

Effect of Plant Ash on Nutrient Quality and Antioxidant Activity of African Yam Bean Seed Porridge in Relation to Cooking Time

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Abstract

The present study aimed to investigate the nutrient quality, antioxidant activity and sensory acceptability of hard-to-cook African yam bean (AYB) seeds cooked for 5 h (control) and for 2 h with plant ash. The plant ash were unripe plantain peel ash (UPA), corn cob ash (CCA) and UPA and CCA mixture. Standard methods of Association of Official Analytical Chemists (AOAC) were used for the proximate and mineral analysis, DPPH, ABTS and FRAP assays were used to investigate the antioxidant activity. A completely randomized design with one way analysis of variance (ANOVA) was used for data analysis. The results showed that cooking of AYB seeds for 2 h with 8 g/100mL plant ash solution improved the nutrient contents, antioxidant activity and sensory scores of the porridge. Higher values of proteins, ash and energy were obtained in 8 g/100mL UPA/CCA and in 8 g/100mL CCA additives. However, moisture, fat and fibre contents were not affected by plant ash additives and were higher in 5 h cooked porridge. Cooking with 8 g/100mL plant ash solution for 2 h significantly increased mineral elements in the porridge. Phenolic compounds (total polyphenols and flavonoids), and antioxidant activity (DPPH, ABTS and FRAP) showed higher values with plant ash additives. This study reveals that addition of plant ash did not only reduce the cooking time of AYB seed by 60%, but also improved the nutrient quality, antioxidant activity and sensory acceptability.

Keywords

African Yam Bean, Plant Ash Porridge, Cooking Time, Nutrient Quality, Antioxidant Activity, Sensory Acceptability

1. Introduction

African yam bean (AYB) (*Sphenostylis stenocarpa*) is an herbaceous leguminous plant with increasing nutritional interest in Nigeria and West African countries. As an important diet in West African countries, it complements the lack of proteins from cereals, roots and tubers. The amino acid profile of AYB seed is comparable to other legumes like cowpea, soybean and pigeon pea [1]. It is also rich in minerals and fiber [2]. However, utilization of AYB seed is limited due to the hard-to-cook (HTC) phenomenon arising from high temperature and relative humidity during storage [3], even up to nine months. This results in long cooking time and high energy expenditure, sometimes, overnight by the local people. Secondly, AYB seed contains some anti-nutritional factors and oligosaccharides which can provoke flatulence and chronic health effects.

Several authors have described the HTC phenomenon to changes occurring in the legume hull, cell wall and cotyledon in relation to legume hardening during storage [3] [4]. Others have linked phenolic compounds to hard-to-cook (HTC) phenomenon in legumes [5] [6].

To reduce the long cooking time and save energy and money, HTC legumes may be cooked using different salt solutions [7]. Trona, known by various names, for example, Akanwu in Igbo language of Nigeria is an alkaline salt that has been used by the locals in West Africa to tenderize or soften AYB seed hull and degrade phenolic compounds, thus reducing cooking time of AYB seed. Due to the purgative effect of trona to many users, plant ash sources have been discovered for use as alternatives tenderizer. Plant ash is obtained after complete incineration of some plant materials. Such materials include dried unripe plantain peel, corn cob, palm bunch and palm inflorescence [8] [9]. Legumes are potential sources of antioxidant compounds. The predominant antioxidant compounds in most legumes are flavonoids, tannins and phenolic acid, and according to Lin and Lai (2006), dark coat seeds possess high amount of phenolic compounds and antioxidant activity. The aim of this research was to determine the effect of solutions of unripe plantain ash (UPA) and corn cob ash (CCA) on the nutrient quality, antioxidant activity and sensory acceptability of African yam bean seed (AYB) porridge in relation to cooking time.

2. Materials and Methods

Sources of raw materials

African yam bean (AYB) seed (*Sphenostylis stenocarpa*) and corn cobs were purchased from Ubani market in Umuahia Metropolis of Abia state, Nigeria. Unripe plantain peel was obtained from Umuariga, Umudike, Ikwuano Local Government Area, Abia state.

Sample Preparation

Production of alkaline plant ash

The unripe plantain peel and corn cob ash were produced according the method of Abubakar *et al.* [10]. Matured unripe plantain peel was washed in water

and allowed to dry in the sun for 21 h. It was incinerated completely to ash on a flat concrete surface. The ash was transferred to a crucible and allowed to cool and then packaged in an air tight container. Corn cobs were sorted to remove unwanted parts. Thereafter, it was sun dried for 24 h and incinerated until only ash was obtained. Thereafter, the corn cob ash was allowed to cool and was packaged in an air tight container.

Preparation of African yam bean (AYB) porridge

Brown colored AYB seeds were sorted to remove sand, stone and dirt. The bean seeds were weighed and divided into 4 portions of 1.5 kg each. The first portion was cooked for 5 h without plant ash (control) according to method of Ukom *et al.* [11]. The second portion was cooked with 8 g/100mL un-ripened plantain ash (UPA) until it was fully done in 2 h. The third portion was cooked with 8 g/100mL corn cobs ash (CCA) until it was fully done in 2 h and fourth portion was cooked with the mixture of 4 g:4 g/100mL (UPA: CCA) until it was fully done in 2 h. Each portion was first parboiled for 15 min with 2.5 L of potable water. The cooking water was drained off and the seeds hand washed with clean water. This was followed by continuous boiling with 3 L of water until the seeds softened in about 90 min. Then other ingredients (pepper, palm oil, salt) were added and it further boiled for additional 15 min. Four cooking stoves were used to achieve the cooking process.

Determination of cooking time

The method described by William *et al.* [12] was used to measure the cooking time. Cooking timing of 1.5 kg of AYB seeds commenced when the cooking water began to boil at 100°C. After boiling for 15 min, two to three seeds were taken with spatula to determine the degree of softening by compression of the seed in between two fingers. This process was continued until the seeds were fully softened with no gritty or grainy feeling in between two fingers. Thereafter, cooking time was recorded.

Analysis and reagents

The proximate, mineral and sensory analysis was done in Food Chemistry laboratory, Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike while the antioxidant activity analysis was done in Biochemistry laboratory, National Root Crops Research Institute, Umudike. All the reagents were of analytical grade.

Proximate and mineral analysis

The proximate composition of the AYB porridge was determined according to the AOAC method for nutrient analysis [13]. Moisture content was determined with 5 g of porridge by the Hot air oven (DHG9053A, England) method at 105°C for 4 h until a constant weight was obtained. Ash content was determined with 5 g of porridge by the dry ash method in a Muffle furnace (SX2-2.5-12NP, China) at 550°C by incineration for 4 h, or until gray ash was obtained. Percentage protein content was determined with 2 g of porridge in three stages: digestion, distillation and titration by the Kjeldahl method (%protein = %nitrogen con-

tent multiplied by 6.25). Two (2) g of porridge was used to determine the fat content by continuous petroleum ether extraction in Soxhlet apparatus with 200 mL of petroleum ether (boiling point 40°C - 60°C). Crude fiber was estimated by the gravimetric method, while carbohydrate content was calculated by difference. Carbohydrate content = 100 - [moisture (%) + crude protein (%) + total fat (%) + crude fiber (%) + total ash (%)].

Iron was determined by the method of James [14]. Calcium was determined by EDTA Versanate complexometric method of James [14]. Potassium was determined by a serial dilution of K solution of 0, 2, 4, 6, 8 and 10 ppm by flame photometry [15].

Antioxidant activity

Total polyphenol was determined by the method described by Jagadish *et al.* [16] with slight modification. Half (0.5) mL of AYB porridge methanolic extract was diluted with 10 mL of distilled water and 2.5 mL of 0.2 N Folin-Ciocalteu phenol reagent added to it in a 25 mL volumetric flask. After 5 min, 2 mL of 2% Na₂CO₃ solution was added and the mixture was made up to 25 mL volume with distilled water and allowed to stand for 90 min. The absorbance was measured at 780 nm versus the prepared blank. Gallic acid was used as standard for the calibration curve. Total polyphenol content was calculated as mg Gallic acid equivalent per gram fresh weight of sample. Flavonoids content was estimated by AlCl₃ method described by Jagadish *et al.* [16]. One and half (1.5) mL of the porridge extract was added to 5 mL of distilled water and 0.3 mL of 5% NaNO₂ in a 10 mL volumetric flask. It was properly mixed and after 5 min, 1.5 mL of 2% methanolic AlCl₃ solution was added and rested for 5 min, then 2 mL of 1 mol dm⁻³ NaOH was added. The volume was made up to 10 mL with distilled water, shaken vigorously for 5 min and incubated for 10 min. The absorbance was read at 367 nm against the reagent blank. Flavonoid content was calculated using a standard calibration curve prepared from quercetin. The flavonoid content was expressed as mg quercetin per gram of fresh extract. ABTS⁺ was prepared by adding solid manganese dioxide (80 mg) to a 5 mM aqueous stock solution of ABTS (20 mL of 75 mM Na/K buffer at pH 7) according to the method of Seeram *et al.* [17]. AYB porridge extract was diluted appropriately in Na/K buffer pH 7 and mixed with 200 µL of ABTS⁺ radical cation solution. The absorbance was read at 750 nm after 5 min in spectrophotometer (Jenway digital, England). ABTS values were calculated from Trolox standard curve and expressed as Trolox Equivalents in µM. The DPPH radical scavenging activity of the porridge was determined by the method described by Manzocco *et al.* [18]. The porridge extract (0.2 mL) was diluted with 10 mL methanol and 2 mL DPPH solution (0.5 mM) was added to it. After 30 min, the absorbance was read at 517 nm. The percentage of the DPPH radical scavenging activity was calculated using the equation given below. % Inhibition of DPPH radical = $(A_0 - A_s)/A_0 \times 100$; Where A₀ = absorbance of the control reaction containing all reagent except test sample, A_s = absorbance of the porridge extract. The FRAP antioxidant assay was

measured by the method developed by [19]. Three (3) mL of FRAP reagent was mixed with 100 μ L of diluted porridge extract. The absorbance at 593 nm was read after 30 min incubation at 37°C. FRAP values was obtained by comparing the absorption change in the porridge extract with those obtained from increasing concentrations of Fe^{3+} and was expressed as μM of Fe^{2+} equivalents per kg.

Sensory evaluation of AYB porridge

A nine-point hedonic scale was used to evaluate the sensory scores of the AYB porridge as affected by plant ash additive and cooking time. The rankings were 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely [20]. An untrained panelists (n = 30), mainly students, aged between 17 - 25 years were used. The AYB porridge was coded and served to 6 of the panelists in a randomized order in ceramic bowls to evaluate for colour, mouthfeel, taste, texture, and general acceptability. Each judge was offered sachet water to rinse the palate.

Statistical analysis

All experiments in this study are reported as mean of duplicate analysis in a completely randomized design (CRD) using the statistical package for Social Science (SPSS) version 18.0. Results were presented as means \pm standard deviations. One way analysis of variance (ANOVA) was used. Comparison of the means and differences between the means were separated using Duncan multiple range test at 95% confidence level ($p < 0.05$).

3. Results and Discussion

Effect of UPA and CCA additives in relation to cooking time on AYB seed porridge

There was substantial decrease in cooking time of AYB seeds as a result of plant ash additives. Changes in hardness of AYB seed during cooking as measured by compression between two fingers were noticeable. Ojimelukwe [21] and Mubaiwa *et al.* [22] have shown that the lesser the compression, the softer the seeds of Bambara groundnut cooked in alkaline salt. The effect of alkaline plant ash (UPA, CCA) on cooking of AYB seeds and the percentage reduction in cooking time, in comparison with traditional (control) cooking in 5 h was 60%. Plant ash, UPA (8 g/100mL), CCA (8 g/100mL) and UPA/CCA (8 g/100mL) had a cooking time of 2 h. Using alkaline salt of 0.5 g/100mL gowa and 0.5 g/100mL NaHCO_3 , Mubaiwa *et al.* [22] found a decrease of 20% and 13% cooking time for red Bambara groundnut cooked for 120 min and 130 min. It has been reported that the structural changes in the breakdown of middle lamellae, solubilization of pectin and proteins, breakdown of phenolic compounds that are linked to hard-to-cook legumes and water absorption caused by alkaline salt additives are other reasons for softening, time and energy reduction in cooking of legumes [22]. AYB seeds were cooked first for 15 min with 1.5 L of water which was drained off so as to reduce associated astringency and flatulence factors inherent

in cooked AYB seed before final cooking and addition of 8 g/100mL plant ash solutions. AYB seed porridge was of brown colour, an indication that tannins solubilized by ash additives may have leached into the cooked porridge, an inference also made by [22], especially in brown or dark coated leguminous seeds [23].

Effect of plant ash on the proximate composition of AYB seed porridge in relation to cooking time

The effect of different plant ash, UPA and CCA on the proximate composition of African yam bean (AYB) porridge in relation to cooking time is shown in **Table 1**. Plant ash additives significantly ($p < 0.05$) increased the protein, ash and energy contents but not the moisture, fat and fibre which were higher in the control porridge. These results show that cooking of AYB porridge for 2 h with ash additive was considerably effective. The moisture content ranged from 32.57% in porridge cooked for 2 h with 8 g/100mL CCA to 34.73% in 5 h cooked porridge (control). The indication was that the powdered ash solution will have effect in binding the free moisture in the porridge, thus reducing the moisture content.

Protein is a major constituent of AYB seed that places the meals on high demand particularly among the low income population. Its protein content ranged from 22.58% to 24.02%. Cooking with plant ash mixture UPA/CCA (8 g/100mL) for 2 h gave the highest value (24.02%). These results indicate the effect of plant ash additive on protein availability in AYB porridge. Although ash is an inorganic substance, it enhanced the solubilization and release of free amino nitrogen in AYB seeds to potentially increase the protein content of the porridge. Baiyeri *et al.* [24] previously reported the protein values of 21.84% to 23.40% in AYB seed, as opposed to 26.35%, 27.87% and 31.80% reported by Ukom *et al.* [11] on AYB porridge after fermenting the seeds for 24, 48 and 72 h, respectively. The fat and fibre contents of AYB porridge was not affected by ash additives and were highest in 5 h cooked porridge (**Table 1**). AYB seeds were not de-hulled upon cooking, and the fat and fibre contents were not affected since there was no plant ash addition. The ash content ranged from 2.67% to 4.02% and increased linearly in descending order: 4.02% (CCA/UPA) > 3.97% (CCA) > 3.73% (UPA) > 2.67% (control). Plant ash contents have corresponding mineral

Table 1. Effect of plant ash on the proximate composition of AYB seed porridge in relation to cooking time.

Samples Code	Moisture content (%)	Crude protein (%)	Fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)	Energy value (Kcal)
501	34.73 ^a ± 0.02	22.66 ^c ± 0.01	4.82 ^a ± 0.01	7.88 ^a ± 0.02	2.67 ^c ± 0.01	27.25 ^c ± 0.06	243.02 ^d ± 0.16
502	32.85 ^c ± 0.02	22.58 ^d ± 0.01	4.44 ^d ± 0.01	7.57 ^b ± 0.01	3.73 ^b ± 0.04	28.88 ^a ± 0.01	245.80 ^c ± 0.13
503	32.57 ^d ± 0.02	23.91 ^b ± 0.01	4.54 ^c ± 0.01	7.47 ^c ± 0.02	3.97 ^a ± 0.01	27.55 ^b ± 0.00	246.70 ^b ± 0.18
504	33.20 ^b ± 0.01	24.02 ^a ± 0.03	4.60 ^b ± 0.01	7.51 ^c ± 0.01	4.02 ^a ± 0.03	26.66 ^d ± 0.06	248.04 ^a ± 0.07

Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different ($p < 0.05$). Keys: 501 (AYB porridge cooked for 5 h [Control]), 502 (AYB porridge cooked for 2 h with 8 g/100mL UPA), 503 (AYB porridge cooked for 2 h with 8 g/100mL CCA) and 504 (AYB porridge cooked for 2 h with 8 g/100mL UPA/CCA).

nutrition in foods, except for being bound and non-available by anti-nutrients. Das *et al.* [25] has opined that foods possessing ash content of 3% and above are ideal for mineral nutrition. Therefore, alkaline plant ash of vegetable origin may be used as a mineral supplement in cases of established mineral deficiency. As it is the case, AYB seeds as legumes have low carbohydrate and energy contents. In comparison to cereals, roots and tubers with high carbohydrate content and energy value, AYB seeds can be used as food for diabetics and convalescence. These results clearly demonstrate that plant ash additives, being alkaline, can degrade and solubilize some hard-to-cook factors and phenolic compounds in AYB seeds [3]. Plant ash used in this study reduced the cooking time and fuel by 60% and positively improved the availability of some nutrient contents.

Effect of plant ash on the mineral content of AYB seed porridge in relation to cooking time

Table 2 shows the mineral contents of AYB porridge cooked with plant ash additives in relation to cooking time. Plant ash additives significantly ($p < 0.05$) increased the mineral nutrients when compared to the control. Porridge cooked for 2 h with the mixture of UPA/CCA had the highest value of Ca (215.43 mg/100g), K (169.02 mg/100g), P (32.21 mg/100g) and Fe (14.07 mg/100g), respectively. These results show the richness of plant ash as a mineral source [9], and increased the Fe, K, Ca and P contents by 28%, 16.5%, 3.1% and 2.6% when compared to the control. The mineral contents of UPA as previously reported by [9] were for Ca (295.16 mg/100g), K (528.58 mg/100g), Fe (7.14 mg/kg) and P (196.02 mg/100g), and in CCA the following mineral contents were reported for Fe (26.18 mg/100g), P (527.33 mg/100g), K (375.25 mg/100g), Mg (21.92 mg/100g) and Ca (17.19 mg/100g) [10]. Mineral nutrition is important in maintaining the health status of the individual. These mineral salts, Ca and K are important regulars of the acid-base balance of the body, Fe works together with Zn mineral to improve the immune defense system, while Ca and P are important in bone mass development especially in children [26]. The mineral nutrients from AYB porridge can contribute substantially to mineral nutrition of the consumers.

Table 2. Effect of plant ash on mineral composition of AYB porridge in relation to cooking time.

Porridge	Potassium (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)	Phosphorus (mg/100g)
501	141.12 ^d ± 0.02	10.15 ^d ± 0.02	208.76 ^d ± 0.03	31.37 ^d ± 0.03
502	164.34 ^c ± 0.02	12.96 ^c ± 0.04	208.94 ^c ± 0.02	31.67 ^c ± 0.01
503	167.55 ^b ± 0.03	13.78 ^b ± 0.02	209.95 ^b ± 0.01	31.75 ^b ± 0.02
504	169.02 ^a ± 0.02	14.07 ^a ± 0.03	215.43 ^a ± 0.04	32.21 ^a ± 0.00

Values are means standard deviation of duplicate determination. Mean values in the same column with different superscript is significantly ($p < 0.05$) different. Keys: 501 (AYB porridge cooked for 5 h without plant ash), 502 (AYB porridge cooked for 2 h with 8 g UPA), 503 (AYB porridge cooked for 2 h with 8 g CCA), 504 (AYB porridge cooked for 2 h with 4 g UPA and 4 g CCA).

Effect of plant ash on antioxidant activity of AYB porridge in relation to cooking time

The effect of plant ash additives on antioxidant activity of AYB porridge in relation to cooking is shown in **Table 3**. Significant ($p < 0.05$) variations were observed in the polyphenol concentrations, with higher value in AYB porridge cooked for 2 h in 8 g/100mL UPA/CCA mixture. However, cooking for 2 h with 8 g/100mL CCA, or 8 g/100mL UPA obtained the higher flavonoids concentrations (47.90 and 47.88 mgCE/100g).

The hard-to-cook (HTC) phenomenon in legumes has been linked to high content of phenolic compounds in beans [6] [27]. To reduce the HTC phenomenon in relation to cooking time and fuel, plant ash was used to tenderize the AYB seed hulls resulting in higher phenolics from solubilized tannins into the porridge. Tannins can be degraded at 100°C (cooking temperature) and increase phenolic compounds [28]. Boiled raw dry mung bean seeds (*Phaseolus aureus*), and soaked and cooked legumes with sodium bicarbonate caused the reduction of tannins from 3.3 mg/g to 45.5% [29], and 66% [30], and would increase the polyphenol content in the case of cooked porridge foods. Antioxidant activity assayed by DPPH, ABTS and FRAP showed significant increases, varying with plant ash additives in 2 h of cooking. The weakest strength was obtained from 5 h cooked porridge (control). For plant ash additives, the strongest value was obtained in UPA/CCA mixture for %DPPH (30%), ABTS (23.97 mgTE/100g), and FRAP (188.01 mgTE/100g). Different antioxidant assays were used in this study in order to determine the antioxidant activities of the phenolic compounds of AYB porridge cooked for 2 h with plant ash. These results indicate strong antioxidant activity in FRAP assay to chelate pro-oxidant metals and reduced Fe^{3+} to Fe^{2+} in the plant ash cooked porridge. The contribution of phenolic compounds to softening of HTC legumes was reported by del-Valle *et al.* [31]. They further stated that chelating and ion-exchange agents can affect the softening of soaked beans. In addition, cooking at 100°C may have effect on AYB seed matrix, and causing the release of bound phenolic compounds from the seed structure that influence total phenolic increase in leguminous seeds [32]. The concentrations

Table 3. Effect of plant ash on antioxidant activity of AYB seed porridge in relation to cooking time.

Porridge	%DPPH	FRAP (mgTE/100g)	Polyphenol (μ molGAE/100g)	Flavonoid (CE/100g)	ABST (TE/100g)
501	28.68 ^d \pm 0.02	87.57 ^d \pm 0.01	77.23 ^c \pm 0.04	47.67 ^b \pm 0.02	23.54 ^c \pm 0.04
502	29.37 ^c \pm 0.02	87.88 ^b \pm 0.02	77.59 ^b \pm 0.02	47.88 ^a \pm 0.02	23.76 ^b \pm 0.02
503	29.45 ^b \pm 0.03	87.82 ^c \pm 0.03	77.63 ^b \pm 0.02	47.90 ^a \pm 0.02	23.77 ^b \pm 0.03
504	30.00 ^a \pm 0.01	88.01 ^a \pm 0.01	79.37 ^a \pm 0.04	47.10 ^c \pm 0.01	23.97 ^a \pm 0.00

Values are means \pm standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different ($p < 0.05$). Keys: 501 (AYB porridge cooked for 5 h [Control]), 502 (AYB porridge cooked for 2 h with 8 g/100mL UPA), 503 (AYB porridge cooked for 2 h with 8 g/100mL CCA) and 504 (AYB porridge cooked for 2 h with 8 g/100mL UPA/CCA).

Table 4. Effect of plant ash on sensory properties of AYB seed porridge in relation to cooking time.

Samples	Colour	Mouthfeel	Taste	Texture	General Acceptability
501	6.83 ^c ± 0.34	6.71 ^{bc} ± 0.38	6.71 ^c ± 0.32	6.79 ^b ± 0.31	7.29 ^{bc} ± 0.27
502	7.79 ^a ± 0.29	7.46 ^a ± 0.22	7.29 ^a ± 0.19	7.29 ^a ± 0.20	8.04 ^a ± 0.18
503	7.33 ^b ± 0.32	6.75 ^b ± 0.31	7.13 ^b ± 0.24	6.63 ^c ± 0.29	7.38 ^b ± 0.24
504	6.38 ^d ± 0.28	6.25 ^c ± 0.25	5.71 ^d ± 0.38	5.21 ^d ± 0.41	6.33 ^d ± 0.34

Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different ($p < 0.05$). Key: 501 (AYB cooked for 5 h without plant ash), 502 (AYB cooked for 2 h with 8 g/100mL of UPA), 503 (AYB cooked for 2 h with 8 g/100mL of CCA), 504 (AYB cooked for 2 hours with blends of ratio 4 g/100mL UPA: 4 g/100mL CCA).

of phenolic compounds (**Table 3**) indicates the positive contribution of plant ash to antioxidant activity in AYB seed porridge.

Effect of plant ash on the sensory properties of AYB seed porridge in relation to cooking time

Table 4 shows the effect of plant ash on sensory properties of AYB seed porridge in relation to cooking time. Several traditional methods are used for processing of AYB seed to acceptable meals. The use of kanwa, (alkaline rock salt), NaHCO_3 or some other salts to cook legume seeds in order to reduce the cooking time was reported by Uzogara *et al.* [7]. Akanwu (Igbo language) is also used to make sponge in abacha (shredded tapioca) snack, and today it is not acceptable by the generality of the people because of its organoleptic quality and health risk factors. This has resulted in an alternative alkaline salt like plant ash for this and other purposes. Variation in cooking time and plant ash additive significantly ($p < 0.05$) affected the mean sensory scores. The sensory mean scores ranged from 5 (neither like nor dislike) to 8 (like very much). Preference was more for UPA additive, followed by CCA before the control. According to Dehghan-Shoar *et al.* [33], sensory scores of foods are a combination of the organoleptic properties like colour, aroma, taste and texture. In this study, colour, mouth-feel, taste, texture and general acceptability were highest in AYB porridge cook for 2 h with UPA. So the use of these plant ashes greatly affected their higher acceptability scores for colour, mouth-feel, taste and texture. The results imply that 8 g/100mL plant ash inclusion in cooking of 1.5 kg AYB porridge for 2 h can be used to replace the traditional method of AYB seeds cooked for 5 h. Overall, alkaline salt used in this study decreased cooking time, increased nutritive value, improved sensory properties of HTC AYB seeds and reduced energy usage by 60% and household income.

4. Conclusion

The effect of plant ash on nutrient quality, antioxidant activity and sensory acceptability of AYB seed porridge in relation to cooking time was studied. The results showed that cooking of AYB seeds for 2 h with plant ash (8 g/100mL) significantly improved the nutrient and sensory qualities, especially the protein,

ash, energy, and mineral contents. However, moisture, fat, fibre was higher in porridge cooked for 5 h without plant ash. Also AYB seed porridge cooked for 2 h with plant ash showed higher concentrations of DPPH, ABTS, FRAP, total polyphenol and flavonoids. It is established that cooking with plant ash caused a breakdown and solubilization of phenolic compounds in AYB seed hull and cotyledon resulting into higher antioxidant compounds in the porridge. Sensory evaluation revealed that AYB seeds cooked for 2 h with plant ash, especially UPA was more preferred in overall acceptability. Cooking of AYB seeds with plant ash for 2 h was able to handle the HTC problem.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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