potravinárstvo®

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 15, 2021, p. 776-783
https://doi.org/10.5219/1677
Received: 28 July 2021. Accepted: 1 September 2021.
Available online: 28 September 2021 at www.potravinarstvo.com

ISSN 1337-0960 (online)

DEVELOPMENT OF NUTRITIONAL MEALS AND GRUELS FROM BLENDS OF PRO-VITAMIN A CASSAVA GRITS AND AFRICAN YAM

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ABSTRACT

The potentials of underutilized African yam bean (AYB) and pro-vitamin A cassava in the development of nutritious food products with acceptable sensory properties were studied. Grits were produced from freshly harvested yellow root pro-vitamin A cassava by peeling, washing, cutting, soaking, dewatering, roasting, sieving, and milling to obtain yellow root cassava grits while AYB flour was obtained by cleaning, roasting, dehulling, milling, and sieving (425 µm). A simple lattice design was used to obtain formulations of blends (100:0; 90:10; 80:20; 70:30; 60:40 and 0:100) of yellow root cassava grits and AYB flour. Gruels were prepared from these formulations using 4:5 w/v in boiling water while meals were prepared using 1:1 w/v of blend in boiling water for 5 min. Moisture, fat, ash, protein, crude fibre, carbohydrate, β-carotene and calorific content of the blends were in the ranges of 4.66 – 7.92%, 2.20 – 2.82%, 2.16 – 2.66%, 2.72 – 20.43%, 1.15 – 1.40%, 68.65 – 83.23%, 1.33 to 3.97 µg/g and 348.37 – 358.96 kcal/100 g, respectively. Saponin, tannin, trypsin inhibitor, hemagglutinin, starchyose, raffinose, phytate and Hydrogen Cyanide ranged from 0.039 – 0.087%, 0.11 – 0.15%, 1.24 – 3.15 mg/g, 1.47 – 3.49 mg/100 g, 1.51 – 1.81%, 0.38 – 0.45%, 0.82 – 2.69 mg/g, 0.07 – 4.47 mg/kg, respectively. The sensory evaluation revealed that the meal and the gruel samples had acceptable sensory attributes. The developed products have the potentials in alleviating the problem of protein malnutrition in developing countries.

Keywords: Cassava; grits; legume; malnutrition; Gruel

INTRODUCTION

Cassava (*Manihot esculenta Crantz*), commonly referred to as manioc, tapioca, or yuca, is a tropical food crop primarily grown for its starchy tuberous roots and consumed as staples for more than 800 million people **(Ikegwu et al., 2009; Vincenza et al., 2016)**. It is mostly consumed in some parts of Africa, Asia and America **(Burns et al., 2010)**. Cassava thrives in low-nutrient and drought-prone environments making it a food security crop especially in developing countries **(Nyerhovwo, 2004; Vinduranga, 2018; Shackelford et al., 2018)**. Common cassava food products include flour, confectionaries, starch, and gari **(Osunde and Fadeyibi, 2011; Aniedu, Aniedu and Nwakor, 2012)**.

African Yam Bean (*Sphenostylis stenocarpa*) is a legume, hard to cook, and underutilized **(George, Obilana and Oyeyinka, 2020)** with a lot of nutritional advantages **(Adegboyega et al., 2020)**. It is mostly cultivated for its tubers in the Central African Republic, Zaire, East Africa, and Ethiopia while the seeds are mostly cultivated in Southeastern Nigeria **(Ndidi et al., 2014)**. A large variation and different accessions of African yam bean have been reported recently **(Aremu and Ibirinde, 2012; Abioye, Olanipekun and Omotosho, 2015; Ajibola and Olapade, 2016; Baiyeri, Uguru and Ogbonna, 2018; Aina et al., 2020)**. The AYB seed is rich in protein and previous reports indicated values ranging between 19 and 30 percent **(George, Obilana and Oyeyinka, 2020)** and the amino acid profile is similar or even better than that of soybeans in terms of lysine and methionine **(Obiakor, 2008; Atinuke, 2015)**. AYB seeds contain high dietary fiber, carbohydrate, and essential minerals such as phosphorus, calcium, iron, zinc, magnesium, potassium **(Abioye, Olanipekun and Omotosho, 2015; Ajibola and Olapade, 2016; Ojuederie and Balogun, 2017; Anya and Ozung, 2019)**. However, it is underutilized due to the characteristic hardness of its seed coat which increases the processing cost and cooking time **(Ene-obong and Okoye, 2007; Iwuchukwu et al., 2017)**, anti-nutritional factors in high concentration **(Oboh et al., 1998; Ajibade et al., 2006; Fasoyiro et al., 2006; Adegboyega et al., 2020)**, beany flavor and the tendency to cause flatulence in humans **(Machuka and Okeola, 2000; Ngwu, Aburime and Ani, 2014)**.

Yellow root Cassava bio-fortification has been developed primarily to help in reducing the prevalence of vitamin A deficiency where cassava is consumed as a staple food. It can be transformed into retinol within a human body, and this bioconversion can contribute to the reduction of vitamin

A deficiency diseases (VAD) among the vulnerable groups. Vitamin A deficiency (VAD) is common in impoverished tropical nations, and it is especially prevalent in Sub-Saharan Africa. **(Maziya-Dixon et al., 2004; Getu et al., 2017)**. Dependence on cassava diets has also been implicated in protein deficit challenges. Consumers who depend solely on cassava and cassava products for their protein sources with few or no high-protein food sources as supplements are at risk of protein malnutrition. More than a few studies have been published in fortification of cassava flour and cassava food products with protein sources such as cowpea **(Oyarekua, 2009; Agbon, Ngozi and Onabanjo, 2010; Pedhuru, Tuarira and Mutetwa, 2017; Maziya-dixon et al., 2017)**, cassava leaf **(Pedhuru, Tuarira and Mutetwa, 2017)**, soybean **(Rokeya et al., 2011; Ajani et al., 2016; Maziya-Dixon et al., 2017)**, groundnut flour **(Ajani et al., 2016)**, African yam bean **(Ogbonnaya, Onumadu and Nwogu, 2018; Ajibola and Olapade, 2019)**.

Hence, there is scanty information on the development of nutritious food products from yellow root cassava grits and AYB flour blends. Therefore, this study aimed at developing nutritious food products with acceptable sensory attributes from yellow root cassava grits and African yam bean seeds flour which could increase the potentials of these crops and also improve the protein intake of the populace where cassava is consumed as a major staple food.

Scientific Hypothesis

This project was carried out to determine the effects of processing and combination of African yam bean and yellow root cassava on the chemical and antinutritional properties of the blends. It also determined the effects of the combination on the sensory properties of the food products.

MATERIAL AND METHODOLOGY

Samples

Yellow root cassava tuber (UMUCASS 37 variety) used for this research was procured from the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. Nigeria. The AYB seeds were bought at an indigenous market and identified at the LAUTECH teaching and research farm.

Cassava grits were produced from yellow root cassava using the method of **Sanni and Jaji (2003)** Grits were produced from freshly harvested yellow root pro-vitamin A cassava by peeling, washing, cutting, soaking (72 h, 28 ±2 °C), dewatering, roasting (120 °C), sieving and milling to obtain yellow root cassava grits while AYB flour was obtained as described by Aniedu and Aniedu (2014) by cleaning, roasting (190 °C, 10 min), dehulling, milling and sieving (425 µm). Simplex lattice design was used to obtain different formulations from blends of yellow root cassava grit and AYB flour. The formulations were done with (60 – 100%) cassava grit and (0 – 40%) AYB flour, while 100% AYB flour and 100% cassava grits were used as controls. The blends were thoroughly mixed for about 20 minutes using a Kenwood mixer (Model: Chef XL KVL4100S, made in China) to achieve uniform blending.

Gruel samples were prepared from different blends of yellow root cassava grit fortified with AYB flour as described by **Ngwu, Aburime and, Ani (2014)**. Four hundred grams (400 g) of each blend was reconstituted with 500 milliliters of water, and 2 liters of water was used to bring it to boil reconstituted flour was progressively added to the hot water while continually whisking to avoid lumps. The mix was left to simmer for around five (5) minutes while being constantly stirred until it was done.

The meal was prepared from different blends of yellow root cassava grit and AYB flour as described by **Aniedu and Aniedu (2014)**. The blends were reconstituted into meals by cooking 100 grams of each of the blends in hundred (100) mL of boiling water while stirring vigorously for 5 minutes.

Laboratory Methods

The proximate composition of the blends was determined as described by the Association of Official Analytical Chemists **(AOAC, 2010)**. Carbohydrate content was determined by difference **AOAC (2010)**. Calorific content was calculated using the values obtained for carbohydrate, fat, and protein values. The β-carotene of the flour mixes was estimated using **Rodriguez-Amaya and Kimura (2004)** method that uses acetone extraction for carotenoid analysis. Tannin was determined with the method based on the fact that tannin-like substances in an alkaline solution diminish phosphotungstomolybdic acid, resulting in a strongly colored blue solution as devised by Adegunwa, **Alamu and Omitogun (2011)**, Spectrophotometer was used to measure the absorbance at 760 (AA Analyse Perkin Nerma)/ Phytate was determined according to AOAC (2010). **Kakade *et al.* (1974)** technique was employed in the determination of trypsin inhibitors. Absorbance reading was taken at 410 nm with a spectrophotometer (AA Analyse Perkin Nerma). The hydrogen cyanide concentration was determined using the method of Alkaline picrate calorimetric while a spectrophotometer was then used to measure the absorbance of elutes from the standard and the sample at 510 nm. **(Mburu, Swaleh and Njue, 2013)**. Raffinose and Stachyose (oligosaccharides) were both determined with HPLC techniques **(František *et al.*, 1995)**. The mobile phase used was demineralized water in a reverse phase HPLC (RP-HPLC) and on a Silica C18 column.

Sensory evaluation of the food products

Sensory attributes of the cooked gruel and meal samples were carried out using a 9-point hedonic scale preference test. A total number of 50 panelists were used and to effectively compare the sensory ratings between the panelists, the panelists were semi-trained. Panelists were given coded samples of meal and gruel and asked to assess the items on a 9-point hedonic scale. (where one represents dislike significantly, and (nine) represents like significantly) for sensory attributes such as flavor, color, consistency, mouthfeel, texture, appearance, taste, and overall acceptability. On the panel were staff and students from the Ladoke Akintola University of Technology's Department of Food Science and Engineering in Ogbomoso, Oyo State, Nigeria.

Description of the Experiment

Number of samples analyzed: 1
Number of repeated analyses: 1
Number of experiment replication: 1

Statistical analysis

Data obtained were analyzed using Analysis of variance (ANOVA) while the means were separated using Duncan's multiple range test (DMRT), a significance level of 5% was considered.

RESULTS AND DISCUSSION

Chemical composition

The proximate components of yellow root cassava grits and AYB seed flour blends are indicated in Table 1. The values obtained for the moisture varied between 4.66 to 7.92 percent and a significant (p <0.05) difference was observed in each of the blends except in the blends that had 10-30% of AYB flour substitution. The roasted AYB flour had the least moisture content which was close to 4.88% reported by **Ndidi *et al.* (2014)** for roasted AYB flour. All of the formulations had low moisture content which could be enough to have long storage when packaged in moisture-proof materials. The fat content of the samples varied significantly 2.20 – 2.82% with the highest fat content in the 100% yellow root cassava grits (2.82%). The values obtained were close to the value reported by **Eleazu and Eleazu (2012)** for yellow root cassava. The total ash (minerals) ranged from 2.16 to 2.66% and the highest value was recorded with roasted AYB flour which is close to the report of **Ndidi *et al.* (2014)**. The protein level of the blended samples ranged between 2.72 and 20.43%, with the highest inclusion of roasted AYB flour having the highest protein content. Significant differences (p <0.05) were recorded among the blends, validating the fact that AYB contributed significantly to the protein composition of the blends. This backs up prior research that shows leguminous plants are good sources of nutrients, including a diverse spectrum of minerals and amino acids **(Fagbemi, Oshodi and Ipinmoroti, 2004; Maphosa and Jideani, 2017)**. The crude protein content of the yellow root cassava grits was consistent with previous observations that cassava root food products are low in protein and that its consumption in meals necessitates the addition of adequate amino acids supplement **(Burrell, 2003; Esonu, 2006; Olugbemi, Mutayoba and Lekule, 2010; Ngiki, Igwebuike and Moruppa, 2014)**. The crude fibre of the samples ranged from 1.15 to 1.40%. Higher fibre content was recorded in flour blends with AYB flour substitution and was significant though the values were lower than the values reported. This could be as a result of the processing method used to process African yam beans into flour. The carbohydrate contents of the blended samples were in the range of 68.65 and 83.23%. These samples' high carbohydrate readings are attributable to the carbohydrate content of their basic raw materials, especially the yellow root cassava tubers **(El-sahy and Siliha, 2008; Awoyale et al., 2015)**.

The beta–carotene of the yellow root cassava grits and AYB flour blends is as shown in Fig 3. It ranged between 1.33 and 3.97 μg/g, the hundred percent yellow root cassava grit had the highest amount of beta–carotene due to the variety of the cassava used, which was enriched with beta–carotene. The value falls within the reported range by **Eyinla et al. (2019)** for food products from yellow root cassava. The blended samples also recorded some amounts of beta-carotene, which is a vitamin A precursor. As the substitution of AYB flour increased, the value of beta–carotene of the blended sample decreased. Consumption of these food products can contribute to the source of vitamin A in the diets of the people where cassava is their major staples. There were significant (p <0.05) differences among the blends.

Antinutritional factors

Saponin levels of the blends ranged between 0.039 to 0.087%. The results are consistent with those obtained by previous researchers for processed African yam beans. **(Ajibola and Olapade, 2016: Anya and Ozung, 2019)**. The least value was observed in 100% yellow cassava grits while the sample with 100% AYB flour had the highest. This is a pointer to the fact that African yam bean contains some anti-nutrients. Saponins bind to iron, zinc, calcium, and vitamins to create insoluble mineral complexes, rendering them inaccessible **(Samtiya, Aluko and Dhewa, 2020)**. There have been reports that processing such as roasting reduced the saponin content in African yam beans **(Onyeike and Omubo-Dede, 2002; Ojuederie, Ajiboye and Babalola, 2020)**. Indicating that the low levels of saponin recorded in the roasted African yam bean were traceable to the effect of heat on the anti-nutrient. It has been found that low quantities of saponins in beans are not harmful to health, but larger concentrations in the diet can be poisonous at about ≥150 mg/kg body weight **(Samtiya, Aluko and Dhewa, 2020)**.

Tannin content was in the range of 0.14 to 0.15%, and in all of the blends, there were no significant changes in the tannin level. For AYB flour, the results were lower than those reported by **Anya and Ozung (2019)** for AYB (0.31 – 0.34%). Tannins are high-molecular-weight (>500), water-soluble phenolic chemicals that can precipitate protein, particularly pepsin **(Adamczyk et al., 2017)**. Studies have shown that tannins are concentrated in the seed coat of legume seeds and are heat resistant. Indicating that the dehulling of the seed coat in the processing method reduced the tannin content in African yam bean flour. Tannin consumption of 1.5 – 2.5 g per day in the diet is considered safe **(Sharma et al., 2019)**.

Therefore, the tannin level found in this study should not have any detrimental effects associated with tannins, such as antagonistic competition reducing accessible protein. Trypsin inhibitor content was in the range of 1.24 and 3.15 mg/g. The values are within the range of 2.22 – 3.05 reported by **Ajibola and Olapade (2016)** for processed AYB seeds.

Phytate concentrations of the flour blends were in the ranges of 0.82 and 2.69 mg/g, and all the blended samples differed significantly (p <0.05). In both animal and human nutrition, phytic acid has been recognized as the most potent antinutritional factor in foods and a source of mineral ion deficit **(Grases, Prieto and Costa-Bauza, 2017)**. The low phytate contents suggest that minerals otherwise chelated by phytate can be much more available. Hydrogen cyanide levels are as shown in Fig 3; they ranged between 0.07 and 4.47 mg/kg. Roasting and fermentation processes involved in the production of cassava grits reduced the hydrogen cyanide to safe levels. As indicated by the Joint FAO/WHO Expert Committee on Food Additives **(JECFA)**, a codex level of 10 mg HCN/kg body weight (10 ppm) in cassava flour does not cause severe toxicity. **(WHO, 2004)**.

Figure 1 Yellow root cassava and African yam bean seeds.

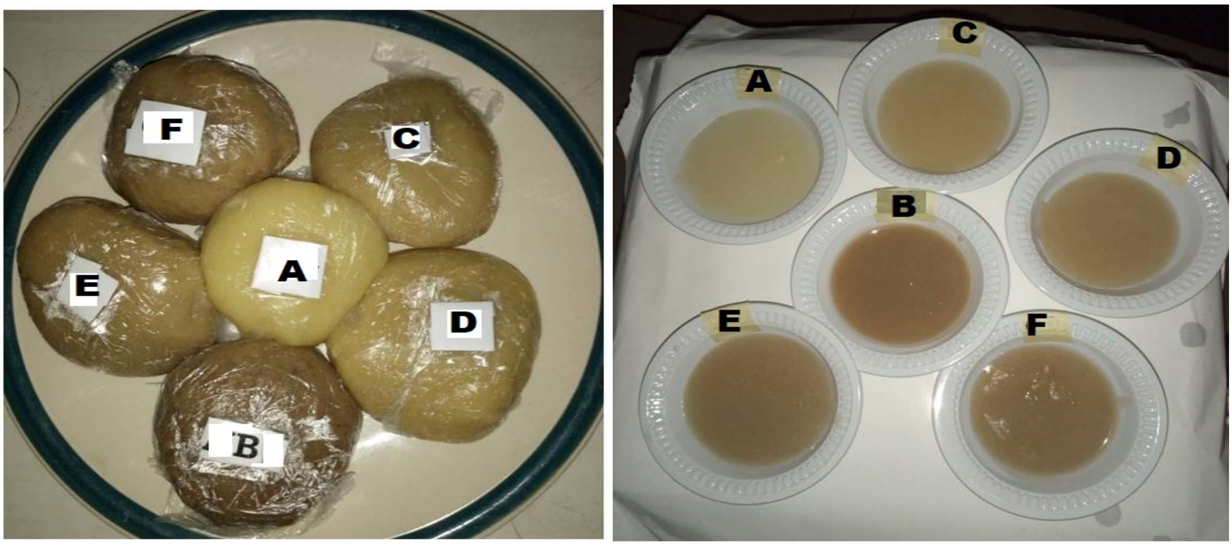

Figure 2 Meal and gruel samples prepared from blends of yellow root cassava grits and AYB flour.
Note: A =100% Yellow root cassava grit, B = 100% AYB flour, C= 90% Yellow root cassava grit and 10% AYB, D = 80% Yellow root cassava grit and 20% AYB, E =70% Yellow root cassava grit and 30% AYB, F = 60% Yellow root cassava grit and 40% AYB.

Indicating that the food products are within the safe level and will pose no hazard to the consumers.

Haemagglutin contents varied from 1.47 to 3.49 mg/100 g. In this investigation, the flour blends containing 100 percent AYB flour had the highest hemagglutin level (3.49 mg/100 g), which is lesser than the 5.30 mg/100 mg reported by **Ngwu, Aburime and Ani (2014)** for roasted AYB.

Stachyose levels ranged from 1.51 to 1.81%, while raffinose ranged from 0.38 to 0.45%. The reduction of stachyose and raffinose in all the blended samples is of interest. This is because oligosaccharides (raffinose and stachyose) are implicated in flatulence and diarrhea.

Sensory Evaluation

The result of the sensory evaluation of gruel samples made with cassava grit and African yam bean flour mixes is as shown in Table 3. All of the samples received good sensory ratings for all of the qualities, as well as overall acceptability. The panelists' ratings for the gruels' taste and flavor were not different significantly (p >0.05) across all samples. In appearance, samples manufactured from 100% AYB flour and 20 – 30% AYB flour substitute did not differ substantially (p <0.05). The sample created with 100 percent AYB flour and the samples manufactured with 10 – 30 percent AYB flour had no discernible variation in general acceptability. but they varied significantly with the samples made from 100% cassava grit and 40% AYB flour substitution. The least score for color, consistency, mouth feels texture, and appearance was observed in the sample with 40% Substitution of AYB flour. The high mean scores observed for flavor, color, consistency, mouthfeel texture, appearance, taste, and overall acceptability indicated that all the gruel samples had acceptable sensory properties. as the percentage of substitution increased up to 30%, the degree of similarity in all of the samples increased for practically all of the criteria. The high mean scores observed for appearance, color, hand feel, mouthfeel, mouldability, and overall acceptability indicated that all the meal samples were of good sensory attributes except the meal prepared from 100% AYB. The highest score for overall acceptability was observed in the sample with 70% yellow root cassava grits and 30% AYB flour.

Table 1 Proximate and calorific content of yellow root cassava grits and AYB flour blends.

Sample (%)	MC (%)	Fat (%)	Ash (%)	Protein (%)	Crude fibre (%)	Carbohydrate (%)	Calorific Content kcal/100 g
A	7.92^{d}	2.82^{c}	2.16^{a}	2.72^{a}	1.15^{a}	83.23^{c}	348.37
B	4.66^{a}	2.20^{a}	2.66^{f}	20.43^{f}	1.40^{f}	68.65^{a}	358.96
C	7.28^{c}	2.66^{b}	2.20^{b}	5.58^{b}	1.22^{b}	81.06^{c}	350.22
D	7.26^{c}	2.64^{b}	2.36^{c}	7.36^{c}	1.29^{c}	79.09^{c}	348.20
E	7.26^{c}	2.67^{b}	2.37^{c}	8.63^{d}	1.33^{d}	77.74^{b}	350.08
F	7.10^{b}	2.71^{b}	2.46^{d}	10.60^{e}	1.39^{e}	75.74^{b}	350.82

Note: The mean values in the same column with varied superscripts are significantly different ($p<0.05$). A =100% Yellow root cassava grit, B = 100% AYB flour, C= 90% Yellow root cassava grit and 10% AYB, D = 80% Yellow root cassava grit and 20% AYB, E =70% Yellow root cassava grit and 30% AYB, F = 60% Yellow root cassava grit and 40% AYB.

Table 2 Anti-nutritional composition of the yellow root cassava grits and AYB flour blends.

Sample	Saponin %	Tannin %	Trypsin Inhibitor (mg/g)	Hemaglutin (mg/100 g)	Stachylose %	Raffinose %	Phytate (mg/g)
A	0.039^{a}	0.14	1.24^{a}	1.47^{a}	1.79^{d}	0.45^{d}	0.82^{a}
B	0.087^{e}	0.15	3.15^{f}	3.49^{f}	1.81^{e}	0.45^{d}	2.69^{f}
C	0.050^{b}	0.11	1.28^{b}	2.14^{b}	1.51^{a}	0.38^{a}	1.07^{b}
D	0.060^{c}	0.12	1.35^{c}	2.42^{c}	1.55^{b}	0.39^{b}	1.19^{c}
E	0.062^{c}	0.13	1.91^{d}	2.69^{d}	1.75^{c}	0.44^{c}	1.40^{d}
F	0.065^{d}	0.14	2.14^{e}	3.03^{e}	1.79^{d}	0.45^{d}	1.62^{e}

Note: The mean values of the same column with different superscripts differ by a significant amount ($p < 0.05$). A =100% Yellow root cassava grit, B = 100% AYB flour, C= 90% Yellow root cassava grit and 10% AYB, D = 80% Yellow root cassava grit and 20% AYB, E =70% Yellow root cassava grit and 30% AYB, F = 60% Yellow root cassava grit and 40% AYB.

Table 3 Sensory evaluation of gruel samples produced from yellow root cassava grits and AYB flour blends.

Sample	Flavour	Colour	Consistency	Mouthfeel Texture	Appearance	Taste	Overall Acceptability
A	6.32^{a}	7.66^{d}	7.18^{d}	7.22^{c}	7.34^{c}	6.14^{a}	7.38^{c}
B	6.58^{a}	6.52^{bc}	5.76^{ab}	6.16^{ab}	6.56^{bc}	5.86^{a}	6.32^{b}
C	6.18^{a}	6.72^{bc}	6.70^{cd}	6.78^{bc}	6.34^{ab}	6.22^{a}	5.94^{b}
D	6.72^{a}	7.20^{cd}	6.24^{abc}	6.14^{ab}	6.62^{bc}	6.20^{a}	6.42^{b}
E	6.68^{a}	6.28^{cd}	6.36^{bc}	6.10^{ab}	6.60^{bc}	5.98^{a}	5.84^{b}
F	6.42^{a}	5.78^{a}	5.50^{a}	5.86^{a}	5.58^{a}	5.56^{a}	5.06^{a}

Note: Mean values in the same column with different superscripts are considerably different from each other ($p < 0.05$). A =100% Yellow root cassava grit, B = 100% AYB flour, C= 90% Yellow root cassava grit and 10% AYB, D = 80% Yellow root cassava grit and 20% AYB, E =70% Yellow root cassava grit and 30% AYB, F = 60% Yellow root cassava grit and 40% AYB.

Table 4 Sensory evaluation of meal samples produced from yellow root cassava grits and AYB flour blends.

Sample	Appearance	Colour	Hand feel	Mouthfeel	Mouldability	Overall Acceptability
A	7.60^{b}	7.52^{c}	7.04^{b}	6.62^{b}	6.14^{b}	6.84^{c}
B	5.48^{a}	6.36^{b}	4.22^{a}	3.86^{a}	3.56^{a}	3.42^{a}
C	7.08^{b}	6.68^{b}	6.54^{b}	6.52^{b}	6.62^{b}	6.60^{c}
D	7.04^{b}	6.64^{b}	6.76^{b}	6.70^{b}	6.52^{b}	6.34^{c}
E	8.26^{c}	7.80^{c}	8.02^{c}	7.80^{c}	7.64^{c}	7.80^{d}
F	5.84^{a}	5.70^{a}	6.28^{b}	6.36^{b}	6.20^{b}	5.50^{b}

Note: The mean values in the same column with different superscripts vary significantly ($p<0.05$). A = 100% Yellow root cassava grit, B = 100% AYB flour, C= 90% Yellow root cassava grit and 10% AYB, D = 80% Yellow root cassava grit and 20% AYB, E =70% Yellow root cassava grit and 30% AYB, F = 60% Yellow root cassava grit and 40% AYB.

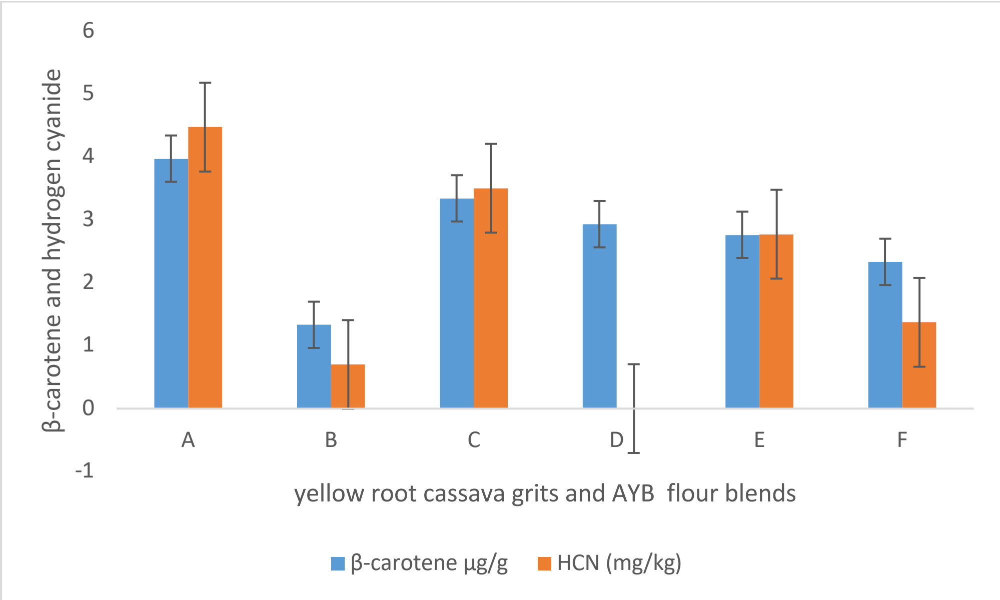

Figure 3 The β-carotene and the hydrogen cyanide contents of the yellow root cassava and AYB flour blends.
Note: A =100% Yellow root cassava grit, B = 100% AYB flour, C= 90% Yellow root cassava grit and 10% AYB, D = 80% Yellow root cassava grit and 20% AYB, E =70% Yellow root cassava grit and 30% AYB, F = 60% Yellow root cassava grit and 40% AYB.

CONCLUSION

This study has shown that nutritious gruel and meals with acceptable sensory properties can be obtained from blends of 80% cassava grits with 20% roasted AYB flour and 70% yellow cassava grit with 30% roasted AYB flour, respectively. The protein content and overall sensory characteristics of prepared meals and gruels were positively affected with AYB flour substitution. Hence, the potential of African yam bean in alleviating the problems of protein malnutrition in the developing world among the most vulnerable groups was established.

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Funds:
This research received no external funding.

Acknowledgments: -

Conflict of Interest:
The authors declare no conflict of interest.

Ethical Statement:
This article does not contain any studies that would require an ethical statement.

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