doughs. In the case of doughs M₀ and Mw₀, *L. confusus* was found to dominate the earlier stages of fermentation (*d*₀). These were later replaced by *Pediococcus* spp. and *L. plantarum* for M₁₋₄ and Mw₁₋₄, respectively. The pattern was one of acid-sensitive heterofermentors being succeeded by more acid-tolerant homofermentors. This was in line with the decrease in pH and the increase in titratable acidity (Table I) as fermentation progressed.

The pattern was less clear for Mr₀₋₄, in which *L. plantarum*, *L. confusus* and *Pediococcus* spp. were present in similar proportions throughout the 4 days' fermentation.

The addition of 20% red and 20% white cowpea resulted in increases in crude protein contents of 29.2% and 20.5%, respectively, for the supplemented products. The values for crude protein content shown in Table II are comparable with those reported earlier⁵ for ogi fortified with cowpeas. With regard to the average essential amino acid contents of maize¹⁸ and cowpea⁶, these values represent, respectively, 76.3, 15.6 and 26.8% increases in lysine, methionine and tryptophan in maize-red cowpea blends and 65.3, 8.2 and 19.5% increases in lysine, methionine and tryptophan, respectively, in maize-white cowpea blends.

The addition of wholegrain cowpea reduced the

Table III Colour parameters of all-maize and cowpea-supplemented kenkey (Hunter *L*, *a* and *b* values)

Kenkey ^a	<i>L</i> (mean ± s.d.)	<i>a</i>	<i>b</i>
M ₄ C ₁	66.89 ± 0.46	0.10 ± 0.74	16.48 ± 1.37
Mw ₄ C ₁	58.86 ± 2.02	3.00 ± 1.25	13.67 ± 2.14
Mw ₄ C ₁ ^b	61.09 ± 1.45	0.44 ± 0.08	15.72 ± 0.36
Mr ₄ C ₁	49.70 ± 3.28	6.30 ± 1.13	10.86 ± 1.37
Mr ₄ C ₁ ^b	54.03 ± 1.87	8.07 ± 0.25	12.19 ± 0.33

^a Sample codes in addition to those in Table I; C = cooked, with subscript cooking time (hours).^b Dehulled cowpeas.

whiteness of the product (Table III). This was more pronounced with the addition of red cowpeas where the colour change was noticeable. Dehulling the cowpeas improved the colour visibly even though the Hunterlab *L* values were still very much lower than for all-maize kenkey. Traditional kenkey is usually wrapped in either banana leaves (fanti kenkey) or corn sheaths (ga kenkey), which results in a slight browning of the surface of the product after cooking. This does not seem to be of concern to the consumer, hence a reduction in whiteness by white cowpea is not expected to be a major setback. Red cowpea will, however, require dehulling to prevent the final product becoming brown. Other authors³ used a Hunterlab Model D25D Color Meter, calibrated with a standardised white tile (*L* = 93.6, *a* = 0.7 and *b* = 0.2), and obtained *L*, *a* and *b* values of 76.94 ± 0.14, -1.14 ± 0.06 and 10.55 ± 0.23, respectively, for traditional fermented maize doughs from Ghana. The differences between those *L*, *a* and *b* values and the values reported here may be due to the use of different standardisation constants. Also, those authors referred to fermented dough and not to the cooked product of fermented doughs used in this project.

Fracture experiments were conducted on kenkey stored at room temperature for 1, 24 and 72 h. The moisture contents were maintained by storing samples well wrapped up with aluminium foil in a closed bucket. Table IV shows that fracture stress (α_f) increased with increasing cowpea levels. This may be due to the fact that cowpea supplementation results in a more homogeneous product, which is less prone to breakage than the traditional all-maize kenkey. In the traditional kenkey, intact maize hulls form areas of local stress concentration, which makes the product more prone to fracturing¹⁹. In addition,

Table IV Effect of cowpea level and storage on hardness of kenkey at constant moisture content

Kenkey ^a	Cowpea level (%)	Storage time (h)	Moisture content (%; w/w)	Stress at fracture ($\times 10^3 \text{Nm}^{-2}$) ^b
M_4C_1	0	1	64	2.40 ± 0.10
		24	63	4.50 ± 0.20
		72	63	4.20 ± 0.20
Mw_4C_1	10	1	63	3.40 ± 0.30
		24	63	6.30 ± 0.10
		72	62	6.50 ± 0.10
Mw_4C_1	20	1	67	3.15 ± 0.10
		24	63	6.35 ± 0.20
		72	63	6.95 ± 0.60
Mw_4C_1	30	1	63	4.30 ± 0.20
		24	63	8.30 ± 0.10
		72	63	8.10 ± 0.20
Mw_4C_1	50	1	65	3.20 ± 0.20
		24	65	8.10 ± 0.10
		72	66	7.90 ± 0.10

^a For abbreviation see Table I and Table III, with the exception that the level of cowpea substitution ranges from 0–50%, as specified above.

^b Mean $\pm$ s.d.; $n = 3$.

starch/protein interactions may contribute to the increased firmness of the product. Fracture stress also increased on storage of the product, the greatest increase occurring in the first 24 h, during which fracture stress (α_f) values doubled. This may be attributable to a number of factors, amongst them setback and retrogradation of starch as the product cools²⁰, resulting in a firmer product.

The sharp sour taste of properly fermented kenkey³ was detected in all samples by all panellists. None registered off-smells resulting from the addition of cowpeas. Kenkey made from mixtures of 80% maize and 20% wholegrain white or dehulled red cowpeas were preferred by all the panellists as these compared very well with the traditional product. Three male panellists also liked the kenkey supplemented with dehulled white cowpea, but the two female panellists thought it was smoother than the traditional product. Kenkey supplemented with wholegrain red cowpeas was rejected by all but one (male) of the panellists on account of its brown colour.

Although the results of product evaluation must be interpreted cautiously, they, nevertheless, place additional weight on the argument that traditional kenkey could be enriched with 20% (w/w) cowpeas without necessarily affecting its basic physical and organoleptic properties. Large-scale product

evaluation is required, however, to establish absolutely the degree of acceptability of cowpea-supplemented kenkey.

Previous reports on cereal-legume mixtures^{6,21}, and the results reported in this paper, suggest that cowpea could be used successfully to supplement traditional cereal-based products. This will undoubtedly go some way towards improving the protein requirements of people of a region where animal sources of protein are often too expensive to be afforded by many people.

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