STUDIES ON KENKEY WITH PARTICULAR REFERENCE TO CALCIUM AND PHYTIC ACID

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ABSTRACT

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Changes in the proximate composition of maize during the kenkey-making process have been determined. With the exception of the fat content, which decreased, the chemical composition of the maize remained virtually unchanged. Calcium and phytic acid received particular attention. Little of either was lost during kenkey manufacture. It was shown that the intake of dietary calcium is too low, if kenkey forms the staple food for children, and some form of calcium enrichment has been suggested. It has been shown that up to 88% of phytic acid can be destroyed by adding wheat or germinated maize flour to the kenkey mix.

Kenkey is a sour fermented maize dumpling which, wrapped in leaves and boiled, is one of the staple foods of a large part of the people of Ghana (1,2) (Fig. 1). There are many varieties of kenkey (3) differing in additives, fermentation time, flour extraction, and method of wrapping (Table I). The traditional method for preparing kenkey is complex and nutritional losses may occur. Therefore, the effect of the kenkey-making process on proximate composition has been studied.

The recommended daily calcium intake for the United Kingdom is the same as that suggested by FAO, *i.e.*, 600 mg for children and 500 mg for adults (4,5). In both instances, the assumption was made that a lower calcium intake was not associated with any ill effects. However, there is evidence that low calcium intakes can be associated with impaired growth and high incidence of osteoporosis.

Maize is low in calcium but high in phosphorus (6). The latter is present mainly in the form of phytin which is the calcium-magnesium salt of phytic acid (inositol hexaphosphate).

There is considerable evidence to suggest that phytic acid phosphorus is not available to the body unless the phytic acid is hydrolyzed. It is also often held that phytic acid may interfere with calcium metabolism in man. The obligatory enrichment of wheat flour with chalk in the U.K. is based on this premise (7–11). However, some authors disagree (12,13).

Because of its importance in Ghanaian nutrition, the effect of kenkey processing on the levels of calcium and phytic acid has been considered. An attempt has been made to hydrolyze the phytic acid in maize in two ways: First, by adding germinated maize (because phytase is produced during germination), and second, by adding wheat flour. The latter contains phytase, which is not present in ungerminated maize (14).

MATERIALS AND METHODS

Kenkey Preparation

Both white flint maize from Ghana and white dent maize from Malawi were

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used to prepare kenkey in the laboratory. The proximate composition is given in Table II.

Cleaned maize (250 g) was weighed into a 1-liter beaker containing 300 ml of distilled water, and was kept covered in a Hearson incubator at 30° ± 1°C for 18

Fig. 1. Kenkey.

TABLE I
Characterization of the Various Types of Kenkey

Type of Kenkey	Color	Approximate Flour Extraction	Additives
Kokui	White	Less than 85%	Salt
Mbor (Ntaw and Nsihu)	Pale yellow to creamy white	Approximately 90%	None
Dokon Pa	Pale yellow to light green	100%	None
Ashanti	White	Less than 85%	Sugar or sweet potato
Nsihu	White	Less than 85%	None
Ntaw	Light brown	100%	None
Ga	Pale yellow to creamy white	100%	Salt

TABLE II
Proximate Composition of Ghanaian and Malawi Maize Used (db)

	Crude Protein (N × 6.25)	Fat	Fiber	Ash	Carbohydrate by Difference
Ghanaian maize (moisture content 15.0%)	10.7	4.9	1.7	1.50	81.2
Malawi maize (moisture content 10.4%)	9.9	5.1	1.9	1.36	81.7

hr. The seeds were then placed on a coarse sieve and drained, and the soaking water was discarded. Surface moisture was removed with a dry muslin cloth. The soaked maize was then ground at setting No. 1 on a Hobart coffee grinder (Model E2120). Then 300 g of the ground maize was placed in a farinograph bowl at 30° C and water added in the usual way.

The dough was mixed to a consistency of 500 Farinograph Units. It was then returned to the beaker, covered, and left to ferment for 2 days at 30° C. Distilled water (100 ml) was added to 150 g of fermented dough. This portion was mixed into a slurry and cooked to a thick porridge. Salt (10 g) was added and the porridge mixed with a second 150-g portion of the uncooked dough. The mixture was molded into balls of 150 g each. The balls were then wrapped in heavy duty aluminum foil although traditionally leaves are used. The wrapped dumplings were then boiled for 20 min in 1000 ml of water in a pressure cooker at 15 lb/in.^{2}, and allowed to cool. (Traditionally, the product is boiled at atmospheric pressure for 2–3 hr.) AACC methods of analysis were used (15).

Calcium Determination

For calcium determination, the samples were ashed and the ash was dissolved in 2–3 ml concentrated HCl and evaporated to dryness. Then 2–3 ml of HCl were added and made up to about 75 ml with water. The solution was passed through a column containing Amberlite 1R 120H resin to remove the phosphates. The column had previously been regenerated with 100 ml of 3*N* HCl.

Standards (0.5, 2, 5, and 10 ppm calcium) from pure calcium carbonate and sample solutions were passed through a Unicam SP 90 atomic absorption spectrophotometer at 422.7 nm (slit width, 0.1 mm; expansion, × 4; acetylene as fuel; light source, a hollow cathode lamp).

Total and Phytic Acid Phosphorus

For phytic acid determination, the method proposed by Wheeler and Ferrel (16) was used, except that phosphorus was determined directly in the iron phytate precipitate. McCance and Widdowson's perchloric acid digest method (17) was used for phosphorus determination in the precipitate.

Potassium hydrogen phosphate, which had previously been dried at 105° C for 2 hr, was used to prepare standard solutions of 1000 – 8000 μg. The colors of both standards and samples were measured on an EEL colorimeter at 470 nm in 1-cm cells after addition of ammonium vanadate-molybdate reagent.

The method of Kent-Jones and Amos (18) was used to determine the total phosphorus present.

To determine the percentage hydrolysis of phytic acid in maize with various amounts of wheat, 1% of whole-meal English wheat was added to 2–3 g of ground maize. Accurately weighed quantities were placed into 250-ml stoppered conical flasks, ten times the weight of acetic acid acetate buffer at pH 5 was added, and the flasks were left in an incubator at 40° C for 2 to 36 hr. At the end of each incubation period, one flask was removed and stored in a freezer at −20° C until required for analysis. The samples were then thawed and analyzed for phytic acid. The procedure was repeated for maize with additions of 5 and 10% wheat flour.

As germinated maize, the variety Golden Bantam was used. Seeds of uniform size were soaked overnight in distilled water at room temperature (21° C). The

seeds were then placed embryo downward between sheets of moist blotting paper in enamel trays at 25° C. The germinated seeds were removed after 1, 2, 3, 4, 5, and 6 days of germination, dried in an oven at 40° C, and milled on a Christy and Norris hammer mill.

To find the rate of destruction of phytic acid during germination, the above samples were weighed into stoppered conical flasks. Acetic acid acetate buffer at pH 5 was added and the samples incubated for 2 hr, after which phytic acid was determined in the usual way.

To prepare kenkey dough containing either wheat or germinated maize, various amounts of these additives were added to the ground maize.

Doughs were prepared and left to ferment in the usual way. Phytic acid before and after fermentation was determined.

RESULTS AND DISCUSSION

With Ghanaian maize, there was a slight increase in crude protein content during soaking and fermentation (Table III). This may be due either to microbial synthesis or loss of nonprotein material.

Christian reported that lactobacilli and yeasts were the predominant microorganisms during the latter stages of dough fermentation (2), and Akinrele and Bassir made a similar observation in Nigerian ogi (19). With Malawi maize, a slight decrease in crude protein was found after soaking (Table IV).

There was a considerable decrease in fat content of both Ghanaian and Malawi maize at the fermentation and cooking stages. Perhaps the fat was hydrolyzed as Zeleny suggested (20), or the quantity and composition of lipid material extracted from flour as crude fat may depend on the type of solvent and method of extraction (21). There is a considerable amount of evidence to show that during mixing, a large proportion of extractable lipid becomes bound (*e.g.*, 22,23).

While Tables III and IV refer to kenkey produced in the Leeds Laboratory, Table V shows type of kenkey, origin, weight, and wrapping material of various samples obtained in Ghana. The figures show clearly the need for commercial standardization of weight. It is also apparent that some producers decrease net weight by using more wrapping material.

Most of the minerals, with the exception of calcium, are normally situated in the maize germ (24). Removing the germ during milling results in a decrease in ash. Ashanti and Nsihu kenkey are made from low extraction flour and therefore have low ash contents. Although Kokui is also made from low extraction flour, it has a relatively high ash content. Kpandu town uses well water which is very hard (water hardness = 250 mg/l.). Kokui kenkey could therefore have gained some minerals from the water.

All the samples from low extraction flours have low fat contents. Among the samples from whole-meal maize, it is possible that the amount of wrapping material used could help prevent leaching of nutrients. For example, the protein content of Ga kenkey is lower than that of Ntaw (Fanti kenkey).

At most, two layers of wrapping material are used in Ga kenkey, whereas at least four layers of dried plantain leaves are used to wrap Fanti kenkey.

It is apparent from Tables III and IV that in processing, a certain loss of calcium occurs. This was 2.72% for Ghanaian maize and 4.67% for Malawi maize.

TABLE III
Analysis of Kenkey and Intermediate Fractions from Ghanaian Maize[a]

	Protein N × 6.25	Fat	Fiber	Carbohydrate	Ash	Calcium mg/100 g	Phosphorus Total mg/100 g	Phosphorus Phytic mg/100 g	Phosphorus Phytic as % Total
Original maize (moisture content 15.0%)	10.7	4.9	1.7	81.2	1.50	5.88	334.6	257.5	77
Steeped maize (moisture content 32.4%)	11.4	4.0	1.8	81.3	1.50	5.13	330.3	242.4	73
Steeping water (moisture content ND)	0.2	Tr	Tr	ND	Tr	0.29	7.8	4.9	63
Fermented dough (moisture content 51.0%)	11.7	1.5	1.7	83.6	1.50		329.3	214.0	65
Cooking water (moisture content ND)	0.2	Tr	Tr	ND	Tr	0.26	9.2	1.2	13.1
Kenkey (moisture content 64.5%)	11.6	1.4	1.7	19.3	1.48	5.72	323.0	212.6	65.8

[a]Results on % dry basis, carbohydrate by difference. ND = Not determined, Tr = Trace.

TABLE IV
Analysis of Kenkey and Intermediate Fractions from Malawi Maize[a]

	Protein (N × 6.25)	Fat	Fiber	Carbohydrate	Ash	Calcium mg/100 g	Phosphorus Total mg/100 g	Phosphorus Phytic mg/100 g	Phosphorus Phytic as % Total
Original maize (moisture content 10.40%)	9.9	5.1	1.9	81.74	1.36	4.71	268.6	201.4	75
Steeped maize (moisture content 31.5%)	9.5	4.4	1.9	82.84	1.36	4.33	254.0	197.0	78
Steeping water (moisture content ND)	0.1	ND	Tr	ND	Tr	0.28	13.7	5.8	43
Fermented dough (moisture content 53.1%)	9.7	3.8	1.9	83.24	1.36	ND	252.6	196.0	78
Cooking water (moisture content ND)	0.1	ND	Tr	ND	Tr	4.50	7.0	191.9	78
Kenkey (moisture content 61.6%)	9.7	1.9	1.8	85.30	1.30	0.20	243.3	4.0	57

[a]Results on % basis, carbohydrate by difference. ND = Not determined, Tr = Trace.

TABLE V
Analysis of Ghanaian Kenkey[a]

Type of Kenkey	Town of Origin	Leaves for Wrapping	Total Weight g	Weight Less Wrapping	Protein (N × 6.25)	Fat	Ash	Calcium mg/100 g	Water Hardness mg/l.	Phosphorus Total mg/100 g	Phosphorus Phytic mg/100 g	Phosphorus Phytic % Total
Kokui	Kpandu	Maize (*Zea mays*)	260 280	240 270	9.3	0.09	1.5	13.2	250	33.8	5.2	15
Mbor (Ntaw and Nsihu)	Winneba	Plantain (*Musa paradisiaca*)	440 425	430 415	9.5	1.62	1.1	16.9	50	322.4	205.2	64
Dokon Pa	Winneba	"Akoronko" (*Sterculia tragacantha*)	575 550	550 480	10.2	1.90	1.5	13.5	50	282.7	220.0	78
Dokon Pa	Yanoransa	"Akoronko" (*Sterculia tragacantha*)	525 500	490 480	9.5	2.74	1.6	20.3	60	170.3	123.0	72
Ashanti	Osino	"Aworom" (*Marantochloa cuspidata*)	330 340	280 280	5.0	0.14	0.2	5.1	60	28.8	2.6	9
Nsihu	Cape Coast	Plantain (*Musa paradisiaca*)	440 410	430 380	8.1	0.19	0.4	8.2	60	54.9	17.8	32
Ntaw	Amosiama	Plantain (*Musa paradisiaca*)	550 525	440 440	9.8	2.35	1.3	19.3	60	159.2	116.0	73
Ga	Accra	Maize (*Zea mays*)	320 310	280 270	8.7	1.70	1.4	16.2	30	287.1	119.0	70

[a]Dry basis, ash corrected for sodium chloride.

TABLE VI
Destruction of Phytic Acid in Ground Maize Plus 1, 5, and 10% Whole Meal Wheat (pH 5, 40° C)

Time hr	1% Wheat		5% Wheat		10% Wheat	
	Phytic acid after incubation mg/100 g	% Hydrolysis	Phytic acid after incubation mg/100 g	% Hydrolysis	Phytic acid after incubation mg/100 g	% Hydrolysis
0	177.0	0	203.7	0	220.19	0
2	131.0	26	133.8	27	88.84	59.80
4	128.8	30	52.4	54	18.62	91.62
8	99.7	44	11.2	95	0	100
10	81.3	54	1.9	99	...	...
12	73.4	59	0	100	...	...
16	50.2	72	0	100	...	...
18	40.6	77	...	...	...	...
24	14.5	92	...	...	...	...
36	1.7	99	...	...	...	...
Phytic acid after 2 days' fermentation mg/100 g	162.0		106.9		26.8	
% hydrolysis	9		48		88	

The calcium content of the various types of kenkey obtained in Ghana ranged from 5.1 to 20.3 mg/100 g. The kenkeys from low extraction flours (Ashanti, Nsihu) had very low calcium contents. Although Kokui was also made from low extraction flour, it had a relatively high calcium content. Possibly the kenkey had gained calcium from the water.

It is apparent from these results that children fed mainly on a maize-based diet such as kenkey will suffer from calcium deficiency. Even in areas like Kpandu, where the water contributed a significant amount of calcium to the diet, a child would have to eat 3000 to 4000 g of kenkey on dry basis per day to meet the requirements of F.A.O. It is therefore highly desirable that calcium be added to the Ghanaian diet.

As with calcium, the whiter type of kenkey from Ghana contained very little total phosphorus (Table V). Osino kenkey contained only 28.8 mg/100 g of phosphorus compared with Ga kenkey, which contained 287.1 mg/100 g (Table III). These results are to be expected, since about 80% of the phosphorus in maize is situated in the germ and is removed during milling.

Maize and all the Ghanaian kenkeys made from whole-meal maize contained enough total phosphorus to meet the daily requirement. However, 70 to 78% of

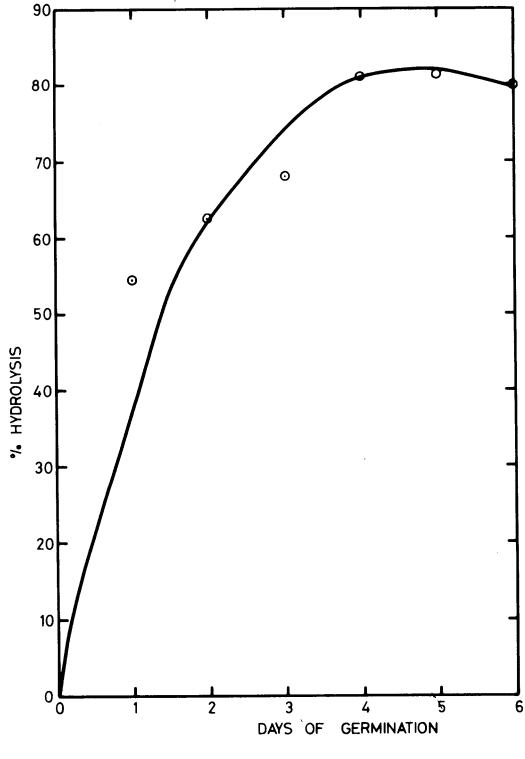

Fig. 2. Phytase activity in maize germinated from 1 to 6 days. Activity expressed as % hydrolysis. Samples incubated for 2 hr.

TABLE VII
Phytic Acid Hydrolysis in Dough from Maize Plus Various Amounts of Germinated Maize

Addition of Germinated Maize to Maize %	Phytic Acid before Fermentation mg/100 g	Phytic Acid after Fermentation mg/100 g	% Hydrolysis of Phytic Acid	pH after Fermentation
5	260.5	174.9	33	4.7
10	255.7	113.7	56	4.7
20	245.1	73.5	70	4.6

the total was present as phytic phosphorus. It has already been pointed out that the body cannot use the phosphorus in phytic acid unless it is first hydrolyzed. This intact phytic acid may also prevent calcium absorption.

It is apparent from Table VI that with the addition of 1% wheat meal, 99% of phytic acid is destroyed in 36 hr; with 10%, 100% destruction occurs in 8 hr (pH 5, 40° C). Therefore, increasing the amount of wheat meal added to ground maize increased the concentration of phytase, thus resulting in a greater rate of phytic acid hydrolysis.

When various amounts of whole-wheat flour were added to kenkey dough, and this was left to ferment for 2 days (Table VI), it was found that 88% of the phytic acid in the dough containing 10% wheat flour had been hydrolyzed.

Figure 2 shows the hydrolysis of phytic acid in maize during 6 days of germination between sheets of moist blotting paper at 25° C. This hydrolysis was taken as a measure of the activity of the enzyme phytase. The amount of phytic acid hydrolyzed increased up to the fourth day of germination and then appeared to decrease. It seems, therefore, that the greatest activity of phytase occurs on the fourth day of germination. Maize germinated for 4 days was used in the subsequent experiment. When 5, 10, and 20% of germinated maize were added to the maize dough (Table VII), it became apparent that wheat was more effective in hydrolyzing the phytic acid than germinated maize. Only 56% of the phytic acid was hydrolyzed when 10% germinated maize was added to the dough, compared to 88% with the addition of 10% wheat.

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