Effect of Modified Traditional Cooking Methods on Nutritional Quality of African Yam Beans (*Sphenostylis stenocarpa*)

Okpalanma, E.F.,[1,2] Ukpong, E.S.,[3] Ezegbe, C.C.[4], Chude, C.O.,[5] and Nwagbo, C.C.[5]

[1] Department of Food Science and Technology, Madonna University, P.M.B. 05 Elele, Rivers State, Port Harcourt, Nigeria

[2] Department of Human Nutrition and Dietetics, David Umahi Federal University of Health Sciences, Uburu P.M.B. 211, Ebonyi State, Nigeria

[3] Department of Human Nutrition and Dietetics, Alex Ekwueme Federal University Ndufu-Alike, P.M.B 1010 Abakaliki, Ebonyi State, Nigeria.

[4] Department of Food Science and Technology, Faculty of Agriculture, Nnamdi Azikiwe University, P.M.B. 0255, Awka, Anambra State, Nigeria.

[5] Department of Food Science and Technology, Chukwuemeka Odumegwu Ojukwu University, P.M.B. 6059, Igbariam, Anambra State, Nigeria

Corresponding Author: felixokpalanma@yahoo.com;   **Phone Number:** +234(0)8033924371

ABSTRACT

Background: The hindrance to the optimum utilization of African Yam Bean (AYB) can be attributed to its hard-to-cook nature, long cooking time, and the presence of anti-nutrients.

Objective: This study aimed to establish a protocol for reducing the cooking time of AYB and compare the efficacy of traditional boiling with modified cooking methods in enhancing its nutritional quality and acceptability.

Methods: Three different species of AYB—cream, brown, and mottled—were soaked separately for 12, 18, and 24 hours for the cooking experiment. The cultivar (brown) that had the least cooking time was then soaked (24 hours), fermented (48 hours), either dehulled or left un-dehulled, followed by either roasting for 30 minutes at 150°C in a hot air oven or steaming for 30 minutes in a pressure cooker until they turned golden brown.

Results: Beans that were soaked for 12 hours had the least cooking time. The cultivar with the least cooking time (130 minutes) was the brown one. There were increments in protein content (26%) and in vitro protein digestibility, IVPD (11%), while decreases in contents of mineral (1–13%), tannin (31–100%), trypsin inhibitor activity (100%), phytic acid (30–70%) and hydrocyanic acid (85–90%) were recorded due to modified cooking methods. Traditional boiling decreased the beans' mineral (10–18%), tannin (20%), trypsin inhibitor activity (85%), phytic acid (10%), and hydrocyanic acid (78%) levels and increased protein (9%) and IVPD (10%), respectively.

Conclusion: Combined processing treatments significantly reduced anti-nutrients in AYB seeds when compared with the traditional boiling treatment.

INTRODUCTION

Legumes are known as affordable sources of dietary protein, especially in the diets of many developing countries (1). Groundnut (*Arachis hypogea*), cowpea (*Vigna unguiculata*), and lima bean (*Phaseolus lunatus*) are among the most important legumes. However, many locally cultivated pulses that are underutilized could help

meet the dietary needs of impoverished populations in remote areas and urban centers (2). African yam bean (AYB) is a lesser-known legume, predominantly grown in southern Nigeria and widely consumed in the southeastern region of the country (3). AYB has various culinary uses and applications and is a cost-effective source of protein and energy compared to cowpea (4)

The high cost of animal protein has limited its accessibility to a large segment of populations in underdeveloped countries (5). As a result, research has focused on identifying oil-bearing seeds and legume proteins as alternative plant-based protein sources (6). While plant proteins are nutritionally inferior to animal proteins due to low biological value and deficiency in some essential amino acids, their combination with animal proteins can complement essential amino acids, ensuring a complete protein profile (7). In southeastern Nigeria, AYB seeds, which contain high crude protein levels (21–29%), play a crucial role in the region's nutrition (8).

Factors limiting the consumption and utilization of AYB include its hard texture, prolonged cooking time, high cooking fuel cost, presence of anti-nutritional factors, and lack of appropriate processing technologies (9). Anti-nutritional compounds found in AYB include oxalate, lectin, phytic acid, saponins, tannins, hydrogen cyanide, stachyose, trypsin inhibitors, alkaloids, and raffinose (10). Identifying the most effective traditional processing methods to address these constraints is essential. Applying suitable processing techniques not only reduces anti-nutritional factors but also enhances protein digestibility, biological value, and overall quality of the crop (11). By integrating processed AYB into household diets—as stews, snacks, flours for porridge or baked goods—communities can enhance dietary diversity and reduce dependency on expensive animal protein sources. The improved digestibility and nutrient profile also make it suitable for children, pregnant women, and the elderly, who are often vulnerable to micronutrient deficiencies. This study aimed to determine the effect of modified traditional cooking methods on the nutritional quality of African yam beans

MATERIALS AND METHODS
Cream, brown, and mottled cultivars of AYB used in this study were obtained from Eke Awka market in Anambra State, Nigeria.

Determination of cooking time for processing
Five hundred grams (500 g) of each of the three AYB cultivars were cleaned and soaked in 2.5 dm³ of distilled water for 12, 18, and 24 hours at room temperature (30 ± 2°C). The soaked samples were drained and used for the cooking experiment. The cooking time of the AYB seeds was determined by boiling the samples in 1 dm³ of distilled water at atmospheric pressure until the seeds could be easily squeezed between fingers. The cooking time was then recorded. The variety that gave the shortest cooking time (brown) was selected for subsequent studies.

Preparation of AYB flour samples
Boiled flour sample: The samples were prepared as described in Fig. 1. AYB seeds were sorted and divided into portions. One part (1 kg) was boiled in 2 dm³ of distilled water, dried in a hot air oven (UNISCOPE SM 9053, England) at 50°C for 24 hours, milled using a laboratory hammer mill (Thomas Willy Mill, model ED-5), and sieved through a 60 µm sieve to obtain flour. The flour was packaged in a plastic tin and labeled BF (boiled flour). The boiling time was taken as the time when 90% of the seeds, selected at random, were soft enough to be macerated between the fingers.

Raw flour sample: The second part (1 kg) was dried, milled, and sieved into flour as described earlier. This flour was packaged in a plastic tin and labeled RF (raw flour), serving as the control.

Soaked, dehulled, fermented, steamed flour sample: The third portion (2 kg) was soaked in 6 dm³ of distilled water for 24 hours at room temperature (30 ± 2°C), after which it was divided into two equal parts. One part (1 kg) was dehulled manually by rubbing the seeds between the palms, while the second part (1 kg) remained un-dehulled (whole).

The dehulled portions were fermented by placing them separately in large plastic containers with lids to ferment naturally at room temperature (30 ± 2°C) for 48 hours. The lids were occasionally opened, and the seeds were stirred using a wooden spoon (12).

The fermented seeds were further divided into two portions. One portion (500 g) was placed on a tray in a steam cooker (Binatone PC-5001, Binatone Lifestyle), covered with a lid, and steamed over 2.5 dm³ of boiling water at normal atmospheric pressure. The steaming time was defined as the time when 90% of the seeds, selected at random, became soft enough to be crushed by pressing between the fingers (13).

After steaming, the seeds were dried, milled, and sieved into flour as described earlier. This flour was packaged in a plastic tin and labeled sDFS (soaked-Dehulled-Fermented-Steamed).

Soaked, dehulled, fermented, roasted flour sample: The other portion (500 g) of the soaked, dehulled, fermented seed was roasted at 150°C in a hot air oven for 30 minutes. The preferred roasting time was when cracking occurred, and the beans turned golden brown without burning (14). The roasted beans were then milled and sieved into flour. This flour was packaged in a plastic tin and labeled sDFR (soaked-Dehulled-Fermented-Roasted).

Soaked, whole, fermented, steamed flour sample: The un-dehulled (whole) portion (1 kg) was also fermented as described earlier, then further divided into two parts. One part (500 g) was steamed, dried, milled, and sieved. This flour was packaged in a plastic tin and labeled sWFS (soaked-Whole-Fermented-Steamed).

Soaked, whole, fermented, roasted flour sample: The other part (500 g) of undehulled, soaked, fermented seeds was roasted as described earlier, milled, and sieved. This flour was packaged in a plastic tin and labeled sWFR (soaked-Whole-Fermented-Roasted).

Chemical analyses

Proximate composition: Standard procedures of the Association of Official Analytical Chemists (15) were used to determine the proximate composition of the samples, including moisture, crude fat, ash, crude fiber, and crude protein. Carbohydrate content was determined by difference.

Determination of selected mineral content: The concentrations of calcium, iron, and zinc in the samples were determined using a Perkin-Elmer Model 372 Atomic Absorption Spectrophotometer (AAS), following standard wet acid digestion procedures as described by AOAC (15).

Determination of anti-nutrient content:

Tannin: Tannin content was determined by the previous method (16). The absorbance was measured at 760 nm using a spectrophotometer. Tannin concentration was calculated from a standard calibration curve prepared with tannic acid, and results were expressed as milligrams of tannic acid equivalent per 100 g of sample.

Phytate: Phytate content was determined according to the method (17). The absorbance of the extract was read at 500 nm using a spectrophotometer. Phytate concentration was calculated from a calibration curve prepared with sodium phytate and expressed as mg/100g of sample.

Trypsin inhibitor activity (TIA): Trypsin inhibitor activity was determined following the AACC Approved Methods (18). The absorbance of the extract was measured at 410 nm using a spectrophotometer. Trypsin inhibitor activity was calculated based on the reduction in trypsin activity compared with the control and expressed as TIU/mg of sample.

Cyanogenic glycosides: Cyanogenic glycosides were quantified as hydrogen cyanide (HCN) equivalents using the standard method (15). Absorbance was measured at 600 nm using a spectrophotometer, and HCN content was calculated from a potassium cyanide standard curve, with results expressed in mgHCN/100g of sample.

Determination of in vitro protein digestibility: In vitro protein digestibility was determined by the multi-enzyme pH-drop method described by (19). A suspension of the sample in distilled water was adjusted to pH 8.0 and maintained at 37 °C. A multi-enzyme solution containing trypsin, chymotrypsin, and peptidase was added, and the decrease in pH was recorded over a 10-minute period. Digestibility was estimated from the pH change, and results were expressed as a percentage.

Statistical analysis

Data were analyzed using SPSS version 17.0 through one-way analysis of variance (ANOVA). Significant differences between the means were tested at $p < 0.05$ using Fisher's least significant difference (LSD) test.
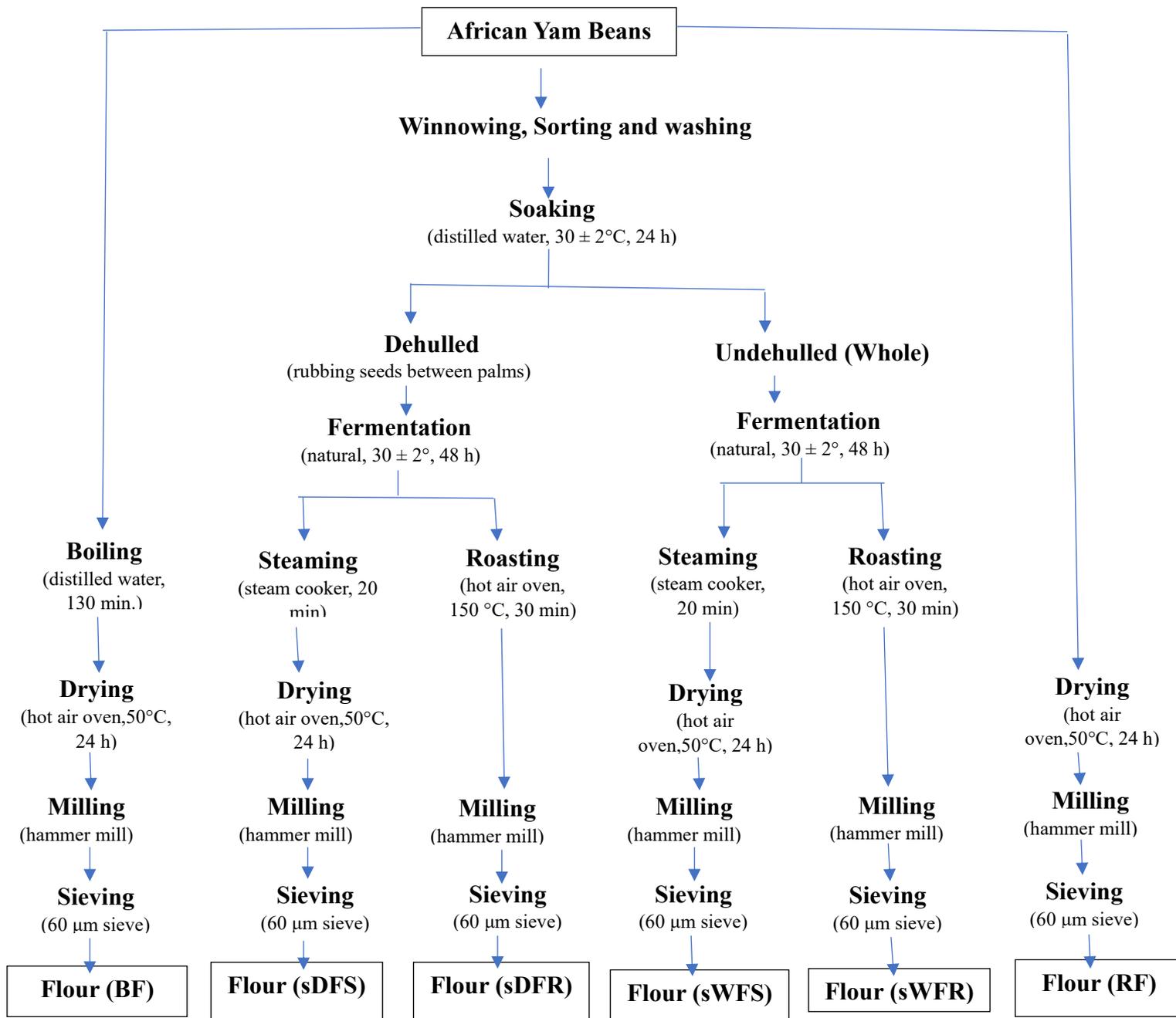
Figure. 1: Processing of African yam bean flour samples
Sample: RF =Raw Flour. BF = Boiled Flour. sDFS = soaked-Dehulled-Fermented-Steamed. sDFR = soaked-Dehulled-Fermented-Roasted. sWFS =soaked-Whole-Fermented-Steamed. sWFR = soaked-Whole-Fermented-Roasted

RESULTS

Effect of soaking on cooking time

The cooking time of unsoaked raw seeds ranged from 130 to 185 minutes, depending on the cultivar (Table 1). The brown cultivar had the shortest cooking time (130 minutes), which was significantly different ($p < 0.05$) from the other cultivars.

Soaking the cream, brown, and mottled beans for 12, 18, and 24 hours led to decreases in cooking time of 61%, 56%, and 49% for cream beans; 57%, 52%, and 37% for brown beans; and 59%, 54%, and 50% for mottled beans, respectively. These reductions were significant ($p < 0.05$), with 12-hour soaking resulting in the shortest cooking times of 72, 56, and 68 minutes for the three cultivars.

Table 1: Effect of soaking on cooking time of AYB

Treatment	Cooking Time (min)		
	Cream	Brown	Mottled
Raw	185 ± 6.3^a	130 ± 3.2^a	165 ± 4.5^a
S_{12}	72 ± 5.10^d	56 ± 6.13^d	68 ± 2.54^d
S_{18}	81 ± 3.41^c	62 ± 8.10^c	75 ± 2.13^c
S_{24}	94 ± 7.12^b	82 ± 4.30^b	82 ± 6.51^b

Values are means ± standard deviation of three determinations. Means in a column not sharing a common superscript letter are significantly ($p<0.05$) different.
Raw = Control. S_{12}, S_{18}, and S_{24} = AYB Soaked (12, 18, and 24 h).

Effects of different processing methods on the proximate composition of the brown AYB cultivar

The proximate composition of AYB flour subjected to single and combined treatments is shown in Table 2. Raw AYB flour contained 7.3% moisture, 22.2% crude protein, 6.3% crude fiber, 4.6% fat, 3.7% ash, and 55.7% carbohydrate. Amongst the treated samples, moisture content ranged from 7.3-10.5%, protein ranged from 19.2-26.0%, carbohydrate ranged from 51.5-59.0%.

Table 2: Effects of different processing methods on proximate composition (%) of the brown AYB cultivar

Treatment	Moisture Content	Crude Protein	Crude fiber	Fat	Ash	Carbohydrate
RF	$7.32^f \pm 0.01$	$22.21^d \pm 0.29$	$6.31^a \pm 0.44$	$4.67^b \pm 0.25$	$3.73^a \pm 0.11$	$55.76^c \pm 0.29$
sDFS	$8.84^c \pm 0.03$	$26.03^a \pm 0.48$	$2.52^d \pm 0.15$	$3.86^d \pm 0.41$	$b.12^e \pm 0.12$	$56.63^b \pm 0.31$
sDFR	$8.44^d \pm 0.05$	$25.52^b \pm 0.11$	$2.02^e \pm 0.12$	$3.12^e \pm 0.33$	$1.84^f \pm 0.01$	$59.06^a \pm 0.54$
sWFS	$9.13^b \pm 0.01$	$24.72^c \pm 0.20$	$5.64^b \pm 0.21$	$4.78^a \pm 0.23$	$4.20^b \pm 0.01$	$51.53^e \pm 0.63$
sWFR	$8.15^e \pm 0.03$	$23.61^c \pm 0.15$	$5.33^c \pm 0.03$	$4.12^c \pm 0.51$	$4.54^d \pm 0.21$	$53.14^d \pm 0.34$
BF	$10.54^a \pm 0.01$	$19.23^e \pm 0.56$	$4.12^c \pm 0.24$	$3.00^e \pm 0.08$	$2.65^c \pm 0.13$	$56.46^b \pm 0.26$

Results are given on a dry matter basis as mean ± SD (n=3). Values with different letters across the column are significantly different from each other ($p<0.05$).
Sample: RF = Raw Flour. BF = Boiled Flour.   sDFS = soaked-Dehulled-Fermented-Steamed. sDFR = soaked-Dehulled-Fermented-Roasted. sWFS = soaked-Whole-Fermented-Steamed. sWFR = soaked-Whole-Fermented-Roasted

Effects of different processing methods on selected minerals of the brown AYB cultivar

Raw AYB had calcium, iron, and zinc concentrations of 44.40, 13.30, and 4.30 mg/100g, respectively (Table 3). Significant reductions ($p<0.05$) in Ca, Fe, and Zn content were observed in all processed samples. Dehulling and roasting treatments caused the highest reductions in mineral content. In the dehulled, fermented, and roasted beans (sDFR), reductions in iron, calcium, and zinc were 23%, 18%, and 9%, respectively. Traditional cooking (BF) resulted in reductions for iron (18%), calcium (15%), and zinc (10%), respectively.

Effects of different processing methods on anti-nutrient contents of the brown AYB cultivar

Tannin: The tannin content of raw AYB was 18.50 mgTAE/100g (Table 4). Soaking, dehulling, fermenting, and subsequent steaming (sDFS) or roasting (sDFR) effectively reduced tannin levels to below detectable limits. Beans that were soaked whole, fermented, and then roasted (sWFR) or steamed (sWFS) also showed significant ($p<0.05$) reductions in tannin levels, ranging from 8.30 to 12.76 mg/g. By comparison, the boiled (BF) beans showed a tannin reduction of 20.13%, resulting in a tannin content of 14.70 mgTAE/100g.

Phytic acid: The phytic acid content of raw African yam bean (AYB) seeds was 7.40 mg/g (Table 4). The phytic acid content in BF (6.6 mg/g) was significantly higher ($p<0.05$) than that in sDFS (3.80 mg/g), sDFR (5.1 mg/g), sWFS (2.2 mg/g), and sWFR (3.25 mg/g). Significant reductions ($p<0.05$) in phytic acid content due to processing methods were observed. Boiling (BF) resulted in a 10.8% reduction, while reductions for sDFR, sDFS, sWFR, and sWFS were 30.34%, 48.42%, 56.10%, and 70.42%, respectively.

Trypsin inhibitor activity: The trypsin inhibitor activity (TIA) in raw brown AYB was 3.20 TIU/g (Table 4). Boiled beans exhibited an 85% reduction in TIA. Each of the combined processing methods—sDFS, sDFR, sWFS, and

sWFR—resulted in a complete (100%) reduction of TIA.

Hydrogen cyanide: Raw AYB contained 223.25 mg HCN/kg of hydrogen cyanide (Table 4). Boiling led to a 78.45% reduction in hydrocyanic acid. Significant ($p<0.05$) cyanide reductions (81-85%) were also observed in beans that were soaked, dehulled, fermented, and then either steamed (sDFS) or roasted (sDFR). Furthermore, beans that were soaked whole, fermented, and then either roasted (sWFR) or steamed (sWFS) showed 87–90% significant reductions ($p<0.05$) in cyanide content.

Table 3. Effects of different processing methods on selected mineral composition (mg/100g) of the brown AYB cultivar

Treatment	Fe	Ca	Zn
RF (Control)	13.30± 0.17[a]	44.40± 1.7[a]	4.30± 1.1[a]
sDFS	10.64± 0.13[d]	37.74± 1.4[d]	4.04± 0.6[c]
sDFR	10.24± 0.21[d]	36.40± 3.2[e]	3.91± 0.2[d]
sWFS	11.57 ± 0.15[b]	41.29± 1.9[b]	4.25± 1.6[a]
sWFR	11.30± 0.13[b]	39.96± 1.2[c]	4.12± 1.5[b]
BF	10.9± 0.31[c]	37.74± 0.11[d]	3.87± 0.11[d]

Results are given on a dry matter basis as mean ± SD (n=3). Values with different letters across the column are significantly different from each other ($p<0.05$).
Sample: RF = Raw Flour. BF = Boiled Flour. sDFS = soaked-Dehulled-Fermented-Steamed. sDFR = soaked-Dehulled-Fermented-Roasted; sWFS = soaked-Whole-Fermented-Steamed. sWFR = soaked-Whole-Fermented-Roasted

Table 4. Effect of different processing methods on anti-nutrient content of the brown AYB cultivar

| Treatment	Tannin (mg TAE/100g)	Phytic acid (mg/g)	Trypsin inhibitor activity (TIU/g)	Hydrogen cyanide (mg HCN/kg)
RF(Control)	18.50 ± 0.13[a]	7.40 ± 0.15[a]	3.20 ±0.22[a]	223.25±35[a]
sDFS	ND	3.80± 0.01[d]	ND	21.38± 2.43[e]
sDFR	ND	5.15± 0.11[c]	ND	27.57±4.23[d]
sWFS	12.76±0.33[c]	2.20± 0.05[e]	ND	33.01± 2.23[c]
sWFR	8.30 ±0.16[d]	3.25± 0.05[d]	ND	41.01±0.13[b]
BF	14. 78±0.05[b]	6.60± 0.03[b]	0.46± 0.04[b]	48.11±2.30[b]

Results are given on a dry matter basis as mean ± SD (n=3). Values with different letters across the column are significantly different from each other ($p<0.05$).
Sample: RF = Raw Flour. BF = Boiled Flour. sDFS = soaked-Dehulled-Fermented-Steamed. sDFR = soaked-Dehulled-Fermented-Roasted. sWFS = soaked-Whole-Fermented-Steamed. sWFR = soaked-Whole-Fermented-Roasted

Effects of different processing methods on in vitro protein digestibility

Raw AYB had IVPD of 73.4% (Figure 2). Boiling raw beans led to a significant ($p<0.05$) 10% improvement in IVPD. The IVPD of whole beans subjected to combined processing methods—soaking, fermentation, and either steaming or roasting—showed further improvements of 11.10–14.20%. However, the improvement in IVPD for dehulled beans that underwent similar treatments was lower, ranging from 5.5% to 8.0%.
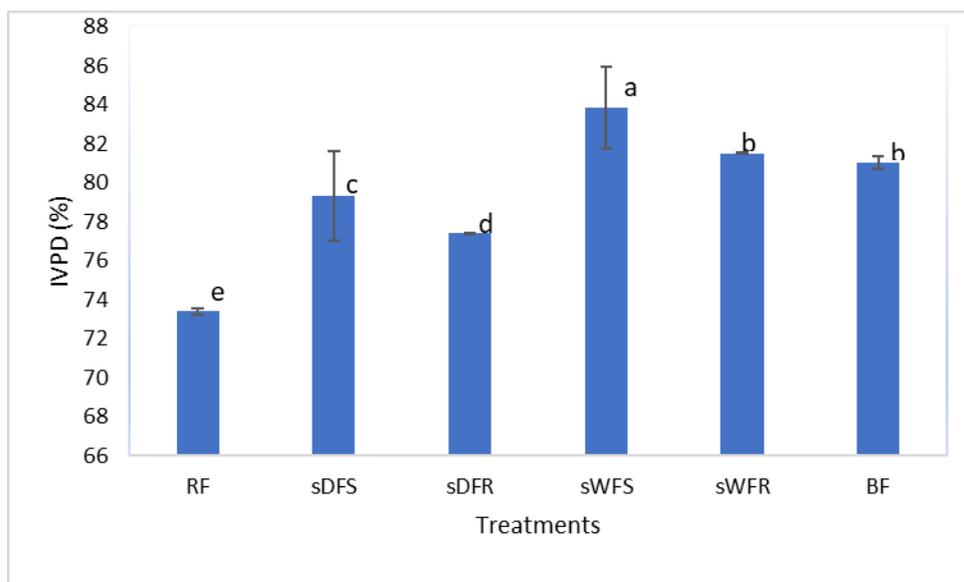
Figure 2: Effect of different processing methods on In Vitro protein digestibility (%) content of the brown AYB cultivar

Results are given on a dry matter basis as mean ± SD (n=3). Values with different letters across the column are significantly different from each other ($p<0.05$).

Sample: RF = Raw Flour. BF = Boiled Flour. sDFS = soaked-Dehulled-Fermented-Steamed. sDFR = soaked-Dehulled-Fermented-Roasted. sWFS = soaked-Whole-Fermented-Steamed. sWFR = soaked-Whole-Fermented-Roasted

DISCUSSION

The results showed that soaking for 12 hours resulted in the shortest cooking time across the three cultivars. This observation aligns with findings in a similar study on Bambara groundnut, where soaking before cooking reduced cooking time (20). A 55.00–56.00% reduction was observed for various cultivars of dry beans soaked for 12 hours (21). Pre-soaked beans require less cooking time due to hydration, which softens the seeds and accelerates the cooking process (22).

The raw AYB protein content was 22.21%. This aligns with reports of slight differences in AYB protein content across variants: 22.72–26.68% (3) and 21.84–23.41% (9). Combined treatments significantly ($p<0.05$) improved protein content (23.61–26.03%) compared to traditional boiling (19.23%). Dehulled samples exhibited higher protein and carbohydrate contents than whole samples, possibly due to concentration effects from soluble starch and dry matter loss during soaking and fermentation (23). Fermentation has been reported to increase crude protein content in pigeon peas (24). Higher carbohydrate content may result from processing breaking down granules, softening cellulose, and increasing starch availability (25). Conversely, whole samples showed higher concentrations of total ash, crude fiber, and fat. Roasting reduced most

proximate parameters except carbohydrates, which were significantly increased ($p<0.05$). This is attributed to the burning of organic matter and volatile compounds during roasting (26).

Traditional and combined processing methods reduced mineral content, consistent with reports of mineral leaching during soaking (27). Fermentation reportedly increases mineral content by reducing phytates (8), though dry matter loss during fermentation may also contribute to this effect as microbes degrade carbohydrates and protein (28). Dehulled beans showed greater mineral reductions than whole beans, as minerals are concentrated in the seed coat (29). Zinc content was relatively stable during processing, showing minimal losses.

Soaking, dehulling, fermentation, and steaming (sDFS) or roasting (sDFR) reduced tannins to undetectable levels. Reductions may be due to leaching, tannin–protein complex formation, or hydrolytic activity by *polyphenolase* enzymes during fermentation (30). A 50–60% tannin reduction in lactic acid-fermented black and marble AYB seeds was earlier reported (12). Dehulling effectively eliminates tannins, as they reside mainly in seed coats (31). Dehulling had been reported to reduce the level of tannins in beans (13). Roasted whole beans (sWFR) had higher tannin reduction (55.2%) than (sWFS) steamed whole beans (31.0%), likely due to seed

coat separation during high-temperature roasting.

Raw AYB seeds contained 7.40 mg/g phytic acid. Boiled bean flour had higher phytic acid content (6.6 mg/g) than flour processed via combined treatments (2.2–5.5 mg/g). Phytic acid reductions were attributed to soaking and fermentation, which enhance phytase activity and leach phytate ions into soaking water (29). Phytate was reported to be significantly reduced by 20-34% by fermentation alone in soybeans (32).

Trypsin inhibitor activity (TIA) was highly sensitive to heat treatment, with a 100% reduction observed in all combined processing methods. A previous study observed that the trypsin inhibitor values were significantly reduced ($p < 0.05$) by the different treatment methods, with heat treatment being the most effective (33).

Processing methods reduced cyanide content significantly ($p < 0.05$), with boiling achieving a 78.45% reduction. Vaporization of free cyanide by heat during processing and leaching out in water, along with both free and bound cyanide (which are water-soluble), may contribute to the decrease observed during processing of samples in water (34). The reduction in cyanogenic glycosides during fermentation may be attributed to bacterial glycosidase action (16). The concentration of cyanogenic glycosides in processed brown beans was safe, being below the lethal dose of 50-60 g/kg (35).

Protein quality can be estimated by in vitro protein digestibility (IVPD). The IVPD of whole beans that received the combined effects of soaking, fermentation, and either steaming or roasting was improved. The observed improvement was largely due to the effects of steaming and soaking. Soaking resulted in a reduction in tannin, phytic acid, and trypsin inhibitor contents, which correlate negatively with IVPD. Steaming deactivates trypsin inhibitor in the AYB, which is a major factor affecting its protein digestibility. Improved protein quality of AYB obtained from the modified processed AYB could contribute significantly to achieving nutrition-sensitive food systems in regions where food insecurity and malnutrition are prevalent. Its potential to be incorporated into community-based nutrition programs or school feeding schemes further emphasizes its value in addressing hunger and malnutrition sustainably.

CONCLUSION

This study concludes that soaking AYB for 12 hours before cooking is a more effective method for reducing cooking time. Dehulling effectively removed tannins, while heat treatments completely inactivated the trypsin inhibitor activity to a non-detectable level. A combination of soaking the dry beans for 24 hours, dehulling, fermenting for 48 hours, and then either steaming for 30 minutes or roasting until the beans turn golden yellow significantly reduces anti-nutrients. Implementing this protocol could potentially enhance nutrient digestibility and bioavailability, making it a key step in the combined processing of beans for nutritional improvement.

REFERENCES

1. Boye, J., Zare, F., & Pletch, A. (2010). Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International*, *43*(2),414–431. https://doi.org/10.1016/j.foodres.2009.09.003

2. Sam, S.M. (2019). Nutrient and antinutrient constituents in seeds of *Sphenostylis stenocarpa* (Hochst. Ex A. Rich.). *Harms*, *13*(4),107-112. https://doi.org/10.5897/AJPS2019.1763

3. Idowu, A. (2014). Development, nutrient composition and sensory properties of biscuits produced from composite flour of wheat and African yam bean. *British Journal of Applied Science and Technology, 4*(13),1925-1933. https://doi.org/10.9734/BJAST/2014/7183

4. Banigo, E.B., & Kiin-Kabari, D.B. (2016). Effect of African yam bean (AYB) (*Sphenostylis stenocarpa*) on the quality characteristics of extended meatball. *Journal of Food and Nutrition Research, 4*(2),121-125. https://doi.org/10.12691/jfnr-4-2-9

5. FAO. (2012). *World agriculture towards 2030/2050: The 2012 revision* (ESA Working Paper No. 12

6. Ghaniyah, O., Ajibola, C., & Abiodun, A. (2021). Chemical composition, anti-nutritional factors and pasting properties of cassava-African yam bean flour blends for noodle preparation. *International Journal of Food,* 10: SI1-SI13.

7. Obi, D. & Okoye I. (2017). Effects of boiling and autoclaving on the chemical composition and functional properties of *Mucuna flagellipes* seed flours. *International Journal*

of Innovative Food, Nutrition and Sustainable Agriculture, 5 (2),18-24.

8. Baiyeri, S.O., Uguru, M.I., Ogbonna, P.E., Samuel-Baiyeri, C.A., Okechukwu, R., Kumaga, F.K., & Amoatey, C. (2018). Evaluation of the nutritional composition of the seeds of some selected African yam beans (*Sphenostylis stenocarpa*). *Agro-Science Journal of Tropical Agriculture, Food and Environmental Extension*, 17(2),37–44. https://doi.org/10.4314/as.v17i2.5

9. Ekwere, M.R., Igile, G.O., Ukoha, H.A., Mbakwe, I.E., & Anegu, B.C. (2017). Anti-nutrient content and in vitro protein digestibility (IVPD) of infant food produced from African yam beans (*Sphenostylis stenocarpa*) and bambara groundnuts (*Vigna subterranea*). *International Journal of Biotechnology and Food Science*, 5(1),10–17.

10. Maphosa, Y., & Jideani, A. I. O. (2017). The role of legumes in human nutrition. In B. Kristbergsson & S. Ötles (Eds.), *Functional food: Improve health through adequate food technology* (pp. 103–121). IntechOpen. https://doi.org/10.5772/intechopen.69127

11. Jaybhaye, R.V., & Srivastav, P.P. (2015). Development of barnyard millet ready-to-eat snack food: Part II. *Food Science Research Journal, 6*(2), 285–291.

12. Azeke, M.A., Fretzdorff, B., Buening-Pfaue, H., Holzapfel, W., & Betsche, T. (2005). Nutritional value of African yam bean (*Sphenostylis stenocarpa* L.): Improvement by lactic acid fermentation. *Journal of Science, Food and Agriculture*, 85(6),963–970. https://doi.org/10.1002/jsfa.2052

13. Nakitto, A.M., Muyonga, J.H., & Nakimbugwe, D. (2015). Effects of combined traditional processing methods on the nutritional quality of beans. *Food Science and Nutrition, 3*(3),233–241. https://doi.org/10.1002/fsn3.209

14. Bhattarya, S., & Prakash, M. (1997). Kinetics of roasting of split chickpea (*Cicer arietinum*). *International Journal of Food Science and Technology*, 32(1),81–84.

15. AOAC. (2010). *Official Methods of Analysis*, 18th edition. Association of Analytical Chemists, Washington D.C., pp. 200–523.

16. Abidemi, O.O. (2013). Phytochemicals and spectrophotometric determination of metals in various medicinal plants in Nigeria. *International Journal of Engineering Science and Invention*, 2(5),51–54.

17. Sivakumaran, K., & Kothalawala, S. (2018). An overview of the analytical methods for food phytates. *International Journal of Chemical Studies*, 6(1), 2016–2020.

18. AACC. (1995) *Approved Methods* (9th ed.). American Association of Cereal Chemists, St. Paul, MN.

19. Hsu, H.W., Vavak, D.L., Satterlee, L.D., & Miller, G.A. (1977). Multienzyme technique for estimating protein digestibility. *Journal of Food Science*, 42(5), 1269–1273. https://doi.org/10.1111/j.1365-2621.1977.tb14476.x

20. Ojo, M.A. (2018). Alleviation of hard-to-cook phenomenon in legumes: Effects of hydrothermal processing techniques on two species of *Vigna subterranean*. *Advances in Journal of Food Science and Technology*, 6(3), 103–107. https://doi.org/10.12691/ajfst-6-3-3

21. Phirke, V., Chavan, K., Jadhar, J., & Salunkhe, K. (1982). Physical properties, chemical composition, and biological activity of the saponins isolated from soybean. *Science, 120*(3114),224–227. https://doi.org/10.1126/science.120.3114.224

22. Vasanthakaalam, H., Karayire, A., & Nyagahungu, I. (2020). Hydration and culinary profile of improved common bean (*Phaseolus vulgaris* L.) cultivars. *Rwanda Journal of Agricultural Sciences, 2*(1), 68–75. https://doi.org/10.4314/rjas.v2i1.7

23. Chinedum, E., Sanni, S., Theressa, N., & Ebere, A. (2018). Effect of domestic cooking on starch digestibility, predicted glycemic indices, polyphenol contents, and alpha-amylase inhibitory properties of beans (*Phaseolus vulgaris*) and breadfruit (*Treculia africana*). *International Journal of Biological Macromolecules*, 106,200–206. https://doi.org/10.1016/j.ijbiomac.2017.08.005

24. Anaemene, D., & Fadupin, G. (2022). Anti-nutrient reduction and nutrient retention capacity of fermentation, germination, and combined germination-fermentation in legume processing. *Applied Food Research*, 2(1), Article 100059. https://doi.org/10.1016/j.afres.2022.100059

25. Agiang, M. A., Umoh, I. B., Essien, A. I., & Eteng, M. U. (2010). Nutrient changes and antinutrient contents of beniseed and beniseed soup during cooking using a Nigerian traditional method. *Pakistan Journal of Biological Sciences, 13*(20), 1011–1015.

https://doi.org/10.3923/pjbs.2010.1011.1015

26. Mugendi, J. B., Njagi, E. N., Kuria, E. N., Mwasaru, M. A., Mureithi, J. G., & Apostolides, Z. (2010). Effects of processing technique on the nutritional composition and antinutrient content of Mucuna bean (*Mucuna pruriens* L.). *African Journal of Food Science, 4*(4), 156–166. https://doi.org/10.5897/AJFS.9000308

27. Ene-Obong, H.N. & Obizoba, I.C. (1996). Effect of domestic processing on the cooking time, nutrients, antinutrients, and in vitro protein digestibility of the African yam bean (*Sphenostylis stenocarpa*). *Plant Foods for Human Nutrition*, *49*(1), 43–52. https://doi.org/10.1007/BF01092521

28. Day, C. N., & Morawicki, R. O. (2018). Effects of fermentation by yeast and amylolytic lactic acid bacteria on grain sorghum protein content and digestibility. *Journal of Food Quality, 2018,* Article 3964392. https://doi.org/10.1155/2018/3964392

29. Ukpong, E.S., Okpalanma, E.F., Attaugwu, R.N., Oladeji, B.S., & Onyeukwu, U.C. (2023). Effects of milling, germination, temperature, and time on nutrients, bioactive compounds, and pasting properties of FARO 44 brown rice. *Journal of Food Chemistry and Nanotechnology*, 9(2), 78–87. https://doi.org/10.17756/jfcn.2023-153

30. Attchelouwa, K. C., & Tano, K. (2021). Effect of spontaneous fermentation time on physicochemical, nutrient, anti-nutrient, and microbiological composition of lima bean (*Phaseolus lunatus*) flour. *Journal of Applied Biosciences, 162*(1), 16800–16811. https://doi.org/10.35759/JABs.162.3

31. Joye, I. (2019). Protein digestibility of cereal products. *Foods*, 8(6), 199. https://doi.org/10.3390/foods8060199

32. Samtiya, M., Aluko, R., & Dhewa, T. (2020). Plant food anti-nutritional factors and their reduction strategies: An overview. *Food Production, Processing and Nutrition*, 2 (1), 6. https://doi.org/10.1186/s43014-020-0020-5

33. Van Der Riet, W.B., Wight, A.W., Cilliers, L., & Date, J.M. (1987). Food chemical analysis of tempeh prepared from South African-grown soybeans. *Food Chemistry*, 25(3), 197–206. https://doi.org/10.1016/0308-8146(87)90146-4

34. Ilelaboye, N.O., Amoo, I.A., & Pikuda, O.O. (2013). Effect of cooking methods on mineral and anti-nutrient composition of some green leafy vegetables. *Archives of Applied Science Research*, 5(3), 254–260.

35. Inuwa, H.M., Aina, V.O., Gabi, B., Aimola, I., & Toyin, A. (2011). Comparative determination of anti-nutritional factors in groundnut oil and palm oil. *Advance Journal of Food Science and Technology*, 3(4), 275–279