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Effect of fermentation periods on the nutrient quality and sensory acceptability of Africa Yam Beans (*Sphenostylis sternocarpa*) porridge

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Abstract

This study evaluated the effect of fermentation periods (24, 48 and 72 h) on the nutrient quality and sensory acceptability of African yam bean (AYB) porridge. The result shows significant ($p<0.05$) effect on the nutrient composition and sensory scores of AYB porridge due to fermentation periods. The unfermented (control) AYB porridge had higher values of fat (7.78%), fibre (4.31%) and ash (2.94%) than the 24 h, 48 h, and 72 h fermented porridge. The reverse was the case as 24 h, 48 h and 72 h fermented porridge had higher values of protein (27.87%, 28.90%, 30.80%) than the unfermented porridge (26.35%). The range of the mineral values for Ca (22.74 - 28.06 mg/100g), Mg(10.88 - 26.13 mg/100g), K (115.25 - 140.86 mg/100g) and anti-nutrients for phytate (0.02 – 0.15 mg/100g), oxalate (0.25 – 4.82 mg/100g), tannin (0.93 – 8.46 mg/100g) showed a decreasing trend from unfermented porridge > 24h > 48 > 72 h fermented porridge, respectively. Fermented porridge especially at 24 h, and at 48 h had better sensory acceptability scores than the unfermented and 72 h porridge. The total microbial population in the fermented liquor indicates that Total Viable and Lactobacillus counts increased with increasing fermentation period, that is, from 24 to 72 h, while total Fungal count decreased from 24 to 72 h fermentation period. This study shows that fermentation periods have significant effect in increasing the nutrient quality of AYB porridge for improved human nutrition and in amelioration of hidden hunger.

Keywords: African yam bean porridge, Fermentation periods, Nutrient quality, Sensory acceptability, improved nutrition

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Introduction

African yam bean (AYB) is an under-utilized trailing legume that grows as intercrop with yam and cassava usually for the edible seeds. The seed can serve as security crop with potential to boost human and animal protein requirement if grown on a large scale in recognition of its high protein content that range from 21 to 28% (Uguru et al., 2001). AYB is important food substitute of cowpea in many parts of Southeastern Nigeria where it is largely grown. For example, it was explored as a source of dietary protein in Southeastern Nigeria during the Biafran-Nigeria Civil war of 1967 – 1970 to feed the malnourished children and refugees (Nwokolo, 1987; Uguru et al, 2001).

Generally, African yam bean (*Sphenostylis sternocarpa*) is a nutritious food source, not only is it high in protein, but also high in mineral, fiber, lipid, carbohydrate and other nutrients (Uche et al., 2014). Its protein contents compares with some major and commonly consumed legumes. Its amino acid profile is reported to be comparable to those of cowpea, soybean and pigeon pea (Obizoba and Nnam, 1992). AYB is believed to have strong potential for the management of malnutrition, some degenerative and chronic non-communicable diseases because of its dietary fibre content (Abioye et al., 2015). Proximate analysis of AYB seed by Abioye et al. (2015) showed that it contains 8.73-9.37% moisture, 28.63-30.43%protein, 2.40-3.33% fat, 3.23-3.70% ash, 2.40-3.05% crude fiber, and 50.80-53.57% carbohydrates. However, AYB contains some anti-nutritional factors (trypsin inhibitors, haemagglutins, phytate, tannin, oxalate and alkaloids) that hinder the availability of the nutrients and cause reduced growth (Nwokolo, 1987; Ajibade et al.,2005; Fasoyiro et al, 2006). One other limitation of AYB meal is the flatulence factor due to high content of oligosaccharide (stachyose and raffinose) (Nwinuka et al., 1997; Oboh et al., 1998), which freedom can be achieved through fermentation and other processing methods. AYB is also hard to cook but can be substantially reduced by pre-cooking treatment.

In Southeast region, AYB is processed and eaten by roasting in pan, the seed coat de-hulled by bruising with hands or bottle on a flat surface and then winnowed to obtain clean and roasted seeds. The roasted seeds are packaged and retailed in cellophane or corked bottles. It is also sorted and washed in water and then cooked over-night, and made into porridge. As porridge, it can be mixed with yam, cocoyam or trifoliate yam in addition with such ingredients like crayfish, salt, pepper, onion, oil and vegetables. This is regarded as a family delicacy in some Communities of Southeastern Nigeria, especially Abia State. AYB seed are used for different food preparations in Nigeria and other West African Countries. Ogbonna and Sokari (1996) had reported on the fermentation of AYB seed for *Owoh* production. Jeff-Agboola (2007) also reported on the production of *Otiru* from AYB seeds through natural fermentation. The nutritional and anti-nutritional composition of AYB seed have been reported by several authors (Ajibade et al., 2005; Ajayi, 2011; Adelekan et al., 2012; Onuoha et al., 2017), unlike the fermented and cooked porridge made from AYB seeds. Studies on fermented and cooked AYB seed is important because the bioavailabilty of nutrients should best be considered based on processed conditions in which the food is consumed.

Fermentation is an important food processing method. It is a less expensive traditional processing method used to improve digestibility, nutritional quality of foods and at the same time, reduce the anti –nutritional factors and toxic substances like phytic acid, polyphenols, oxalic acid, hydrogen cyanide, raffinose and stachyose (Aburime, 2012).Fermentation modifies natural products and makes it a more acceptable nutrition with characteristic taste and aroma. Odunfa (1988) isolated some microorganisms like *Lactobacillus* and *Bacillus* spp in the fermentation of AYB. Ajayi (2011) also reported on the isolation of *Aerococcus viridians* and *Pediococcus cerevisiae* from AYB during fermentation. It is reported that undesirable anti-nutrient compounds are degraded by fermenting micro flora (Adanne et al., 2013), resulting in the enhancement of sensory and nutritional values of fermented products when compared to unfermented foods and substrates. Bearing in mind the importance of fermentation in food processing, this study was designed to understand the effect of fermentation periods on quality characteristics of Africa yam bean (*Sphenostlis sternocarpa*) porridge. The effect of fermentation periods (24, 48 and 72 h) at ambient temperature on the nutrient quality of Africa yam bean (*Sphenostylis sternocarpa*) porridge, the sensory acceptability and the microbial population involved in the natural fermentation were the major aims of this study.

Materials and Methods

Raw material

African yam bean (AYB) (*Sphenostylis Stenocarpa*) was purchased from Ubani market in Umuahia metropolis of Abia State, Nigeria. The chemicals and equipment were from Central Laboratory Service Unit of National Roots Crops Research Institute (NRCRI) Umudike, Umuahia, Nigeria.

Sample preparations and natural fermentation

Five (5) kg of cream colored AYB seeds were sorted, weighed and divided into three portions of 1.5kg each. These portions were labeled 24h fermentation, 48h fermentation and 72 h fermentation. Each portion was washed and soaked in tap water in the ratio of 1:3 for 24h natural fermentation at room temperature (30 ^{0}C ± 2). The same procedure was used for 48 h and 72 h fermentation.

Preparation of African yam bean porridge

The AYB porridge was prepared according to the method in Figure I. After the fermentation process (24, 48 and 72 h), the beans was rinsed thoroughly with clean water. Each of the 1.5kilograms of the fermented and unfermented beans (control) was boiled with 2.5 liters of water for 90 minutes. The same amount and types of ingredients were added, mixed with wooden spatula and boiled further for 15 minutes and the porridge was made ready for analysis.

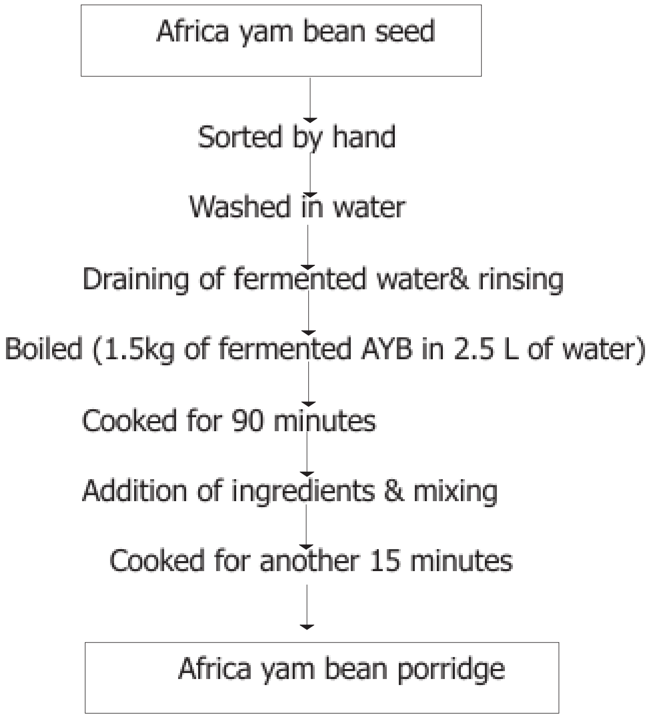

Fig. 1: Preparation of AYB porridge

Proximate Analysis

Moisture, crude protein, crude fat, crude fibre, ash contents were determined according to the standard methods of Association of Official Analytical Chemists (AOAC), (2010). Carbohydrate was determined by difference as follows: %Carbohydrates = 100 – (%moisture + %fat +%ash + %protein + %crude fibre).

Determination of Mineral contents

Calcium was determined using the method described by Pearson (1976).
Flame photometry was used to determine the concentration of potassium and magnesium as described by James (2005).

Determination of Anti-nutrients content

Tannin was determined by the method of Harbone (1993), phytate was determined using the Biphyrimidine colorimeter method described by Onwuka (2005), while oxalate content was determined by the titration method described by Day and Underwood (1986).

Determination of microbial population of AYB fermented liquor

The method described by Ezeama (2007) was adopted. One (1) mL of the sample dilution from 24h, 48h and 72h fermented liquor was inoculated by spread plates in Nutrient Agar, Potato Dextrose Agar, MRS and MacConkey Agar and were incubated at 37^{0}C while the PDA plates were incubated at room temperature (28^{0}C). At the end of incubation, colonies were counted with a colony counter.

Data analysis

Mean and standard deviation were calculated for duplicate determinations using the Statistical Package for Social Sciences (SPSS) version 10 Statistic Software Package. Data were expressed as mean ± standard deviation (SD). Comparisons between groups were performed with analysis of non-parametric test. A value of $P< 0.05$ was considered statistically significant.

Results and Discussion

Proximate composition of Africa yam bean porridge

The proximate composition of the fermented and unfermented AYB porridge is shown in Table 1. There were significant ($p<0.05$) variations in the results obtained. The moisture content of the fermented porridge was higher than the unfermented one. The same trend was observed in the protein content of the fermented porridge which were not statistically ($p>0.05$) different, but showed slight progressive increase from unfermented < 24 h < 48 h < 72 h fermented porridge (26.35 - 30.80%). The results shows the protein increased as the fermentation time increased. The fibre content shows that the values of the unfermented, 24 and 48 h AYB porridge were significantly ($p<0.05$) higher (4.0 - 4.31%) than that of 78 h value which showed the least value

(2.98%). The fat content of unfermented porridge (7.78%) was higher than their fermented counterpart. The result shows that the fat content progressively decreased as fermentation time increased from 24 h (4.86%), 48 h (2.91%) and 72h (2.69%), respectively. The same trend was observed in the ash content of the porridge. There was a progressive decrease in the ash content from unfermented porridge > 24 h > 48 h > 72h, respectively. Fat (7.78%), fibre (4.31%) and ash (2.94%) contents of unfermented AYB porridge were higher than those of the 24 h, 48 h and 72 h fermented porridge. The reverse was the case in the moisture and protein contents of the porridge which indicated significant increases in the fermented porridge than the unfermented porridge. The carbohydrate values were not statistically different irrespective of the fermentation time.

Protein content increased with increase in the fermentation time. Fat, ash and fibre contents decreased as fermentation progressed from 24 to 72 h. This may be due to microbial metabolism of these nutrients or their lixiviation in the soaked/fermenting water. The level of this decrease were as follows for fibre (4.31 to 2.98%), fat (7.78 to 2.69%) and ash (2.94 to 1.68%), respectively. Unfermented AYB porridge protein (26.35%) was higher than the values in AYB seed protein previously reported by Emiola (2011) (24.7%), much higher than 4.14 – 8.48% protein content reported by Adelekan et al. (2012) on AYB-shrimp-maize based cereal blends, but maintained the same range with those reported by Onuoha et al. (2017) (27.80%) on AYB flour and Ajayi (2011) (33.03%) on 24 h fermented AYB seed with *Pediococcus cerevisiae* culture. High protein content is major requirement in food formulation for infants and adults alike.

Fermentation of AYB seeds showed active microbial involvement that resulted in higher proteins content than the unfermented AYB porridge. This shows the impact of fermentation on protein availability which corroborates with the work of Ajayi (2011).

Table 1: Proximate composition of African yam bean porridge (%)

Samples	500	501	502	503
Moisture	$27.56^{b}\pm0.01$	$30.56^{a}\pm0.01$	$31.74^{a}\pm0.01$	$31.80^{a}\pm0.01$
Protein	$26.35^{d}\pm 0.01$	$27.87^{c}\pm 0.01$	$28.90^{b}\pm 0.01$	$30.80^{a}\pm 0.01$
Fibre	$4.31^{a}\pm 0.01$	$4.25^{a}\pm 0.01$	$4.00^{a}\pm 0.01$	$2.98^{b}\pm 0.01$
Fat	$7.78^{a}\pm 0.01$	$4.86^{b}\pm 0.01$	$2.91^{c}\pm 0.01$	$2.69^{c}\pm 0.01$
Ash	$2.94^{a}\pm 0.01$	$2.00^{b}\pm 0.01$	$1.76^{bc}\pm 0.01$	$1.68^{c}\pm 0.01$
Carbohydrate	$31.06^{a}\pm 0.01$	$30.46^{a}\pm 0.01$	$30.69^{a}\pm 0.01$	$30.05^{a}\pm 0.01$
Energy Kcal	$268.43^{c}\pm0.13$	$271.57^{ab}+0.01$	$274.36^{a}\pm0.13$	$270.22^{bc}\pm0.01$

Values are means$\pm$ standard deviation of duplicate determinations. Means with the same superscripts within the same rows are not significant differences at 0.05 confidence level ($p<0.05$).
Keys: 500 = unfermented AYB porridge (Control)**,** 501 = 24h Fermented AYB porridge**,** 502 =48h Fermented AYB porridge**,** 503 = 72h fermented AYB porridge.

Mineral composition of Africa Yam Bean porridge

Significant ($p<0.05$) variation was observed in the mineral content of AYB porridge (Table 2). The result shows progressive decrease in the minerals during fermentation time. The calcium content of the porridge ranged from 22.74 (72 h fermented porridge) to 28.06 mg/100g (unfermented porridge).Magnesium content ranged from 10.88(72 h fermented porridge) to 26.13 mg/100g (unfermented porridge). Potassium ranged from 115.25 (72 h fermented porridge) to 140.86 mg/100g (unfermented porridge). This study reveals that unfermented porridge had higher values of Ca, Mg and K > 24 h > 48 h > 72 h fermentation, respectively. As fermentation time increased, the mineral contents decreased. The relative loss of minerals in the fermented porridge may be due to mineral utilization by microorganisms during the fermentation period. Adane et al. (2013) and Ukom and Okerue (2018) had reported similar loss of mineral elements during fermentation of cocoyam *Colocasia esculenta* and *Xanthosoma sagittifolium*. The result of mineral contents obtained in this study shows that AYB porridge can support active mineral nutrition for humans.

Table 2: Mineral compositions of African yam bean porridge (mg/100g)

Samples	500	501	502	503
Calcium	28.06[a]±0.00	26.71[b] ±0.01	24.68[c] ±0.01	22.74[d] ±0.01
Magnesium	26.13[a] ±0.01	20.56[b] ±0.01	18.27[c] ±0.01	10.88[d] ±0.01
Potassium	140.86[a] ±0.01	132.62[b] ±0.01	128.41[c] ±0.01	115.25[d] ±0.01

Values are Means ± standard deviation of duplicate determinations [a-d] Means with the same superscripts within the same rows are not significantly different (P=<0.05)

Keys: 500 = unfermented AYB porridge, 501 = 24 h fermented AYB porridge, 502 = 48 h fermented AYB porridge, 503 = 72 h fermented AYB porridge.

Anti-nutrient compositions of Africa yam bean porridge.

The anti-nutrient composition of AYB porridge is shown in Table 3. The result shows progressive reduction of the anti-nutrient phytate from unfermented (0.15 mg/100g) > 24 h (0.11 mg/100g) > 48 h (0.05 mg/100g) > 72 h (0.02 mg/100g) fermented porridge. It shows that the phytate content at 72 h fermentation had the lowest value (0.02 mg/100g), while the unfermented porridge had the highest value (0.15mg/100g). This result indicates the effect of fermentation time on phytate metabolism by fermenting microorganism. Phytate is mainly found in tubers and roots, cereals, vegetables, most legumes such as soya bean, palm kernel seed and cotton seed meal. It forms insoluble salts with divalent metal ions (calcium, magnesium, iron and zinc), and hence interferes with mineral availability since it renders the minerals unavailable for absorption into the body. Phytate also affects protein digestibility by binding with proteolytic enzyme (Onyeike, 2012).

For oxalate content, the unfermented AYB porridge had the highest value (4.82 mg/100g), followed by 24 h fermentation (3.01 mg/100g), and 48 h fermentation (2.66 mg/100g), while the 72 h fermented AYB porridge had the least value (0.25/mg/100g). The result shows that oxalate content reduced considerably during fermentation. Ingestion of foods containing oxalates has been reported to cause caustic effects and irritation to the throat and intestinal tract (Adane et al., 2013). Soaking, fermentation and boiling were found to reduce the oxalate content of the fermented AYB possibly due to the effect of leaching and enzyme hydrolysis of starch during fermentation that resulted in oxalate reduction from 4.71 to 0.25 mg/100g in fermented AYB porridge.

Likewise, the tannin content of 72 h fermented AYB porridge had the lowest value (0.93/mg/100g), while the unfermented had the highest value (8.46mg/100g) This indicates high significant ($p<0.05$) decrease from 8.46 mg/100g to 0.93 mg/100g during 24 to 72 h fermentation period. The browning of AYB porridge (not shown) can be attributed to the high tannin content, which resulted into mild astringency. Fermentation of AYB seed for 24 h by *Pediococcus cerevisiae* (Ajayi, 2011) showed considerable reduction of phytic acid from 17.4 to 10.92 mg/100g, while tannic acid and oxalic acid increased from 0.24 to 1.49 mg/100g and from 0.04 to 1.22 mg/100g during fermentation process. These values are in disagreement with the results in this study (Table 3), probably on the basis of their variety, geographical location and fermentation time.

Table 3: Anti-nutrient composition of Africa yam bean porridge (mg/100g)

Analysis (%)	500	Samples 501	502	503
Phytate	0.15[a]± 0.01	0.11[a] ± 0.01	0.05[b] ± 0.01	0.02[b] ± 0.00
Oxalate	4.82[a]± 0.01	3.01[b] ± 0.01	2.66[c] ± 0.01	0.25[d] ± 0.01
Tannin	8.46[a] ± 0.01	5.55[b] ± 0.01	2.37[c] ± 0.01	0.93[d] ± 0.01

Values are Means ± standard deviation of duplicate determinations [a-d] Means with the same superscripts within the same rows are not significantly different (P=<0.05)

Keys: 500 = unfermented AYB porridge, 501 = 24 h fermented AYB porridge
502 = 48 h AYB porridge, 503 = 72 h fermented AYB porridge.

Sensory Acceptability of AYB porridge

The results of the sensory acceptability score is presented in Table 4. The results show significant ($p<0.05$) differences. Sensory scores were carried out by 45 panelists on a 9 scale hedonic scale for attributes of aroma, texture, taste, appearance, and general acceptability. Result shows that 24 and 48h fermented porridge had higher values in all the parameters tested and were preferred to other samples, showing higher general acceptability.

Unfermented AYB porridge was the least accepted followed by the 72h fermented porridge. The general acceptability of 24 and 48 h fermented porridge was due to its moderate taste and texture. The results suggest that fermentation for at least 24h, but not exceeding 48h, will greatly enhance the sensory acceptability of AYB porridge.

Fermentation degrades anti-nutrients, extends shelf life, enhance nutritional value and sensory properties of some food products including AYB porridge. With this result, AYB porridge can serve as food substitute for the vulnerable people and diabetics.

Table 4: Sensory acceptability score of African yam bean porridge

Attributes	500	501	502	503
Aroma	$3.08^b \pm 0.03$	$6.60^a \pm 0.85$	$6.12^a \pm 1.40$	$4.36^{ab} \pm 0.59$
Texture	$3.12^c \pm 0.04$	$6.68^a \pm 0.92$	$6.20^a \pm 0.89$	$4.56^{bc} \pm 0.62$
Taste	$2.98^c \pm 0.06$	$7.08^a \pm 0.24$	$5.40^b \pm 0.70$	$4.80^b \pm 0.33$
Sour	$3.03^b \pm 0.66$	$6.20^a \pm 0.44$	$6.04^a \pm 0.93$	$4.44^{ab} \pm 0.69$
Appearance	$2.30^c \pm 0.06$	$5.96^a \pm 0.08$	$6.60^a \pm 1.00$	$4.12^b \pm 0.25$
After taste	$2.40^c \pm 0.47$	$6.44^a \pm 0.62$	$6.16^{ab} \pm 0.48$	$4.88^b \pm 0.61$
Overall Acceptability:	$3.10^b \pm 0.08$	$7.00^a \pm 0.66$	$6.80^a \pm 0.61$	$5.48^a \pm 0.75$

Values are Means ± standard deviation of duplicate determinations $^{a-d}$ Means with the same superscripts within the same rows are not significantly different (P=<0.05)

Keys: 500 = unfermented AYB porridge, 501 = 24 h fermented AYB porridge, 502 = 48 h fermented AYB porridge, 503 = 72 h fermented AYB porridge

Microbial population of AYB fermented liquor evaluated at 10^{-6} dilution factor

Table 5 describes the microbial population on the nutrient agar plates. There was no microbial report in the cooked porridge since the microorganisms would have been killed during the cooking process. Only the fermented liquor at 24, 48 and 72h were evaluated for microbial growth. The PDA and MRS plate shows significant growth of microbes on the fermented liquor while the MacConkey agar plates had no presence of Coliform. The result shows that at 24 h fermentation, the total viable count was 1.42×10^{-8}cfu/g, it increased to 2.00×10^{-8}cfu/g at 48 h and to 2.48×10^{-8}cfu/g at 72 h. Fungal growth in PDA at 24 h fermentation gave a load of 4.00×10^{-7}cfu/g, while in 48 and 72h fermentation, they reduced to 1.40×10^{-8} and 1.48×10^{-8} cfu/g, respectively. Lactobacillus growth in MRS had a load of 2.00×10^{-6}cfu/g in 24 h fermentation, it increased to 6.00×10^{7}cfu/g and 6.80×10^{7}cfu/g during 48 and 72 h fermentation, respectively. The clear observation was a progressive microbial population increase as fermentation time increased for Total viable count and Lactobacillus count which agreed with the observation of Jeff-Agboola (2007) on the fermentation of AYB seed in 24 to 72h. The high Total viable and Lactobacillus count may be due to high protein content of AYB and increased temperature generated during the fermentation process. In all the fermentation time carried out, there was no identification of the presence of Coliform organism.

Isolation of microorganisms involved in AYB seed fermentation was reported by Ajayi (2011) to include *Pediococcus cerevisiae* and *Aerococcus viridians*. Jeff-Agboola (2007) also isolated the following bacteria, *Lactobacillus jensenii, Bacillus coagulans, Aerococcus viridians, Pediococcus cerevisiae* and yeast, *Saccharomyces cerevisiae* and *Candida mycorderm* from natural fermented AYB at 30 ^{0}C for 72, 96 and 120 h, respectively. We did not attempt to isolate the microorganisms involved in the sample fermentation periods because earlier researchers have identified some which constituted the fermenting micro flora of AYB seeds for porridge production.

Table 5: Microbial population of AYB fermented liquor evaluated at 10^{-6} dilution factor (cfu/g)

Sample	Fermentation duration (h)	TVC	TFC	TLC	TCC
501	24	1.42×10^8	4.00×10^7	2.00×10^6	$<10^1$
502	48	2.00×10^8	1.40×10^8	6.00×10^7	$<10^1$
503	72	2.48×10^8	1.80×10^8	6.80×10^7	$<10^1$

Keys: TVC = Total viable count, TFC = Total fungal Count, TLC = Total Lactobacillus Count, TCC = Total Coliform Count, $<10^1$= growth of microbes insignificantly far less than 10 CFU/g and CFU = Colony forming units of microorganisms.

Conclusion

The effect of fermentation periods (24, 48 and 72 h) on the quality characteristics of Africa yam bean (*Sphenostylis sternocarpa*) porridge showed that protein increased as fermentation time increased, while fibre, fat, ash, minerals and anti-nutritional contents showed varying levels of reduction as fermentation time increased probably as a result their microbial utilization and lixiviation. The results also showed that AYB porridge produced at 24 h fermentation, but not exceeding 48 h fermentation will have better sensory acceptability. The microbial population for Total viable and Lactobacillus counts showed increases as fermentation time increased from 24 to 72 h, while Fungal growth reduced as fermentation time increased from 24 to 72 h. Coliform (pathogenic) organism was not noticed throughout the duration of fermentation. From this study, the production of porridge from AYB seed and its nutritional qualities at different fermentation periods have been highlighted. The high nutritional value and reduced anti-nutritional factors in AYB porridge makes it a valuable nutrient dense food source for all groups of people.

References

Aburime, L.C. (2012). Effect of different processing methods on the chemical composition of African yam bean (*Sphenostylis stenocarpa*) flours and organoleptic characteristics of their gruels. Master Thesis, Department of Home Science, Nutrition and Dietetics. University of Nigeria, Nsukka.

Adane, T., Shimelis, A., Negussie, R., Tilahun, B and Haki, G.D. (2013). Effect of processing method on the proximate composition, mineral and anti-nutritional factors of Taro (*Colocasia esculenta*, L) grown in Ethiopia. Afri. J. Food, Agric., Nutr. And Dev., 13 (2): 7383-7397.

Adelekan, A. O., Arisa, N. U and Laguda, O. O. (2012).The use of African yam beans and shrimps in the production of maize-based cereal blends. J. Nutr. Food Sci, 2(8): 1-4

Ajayi, A. O. (2011). Sustainable dietary supplements: An analytical study of African yam bean- *Sphenostylis stenocarpa* and maize- *Zea Maiz*. European J. Experim Biology, 1 (4): 189-201

Ajibade, S.R., Balogun, M.O., Afolabi, O.O., Ajomole, K.O. and Fasoyiro, S.B. (2005). Genetic variation in nutritive and anti-nutritive contents of African yam bean (*Sphenostylis stenocarpa*). Trop. Sci., 45(4): 144-148.

Alozie S. D., Achinewhu S.C., and Isichei, M. (1990).The nutritive evaluation of fermented Africa Yam Bean seeds. Discovery and Innovation, 2: 62-65.

Day, J.R. A and Underwood, A. L (1986). Quantitative Analysis 5th Ed., Prentice-Hall publications, London. Pp701.

Harborne, J.B (1973). Phytochemical Methods. Chapman and Hall Ltd, London. Pp.149-188.

Emiola, I.A. (2011). Processed African yam bean (*Sphenostylis stenocarpa*) in broiler feeding performance characteristics and nutrient utilization. J. Environ. Issues Agric. Dev. Ctries, 3(3): 123-131.

Ezeama, F.C and Ezeronye, O. U (2007). Food Microbiology, fundamentals and Application. 6(1):64-72

Fasoyiro, S.B., Ajibade, S. R.., Omole, A. J., Adeniyan, O. N., and Farinde, E.O (2006). Proximate, minerals and anti-nutritional factors of some underutilized grain legumes in south-western Nigeria. Nutrition and Food Science, 36 (1): 18 – 23.

Fasoyiro, S. B., Ajibade, S. R., Omole, A. J., Adeniyan, O. N and Farinde, E. O. (2006). Proximate, mineral and anti-nutritional factors of some underutilized grain legumes in south-western Nigeria, Nutrition Food Sciences, 36: 18-23.

James, S.C. (1995). Analytical chemistry of food. Chapman and Hill printers, London.25.

AOAC. (2010). Official Methods of Analysis. 18th Edition, Revision 3, Association of Official Analytical Chemists, Washington DC.

Jeff-Agboola, Y. A. (2007). Microorganisms associated with natural fermentation of African yam bean (*Sphenostylis stenocarpa Harms*) seeds for the production of Otiru. Research. J. Microbiol., 2(11): 816-82

Nout, M. I. R and Sarkar, P. K (1999). Lactic food fermentation in tropical climates. Ant. Leeuwen Hoek, 76: 395-401

Nwinuka, N. M., Abbey, B. W., Ayalogu, E. O. (1997). Effect of processing on flatus producing oligosaccharides in cowpea (*Vigna unguiculate*) and the tropical African yam bean (*Sphenostylis stenocarpa*). Plant Food Hum Nutr, 51: 209-218.

Nwokolo, E. (1987). A nutritional assessment of African yam bean (*Sphenostvlis stenocarpa Hochst* ex A Rich Harms) and bambara groundnut (*Voandzeia subterranean* L.).J. Food Sci. and Agric. 41:123-129

Obizoba, I. C and Nnam, N. (1992). Effects of sprouting time on the nutritive value of two varieties of African yam beans (*Sphenostylis stenocarpa*). Plant Foods Hum. Nutr., 42: 319-327

Obizoba, I. C. and Atti, J. V. (1994). Evaluation of the effect processing techniques on the nutrient and antinutrient contents of Africa yam bean (*Sphenostylis stenocarpa*) seeds. Plants Foods for Human Nutrition. 45: 23-34.

Oboh, H. A., Muzquiz, M., Burbano, C., Cuadrado, C., Pedrosa, M. M., Ayet, G., Osagie, A. U (1998). Anti-nutritional constituents of six underutilized legumes grown in Nigeria. J. Chromato 82: 307-312.

Odunfa, S. A. (1988). Review: African fermented foods arts and science, MIRCEN J, 4: 259-273

Ogbonna, D. N and Sokari, T. G. (1996). Fermentation of African yam beans for Owoh production optimization starter culture. Niger Delta Biologia 1(2): 49-53

Onuoha, C. H. I., Harry, B. J., and Eze, S. O. (2017). Evaluation of nutrients and antinutritional factors of different species of African yam beans (*Sphenostylis stenocarpa*). European J. Basic and Applied Sci., 4 (1):1-8

Onyechi, U.A and Nwachi, I.C. (2008). Organoleptic attributes and acceptability of AYB (*Sphenotylis stenocarpa*) porridge. Nigerian Journal of Nutritional Sciences, 29(1), 256-260

Onyechi, U.A., Ibeanu, V.N., and Ugwumba, N.G (2008). Formulation of breakfast porridges from three Nigerian legumes-*Afzelia africana* (Counterwood seed), *Detarium microcarpium* (Tallow seed) and *Sphenostylis stenocarpa* (African yam bean seed) blended with corn flour: Their nutrient composition and sensory evaluation. Pak J. Nutr. 13 (8): 473-479.

Onyeike, E. N. and Domubo-Dede, T. T. (2002). Effect of heat treatment on the proximate composition, energy values, and levels of some toxicants in African yam bean (*Sphenostylis stenocarpa*) seed varieties. Plant Foods for Human Nutrition 57:223–231.

Uguru, M.I and Madukaife, S.O (2001). Studies on the variability in agronomic and nutritive characteristics of African yam bean (*Sphenostylis stenocarpa* Hochst ex. A.Rich. Harms). Plant Production and Research J, 6: 10-19.

Ukom, A. N and Okerue, C.F.L. (2018). Determination of the Nutrients, Anti-Nutrients and Functional Properties of Processed Cocoyam (*Xanthosoma sagittifolium*) Cultivars Grown in Southeast, Nigeria. J. Sustainable Food Production, 1: 11-21.