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Quality Changes and Mineral Content of Cowpea (*Vigna unguiculata* L. Walp) Seeds Processed with 'Kanwa' Alkaline Salt

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ABSTRACT

The effects of processing with alkaline salts, kanwa and sodium bicarbonate, on some quality attributes and mineral contents of cowpea seeds were investigated. Analysis included objective measurements of texture and colour, cooking time, water absorption, leached solids, pH, proximate composition and minerals in treated and control beans. Cooking with kanwa or sodium bicarbonate by normal boiling increased softness, water absorption, solid loss, pH and mineral content of the beans but decreased cooking time and produced dark coloured beans. Kanwa gave greater increases in some minerals and caused more darkening in the cooked product than cooking in sodium bicarbonate. Pressure cooking beans in the alkaline solutions produced lighter and yellow coloured samples, caused greater increases in softness and water absorption than atmospheric boiling and also affected the mineral content of the beans. There were small changes in the proximate composition of the cooked beans.

INTRODUCTION

Cowpeas (*Vigna unguiculata* L. Walp) also called 'beans' in Nigeria, are an important grain legume and source of protein, essential amino acids, minerals, vitamins and dietary fibre in the diet of West Africans. They add variety to tropical diets, particularly starchy staples like cereals, tubers and

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plantains. Because they form complementary mixtures with cereal staples, cowpeas are incorporated into traditional weaning foods based on cereal paps (Oyeleke *et al.*, 1985). The high yield, even in regions not suitable for growth of other legumes, makes them an easily available alternative source of protein for vegetarians and people avoiding certain taboo meats. Despite the good nutritional values and high yield, cowpeas are under-utilized as food and malnutrition still persists in some West African and other tropical countries.

Cowpeas are consumed in Nigeria in a variety of ways, including boiling rehydrated dry or fresh seeds either alone or in combination with other foods. One of the constraints to their use as food includes an extended cooking time. The beans must be properly cooked to develop an acceptable flavour and texture, to improve digestibility, to increase nutritional value and to destroy toxins. This can require excessive use of firewood or other scarce fuels. Many village housewives in Nigeria traditionally resort to the use of kanwa (also known as 'akanwu', 'ikaun', 'kanwan', 'karu', 'kaun', 'kawe', 'kowun', 'potash') to cook and tenderize not only dry beans but other tough foods and to reduce the cooking time.

Kanwa is a naturally occurring alkaline rock salt and is used not only as a tenderizer but also as a flavouring agent, food preservative and as a prophylactic. It is sometimes misnamed 'potash' in Nigeria because of the erroneous belief that it is a complex potassium salt. Kanwa is 'trona' or sodium sesquicarbonate with trace amounts of Ca, Mg, Fe, Zn, S, Cl, Si, P, K, Al, (Makanjuola & Beetlestone, 1975). Crude kanwa occurs in a variety of colours and flavours and is mined from rock salt deposits or quarries in the Lake Chad and Benue-Plateau regions of Northern Nigeria as well as at Abakaliki and Uturu in Eastern Nigeria (Omene & Onwuejeogwu, 1986).

Recent reports indicate that alkaline processing of some foods can cause quality changes leading to nutritional and toxicological consequences (Friedman *et al.*, 1984; Kikutani *et al.*, 1984). Although several studies have described the effect of processing with kanwa on some physical properties, vitamin content and sensory qualities of cowpeas (Priestley & Avumatsodo, 1977; Ankra & Dolvo, 1978; Edijala, 1980; Onayemi *et al.*, 1986), little is known of its effects on mineral composition or the influence of processing methodology on quality attributes of kanwa-cooked cowpeas. The amount of kanwa added to foods varies with individual preferences and localities and as much as 10% kanwa relative to the weight of cowpeas have been observed in parts of Northern Nigeria (Dolvo *et al.*, 1976). Such high levels of kanwa may lower the organoleptic quality of the cooked product.

Our objectives were to establish optimal conditions for cooking cowpeas with kanwa and sodium bicarbonate and to assess quality changes and mineral content of the cooked product.

MATERIALS AND METHODS

Source of samples

Kanwa samples were obtained from a local market in Eastern Nigeria. The mineral was ground to a fine powder in a mortar and sieved through a 60-mesh screen. The sieved powder was dried for 5 h at 105°C in an air oven (FC 200 oven, Griffin, UK), cooled in a desiccator and stored in dry stoppered glass bottles.

Sodium bicarbonate, $NaHCO_3$ (BDH, Poole, UK) and other chemicals used were of analytical grade.

Cowpea seeds (*Vigna unguiculata* L. Walp cv. 'Blackeye') were purchased locally in London in bulk. After preliminary cleaning, suitable samples in terms of size, shape and colour were selected and stored in polythene bags at 5°C. Split or cracked beans were excluded from the experiments.

Soaking experiments

Beans were soaked at room temperature in tap or double distilled water for 1, 3 and 6 h and in solutions of kanwa or sodium bicarbonate at concentrations of 0 (double distilled water), 0·05, 0·15, 0·45 and 1·35% (w/v), for 1 and 3 h, at a bean:water ratio of 1:20 (w/v). Water absorption and texture of the processed beans and the initial and final pH of the soaking solutions were measured as described under the cooking experiments. Some bean testa were also soaked overnight in the alkaline solutions to determine the effect of treatment on the solubility of the testa as well as the coloration of the soak solution.

Cooking experiments

Cowpeas were cooked either by atmospheric boiling at 100°C in large glass beakers covered with aluminium foil to avoid excessive evaporation or by pressure cooking at 121°C (Prestige Group plc, Derby, UK). Cooking solutions were double distilled water, kanwa or sodium bicarbonate solutions at concentrations of 0, 0·05, 0·1, 0·5 and 1·0% (w/v). All solutions, including those used in soaking studies, were prepared daily in double distilled water to avoid possible changes in pH before processing. The pH of the cooking solution was recorded before and after processing, using a pH meter (Kent EIL 7020, Surrey, UK) calibrated with commercially prepared pH 4·0, 7·0 and 11·0 buffers.

For atmospheric cooking, 10 g cowpeas were rinsed in water, boiled in

200 ml cooking solution and the cooking time recorded from when the solution started to boil.

For pressure cooking, 50 g cowpeas were rinsed and cooked in 1 litre of cooking solution. Cooking time was recorded when the temperature reached 121°C. All experiments were conducted in triplicate.

For each treatment, the beans were cooked for 10, 15, 20, 25 and 30 min by pressure cooking and for 10, 20, 30, 35, 40, 45 and 50 min by atmospheric boiling. At the end of cooking, the solution was decanted into clean beakers, the beans were collected and weighed after excess water had been removed with absorbent tissue paper. The water absorption was determined as the increase in weight of dry beans.

The optimal cook time for each treatment was that corresponding to the softest beans. The drained beans from the optimal cook time were slurried with double distilled water, frozen and freeze-dried (New Brunswick freeze-drier, FTS Systems Inc., Stone Ridge, New York). Untreated (raw) cowpea flour was similarly freeze-dried. The freeze-dried sample was ground into a fine powder (20-mesh) and stored at 5°C for later analysis.

The cooking solution from the optimal cook time was freeze-dried and weighed. The solid loss in cooking was determined from the total dry matter in the cook water. The leached solids were ground into a fine powder (20-mesh) and stored at 5°C for subsequent analysis.

After establishing the optimal cooking conditions, beans were processed accordingly with 0·1% w/v concentrations of alkali by both atmospheric boiling and pressure cooking. Quality attributes of texture, colour, water absorption, leached solids and pH, as well as mineral and proximate composition, were determined in the cooked beans.

Texture measurement

The textural quality was determined objectively on intact soaked or cooked beans using a constant-force needle penetrometer (Stanhope Seta Ltd, Surrey, UK) as described by Sherman (1970). Each bean was positioned on its flat side on the base platform of the instrument with the hilum of the bean facing the experimenter. The depth of penetration was recorded in 1/10 mm units after 5 s. The penetration was repeated on the other flat side of the bean (with the hilum still facing the experimenter) and the mean penetration distance calculated for each bean. Higher penetrometer readings corresponded to softer beans. One hundred intact bean seeds per 50 g sample in pressure cooking, or 20 intact seeds per 10 g sample in atmospheric boiling or soaking, were measured on the penetrometer. This large number of beans had to be tested to compensate for the high variation in texture of individual beans.

Colour measurement

Instrumental colour measurements of the freeze-dried powders from the bean solids and the cook water leachates were made with a Harrison Colorimeter (W. Harrison Ltd., Preston, UK), standardized against a white ceramic tile No. L.L.A. having a reflectance reading for *X*, *Y*, and *Z* as 82·6, 81·9 and 76·7%, respectively. The freeze-dried powder was packed tightly into a small clear petri dish, covered to eliminate interfering light during colour measurements, and the colour values measured in triplicate. The reflectance values obtained for *X*, *Y* and *Z* were converted to Hunter values *L*, *a*, *b*, respectively, using Scofield's (1943) equation and then used to determine the colour differences.

Proximate composition of beans

Freeze-dried powders of both the raw bean flour and cooked bean solids were analyzed in triplicate for moisture, ash, crude protein and fat by established methods (AOAC, 1984). Protein was calculated from the Kjeldahl nitrogen using the *N*-factor of 6·25. Available carbohydrate was determined by the colorimetric anthrone method.

Elemental composition of kanwa

Samples of kanwa for mineral analysis were prepared by dry ashing 5 g kanwa powder at 550°C in a temperature-regulated muffle furnace (Gallenkamp, UK). The elements were extracted with the appropriate acids as described by Egan *et al.* (1981). Sodium and potassium were determined by flame photometry (Corning 410 flame photometer, Corning Ltd., Halstead, Essex, UK), while calcium, magnesium, iron, zinc and copper were determined by atomic absorption (Perkin Elmer 2380 atomic absorption spectrophotometer, Norwalk, Connecticut). Carbonate and bicarbonate were determined titrimetrically (Basset *et al.*, 1978); chloride was determined using the Corning 928 chloride analyzer, while phosphate was determined as P_2O_5 by the vanado-molybdate colorimetric method (Egan *et al.*, 1981). Results for minerals were calculated as gram per 100 g kanwa sample. Means and standard errors were calculated.

Mineral composition of the beans

Five grams of freeze-dried raw and cooked bean solids were charred on a low flame and then dry-ashed at 550°C. Ash samples were extracted with appropriate acids and the elements Na, K, Ca, Mg, Zn, Cu, Fe, P determined as described for kanwa powder. Results were calculated as milligrams of mineral per 100 g beans. Means and standard errors of the means were calculated.

RESULTS AND DISCUSSION

Effects of soaking in alkaline solutions on quality of cowpeas

The soak water was uniformly dark brown when beans were soaked in kanwa solutions but yellowish brown when soaked in sodium bicarbonate solution (Table 1). The discoloration suggested that some pigments, probably polyphenols, had leached out when the beans were processed with alkaline salts. Cowpeas soaked in alkaline solutions had marginal in-

TABLE 1
Soaking Characteristics of Cowpea Grains in Kanwa and Sodium Bicarbonate Solutions at 22°C (Room Temperature)

Soaking solution (%)	*Soak time (h)*	*Water absorption (%)*[a]	*Texture* ($mm \times 10^{-1}$)[a]	*pH of soak solution*		*Colour of soak solution (visual observation)*
				Initial	*Final*	
Tap water	1	65·3 ± 0·4	14·3 ± 0·5	7·8	7·2	Colourless
Double distilled water	1	75·9 ± 1·0	21·4 ± 0·8	4·6	5·5	
Kanwa						
0·05	1	78·7 ± 0·7	23·6 ± 0·7	9·8	9·6	Brown
0·15	1	82·7 ± 0·8	27·1 ± 1·5	10·5	10·2	
0·45	1	92·5 ± 0·6	26·2 ± 1·0	10·9	10·7	
1·35	1	83·2 ± 0·5	25·9 ± 1·6	11·2	10·9	
Sodium bicarbonate						
0·05	1	78·7 ± 0·7	23·5 ± 0·6	7·6	7·2	Light brown
0·15	1	78·9 ± 0·3	24·7 ± 1·1	8·0	7·8	
0·45	1	75·6 ± 3·1	20·7 ± 1·0	8·1	8·0	
1·35	1	72·9 ± 0·8	22·8 ± 1·1	8·1	8·1	
Tap water	3	97·5 ± 0·1	24·4 ± 0·8	7·8	6·7	Light yellow
Double distilled water	3	106·2 ± 0·8	22·8 ± 0·6	4·6	5·3	Colourless
Kanwa						
0·05	3	105·2 ± 1·7	24·1 ± 0·6	9·8	9·2	Dark brown
0·15	3	108·2 ± 0·3	24·9 ± 0·7	10·5	10·0	
0·45	3	110·7 ± 0·7	26·7 ± 0·7	10·9	10·5	
1·35	3	105·5 ± 0·4	29·5 ± 0·9	11·2	10·7	
Sodium bicarbonate						
0·05	3	104·8 ± 0·8	24·4 ± 0·7	7·6	6·8	Brown
0·15	3	105·8 ± 1·4	25·1 ± 0·6	8·0	7·4	
0·45	3	99·2 ± 0·2	27·2 ± 0·8	8·1	7·9	
1·35	3	94·3 ± 0·5	30·5 ± 1·0	8·1	8·1	

[a] Values are means ± standard errors of means (SEM) of two triplicate determinations.

creases in water absorption and softness compared to controls, although changes were not directly proportional to the concentration. The higher levels of kanwa and sodium bicarbonate (0·45–1·35%) tended to decrease water absorption after 3 h of soaking compared to the lower levels, probably due to increased viscosities as observed by Hsu *et al.* (1983), for soybeans. There was a drop in pH of the soak solution, probably due to leaching of acidic substances like pectins. The drop in pH was more pronounced in kanwa than in bicarbonate-soaked samples.

Effect of cooking with kanwa and sodium bicarbonate on cooked bean quality

Cooking time

Optimal cooking time was reduced when beans were processed in alkaline solutions (Table 2). The optimal cooking time of 35 min obtained with 0·1% alkaline solutions was comparable to that reported by Ankra & Dolvo

TABLE 2
Effect of Normal Boiling (100°C) in Alkali on Quality of Cooked Cowpea Grains

Cooking solution (%)	*Cooking time* (*min*)[a]	*Water absorption* (%)[c]	*Texture* (*softness*) ($mm \times 10^{-1}$)[a,c]	*Initial pH* (*pH I*)	*Final pH* (*pH II*)	*Visual observation and finger pressure* (*organoleptic quality*)
Tap water	60	139·0 ± 1·7	85·9 ± 1·3	7·7	7·1	light brown, slightly soft, no splits
Double distilled water	45	157·8 ± 1·1	90·1 ± 1·2	4·7	6·1	greyish white, soft, splits
Kanwa[b]						
0·05	40	160·3 ± 3·5	94·4 ± 0·9	10·0	8·5	brown, soft splits
0·1	35	184·5 ± 5·5	96·5 ± 1·8	10·3	9·2	brown, very soft, splits, mushy
0·5	35	163·6 ± 2·5	96·3 ± 1·3	10·8	10·0	dark brown, very soft, few splits
1·0	35	137·6 ± 3·6	94·4 ± 1·2	11·1	10·3	dark black, slightly soft, no splits
Sodium bicarbonate[b]						
0·05	35	165·2 ± 2·4	102·1 ± 1·4	7·5	8·4	creamy white, very soft, splits
0·1	35	175·3 ± 8·9	106·1 ± 1·4	8·0	9·3	light brown, very soft, splits
0·5	45	155·5 ± 1·1	101·9 ± 2·4	8·2	9·8	brown, soft, splits
1·0	45	134·0 ± 2·9	99·8 ± 1·7	8·2	10·0	brown, soft, splits

[a] The optimal cooking time was estimated as the time corresponding to maximum penetrometer reading or softness score.
[b] Standard solutions of alkali were made up in double distilled water and solutions were prepared fresh each day.
[c] Values are means ± standard error of the means of two triplicate determinations.

TABLE 3
Effect of Pressure Cooking (121°C) in Alkali on Quality of Cooked Cowpea Grains

Cooking solution (%)	*Cooking time (min)*	*Water absorption % ± SEM*[a]	*Texture (mm × 10⁻¹) ± SEM*[a]	*pH I*	*pH II*	*Organoleptic quality*
Tap water	25	169·2 ± 6·2	104·0 ± 1·1	7·7	7·7	Light brown, soft, uniform, smooth appearance
Double distilled water	20	192·8 ± 0·6	107·6 ± 0·9	4·7	6·0	Very soft, smooth appearance creamy white,
Kanwa						
0·05	15	191·5 ± 7·2	105·7 ± 1·1	9·9	9·3	Very soft, yellowish brown, smooth appearance
0·1	15	191·9 ± 7·8	105·8 ± 2·2	10·3	9·9	Very soft, yellowish brown mushy
Sodium bicarbonate						
0·5	15	199·3 ± 7·9	110·2 ± 1·1	7·7	9·0	Very soft, creamy white, smooth appearance
0·1	15	188·7 ± 1·8	108·6 ± 0·5	8·0	9·7	Very soft, mushy, light yellow

[a] Values are means ± standard errors of means of two triplicate determinations.

(1978) and Edijala (1980). Pressure cooking in alkali (Table 3) reduced the cooking time to 15 min compared to 45 min for atmospheric boiling in water (Table 2). Cooking time was not reduced further by presssure cooking at higher concentrations of alkali. The long cooking time in tap water is attributed to its hardness.

Water absorption

Both alkalis increased water absorption in the cooked beans (Fig. 1), though absorption appeared to be greater following treatment with kanwa. Pressure cooked beans also absorbed more water than beans cooked by normal boiling (Table 3). The increased water absorption and consequent softening is believed to be due to a higher degree of starch gelatinization caused by the alkali treatment, thereby permitting more inter- and intra-molecular hydrogen bondings (Priestley & Avumatsodo, 1977). Higher levels of alkali led to lower water absorption. This could be due to higher viscosities and lower water activities associated with the more concentrated alkaline solutions (Hsu *et al.*, 1983).

Texture

Both kanwa and sodium bicarbonate increased softness of the cooked beans compared to the control (Fig. 2). Beans pressure cooked in alkaline solutions

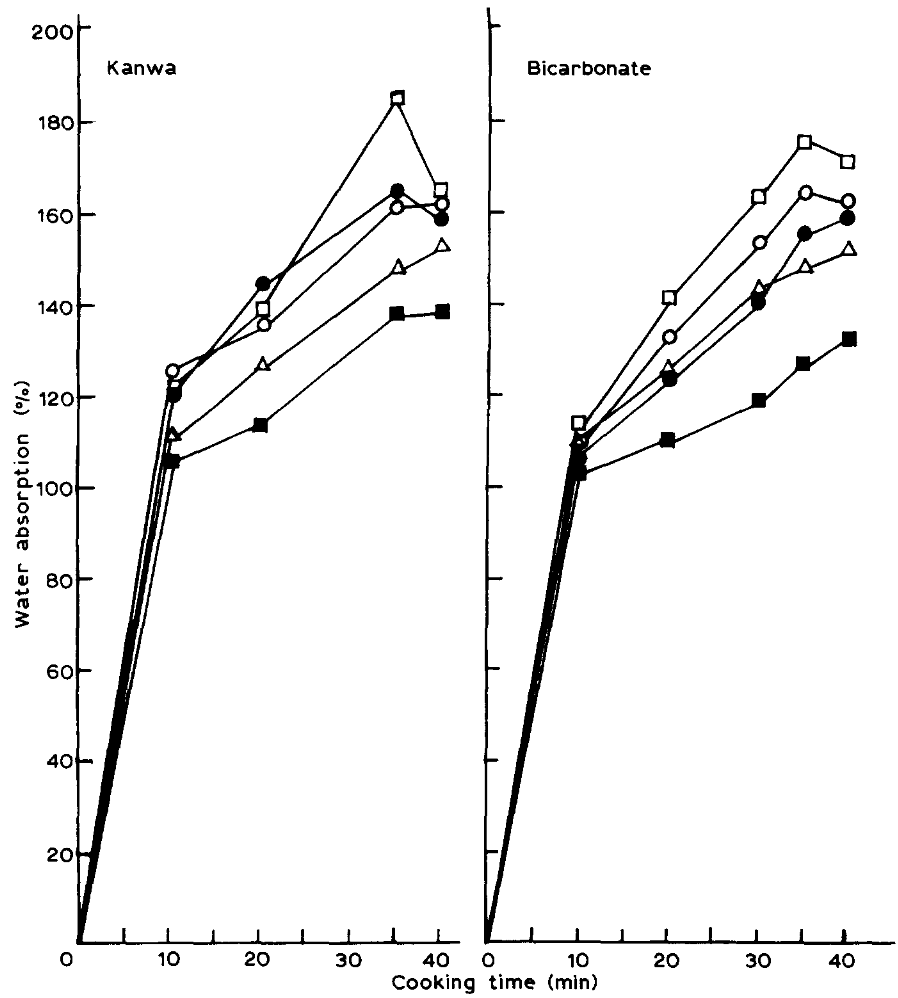

Fig. 1. Effect of cooking time on water absorption of unsoaked cowpea grains cooked in various alkaline solutions at atmospheric pressure. △——△, 0%; ○——○, 0·05%; □——□, 0·1%; ●——●, 0·5%; ■——■, 1·0% (w/v) alkaline concentrations.

were softer than those cooked by atmospheric boiling in similar solutions (Table 3). Probably increased cell separation and disruption of hydrogen bonds in bean cells occurred in pressure cooking leading to more softening. This is in agreement with the observations of Edijala (1980) and Onayemi *et al.* (1986). Kanwa and sodium bicarbonate contain monovalent cations. The monovalent cations, especially Na^+, could influence the texture of the cooked beans by two possible mechanisms: (a) the Na^+ ions in the cooking solution might undergo a process of ion -exchange, displacing divalent cations, mainly Ca^{+2}, in the insoluble pectins of the middle lamella of the

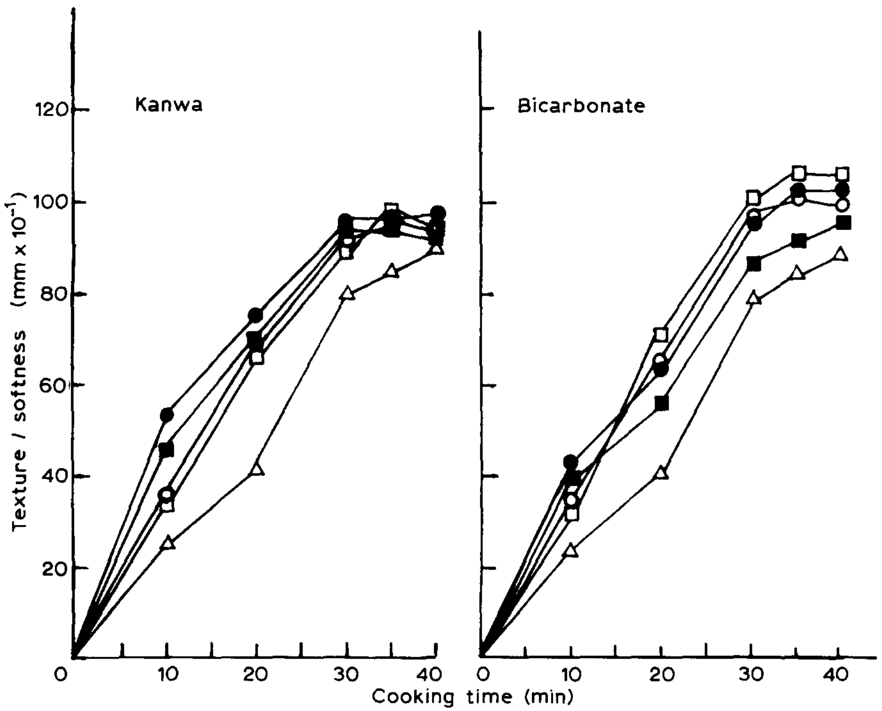

Fig. 2. Effect of cooking time on texture (softness) of unsoaked cowpea grains cooked in various alkaline solutions at atmospheric pressure. △——△, 0%; ○——○, 0·05%; □——□, 0·1%; ●——●, 0·5%; ■——■, 1·0% (w/v) alkaline concentrations.

cells. This and the subsequent formation of soluble sodium and potassium pectates would lead to softening. (b) The softening effects of the monovalent cations might also be attributed to their ability to enhance β-elimination reactions whereby pectic substances are degraded (Keijbets & Pilnik, 1974). Recent studies (Stanley & Aguilera, 1985; Sievwright & Shipe, 1986; Vindiola *et al.*, 1986) seem to suggest multiple mechanisms of action of salts in legume softening. The lower levels (0·05 and 0·1%) of these alkaline salts were more effective in softening the cowpeas than the higher levels, probably because of the decreased viscosities and increased water absorption as explained above.

The sodium bicarbonate-treated samples had higher penetrometer (softness) readings (Tables 2 and 3) compared to kanwa-treated samples or controls. Probably the cation composition of crude is exerting some effect on texture. Elemental composition of kanwa (Table 4) shows that it contains trace amounts of divalent cations, Ca, Mg, Zn, Cu, Fe, which might exert some firming effect on the cooked beans. The net effect of Na and the divalent cations in kanwa would result in a cooked product with lower softness scores compared with pure sodium bicarbonate.

TABLE 4
Composition of Kanwa

Constituent	*Mean* ± *SEM* (%)
Moisture	23·6 ± 0·0
Sodium (Na)	32·3 ± 0·3
Potassium (K)	1·3 ± 0·1
Calcium (Ca)	2·3 ± 0·1
Magnesium (Mg)	0·4 ± 0·0
Iron (Fe)	0·3 ± 0·0
Zinc (Zn)	0·001 ± 0·000
Copper (Cu)	0·002 ± 0·000
Phosphate (P_2O_5)	0·18 ± 0·01
Bicarbonate (HCO_3^-)	13·7 ± 0·0
Carbonate (CO_3^{2-})	23·9 ± 0·0
Chloride (Cl^-)	1·88 ± 0·02

Colour

Beans cooked in kanwa and sodium bicarbonate at atmospheric pressure were darker in colour compared to those cooked in double distilled water (Table 5). Rizley & Sistrunk (1979) also observed that bicarbonate treatment of southern (blackeyed) peas resulted in less desirable colour but softer texture and better flavour compared to other treatments. Samples cooked by atmospheric boiling in alkaline solutions resulted in the darkest and most red-coloured cowpeas as indicated by their lowest '*L*' and highest '*a*' values (Table 5) for both freeze-dried bean solids and cook water. However, in pressure cooking, the kanwa and bicarbonate samples resulted in the most yellow cowpeas as indicated by their highest '*b*' and '*L*' values for both freeze-dried solids and cook water. The cooking method and cooking solution must have interacted to affect the colour and other quality attributes of the cooked beans. The darkening of the kanwa and sodium bicarbonate samples cooked by atmospheric boiling may be due in part to the formation of Maillard browning products in the beans and to oxidation products of pigments leached from the beans. The colour could also be due to formation of complexes between the bean pigments and trace metals from the cooking solution (Kilgore & Sistrunk, 1981; Culver & Cains, 1952). Results of the alkaline soaking of cowpeas testa at room temperature (Table 1) seem to support the suggestion that part of the browning of the soak or cook solution was due to leached pigments.

Post-cooking pH

The final pH of the cook solution rose in sodium bicarbonate treatment (Tables 2 and 3). Perhaps the sodium bicarbonate led to leaching of cations

TABLE 5

Characteristics of Cowpea Grains Cooked in 0·1% Alkaline Solutions by Atmospheric Boiling or Pressure Cooking

Treatment code[a,b]	*Cooking time (min)*	*Solid loss (%)*[c]	*pH of cook solution*		*Colour measurements (Hunter values)*					
					Bean solids			*Bean cook water*		
			pre-cooking	*post-cooking*	*L*	*a*	*b*	*L*	*a*	*b*
TC	45	15·0 ± 0·7	4·7	6·1	218 ± 0·3	257 ± 4·9	799·3 ± 1·5	170·6 ± 5·5	213·0 ± 6·1	808·7 ± 32·8
TK	35	19·7 ± 0·6	10·3	9·2	201·4 ± 1·0	295·4 ± 1·1	887·9 ± 2·1	132·3 ± 2·2	515·1 ± 3·1	925·8 ± 15·4
TB	35	16·8 ± 0·8	8·0	9·3	213·3 ± 1·5	268·8 ± 4·1	851·6 ± 3·2	134·5 ± 2·4	541·0 ± 14·3	941·8 ± 16·7
TP	20	13·0 ± 1·6	4·7	6·0	226·9 ± 0·3	124·5 ± 1·0	873·8 ± 7·5	178·9 ± 2·0	314·2 ± 4·2	818·4 ± 2·1
TPK	15	16·1 ± 2·2	10·3	9·9	220·7 ± 2·3	91·5 ± 9·4	955·5 ± 15·1	173·7 ± 0·8	446·4 ± 8·5	1 154·9 ± 3·1
TPB	15	16·7 ± 0·4	8·0	9·7	222·5 ± 0·7	84·3 ± 4·8	948·0 ± 22·8	176·5 ± 2·1	420·5 ± 3·9	1 136 ± 1·7
UT	—	—	—	—	252·2 ± 0·2	246·4 ± 2·4	726·2 ± 7·7	—	—	—

[a] TC, control cowpea grains cooked by atmospheric boiling in 0% alkaline solution (double distilled water); TK, cowpeas cooked by atmospheric boiling in 0·1% kanwa solution; TB, cowpeas cooked by atmospheric boiling in 0·1% bicarbonate solution; TP, cowpeas cooked by pressure cooking in 0% (double distilled water) alkaline solution; TPK, cowpeas cooked by pressure cooking in 0·1% kanwa solution; TPB, cowpeas cooked by pressure cooking in 0·1% bicarbonate solution; UT, raw cowpea flour (untreated).

[b] All samples were freeze-dried.

[c] Values are means ± standard error of the means of two triplicate determinations.

such as Ca^{2+}, Mg^{2+}, K^{+} from the bean middle lamella into the cook solution in exchange for Na^{+} of the bicarbonate. The leached alkaline cations would cause an increase in the final pH as well as contributing to the enhanced softness of the bicarbonate-cooked cowpeas. Varriano-Marston & Omana (1979) also observed increases in pH during cooking of black beans with alkaline buffers. On the other hand, the gradual fall in the pH of kanwa cooked samples might be due to greater leaching of acidic substances, such as pectic acids, into the cook water. Despite the observed fall in pH of the kanwa cooking solution, the final pH value was still highly alkaline (pH 8·5–10·3) (Tables 2 and 3).

Solid loss

More solids were leached (Table 5) from kanwa and sodium bicarbonate cooked samples compared to controls cooked in double distilled water. Atmospheric boiling in kanwa solution caused more solid loss in the cooked beans compared to atmospheric boiling in sodium bicarbonate or controls. The greater loss of solids may be due to increased cell separation and permeability, membrane degradation and water absorption of bean cells. This would cause testa sloughing and splitting of the cotyledons, leading to greater leakage of the bean cell components such as proteins, gelatinized starch and other substances into the cooking solution. Fewer solids were lost in pressure cooking, probably due to less splitting of the cooked samples.

Effect of soaking followed by alkaline cooking

Soaking cowpeas in water prior to cooking in alkaline solutions produced more difference in texture, cooking time and water absorption when

TABLE 6

Effect of Soaking in Distilled Water Coupled with Cooking in Alkali on the Quality of Cowpea Grains

Pretreatment	*Cooking solution*	*Cooking time (min)*	*Water absorption (%)*[a]	*Texture (mm × 10^{-1})*[a]	*pH I*	*pHII*
Unsoaked	Distilled water	45(AB)	157·8 ± 1·1	90·1 ± 1·2	4·7	6·1
Soaked (6 h)	Distilled water	40(AB)	157·9 ± 1·2	89·1 ± 1·0	4·6	6·0
Soaked (6 h)	0·1% kanwa	25(AB)	163·5 ± 3·8	91·2 ± 1·2	10·3	9·3
Soaked (6 h)	0·1% bicarbonate	25(AB)	179·9 ± 2·4	102·7 ± 1·3	7·9	9·3
Unsoaked	Distilled water	20(PC)	192·8 ± 0·6	107·6 ± 0·9	4·7	6·0
Soaked (6 h)	Distilled water	15(PC)	193·6 ± 3·0	109·3 ± 0·9	4·6	6·3

[a] Values are means ± standard errors of triplicate determinations.
AB, atmospheric boiling; PC, pressure cooking.

compared to unsoaked beans cooked in distilled water at atmospheric pressure (Table 6). Further increase in softness and water absorption and decrease in cooking time were observed in distilled water-pressure-cooked beans. Soaking as recommended in many bean recipes can be used as a processing step in the cooking of legumes when the cook has no intention of adding alkali to tenderize the product since soaking also led to softening.

Proximate composition

The proximate composition of raw and cooked freeze-dried bean powder is shown in Table 7. There were slight differences in ash, moisture, protein, fat and available carbohydrates. Cooking in alkaline solutions did not cause significant differences in the proximate composition of the cooked product.

Mineral composition

Table 8 shows selected minerals in raw, control and alkali-cooked cowpea samples. Of all the minerals, the one most affected by the alkaline processing was Na, which increased several-fold compared to control samples cooked in double distilled water. There were also significant increases in P, Ca, Mg and Fe in kanwa-cooked compared to bicarbonate-cooked samples or controls. Indigenous salts similar to kanwa tend to contain higher levels of trace elements compared to commercially refined salts (Kuhnlein, 1980) and native foods cooked with indigenous salts are also higher in essential minerals (Calloway *et al.*, 1974). The P and K values in both raw and treated samples were slightly higher than noted in the literature, perhaps due to

TABLE 7
Proximate Composition of Cowpeas (Freeze-dried bean solids)

Treatment code	*g% (Mean ± SEM)*[a]				
	Moisture	*Ash*	*Protein*	*Fat*	*Available carbohydrate*
TC	1·6 ± 0·1	2·1 ± 0·0	24·2 ± 0·3	1·9 ± 0·0	53·6 ± 1·2
TK	2·7 ± 0·1	2·7 ± 0·0	24·9 ± 0·2	1·8 ± 0·0	53·7 ± 0·8
TB	3·1 ± 0·4	2·5 ± 0·0	25·0 ± 0·2	1·8 ± 0·1	53·9 ± 1·6
TP	0·7 ± 0·0	2·5 ± 0·0	24·7 ± 0·1	2·0 ± 0·0	50·2 ± 0·6
TPK	1·0 ± 0·1	3·2 ± 0·0	24·4 ± 0·3	2·1 ± 0·0	49·0 ± 0·1
TPB	0·9 ± 0·1	3·0 ± 0·0	25·2 ± 0·1	2·1 ± 0·0	46·8 ± 0·2
UT	2·5 ± 0·1	3·5 ± 0·0	24·2 ± 0·1	1·2 ± 0·0	54·4 ± 0·9

[a] Values are means ± standard errors of the means of two triplicate determinations.

TABLE 8
Minerals in Freeze-Dried Bean Solids (mg/100 g ± SEM)[a]

Treatment code	*Ca*	*Mg*	*Fe*	*Cu*	*Zn*	*K*	*Na*	P_2O_5
TC	131·2 ± 0·0	143·3 ± 2·0	6·3 ± 0·1	1·2 ± 0·0	4·0 ± 0·0	712·9 ± 15·9	8·7 ± 1·1	682·9 ± 38·2
TK	150·1 ± 1·9	163·9 ± 1·6	8·2 ± 0·3	1·0 ± 0·0	3·8 ± 0·1	621·3 ± 8·7	309·8 ± 5·3	1 064·0 ± 6·9
TB	100·1 ± 2·8	150·6 ± 1·7	6·4 ± 0·1	0·9 ± 0·1	3·8 ± 0·1	643·2 ± 20·3	266·6 ± 3·4	519·9 ± 9·0
TP	87·3 ± 5·6	130·3 ± 2·8	5·3 ± 0·1	1·4 ± 0·0	4·5 ± 0·1	802·4 ± 3·7	5·5 ± 0·1	583·6 ± 42·6
TPK	79·1 ± 1·3	170·9 ± 1·5	6·9 ± 0·1	1·3 ± 0·1	3·6 ± 0·0	813·0 ± 13·2	293·2 ± 8·7	817·1 ± 10·3
TPB	63·5 ± 1·0	168·3 ± 1·1	6·1 ± 0·1	1·3 ± 0·0	4·0 ± 0·0	796·5 ± 3·4	248·3 ± 4·4	902·5 ± 21·7
UT	64·6 ± 2·9	128·7 ± 2·9	6·2 ± 0·1	1·5 ± 0·0	4·4 ± 0·0	1 492·1 ± 12·8	11·1 ± 0·8	672·2 ± 25·7

[a] Values are means ± standard errors of the means of two triplicate determinations.

varietal differences. Pressure cooking increased total mineral (% ash) content of the beans. However, levels of some minerals decreased, probably due to extensive leaching into the cook water.

The sodium content of kanwa-cooked cowpeas could have medical implications. High loading of indigenous foods with kanwa in parts of Northern Nigeria has been associated with peripartum cardiac failure (Davidson *et al.*, 1974). Kanwa, salt water from lakes or rivers and ash from herbs all constitute 'latent' sources of sodium in the diet of West Africans. The common practice of combined use of table salt and kanwa in Nigerian dishes would result in excessive intake of dietary sodium which has been implicated as one of the causes of essential hypertension in West Africans (Wilson, 1986). Increased intake of sodium in the form of table salt and/or latent salt coupled with consumption in Nigeria of some fermented foods high in tyramine (Uzogara *et al.*, 1987) can lead to large increases in blood pressure. The level of kanwa in native dishes should therefore be decreased when table salt is also used in cooking, and vice versa.

CONCLUSIONS

Cooking cowpeas by atmospheric boiling in alkaline solutions led to decreased cooking time but increased softness, pH, leached solids and water absorption. Cooking cowpeas with kanwa or sodium bicarbonate at an optimal concentration of 0·1% w/v enhanced the cooking quality of cowpeas at an optimal cook time of 35 min and produced an appropriately tenderized product. Higher concentrations of alkali, especially kanwa, produced darker coloured cowpeas. Cooking the beans in higher concentrations of the alkali gave slightly firmer products than cooking in the lower concentrations. The tenderizing effects of the alkali on cowpeas seemed to be dependent on concentration rather than the pH of the alkaline solutions. Pressure cooking in alkali caused more decreases in cooking time and solid loss but increases in softness and water absorption. Higher levels of alkali did not seem to reduce the cooking time further in pressure cooking.

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