Effect of Local Food Processing on Phytate Levels in Cassava, Cocoyam, Yam, Maize, Sorghum, Rice, Cowpea, and Soybean

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Phytate levels in the unprocessed foods were 6.24 ± 0.22 mg of phytate/g of sample (cassava), 8.55 ± 0.45 mg/g (cocoyam), 6.37 ± 0.32 mg/g (yam), 7.34 ± 0.31 mg/g (white maize), 6.86 ± 0.12 mg/g (yellow maize), 8.86 ± 0.20 mg/g (red sorghum), 4.49 ± 0.22 mg/g (rice), 8.24 ± 0.22 mg/g (cowpea), and 6.88 ± 0.52 mg/g (soybean). Seventy-two hours of fermentation substantially reduced phytate levels in these foodstuffs, ranging from 80% to 98% for rice, cassava, and cocoyam and from 52% to 65% for sorghum, maize, soybean, cowpea, and yam. Lowering of phytate levels was most rapid within the first 48 h of fermentation. Cooking had little reducing effect on phytate levels in whole cereals and legumes but had considerable reducing effect on phytate levels in the tubers. Further processing of all the intermediate products to ready-to-serve foods achieved reductions in phytate levels. The pH of the maize dough fell from pH 6.21 to pH 3.10 during fermentation.

INTRODUCTION

Maize, rice, sorghum, cowpea, soybean, cassava, cocoyam, and yam are among the most popular stable foods consumed in Africa. Phytates, a general term used to describe hexaphosphate esters of inositols, are naturally occurring substances found in a variety of plant seeds and in many roots and tubers (Harland and Oberleas, 1986). Phytates bind minerals in the gastrointestinal tract, making dietary minerals unavailable for absorption and utilization by the body (Oberleas, 1983). Phytate affects the homeostasis of zinc and may also affect bioavailability of other essential minerals (Prasad, 1966). In addition, complex formation of phytate with proteins may inhibit the enzymatic digestion of proteins (Singh and Krikorian, 1982). The possible adverse nutritional effect of phytate has, to some extent, limited the use of many plant materials which are rich in amino acids like lysine and sulfur-amino acids (Gillberg and Tornell, 1976). For example, feeding rats with rapeseed protein diets containing 1.24% phytate resulted in reduced growth rate, diet consumption, and efficiency of protein utilization in these animals (Atwal et al., 1980). Addition of phytate to nonrachitogenic or slightly rachitogenic diets was reported to enhance rickets in young dogs (Harrison and Mellanby, 1939). Furthermore, iron and zinc deficiencies occur in populations that subsist on unleavened whole-grain bread and rely on it as a primary source of these minerals (Khan et al., 1986).

Phytate levels in plant minerals are reduced during certain food-processing operations. For example, cooking reduced phytate content of peas by 13% (Beal and Mehta, 1985), while baking lowered phytate levels in leavened and unleavened Iranian flat bread (Ter-Sarkissian et al., 1974). Phytate levels are also reduced significantly during bread making (Harland and Harland, 1980). There are procedures available for removing phytate from soybean isolates, etc., but these require extensive processing (Okubo et al., 1975). Cereals and legumes form the bulk of the diet of many Africans, and these foods are generally eaten unrefined. It is inferred from this that some of these people may be consuming high levels of phytate with their diets if the local food-processing methods do not effectively reduce phytate levels. This paper is a report on an investigation on the effect of local food-processing operations on phytate levels in selected food materials found in West Africa.

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MATERIALS AND METHODS

The grains, maize (*Zea mays*), rice (*Oryza sativa*), sorghum (*Sorghum moench*), cowpea (*Vigna unguiculata*), and soybean (*Soja max*), used in this study were purchased from a local market in Ile Ife, while the tubers, cassava (*Manihot esculentis*), cocoyam (*Colocasia esculentis*), and white yam (*Discorea rotundatapoir*), were obtained from the University of Ife farm in Ile Ife.

Cereals: Maize, Rice, and Sorghum. Defective seeds and extraneous materials were manually removed from the samples. The samples were then subjected to the same processing procedures usually employed by many African women in food preparation. The samples were milled into meals of particle sizes <0.5 mm. The details for the formulation of the various food products are given below.

Corn or Maize Dough. Maize meal was mixed with water at a ratio of 3:1 (w/v) by hand until a thick consistent paste (corn dough) was obtained. The corn dough so formed was left to ferment for 48-72 h at ambient temperature. The fermented dough was used to prepare a number of food products as described below.

"Kenkey". Kenkey was prepared from fermented whole-maize dough by first dividing the dough into two portions. Water was added to one portion of the dough at a ratio of 1:3 (v/w), and the paste formed was salted to taste. The salted corn paste was then boiled for ~30 min to form a sticky semisolid paste and then mixed thoroughly with the uncooked half of the dough from the first step. The dough formed was then made into balls and carefully wrapped in clean plantain leaves (as a source of flavor) and packed into a pot and cooked for ~2.5 h.

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Table I. Proximate Composition of Some Cereals, Legumes, and Tubers (dwb)

sample description	composition, %					
	moisture	fat	protein	fiber	ash	CHO[a]
cereals						
white maize	6.53 ± 1.31	3.58 ± 0.62	10.57 ± 1.07	1.60 ± 0.51	1.20	76.52
yellow maize meal	5.23 ± 0.89	3.81 ± 0.73	10.21 ± 0.89	1.80 ± 0.43	1.41	77.49
red sorghum meal	6.14 ● 1.76	5.06 ± 1.20	8.12 ± 0.84	1.40 ± 0.21	1.90	77.38
rice (short grain local variety)	3.70 ± 0.22	1.30 ± 0.09	10.40 ± 0.66	0.60 ± 0.22	0.80	83.20
legumes						
cowpea meal	6.44 ± 0.57	1.98 ± 0.45	25.70 ± 1.20	3.80 ± 0.34	3.80	58.28
soybean mean	9.00 ± 0.11	18.30 ± 1.44	32.40 ± 1.82	4.30 ± 0.33	4.60	31.14
tubers						
cassava	55.20 ± 1.53	0.34 ± 0.18	1.50 ± 0.09	1.60 ± 0.21	1.91	39.45
cocoyam	58.10 ± 1.42	0.20 ± 0.10	2.90 ± 0.06	0.70 ± 0.10	0.90	38.30
yam	59.80 ± 1.62	0.35 ± 0.15	2.10 ± 0.19	0.55 ± 0.08	0.70	36.50

[a] CHO, carbohydrate by difference. Data are presented as mean values ± SD; n (number of determinations) = 3.

The level of cooking water was replenished periodically throughout the cooking period, and the cooked balls of kenkey were transferred from the pot into a large bowl to cool.

"Agidi/Eko" (*Maize Pudding*). This product was prepared from fermented dough by adding approximately 500 mL of water to 1 kg of dough and stirring to form a smooth and light slurry. The slurry was then strained through a sieve of 0.5-mm pore size to remove unwanted testa. The sieved slurry was then boiled to form a thick paste, which was then distributed into clean leaves with a wooden ladle, wrapped up, and allowed to cool into a semirigid product. Agidi may be eaten with soup or stew.

"Koko" (*Porridge*). Koko was prepared in the same way as agidi except that koko contained more water and was of a more watery consistency than agidi. Approximately 100 g of sieved dough was mixed with 500 mL of water and boiled for about 20 min. The mixture was stirred continuously during cooking to avoid formation of a product with a lumpy texture. Some sugar and salt are usually added to improve taste, but in this experiment salt and sugar were not added. Both agidi and koko are often fed to adults, children, and babies at home and in the hospitals in West Africa. In fact, koko is generally eaten as breakfast by many people in West Africa.

Doughs were also prepared from sorghum and rice and used to prepare products similar to those described for maize.

Legumes: Cowpea and Soybean. *"Akla/Koosê"* (*Cowpea Doughnut*). Cowpeas and soybean seeds were separately milled into meals and then mixed with water at a ratio of 5:3 (w/v). The paste was left to ferment for 1–2 h and then deep-fried in vegetable oil into koosé. Bean balls are not formed if the mixture is fried immediately without fermentation.

Tubers: Cassava, Cocoyam, and Yam. *"Ampesi"*. This product was prepared by peeling and cutting cassava into pieces, which were then cooked for ~20 min. The product is called ampesi and it is eaten with stew.

"Fufu". This product was prepared by peeling and cutting cassava into slices, followed by cooking the sliced cassava for ~20 min. The cooked material was then pounded in a mortar with a pestle into a paste called fufu which is eaten with soup.

"Tuo" or "Kokonte". This product was prepared by peeling and cutting cassava into rough cubes (4–6 cm long). The cassava cubes were then sun-dried and milled into a meal which was mixed with water at a ratio of 3:2 (w/v) and then cooked for ~30 min. The mixture was stirred with a wooden ladle throughout the cooking period till a paste with a thick consistency was obtained. This product, called tuo or kokonte, is eaten with okra soup often containing green leafy vegetables.

"Gari". This product was prepared by peeling and cutting approximately 5 kg of fresh cassava into small pieces, which were milled into a pulp and then packaged into a jute bag. The bag and contents were secured with a rope and placed under a large, heavy stone to squeeze out excess water. The pulp was fermented for 72 h and roasted in a hot iron plate for approximately 45 min. This product, gari, is eaten in different forms, with stew or soup or together with milk, sugar, salt, and water.

"Eba". This product was prepared by stirring approximately 250 g of gari in 500 mL of boiling water with a wooden ladle for ~10 min to form a smooth paste. The product, eba, is usually eaten with either soup or stew.

Cocoyam and yam were processed in the same way into identical products as described for cassava. Normally, gari is not made from cocoyam and yam, but in this study, gari was produced from both cocoyam and yam for comparative studies of the effect of fermentation and frying on their phytate contents.

Proximate Composition. Moisture, fat, protein, ash, and crude fiber were determined according to standard AOAC (1984) procedures. Carbohydrate was calculated by difference.

Phytate Determination. The concentration of phytate in each sample was determined by using the method of Harland and Oberleas (1986). Approximately 2 g of each sample was weighed into a 100-mL Erlenmeyer flask and extracted with 50 mL of 2.3% HCl for 3 h at room temperature on a Gallenkamp mechanical shaker. Each extracted sample was filtered through Whatman No. 1 filter paper, and the filtrates were stored at 4 °C. A 1-mL aliquot of each filtrate was mixed with 1 mL of Na_2EDTA–NaOH reagent, and the final volume was made up to 25 mL with deionized water and applied to a column containing 0.5 g of AGI-X4 100–200 mesh anion-exchange resin. Inorganic phosphate was eluted with 0.1 M NaCl solution, and phytate was eluted with 0.7 M NaCl solution and collected into a Kjeldahl flask and wet digested with a mixture of concentrated H_2SO_4 (0.5 mL) and concentrated HNO_3 (3 mL). The digested material was dissolved and quantitatively transferred into a 50-mL volumetric flask. To this were added 2 mL of molybdate solution and 1 mL of sulfonic acid solution, and the solution formed was thoroughly mixed and made up to a final volume of 50 mL with deionized water. The absorbance of the resulting solution was read at 640 nm after 10 min in a Pye Unicam spectrophotometer. A sample obtained from the American Association of Cereal Chemists with phytate concentration of 3% was used as an internal standard. Phytate content was calculated after the procedure described by Harland and Oberleas (1986). Samples of the fermenting doughs were taken at 24-h intervals for phytate determination during the fermentation period.

RESULTS AND DISCUSSION

Proximate compositions of food materials that were analyzed for phytate are presented in Tables I and II. The moisture contents of the tubers were much higher than those found for the cereals and legumes investigated. Cocoyam had the lowest fat content but the most protein among the tubers; for the cereals, sorghum had the highest amount of fat but the lowest amount of protein. For the legumes investigated, soybeans contained more fat and more protein than cowpeas (Table I). The legumes were found to contain the highest crude fiber content as compared with the cereals and tubers used in the study. The crude fiber content of cassava was similar to values found for the cereals, maize, and sorghum. Rice, yam, and cocoyam had the lowest crude fiber content in the materials

Table II. Proximate Composition of Some Fermented Doughs and Food Products (dwb)

sample description	composition, %					
	moisture	fat	protein	fiber	ash	carbohydrate
white maize dough	47.20 ± 2.10	1.40 ± 0.21	5.30 ± 0.61	1.00 ± 0.20	0.60	44.50
yellow maize dough	48.00 ± 1.40	1.22 ± 0.20	1.81 ± 0.44	0.30 ± 0.08	0.43	48.24
kenkey (white maize)	47.11 ± 1.31	1.32 ± 0.26	4.90 ± 0.21	1.00 ± 0.31	1.11	44.56
kenkey (yellow maize)	48.01 ± 2.00	1.35 ± 0.09	4.75 ± 0.41	1.90 ± 0.22	1.22	42.77
moko (porridge white maize)	74.32 ± 3.80	3.31 ± 0.21	4.21 ± 0.29	1.31 ± 0.24	0.81	19.04
koko (porridge yellow maize)	75.31 ± 1.56	1.13 ± 0.16	4.90 ± 0.22	0.70 ± 0.81	0.81	17.01
koko (porridge sorghum)	76.13 ± 2.10	0.41 ± 0.11	1.11 ± 0.16	0.21 ± 0.08	0.21	21.93
agidi (maize pudding white maize)	70.51 ± 1.76	0.12 ± 0.11	1.23 ± 0.22	0.60 ± 0.12	0.52	37.04
agidi (yellow maize)	60.60 ± 1.44	0.14 ± 0.14	1.30 ± 0.21	0.50 ± 0.11	0.49	37.17
akla/koose (cowpea doughnut)	43.20 ± 1.01	17.80 ± 1.89	8.40 ± 0.31	0.30 ± 0.03	0.50	29.80
cassava dough	48.90 ± 2.11	0.30 ± 0.09	0.90 ± 0.09	1.50 ± 0.04	1.60	46.80
cocoyam dough	47.80 ± 1.424	0.16 ± 0.01	3.02 ± 0.44	0.80 ± 0.06	1.10	47.12
yam dough	47.40 ± 1.364	0.28 ± 0.05	1.95 ± 0.45	0.60 ± 0.01	0.74	49.03

[a] Data are presented as mean values ± SD; $n = 3$.

Table III. Effect of Fermentation on Phytate Levels[a] in Some Cereals, Legumes, and Tubers

sample	fermentation period				loss of phytate on fermentation[b]	% loss on phytate due to fermentation
	0 h	24 h	48 h	72 h		
cereals						
white maize	7.34 ± 0.31	5.82 ± 0.50	4.16 ± 0.41	3.05 ± 0.02	4.29	58.45
yellow maize	6.86 ± 0.12	4.68 ± 0.60	3.20 ± 0.21	3.07 ± 0.06	3.79	55.24
red sorghum	8.86 ± 0.20	6.98 ± 0.37	5.34 ± 0.34	4.25 ± 0.28	4.61	52.03
local rice (short grain)	4.49 ● 0.22	2.49 ± 0.43	1.16 ± 0.15	0.88 ± 0.12	3.61	80.40
legumes						
cowpea	8.24 ± 0.22	4.80 ± 0.22	3.86 ± 0.24	2.91 ± 0.14	5.33	64.68
soybean	6.88 ± 0.52	14.66 ± 0.19	3.11 ± 0.33	2.65 ± 0.32	4.23	61.48
tubers						
cassava	6.24 ± 0.22	1.16 ± 0.11	0.99 ± 0.12	0.90 ± 0.15	5.34	85.58
cocoyam	8.55 ± 0.45	1.80 ± 0.12	0.28 ± 0.04	0.13 ± 0.03	8.42	98.48
yam	6.37 ± 0.32	1.94 ± 0.28	2.96 ± 0.16	2.22 ± 0.16	4.15	65.15

[a] Phytate content in milligrams per gram. [b] Loss in phytate is the decrease in phytate after 72 h of fermentation expressed in milligrams per gram of raw sample. Data are presented as mean values ± SD; $n = 3$.

studied. A summary of phytate levels as well as the effect of fermentation on phytate levels in the food materials investigated is presented in Table III, which indicates that levels of phytate in the samples ranged from 4.49 to 8.86 mg/g. Red sorghum, cocoyam, and cowpea were found to contain the highest levels of phytate, while local rice had the lowest phytate content. Previous workers have reported various concentrations of phytate in various food materials. For example, Henderson et al. (1986) reported phytate levels of 11 mg/g for cucurbita seed meals and 14 mg/g for soybean meal, while Harland and Oberleas (1986) found phytate levels ranging from 2.4 to 3 mg/g in uncooked ground rice and from 3.3 to 4.7 mg/g in whole wheat bread. Table III also shows that the fermented products of all samples investigated had relatively lower levels of phytate as compared with the unfermented samples, especially for the tubers, where the extent of reduction of phytate content by fermentation was about 86%, 98%, and 65% for cassava, cocoyam, and yam, respectively. For the cereals, the greatest loss of phytate was found in rice (80%) and the least loss was observed with yellow maize (55.24%). Reduction of phytate levels was more pronounced up to 48 h of fermentation and became more gradual after this period. The fermentative microorganisms contain enzymes phytase and phosphatase which hydrolyze phytate into inositol and orthophosphate (Reinhold, 1975), and it has been suggested that the loss of phytate during fermentation might be due to activity of the enzyme phytase naturally present in the cereals, legumes, and tubers and the fermentative microorganisms in the dough (Faridi et al., 1983). Khan et al. (1986) and Reinhold (1975) also reported reductions in phytate content during fermentation of bread and other wheat products. Approximately 55–82% of the total phytate in the whole-seed meal was lost as a result of fermentation, which led Harland and Harland (1980) to suggest that yeast fermentation in bread is an effective way of reducing phytate in wheat.

The decrease in the capacity of fermentation to lower phytate levels which occurred after 48 h may be due to denaturation of phytase, product inhibition of phytase, or inaccessibility of phytate (Tangkongchitr et al., 1982). Ranhotra et al. (1974) proposed that inorganic phosphate (P_i) might inhibit the action of phytase in fermenting doughs. Apart from the factors mentioned above, the drop in pH from 6.21 to 3.10, which was observed in the doughs during the fermentation, probably contributed to the slow breakdown of the phytate after 48-h of fermentation. The optimum pH for the activity of wheat enzyme phytase ranges from 5.1 to 5.3 (Harland and Harland, 1980; Mollgard et al., 1946; Peers, 1953; Gibbins and Morris, 1963). Peers (1953) reported a very rapid decrease in phytase activity on either side of the optimum. The drop in pH was probably the result of microbial activities on the dough converting some of the carbohydrate into organic acids such as lactic, citric, and acetic acids. Even though the presence of these acids was not specifically looked for in this study, it is to be expected that these acids were present on the basis of the findings made by Roukas and Kotzekiduo (1987) and Kotzekiduo and Roukas (1987) that citric acid, lactic acid, and acetic acid were produced during fermentation of various substrates by microorganisms.

Further processing of the fermented doughs into ready-to-serve food products consumed in restaurants and homes also resulted in significant loss of phytate (Table IV). The percentage reduction of phytate in the fermented dough ranged from 20% to 67%. The losses of phytate in kenkey and koosé were relatively small compared with those in agidi and koko. The removal of the testa by sieving the

Table IV. Effect of Processing on Phytate Levels in Diets Prepared from Maize, Sorghum, Cowpea, and Soybean Meals

sample	moisture, %	phytate in fermented dough, mg/g	phytate in product, mg/g	loss in phytate, mg/g	loss on products: as % of phytate in fermented dough	loss on products: as % of total phytate in the grain
white maize		(7.34 mg[a])				
agidi/eko	60.51 ± 2.33	3.00 ± 0.08	0.99 ± 0.50	2.11	67.0	86.52
koko (porridge)	74.32 ± 2.13	3.00 ± 0.13	1.05 ± 0.30	1.95	65.0	85.70
kenkey	47.11 ± 2.41	3.00 ± 0.41	2.94 ± 0.11	0.06	20.0	59.95
yellow maize		(6.86 mg/g[a])				
agidi/eko	60.60 ± 1.66	3.02 ± 0.56	1.12 ± 0.37	1.90	63.1	83.68
koko	75.31 ± 3.12	3.02 ± 0.23	1.02 ± 0.22	1.94	64.0	65.14
kenkey	48.01 ± 0.87	3.02 ± 0.09	2.95 ± 0.15	0.08	20.0	57.00
sorghum		(8.86 mg/g[a])				
koko	76.13 ± 2.17	3.01 ± 0.45	1.21 ± 0.60	1.80	59.8	86.33
cowpea		(8.24 mg/g[a])				
akla/koosé	43.20 ± 0.74	2.73 ± 0.36	2.11 ± 0.7	0.59	21.6	74.89
soybean		(6.88 mg/g[a])				
akla/koosé	45.31 ± 0.85	2.49 ± 0.33	1.92 ± 0.31	0.57	22.89	82.10

[a] Total phytate levels in the raw whole seed. Data are presented as mean values ± SD; $n = 3$.

Table V. Effect of Processing on Phytate Levels in Diets Prepared from Cassava, Cocoyam, and Yam Meals

	total phytate in sample, mg/g	phytate lost due to processing, mg/g	loss as of total phytate in raw tuber, %
unprocessed cassava	(6.24 ± 0.22[a])		
cassava meal	4.28 ± 0.80	1.96 ± 0.15	31.41
tuo from cassava meal	1.44 ± 0.55	4.30 ± 0.36	67.19
gari from cassava	0.70 ± 0.65	5.54 ± 0.53	88.78
eba from cassava gari	0.55 ± 0.08	5.69 ± 0.61	91.19
ampesi from cassava	1.96 ± 0.42	4.28 ± 0.34	68.59
fufu from cassava	1.88 ± 0.99	4.36 ± 0.56	69.87
unprocessed cocoyam	(8.55 ± 0.45[a])		
cocoyam meal	5.53 ± 0.57	3.02 ± 0.39	35.32
tuo from cocoyam meal	2.63 ± 0.63	4.28 ± 0.38	69.24
gari from cocoyam	0.09 ± 0.02	8.46 ± 0.31	98.95
eba from cocoyam gari	0.08 ± 0.02	8.47 ± 0.48	99.06
ampesi from cocoyam	2.63 ± 0.61	5.92 ± 0.88	69.24
fufu from cocoyam	2.57 ± 0.31	5.98 ± 0.44	69.44
unprocessed yam	(6.37 ± 032[a])		
yam meal	3.98 ± 0.67	2.39 ± 0.07	37.52
tuo from yam meal	2.59 ± 0.29	4.28 ± 0.42	67.19
gari from yam	1.88 ± 0.45	4.49 ± 0.73	70.49
eba from yam gari	1.79 ± 0.35	4.58 ± 0.81	71.90
ampesi from yam	2.25 ± 0.42	4.12 ± 0.48	66.72
fufu from yam	2.09 ± 0.24	4.28 ± 0.53	67.19

[a] Total phytate level in the raw, unprocessed sample. Data are presented as mean values ± SD; $n = 3$.

dough and followed by cooking into agidi or koko may account for the large loss in phytate. Clydesdale and Camire (1983) reported that removal of fractions of seeds, especially the bran, leads to reduction in phytate content of the food. Kenkey, which was prepared from a whole-cereal meal, contained more phytate than the agidi and koko, which were prepared from sieved meal.

Frying of cowpea and soybean doughs into koosé achieved 21.6% and 22.89% reduction in phytate levels. This level of phytate reduction was relatively small compared with the 63% and 67% reductions recorded when doughs were processed into agidi and koko, respectively. Thus, frying appears to have little effect on phytate contents in cowpea and soybean, unlike the findings made by Khan et al. (1981) to the effect that frying of rolled dough (raw puri) in edible oil to a brown color reduced phytate content by 85%. The difference may be due to the fact that the cowpea and soybean doughs were fermented, while the rolled dough was made from raw puri. It should also be pointed out that the total amount of phytate lost by both fermentation and frying of cowpea and soybean doughs was about 74.89% and 82.10%, respectively (Table IV).

Table V shows that processing of the tubers to gari and/or eba resulted in higher losses of phytate than when these tubers were processed into ampesi, fufu, or tuo. The effect of cooking on phytate levels in whole cereals and legumes is presented in Table VI, which shows that the whole grains (maize, rice, sorghum, cowpea, and soybean) did not lose much phytate during cooking as compared to fermentation (Table III). Beal and Mehta (1985) reported that cooking of peas resulted in only 13% phytate reduction. The loss of phytate due to cooking was highest for rice (~31%) and was virtually the same (16–18%) for the rest of the samples tested (Table VI); this difference was probably due to some of the following considerations: (i) it was relatively easier for phytate to leach out of the polished rice than it was for the other samples which were not polished; (ii) naturally present phytases in the samples varied in their activity and/or concentrations; or (iii) naturally present inhibitors of phytase were present at different levels and/or did not affect the enzyme to the same extent in the various samples investigated.

Tables VI and VII show that cooking had a greater reducing effect on phytate levels in the tubers (yam, cocoyam, and cassava) than on phytate levels in the cereals and legumes (maize, sorghum, cowpea, and soybean). The decrease in phytate levels ranged from 66% to 69% for the tubers but was only from 16% to 32% for the cereals and legumes. Clydesdale and Camire (1983) reported that boiling or toasting reduced the mineral-binding potential of the naturally present phytate. The losses of phytate

Table VI. Effect of Cooking on Phytate in Whole Dry Maize, Sorghum, Rice, Cowpea, and Soybean Seeds

sample	moisture, %	phytate in whole seed, mg/g	phytate in cooked seed, mg/g	loss in phytate on cooking, mg/g	% loss of phytate on cooking[a]
cereals					
white maize	6.53	7.34 ± 0.31	6.07 ± 0.24	1.27	17.50
yellow maize	5.23	6.86 ± 0.12	5.74 ± 0.31	1.12	16.33
rice	3.70	4.49 ± 0.12	3.0 ± 0.16	1.40	31.18
sorghum	6.14	8.86 ± 0.22	7.42 ± 0.41	1.44	16.25
legumes					
cowpea	6.44	8.24 ± 0.22	6.83 ± 0.33	1.41	17.11
soybean	9.00	6.88 ± 0.52	5.72 ± 0.19	1.16	16.86

[a] Loss expressed as a percent of total phytate in the raw sample. Data are presented as mean values ± SD; n (number of determinations) = 3.

Table VII. Effect of Oven Drying and Cooking on Cassava, Cocoyam, and Yam

sample	moisture, %	unprocessed sample, mg/g	meal from sample oven dried at 60 °C		ampesi (sample sliced and boiled at 100 °C for 30 min)	
			loss, mg/g	loss, %	loss, mg/g	loss,[a] %
cassava	55.20	6.24	1.96 ± 0.15	31.40	4.28 ± 0.34	68.59
cocoyam	58.10	8.55	3.02 ± 0.39	35.32	5.92 ± 0.38	69.24
yam	59.80	6.37	2.39 ± 0.07	37.52	4.12 ± 0.48	66.72

[a] Loss expressed as a percent of total phytate in the raw sample. Data are presented as mean values ± SD; $n = 3$.

content in the tubers due to fermentation, cooking, and other processes were similar to the findings made by Ter-Sarkissan et al. (1974) and Khan et al. (1986), who reported a significant loss of phytate (50.6%) during the preparation of unleavened Iranian flat bread and the processing of Roti or Morida bread from a commercial wheat. Table VII further indicates that oven drying of yam, cassava, and cocoyam and subsequent processing into meal resulted in losses of 37.52%, 31.40%, and 35.32% phytate, respectively. The results show that oven drying had a lesser reductive effect on phytate levels compared with fermentation (Table III). For example, while fermentation reduced phytate level in cassava by 85.58% within 72 h, oven drying reduced the phytate level by only 31.40%. Similar observations were made with yam and cocoyam (Tables III and VII).

The amount of phytate lost due to conversion of cassava to tuo, fufu, or ampesi was about the same (Table V). Similar observations were made with cocoyam and yam. Tables V and VII show that further processing of boiled tubers (e.g., yam, cassava, or cocoyam) to fufu (by pounding) did not achieve substantial reductions in phytate levels. Processing of cassava and cocoyam into gari and then eba seemed to be the most effective method of eliminating phytate in cassava and yam. It is inferred from these observations that consumers of eba ingest lesser amounts of phytate as compared to those who eat ampesi, fufu, or tuo.

Conclusion. The study has shown that local methods of processing selected local foodstuffs (i.e., by fermentation, drying, frying, and cooking) into various ready-to-serve local diets such as ampesi, fufu, eba, tuo, kenkey, agidi, koko, and koosé substantially reduced phytate levels in these food materials. It may be inferred from this that the local methods of food processing used in the present study minimize the concerns posed by metal chelation and protein binding action brought about by the phytate naturally present in food materials of plant origin.

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