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Research Article

Effects of Soaking Followed by Hydrothermal Processing on Proximate Composition and Mineral Elements of *Cassia hirsutta*: An Underutilised Hard-to-Cook Legume

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Abstract

Background and Objective: *Cassia hirsutta* is an underutilised hard-to-cook legume in South-West Nigeria. This study was designed to investigate the effects of soaking prior to application of four hydrothermal techniques on the nutrient contents of *Cassia hirsutta*. **Materials and Methods:** Four hydrothermal processing techniques (atmospheric boiling, atmospheric steaming, pressure boiling and pressure steaming) were used to process the seeds of *Cassia hirsutta* after aqueous soaking at varying hydration levels. **Results:** Soaking of the seeds prior to hydrothermal processing caused reduction in cooking time. The hydrothermal techniques had significant ($p<0.05$) effects on the nutrients. Maximum reduction of 58.86% in cooking time was effected when the seeds were hydrated to 100% followed by boiling at elevated pressure. The protein content was better conserved when seeds were processed at elevated pressure. Legume samples cooked at 100% hydration levels have better retention of mineral elements. **Conclusion:** Although all the hydrothermal processing techniques caused varying degree of seepage, the cooked legume seed is a good source of nutritionally important nutrients. Further adaptation of this underutilised legume in human diets and feeds will alleviate the problem of food and nutrition insecurity in developing countries.

Key words: *Cassia hirsutta*, human diets, hydrothermal techniques, nutrients, underutilised legume

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The world of today and especially the developing countries is faced with the problem of hunger and malnutrition for the human population and feed for the livestock industries. One in every seven people in the world today go to bed hungry and more than twenty thousand children under the age of five die daily from hunger[1]. Production of conventional legumes that could be used to solve the problem of food scarcity and malnutrition is grossly insufficient to meet the increasing demand of human population and livestock industries. Protein energy malnutrition (PEM) is on the increase in developing countries. Therefore, there is a need for exploitation of hitherto neglected underutilised legumes. Since legumes are known to be good sources of plant protein, one of the most valuable and practical approaches for tackling the problem of protein deficiency is the continued search for and utilisation of protein rich plants. Hence, the use of lesser known underutilised legumes that contain appreciable quantity of protein becomes paramount for making more protein available at affordable prices. Legumes contain varying concentrations of proteins, lipids, carbohydrates and minerals[2]. However, utilisation of legume is limited because of the presence of antinutritional components which can interfere with the digestive process and prevent efficient utilisation of nutrients[3].These antinutritional components include hemagglutinin, phytic acid, tannin, saponin, cyanide, protease inhibitors and oligosaccharides[4,5]. Legumes have health promoting benefits. Regular consumption of legumes had been reported to assist in weight management as well as in controlling glycemic index, hypercholesterolemia and atherosclerosis[6,7].

Cassia hirsutta is an underutilised legume in South West Nigeria. Traditionally, the legume is prepared for consumption by boiling in water with the addition of tenderiser such as trona to hasten softening. There is paucity of information on the health implication of trona on human physiology. The hard-to-cook nature of *Cassia hirsutta* constitutes hindrance to its utilisation. Information on the nutritional and antinutritional components are available in an earlier study[8]. However, there is paucity of information on the effect of soaking as well as hydrothermal processing methods on the proximate composition and mineral elements in *C. hirsutta*. It is hoped that a good understanding of the effects of hydrothermal processing techniques on the nutrients in *C. hirsutta* will form the basis for enhancing the utilisation of this hard-to-cook underutilised specie of legumes. Further food and industrial utilisation of this legume will make significant contributions to solve the problems of PEM and food insecurity in developing countries. So, this study was conducted to investigate the effects of soaking prior to application of four hydrothermal techniques on the nutrient contents of *Cassia hirsutta*.

MATERIAL AND METHODS

Sample and preparation: The seeds of *Cassia hirsutta* (*Sese omode*), (Fig. 1), were obtained from a local market in Ago-Are (8.67°N, 3.40°E), Atisbo Local Government Area of Oyo State, Nigeria. The seeds were dry-cleaned thoroughly and the immature seeds and extraneous particles were removed. The cleaned seeds were stored at room temperature until further processing and analysis. Whole seeds of the legume were subjected to the following processing methods: soaking, atmospheric boiling, boiling in pressure cooker, atmospheric steaming and steaming at high steam pressure, as described below.

Soaking and determination of soaking time: Soaking and determination of hydration rate of the legume seeds were carried out[9]. The legume sample (500 g) was cleaned and soaked in 2500 cm^3 of distilled water in a glass jar at ambient temperature ranging from 23-28°C for up to 24 h. Water absorption (increase in moisture) of the legume during soaking was measured hourly for the initial 0-6 h. The soaked legumes was blotted with a woollen hand towel at appointed time to remove excess water before weighing and returning back into soaking water. Moisture content of soaked seeds was calculated based on weight differences after water absorption. Furthermore, the water absorption curve was plotted to show the kinetic increase of the moisture content

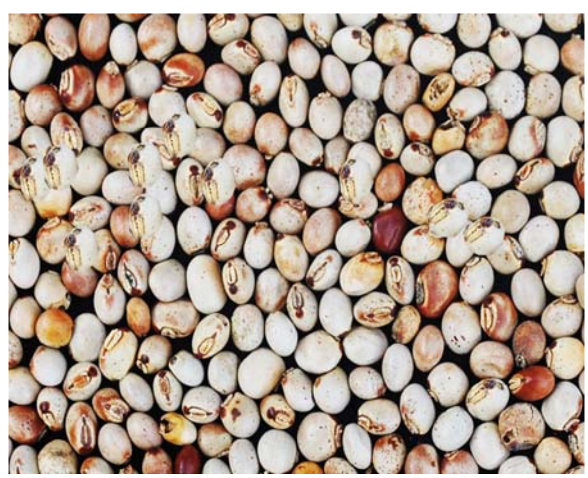

Fig. 1: *Cassia hirsutta* (*Sese omode*)

with time. The plateau phase of water absorption curve was defined as 100% hydration level. Soaking time of the legume with desired hydration level was calculated through polynomial equation of the water absorption curve.

For the subsequent boiling and steaming experiments, the legume was pre-soaked to the desired hydration levels of 0,10, 25, 50,75 and 100% by controlling soaking time. The soaked seeds were then drained and boiled or steamed by the following methods:

Atmospheric boiling (AB): Atmospheric boiling under normal atmospheric pressure of the sample was done[9]. The boiling of each of the legume samples was conducted using a domestic cooker(Tower, TG, Nigeria). Pre-soaked samples (500 g) with varying hydration levels were boiled in water. Determination of cooking time for the atmospheric boiling of the legume was conducted by tactile method in which the cooked legume was squeezed between the forefinger and thumb with moderate pressure[10]. A seed was considered to be cooked when it could be squeezed by finger easily. Cooking time was defined as the time duration, in minutes, of at least 90% of seeds subjected to cooking. The penetrometer (Seta 1700-0, Surrey, England) reading of 9-10 10th mm within 5 sec was observed for the cooked legume when a flat-end punch of 2.45 mm diameter and 281 g was attached to the penetrometer for measurement in a 100 cm^3 beaker. After boiling treatments the legume was drained and both the cooking water and the drained legume were cooled in plastic containers. Subsequently, the cooked legume and cooking water were dried at 45-50°C using a cabinet drier (Uniscope, SM 9053, England). The dried sample was stored in a plastic container prior to analysis.

Pressure boiling (PB): Pressure boiling was performed using a domestic pressure cooker (Binatone PC-5001) at about 80±8 KPa. Five fold of distilled water was added to the pre-soaked legume (500 g) at varying hydration levels as described under atmospheric boiling in a glass flask which was covered with aluminium foil. The content of the flask was brought quickly to boiling on a hot plate. The legume sample with boiling water was placed into pre-heated pressure cooker (Binatone PC-5001) with 2500 cm^3 of boiling water and the lid was locked in place. The cooking time was counted from when steam began to spurt out from pressure lid. Cooking time was determined by tactile method[10]. When the legume has been boiled under pressure to the desired cooking time, the pressure cooker was then removed from the heat source and the pressure released. Boiled water and legume sample were cooled to room temperature (26-28°C)and dried at 45-50°C using a cabinet drier(Uniscope, SM 9053, England). The dried sample was then stored in a plastic container before analysis.

Atmospheric steaming (AS): Steaming and determination of steaming time were carried out at normal atmospheric pressure using steam cooker (Binatone PC-5001). The pre-soaked legume samples (500 g by weight) with varying hydration levels were placed on a tray in the steam cooker covered with lid and were steamed over 2500 cm^3 of boiling water. Steaming times were determined by tactile method[10]. After the steaming process, legumes were cooled and dried at 45-50°C in a cabinet drier (Uniscope, SM 9053, England). The dried samples were then stored in a plastic container before analysis.

Pressure steaming (PS): Steaming under pressure was performed using a pressure cooker (Binatone PC-5001) at about 80±8 KPa. Pre-soaked samples (500 g by weight) of varying hydration levels were placed on a tray in a pressure cooker and steamed over boiling water under selected high pressure (80±8 KPa). Steamed samples were placed in plastic containers, cooled and then dried at 45-50°C in a cabinet drier (Uniscope, SM 9053, England).. The dried samples were stored in plastic containers before analysis.

Determination of proximate composition: The proximate composition of unprocessed and processed samples were determined using standard methods[11,12]. The proximate parameters determined were crude protein, crude fat (ether extract), crude fibre, total ash and moisture content. The total carbohydrate was determined by difference.

Determination of mineral elements: Analysis was carried out for some mineral elements [Calcium (Ca), Zinc (Zn), Sodium (Na), Iron (Fe), Magnesium (Mg), Phosphorus (P) and Potassium (K)] using atomic absorption spectrophotometric method[11,13]. The pulverized sample was weighed and ashed in a muffle furnace (Fisher, Pittsburgh, PA, USA) at 550°C until properly ashed. The ash was dissolved in 100 cm^3 solution of 10% v/v HCl (BDH Chemical, Poole, England) which was subsequently used in mineral content determination. The determination of mineral elements was carried out using atomic absorption spectrophotometer(Bulk Scientific, 205, USA). Its hollow cathode lamp supplied resonance line radiation of each element. Standard calibrations were employed in the analysis.

Statistical analysis: All the analyses were conducted in three replicates and expressed as mean data±SD (standard deviation). Statistical analysis was performed using Statistical Analysis System software (version 15.0, SAS Institute Inc., Cary, NC). All data were subjected to one-way Analysis of Variance [ANOVA] and the significant differences were determined at $p<0.05$. Duncan's multiple-range tests were used to separate the means[14].

RESULTS AND DISCUSSION

Effects of soaking on cooking time of *Cassia hirsutta*: The water absorption curve for the legume is shown in Fig. 2. Table 1 shows the effects of soaking at varying hydration level followed by different hydrothermal processing methods on the duration of cooking of *C. hirsutta*. The cooking duration and the corresponding volumes of water for each processing operation are presented in Table 1. At 0% hydration level (i.e the raw sample), It took 158 min to process the seeds by boiling at atmospheric pressure (AB) while the duration for cooking by boiling at elevated pressure (PB) was 91 min. Hydration level of 10% did not cause any significant difference ($p<0.05$) in cooking time for each of the four hydrothermal methods. The similarity between the cooking times of the hydrothermal processing methods at 0% (raw sample) and 10% hydration levels was due to the fact that hydration of the seeds to 10% level is insufficient to cause the seeds to absorb enough water required to effect softening prior to cooking. At hydration levels of 25 and 50% there was reduction in the cooking time when the legume was processed by each of the hydrothermal techniques except AS. The percentage reduction of 31.01% for AB, 8.86% for AS, 57.59% for PB and 37.97% for PS were recorded at 75%. At 100% hydration level, the percentage reduction in cooking time ranged from 41.13% for SAP to 58.86% for PB and PS.

It can be inferred from the results in Table 1 that when consideration of cooking time is of importance during processing of *C. hirsutta*, AB is preferred to AS at normal atmospheric pressure. Also, PS has a comparative advantage of saving time more than AB. Generally, there was decrease in the cooking time as the level of hydration increased. Similarly, the quantity of water used for each processing operation decreased with increase in hydration level. Of all the hydrothermal techniques employed, PB was observed to save time most.

Most foods cook by boiling at 100°C. This is because water boils at 100°C at normal atmospheric pressure (760 mm Hg^{-1}). By increasing the pressure, the temperature inside the pressure cooker rises. In a study, the pressure inside a pressure cooker was increased to 15 Ibs per square inch above atmospheric pressure. This increase in pressure caused cooking temperature to rise by about 21.5°C. If the temperature of cooking is raised, foods cook much faster[15,16].

The phenomenon of prolong cooking poses a serious problem in legume processing. The hard-to-cook nature of *C. hirsutta* constitutes hindrance to its scope of consumption.

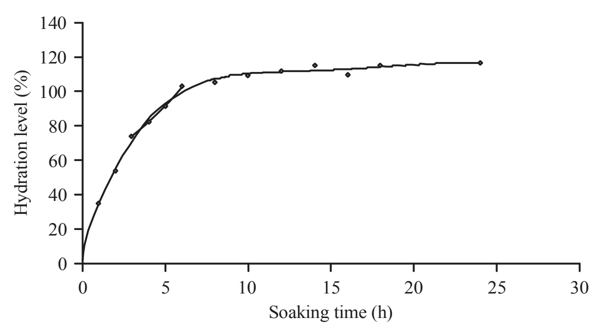

Fig. 2: Water absorption curve for *Cassia hirsutta*

Table 1: Effect of hydrothermal processing techniques on cooking times of *Cassia hirsutta* at varying hydration levels

	Volume of H_2O used (cm^3)				Cooking times (min)			
Hydration level	AB	AS	PB	PS	AB	AS	PB	PS
0%	2000±0.00^c	2550±70.71^d {21.57}*	1450±14.14^a {27.50}	1750±70.57^b {12.50}	158±2.00	209±3.00^d {24.40}*	91±1.00^a {42.41}	119±1.00^b {24.68}
10%	2000±20^c {0.00}	2550±50^d {21.57}*	1450±20^a {27.50}	1750±10^b {12.50}	158±0.00^c {0.00}	209±1.41^d {24.40}*	91±1.41^a {42.41}	119±5.65^b {24.68}
25%	1800±0.00^b {10.00}	2550±70.68^c {21.57}*	1400±0.00^a {30.00}	1750±56.56^b {12.50}	149±1.41^c {5.70}	197±0.71^d {19.80}*	85±2.12^a {46.20}	110±0.00^b {30.38}
50%	1600±31.81^b {20.00}	2000±35.36^c {0.00}	1300±14.14^a {35.00}	1620±14.14^b {19.00}	126±2.83^c {20.25}	160±0.00^d {1.25}*	77±0.70^a {51.27}	100±0.00^b {36.71}
75%	1500±42.43^c {25.00}	1850±3.52^d {7.50}	1300±35.36^a {35.00}	1560±42.43^b {22.00}	109±0.71^c {31.01}	144±2.83^d {8.86}	67±0.70^a {57.59}	98±1.41^d {37.97}
100%	1650±56.57^b {17.50}	1690±63.64^b {15.50}	1200±70.71^a {40.00}	1450±49.50 {27.50}	70±0.00^b {55.70}	93±0.00^c {41.13}	65±0.00^a {58.86}	65±0.00^a {58.86}

Data are means of 3 replicates±standard deviation, means with different letters on the same row are significant ($p<0.05$). Values in parenthesis represent percentage reduction. Values with * represent percentage increase. AB: Atmospheric boiling, AS: Atmospheric steaming, PB: Pressure boiling, PS: Pressure steaming

Many methods have been tried to solve the problem of prolonged cooking. In this study, it is observed that, although soaking as a pre-processing unit operation is not an absolute method, it is a desirable technique to solve the problem of prolonged cooking time of this hard-to-cook underutilised legume. This is certainly a better alternative to the traditional use of a tenderiser such as trona, the safety limit of which is yet to be established and no effect of its consumption on human physiology has, as far as we know, been reported.

Effects of soaking followed by hydrothermal processing on proximate composition of *C. hirsutta*: Hydrothermal processing of the legume seeds had significant effects ($p<0.05$) on the proximate composition. The effects of hydrothermal processing methods on the proximate constituents of legume seeds are presented in Table 2. The crude protein content of the dried, raw sample of *C. hirsutta* which was 21.15% decreased by 19.85 and 21.93% after boiling and steaming, at normal atmospheric pressure, respectively. Soaking of the seeds to 10, 25, 50, 75 and 100%

Table 2: Effect of soaking followed by hydrothermal processing on proximate composition of *Casia hirsutta*

Hydration level	Proximate component (%)	RS	AB	AS	PB	PS
0%	Moisture content	10.66±0.53^{d}	9.50±0.53^{c}{10.88}	9.09±0.41^{b}{14.72}	8.11±0.23^{a}{12.33}	8.11±0.01^{a}{23.92}
	Ash	4.08±0.05^{e}	3.00±0.01^{b}{26.47}	2.34±0.02^{a}{42.64}	3.14±0.10^{d}{23.03}	3.08±0.02^{c}{24.50}
	Crude protein	21.15±1.01^{e}	16.95±0.62^{b}{19.85}	16.51±0.06^{a}{21.93}	19.90±0.70^{d}{5.91}	18.35±0.31^{c}{13.23}
	Ether extract	0.91±0.03^{c}	0.85±0.00a{6.59}	0.85±0.02^{a}{6.59}	0.87±0.00^{b}{4.39}	0.86±0.01^{b}{5.49}
	Crude fibre	7.19±0.20^{e}	6.72±0.32^{b}{16.53}	6.23±0.05^{a}{13.35}	6.87±0.20^{d}{4.45}	6.76±0.08^{c}{5.98}
	Carbohydrate	56.01±0.98	62.95±0.72^{e}{11.02}	54.98±1.02^{a}{1.83}	61.11±0.75^{c}{8.34}	62.84±1.01^{d}{10.86}
	Total dry matter	89.34±1.34^{a}	90.50±1.01^{b}{1.28}	90.91±0.66^{c}{1.72}	91.89±1.0^{d}1{2.70}	91.89±1.13^{d}{2.70}
10%	Moisture content	10.66±0.53^{e}	9.47±0.20^{d}{11.16}	9.10±0.07^{c}{14.63}	8.30±0.21^{b}{22.14}	8.12±0.01^{a}{23.83}
	Ash	4.08±0.05^{e}	3.00±0.01^{b}{26.47}	2.34±0.01^{a}{42.65}	3.14 ±0.10^{d}{23.0}{	3.12±0.01{23.53}
	Crude protein	21.15±1.01^{e}	17.01±0.09^{b}{19.57}	16.65±0.0^{a}{21.28}	19.90±0.56^{d}{5.91}	18.3±0.31^{c}{13.23}
	Ether extract	0.91±0.03^{d}	0.85±0.00^{a}{6.59}	0.85±0.02^{b}{6.59}	0.87±0.00^{c}{4.40}	0.86±0.01^{c}{5.49}
	Crude fibre	7.19±0.20^{e}	6.72±0.07^{b}{6.54}	6.23±0.05^{a}{13.35}	6.88±0.20^{d}{4.31}	6.76±0.10^{c}{5.98}
	Carbohydrate	56.01±0.98^{a}	62.95±0.81^{d}{11.02}	64.83±0.99^{a}{13.60}	60.91±0.80^{b}{8.01}	62.79±1.01^{c}{10.80}
	Total dry matter	89.34±1.34^{a}	90.53±1.23^{b}{1.31}	90.90±0.74^{c}{1.72}	91.70±1.05^{d}{2.57}	91.88±1.20^{e}{2.76}
25%	Moisture content	10.66±0.53^{e}	9.53±0.21^{d}{10.60}	9.10±0.22^{c}{14.63}	8.30±0.22^{b}{22.14}	8.05±0.01^{a}{24.48}
	Ash	4.08±0.05^{e}	3.20±0.02^{b}{21.57}	2.86±0.02^{a}{29.90}	3.29±0.12^{d}{19.36}	3.28±0.03^{c}{19.61}
	Crude protein	21.15±1.01^{e}	17.55±0.32^{b}{17.02}	17.19±0.11^{a}{18.72}	19.90±0.64^{d}{5.91}	19.80±0.40^{c}{6.38}
	Ether extract	0.91±0.03^{c}	0.85±0.01^{a}{6.59}	0.85±0.02^{a}{6.59}	0.87±0.01^{b}{4.40}	0.87±0.01^{b}{4.40}
	Crude fibre	7.19±0.20^{e}	6.75±0.08^{b}{6.12}	6.38±0.03^{a}{11.26}	6.87±0.18^{d}{4.45}	6.76±0.15^{c}{5.98}
	Carbohydrate	56.01±0.98^{a}	61.85±0.46^{d}{8.44}	63.6±0.98^{e}{11.93}	60.77±0.80^{b}{7.83}	61.24±0.98^{c}{8.54}
	Total dry matter	89.34±1.34^{a}	90.47±0.95^{b}{1.25}	90.90±0.95^{c}{1.72}	91.70±1.23^{d}{2.57}	91.95±0.21^{e}{2.84}
50%	Moisture content	10.66±0.53^{e}	9.49±0.05^{d}{10.98}	9.08±0.07^{c}{15.01}	8.31±0.02^{b}{22.05}	8.10±0.00^{a}{0.24}
	Ash	4.08±0.05^{e}	3.20±0.01^{b}{21.57}	2.89±0.00^{a}{29.17}	3.33±0.10^{d}{18.38}	3.28±0.02^{c}{19.61}
	Crude protein	21.15±1.01^{e}	18.56±0.23^{b}{12.25}	18.21±0.10^{a}{13.90}	19.96±0.72^{d}{5.63}	19.81±0.32^{c}{6.34}
	Ether extract	0.91±0.03^{b}	0.87±0.01^{a}{4.40}	0.87±0.10^{a}{4.40}	0.87±0.01^{a}{4.40}	0.87±0.01^{a}{4.40}
	Crude fibre	7.19±0.20^{d}	6.87±0.21^{b}{4.45}	6.57±0.02^{a}{8.62}	6.89±0.17^{c}{4.17}	6.87±0.16^{b}{4.45}
	Carbohydrate	56.01±0.98^{e}	61.01±0.68^{d}{8.20}	62.38±1.00^{c}{10.21}	60.65±0.66^{b}{7.65}	61..07±0.89^{a}{8.29}
	Total dry matter	89.34±1.34^{a}	90.51±0.99^{b}{1.29}	90.92±0.95^{c}{1.74}	91.79±1.25^{d}{2.67}	91.90±0.99^{e}{2.79}
75%	Moisture content	10.66±0.53^{e}	9.48±0.03^{d}{11.07}	9.09±0.15^{c}{15.01}	8.34±0.20^{b}{21.76}	8.06±0.02^{a}{24.39}
	Ash	4.08±0.05^{e}	3.52±0.01^{b}{13.73}	3.22±0.02^{a}{21.08}	3.92±0.11^{d}{3.92}	3.84±0.03^{c}{5.88}
	Crude protein	21.15±1.01^{e}	20.14±0.20 ^{b}{4.78}	19.78±0.20^{a}{6.78}	20.69±0.64^{d}{2.18}	20.54±0.35^{c}{2.88}
	Ether extract	0.91±0.03^{d}	0.89±0.01 ^{b}{2.20}	0.88±0.01^{a}{3.30}	0.90±0.01^{c}{1.10}	0.90±0.02^{c}{1.10}
	Crude fibre	7.19±0.20^{e}	7.18±0.21^{d}{0.14}	6.88±0.41^{a}{4.31}	7.08±0.20^{c}{1.53}	6.95±0.18^{b}{3.34}
	Carbohydrate	56.01±0.98	58.79±0.73^{c}{4.73}	60.15±0.75^{a}{6.88}	9.20±0.56^{a}{5.39}	59.71±0.51^{d}{16.20}
	Total dry matter	89.34±1.34^{a}	90.52±1.12^{b}{1.30}	90.91±0.80^{c}{1.73}	91.66±1.20^{d}{2.53}	91.94±1.03^{e}{2.83}
100%	Moisture content	10.66±0.53^{e}	9.48±0.03^{d}{11.07}	9.09±0.15^{c}{14.73}	8.34±0.20^{b}{21.76}	8.06±0.02^{a}{24.39}
	Ash	4.08±0.05^{e}	3.52±0.01^{b}{13.73}	3.22±0.02^{a}{21.08}	3.92±0.11^{d}{3.92}	3.84±0.03^{c}{5.88}
	Crude protein	21.15±1.01^{e}	20.14±0.20^{b}{4.78}	19.78±0.20^{a}{6.48}	20.69±0.64^{d}{2.17}	20.54±0.35^{c}{3.07}
	Ether extract	0.91±0.03^{d}	0.89±0.01^{b}{2.20}	0.88±0.01^{a}{3.30}	0.90±0.01^{c}{1.10}	0.90±0.02^{c}{1.10}
	Crude fibre	7.19±0.20^{e}	7.18±0.21^{d}{0.14}	6.88±0.41^{a}{4.31}	7.08±0.20^{c}{1.53}	6.95±0.18^{b}{3.34}
	Carbohydrate	56.01±0.98^{a}	58.79±0.73^{b}{4.72}	60.15±0.75^{e}{6.88}	59.20±0.56^{c}{5.38}	59.71±0.51^{d}{6.19}
	Total dry matter	89.34±1.34^{a}	90.52±1.12^{b}{1.30}	90.91±0.80^{c}{1.72}	91.66±1.20^{d}{2.53}	91.94±1.03^{e}{2.82}

Data are means of 3 replicates±standard deviation; means with different letters on the same row are significant ($p<0.05$), Values in parenthesis represent percentage change in concentration after processing. RS: Raw dried sample, AB: Atmospheric boiling, AS: Atmospheric steaming, PB: Pressure boiling, PS: Pressure steaming hydration levels before boiling at normal atmospheric pressure caused the protein to reduce by 19.57, 17.02, 12.25,4.78 and 4.78, respectively. Steaming of *C. hirsutta* at elevated pressure also resulted in a protein reduction of 13.23 at 10% hydration level and 30.07 at 100% hydration level. With increasing hydration level, the percentage reduction in protein content decreased. This is true for all the hydrothermal methods employed. There was relatively low percentage reduction in protein content during processing at elevated pressure. This might not be unconnected with the fact that increase in pressure caused decrease in cooking times (Table 1). This decrease in cooking time prevent prolong cooking and thus minimizing protein leaching into the cooking water[6]. Moreover, there was more reduction in the protein content of the seeds that were processed without soaking. The percentage reduction due to soaking could be attributed to decrease in cooking times caused by increase in hydration levels. Soaking before processing predisposes soluble components of protein to leaching. The observed decrease in protein content during hydrothermal processing agrees with the study on an unconventional legume *Senna occidentalis* in which the protein content decreased significantly from 19.64% in the raw seeds to 17.60% in the cooked seeds[17]. Unlike boiling, steaming or toasting, fermentation and germination increased the crude protein contents of full at fluted pumpkin seed flour by 50.25 and 10.25%, respectively while boiling reduced it by 1.64%[18]. The oil content of the seed was low (0.91%) and hence the seeds do not qualify as oil seeds. The hydrothermal techniques did not induce remarkable change in the oil content after process.

All the hydrothermal techniques had significant effect ($p<0.05$) on the total ash. The total ash content of the raw sample was 4.08%; after hydrothermal processing the percentage reduction ranged from 3.22% for AS to 3.92% for PB at 100% hydration level. Reduction in the concentration of ash might be due to leaching. This is in agreement with an earlier study in which the total ash content of *Vigna unguiculata* decreased after domestic boiling[19]. The total ash content of raw dried *Telfairia occidentalis* which was 5.80% decreased to 2.55% after boiling while fermentation and germination decreased it to 2.06 and 2.50%, respectively[20]. Although loss of ash was minimized by drying the cooking water with the seeds; the traditional practice in some localities of changing the cooking water during cooking will result in very high loss of essential nutrients. This practice should be discouraged. At varying hydration levels, the legume exhibited varying degrees of percentage reduction in the crude fibre. The percentage reduction in the crude fibre varied from 4.31% for PB to 13.35 for AS at 10% hydration level and 0.14% for AB to 4.31% for AS at 100% hydration level. The change in the crude fibre content after hydrothermal processing might be due to modification of texture of plant tissue attributed to change in pectin conformation which mostly occur in the middle lamella of the cell walls in association with insoluble cellular solid inclusions[21,22]. Processing operations such as canning, frying, dehydration and boiling have been associated with change in texture of plant tissues[23-25].

Change in mineral elements composition during hydrothermal processing: Mineral elements composition of the legume seeds before and after hydrothermal processing is presented in Table 3. Table 4 shows the mineral element weight ratios. All the hydrothermal processing methods significantly ($p<0.05$) affected the concentration of the mineral elements in the legume. Potassium content of the raw seeds was 220.11 mg/100 g. Boiling and steaming at normal atmospheric pressure reduced the content of potassium by 24.87 and 30.74%, respectively while boiling and steaming at elevated pressure reduced it by 35.89 and 36.41%, respectively. The loss of potassium was lower but agrees with the findings of Fagbemi[20] who reported 63% reduction in *Telfaria occidentalis*. *Cassia hirsutta* is a good source of phosphorus containing 410.03 mg/100 g. The percentage reduction ranged from 35.89% at 10% hydration level to 26.63% at 100% hydration level after processing by BEP. In human nutrition, phosphorus helps to regulate the absorption of fat[26].

Magnesium is another nutritionally important mineral element detected at the concentration of 115.18 mg/100 g. Magnesium helps in transmission of nerve impulses, muscular contractions and regulation of the heart beat[26]. PB caused the least reduction in the concentration of this mineral element. Iron in the legume also experienced leaching after processing. Iron unlike water soluble electrolytes such as potassium is less prone to leaching during boiling. When cooking times were short as in the case of boiling, retention of iron in the processed legume was observed. Thus, iron content of raw sample of *C. hirsutta* which was 5.60 mg/100 g decreased by 6.25% after boiling (PB) and steaming (PS) at elevated pressure. Reduction in the quantity of foods minerals following boiling of foods were observed for iron, phosphorus, magnesium, zinc and manganese. This was attributed to leaching[27].

The Ca/P and Ca/Mg weight ratio of the raw legume sample were low compared with those of the processed samples (Table 4). This might not be unconnected with the

Table 3: Effect of hydrothermal techniques on mineral elements in *Cassia hrsutta* at varying hydration levels

Hydration level	Mineral elements (mg/100 g)	RS	AB	AS	PB	PS
0%	Calcium	90.54±0.98^{e}	72.43±0.22^{a}{20.01}	73.86±0.54^{b}{18.43}	78.91±0.31^{d}{12.85}	78.68±0.41^{c}{13.10}
	Zinc	6.12±0.03^{e}	4.97±0.04^{a}{18.79}	4.98±0.03^{b}{18.62}	5.30±0.04^{d}{13.39}	5.28±0.04^{c}{13.73}
	Sodium	39.96±0.74^{e}	31.92±0.38^{b}{20.12}	30.87±0.72^{a}{22.75}	34.37±0.02^{d}{13.99}	34.34±0.51^{c}{14.06}
	Iron	5.60±0.01^{e}	4.26±0.04^{b}{23.93}	4.09±0.03^{a}{26.96}	4.86±0.01^{d}{13.21}	4.85±0.02^{c}{14.29}
	Magnesium	115.18±0.84^{e}	73.47±0.68^{b}{36.21}	72.00±1.00^{a}{37.49}	98.92±0.68^{d}{14.12}	98.58±1.01^{c}{14.41}
	Phosphorus	410.03±2.24^{e}	232.68±1.34^{b}{43.25}	225.07±1.35^{a}{45.11}	262.84±1.00^{d}{35.89}	260.75±0.87^{c}{36.41}
	Potassium	220.11±1.00^{d}	154.26±0.68^{b}{24.87}	152.45±1.32^{a}{30.74}	183.40±0.64{16.68}	183.40±0.80^{c}{16.68}
10%	Calcium	90.54±0.98^{e}	72.42±0.08^{a}{20.02}	73.88±0.40^{b}{18.41}	78.89±0.24^{d}{12.87}	78.77±0.36^{c}{13.00}
	Zinc	6.12±0.03	4.97±0.03^{a}{18.79}	4.98±0.02^{b}{18.63}	5.32±0.03{13.07}	5.45±0.04^{d}{10.95}
	Sodium	39.96±0.74^{e}	31.93±0.32^{b}{20.09}	30.87±0.09^{a}{22.75}	34.37±0.04^{d}{13.99}	34.35±0.32^{c}{14.04}
	Iron	5.60±0.01^{e}	4.26±0.03^{b}{23.93}	4.09±0.03^{a}{26.96}	4.86±0.00^{d}{13.21}	4.85±0.02^{c}{13.39}
	Magnesium	115.18±0.84^{e}	73.49±0.53^{b}{36.19}	72.01±1.01^{a}{37.48}	98.92±0.52^{d}{14.12}	98.58±1.03^{c}{14.41}
	Phosphorus	410.03±2.24^{e}	232.68±1.34^{b}{43.26}	225.07±1.52^{a}{45.11}	262.84±1.08^{d}{35.89}	260.75±1.37^{c}{36.41}
	Potassium	220.11±1.00^{d}	154.31±0.72^{b}{29.89}	152.45±0.38^{a}{30.74}	183.40±0.59{16.68}	183.40±0.43^{c}{16.68}
25%	Calcium	90.54±0.98^{e}	72.71±0.15^{a}{19.70}	75.60±0.32^{b}{16.51}	79.67±0.19^{d}{12.01}	79.39±0.25^{c}{12.32}
	Zinc	6.12±0.03^{e}	5.02±0.10^{b}{17.97}	5.00±0.10^{a}{18.30}	5.60±0.02^{d}{52.00}	5.45±0.03^{c}{10.95}
	Sodium	39.96±0.74^{e}	32.50±0.26^{b}{18.67}	32.24±0.67^{a}{19.32}	35.68±0.05^{d}{10.71}	34.80±0.70^{c}{12.91}
	Iron	5.60±0.01^{d}	4.26±0.04^{b}{23.92}	4.24±0.01^{a}{24.29}	4.86±0.01{13.21}	4.86±0.07^{c}{13.21}
	Magnesium	115.18±0.84^{e}	73.49±0.46^{b}{36.20}	72.30±0.92^{a}{37.23}	101.27±0.28^{d}{12.08}	101.25±0.92^{c}{12.09}
	Phosphorus	410.03±2.24^{e}	259.45±2.04^{b}{36.72}	250.23±1.48^{a}{38.97}	293.68±0.91^{d}{28.38}	275.91±1.40^{c}{32.71}
	Potassium	220.11±1.00^{e}	164.27±0.67^{b}{25.34}	161.34±0.52^{a}{26.70}	196.20±0.37^{d}{10.86}	195.15±0.54^{c}{11.34}
50%	Calcium	90.54±0.98^{e}	73.70±0.25^{a}{18.60}	77.49±0.51^{b}{14.42}	81.01±0.28^{d}{10.53}	80.58±0.25^{c}{11.01}
	Zinc	6.12±0.03^{e}	5.18±0.06^{b}{15.36}	5.12±0.03^{a}{16.34}	5.61±0.03^{d}{8.33}	5.47±0.03^{c}{10.62}
	Sodium	39.96±0.74^{e}	32.84±0.17^{b}{17.82}	32.58±0.28^{a}{18.47}	35.73±0.03^{d}{10.59}	34.84±0.71^{c}{12.81}
	Iron	5.60±0.01^{e}	4.50±0.01^{b}{19.64}	4.27±0.00^{a}{23.75}	5.08±0.04^{d}{19.29}	5.02±0.04^{c}{10.36}
	Magnesium	115.18±0.84^{e}	73.90±0.74^{b}{35.84}	73.62±1.20^{a}{36.08}	101.90±0.19^{d}{11.53}	101.25±1.12^{c}{12.09}
	Phosphorus	410.03±2.24^{e}	259.45±1.67^{b}{36.72}	252.17±1.09^{a}{38.50}	294.42±0.82^{d}{28.20}	293.20±0.93^{c}{28.49}
	Potassium	220.11±1.00^{e}	164.38±0.67^{a}{25.31}	164.96±2.31^{b}{25.06}	196.27±0.38^{d}{10.83}	196.15±1.01^{c}{10.89}
75%	Calcium	90.54±0.98^{d}	76.34±0.31^{a}{15.69}	80.21±0.10^{b}{11.41}	84.03±0.30{7.20}	84.03±0.40^{c}{7.20}
	Zinc	6.12±0.03^{e}	5.18±0.04{15.35}	5.12±0.02^{a}{16.33}	5.95±0.05^{d}{2.77}	5.50±0.02^{c}{10.13}
	Sodium	39.96±0.74^{e}	33.23±0.41^{b}{16.84}	32.60±0.53^{a}{18.41}	36.32±0.03^{d}{9.10}	36.01±0.53^{c}{9.88}
	Iron	5.60±0.01^{d}	4.50±0.03^{b}{19.64}	4.27±0.01^{a}{23.75}	5.25±0.03^{c}{6.25}	5.25±0.02^{c}{6.25}
	Magnesium	115.18±0.84^{d}	75.39±0.42^{b}{34.54}	74.43±0.84^{a}{35.37}	104.41±0.52^{c}{9.35}	104.42±1.21^{c}{9.34}
	Phosphorus	410.03±2.24^{e}	260.43±1.22^{b}{36.48}	260.40±1.60^{a}{36.49}	298.44±1.01^{d}{27.21}	298.40±1.53^{c}{27.21}
	Potassium	220.11±1.00^{e}	170.39±0.51^{b}{22.58}	165.42±1.53^{a}{24.84}	203.09±0.51^{d}{7.73}	199.66±1.01^{c}{9.329}
100%	Calcium	90.54±0.98^{e}	76.33±0.16^{a}{15.69}	80.21±0.04^{b}{11.41}	84.00±0.29^{d}{7.22}	83.74±0.50^{c}{7.51}
	Zinc	6.12±0.03^{e}	5.35±0.03^{b}{12.59}	5.16±0.01^{a}{15.69}	5.95±0.04^{d}{2.78}	5.50c±0.02^{c}{10.13}
	Sodium	39.96±0.74^{e}	34.09±0.32^{b}{14.56}	33.33±0.30^{a}{16.47}	36.38±0.02^{d}{8.82}	36.20±0.23^{c}{9.27}
	Iron	5.60±0.01^{e}	4.65±0.02^{b}{16.96}	4.49±0.00^{a}{19.82}	5.25±0.03^{d}{6.25}	5.25±0.02^{c}{6.25}
	Magnesium	115.18±0.84^{e}	78.88±0.52^{b}{31.50}	76.81±0.76^{a}{33.31}	107.97±0.41^{d}{6.26}	105.34±0.93^{c}{8.54}
	Phosphorus	410.03±2.24^{e}	26 5.23±1.07^{b}{35.31}	261.41±0.50^{a}{36.25}	300.83±1.22^{d}{26.63}	299.56±1.33^{c}{26.94}
	Potassium	220.11±1.00^{e}	171.08±0.76^{b}{22.28}	169.54±1.08^{a}{22.97}	203.09±0.46^{d}{7.73}	201.82±1.12^{c}{8.31}

Data are means of 3 replicates±standard deviation; means with different letters on the same row are significant ($p<0.05$).Values in parenthesis represent percentage change in concentration after processing. RS: Raw dried sample, AB: Atmospheric boiling, AS: Atmospheric steaming, PB: Pressure boiling, PS: Pressure steaming

Table 4: Computed mineral weight ratios for *Cassia hirsutta* seed

Mineral ratio	RS	AB	AS	PB	PS
K/Na	5.51±0.12^{d}	4.83±0.04^{a}	4.94±0.06^{b}	5.53±0.01^{c}	5.34±0.28^{c}
Ca/P	0.22±0.01^{a}	0.31±0.01^{b}	0.33±0.01^{b}	0.30±0.02^{b}	0.30±0.01^{b}
Ca/Mg	0.79±0.00^{a}	0.99±0.01^{b}	1.03±0.04^{b}	0.80±0.01^{a}	0.08±0.01^{a}
K/[Ca+Mg]	1.07±0.03^{a}	1.06±0.04^{a}	1.05±0.07^{a}	1.03±0.04^{a}	1.03±0.04^{a}

Values with different letters in the same row are significantly different ($p<0.05$). RS: Raw dried sample, AB: Atmospheric boiling, AS: Atmospheric steaming, PB: pressure boiling, PS: Pressure steaming

presence of antinutritional components including phytic acid. Phytic acid can form stable complexes with mineral ions rendering them unavailable for intestinal uptake[28]. After hydrothermal processing, there was improvement in the values of Ca/P and Ca/Mg. This was true for each of the hydrothermal techniques. Increase in the weight ratios of Ca/P and Ca/Mg after hydrothermal processing was probably due to reduction in the level of phytic acid. The Ca/Mg weight ratio, as presented in Table 4, ranged from 0.79 for the raw sample to 1.03 for the sample processed by AS. The Ca/Mg weight ratio recorded for the raw and processed samples were low when compared with the recommended ratio of 2.2[29]. Similarly, Ca/P ranged from 0.22-0.33. The recommended value of Ca/P ratio is 1.0[29]. Ca/Mg and Ca/P are important in the formation of bones and teeth as well as in controlling the level of Ca in the blood[20,29].

In general, samples cooked at higher hydration levels have better retention of mineral elements. This was probably due to the fact that samples with higher hydration levels required less time for cooking. In addition, the degree of cell wall damage can affect the degree of leaching of mineral elements from the seeds during hydrothermal processing. This degree of cell wall damage is a function of time. Although the hydrothermal techniques caused varying seepage, the legume seed is a good source of these mineral elements even after hydrothermal processing. High amounts of calcium, potassium and magnesium have been reported to reduce high blood pressure[26,30]. This makes consumption of this lesser known legume a necessity for patients suffering from hypertension. Thus, frequent intake of this legume may cause significant reduction in high blood pressure.

CONCLUSION

Soaking as a pre-processing technique is a desirable unit operation that could alleviate the problem of prolong cooking in *Cassia hirsutta* and thus encourages wider scope of utilisation. The concentrations of nutritionally important nutrients in the legume seeds after hydrothermal processing justifies the need to promote its adoption in human diets and feeds. This study will encourage adaptation of this underutilised legume, strengthen dietary diversity and healthy eating habit. This will not only prevent imminent extinction of this lesser known food crop, it will encourage further utilisation for new food and feed formations thereby alleviating the problem of food and nutrition insecurity in developing countries.

SIGNIFICANCE STATEMENT

This study discovers that hydration of seeds of *Cassia hirsutta* prior to hydrothermal processing lessens the problem of prolonged cooking time. Of all the four hydrothermal techniques employed, boiling at elevated pressure has comparative advantage of conserving inherent nutrients. The study will help food processors to save time and energy during processing, encourage more utilisation of this nutritionally important underutilised food crop and thus help to alleviate the problem of protein energy malnutrition in developing countries.

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