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Nutritional value of African yambean (*Sphenostylis stenocarpa* L): improvement by lactic acid fermentation

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Abstract: Tropical African yambean (*Sphenostylis stenocarpa* L) is an under-utilised hardy, protein-rich legume. Antinutrients and the excessively long cooking time (4–6 h), among other factors, limit the food use of African yambean seeds. To reduce these limitations, non-traditional, less energy-consuming processing methods are required. Seeds of different varieties were (i) examined for ingredients and (ii) fermented with *Lactobacillus plantarum*. Comparisons with traditionally cooked beans were made. Protein content and *in vitro* protein digestibility were increased slightly by fermentation or cooking. Reductions in trypsin and α-amylase inhibitor activity and tannin ranged from significant to complete. The contents of potentially very toxic cyanogenic glycosides and flatulence-causing α-galactosides were high in raw beans. Reduction by fermentation (by 85%) was clearly more effective than by traditional cooking (10–20%). The results demonstrate (i) that fermentation can substantially improve the nutritional quality and (ii) that the energy requirement to produce a basic consumable fermented food from African yambean is only 10% of that of traditional cooking. On these grounds, widespread application of lactic acid fermentation by individuals or small-scale industries would be advantageous in the context of small-household economy, environmental protection, health and long-term sustainable agriculture in Nigeria.

Keywords: *Sphenostylis stenocarpa*; *Lactobacillus plantarum*; antinutrients; cyanogenic glycosides; lactic acid fermentation; *in vitro* protein digestibility; under-utilised crops

INTRODUCTION

African yambean is among the lesser-known legumes of the humid tropics. It is cultivated in West Africa for its seeds and in East and Central Africa mainly for its tubers. In southern Nigeria, African yambean seeds have been preferred to other legumes in the past because they are filling, and for unclear cultural reasons, though cowpea is now the preferred legume. Brown and black African yambean seeds are preferred in the lowlands and light-coloured seeds in mountainous regions of Nigeria. Health problems, acute and chronic, are associated with African yambean consumption. Consumers in Edo State were interviewed in 2002 about health problems experienced with African yambeans. Questionnaires were not applicable under the given conditions. In order of frequency, flatulence, stomach cramps, diarrhoea and even dizziness were the most common problems experienced by consumers. Although all people interviewed reported the occurrence of the whole spectrum of health problems, the frequencies reported were different: flatulence was general and severe with black and brown seeds, whereas stomach cramps were experienced with all varieties but at a lower frequency. The interviews confirmed that the common method of processing is cooking in water for as long as 6–8 h, which, nonetheless, leaves the beans stodgy.

Asuzu and Undie[1] investigated the physiological basis for these unwanted effects using pig ileum and rabbit jejunum. They observed marked spasms induced by aqueous extracts from African yambeans. Boiling for up to 6 h did not alleviate the spasms, but extensive boiling for 12–14 h completely eliminated them. This stresses the absolute requirement for excessive cooking of African yambeans, even longer than the traditional 4–6 h. Preferably, more efficient

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processing methods, such as lactic acid fermentation should be developed. As for the cause of diarrhoea and cramps, Asuzu and Undie[1] concluded that increased peristaltic movement of the intestine together with quick passage of the intestinal content, which results from the stimulation of muscarine receptors, is the mechanism underlying diarrhoea. Published work on African yambeans has focused on their proximate composition, protein availability and functional properties and on the effects of modifying basic processing parameters such as soaking, dehulling and heat treatment.[2–8] These include soaking in different media before cooking in water,[9] though the serious problem of the unduly long cooking time was not the focus of that work. Alternative processing methods for African yambean have not been given much attention in the past. A vegetable milk product was prepared from a blend of spontaneously fermented African yambeans and maize.[10] Ogbonna *et al*[11] made an alkaline fermented product from African yambeans by spontaneous fermentation of the cooked seeds. Protein content was about 30%, with high levels of calcium, phosphorus, iron, zinc and potassium. The major shortcoming of this process is again the long cooking time of 8–10 h before fermentation takes place. This means that no time or energy saving is achieved. In the present study, in an attempt to effectively reduce both energy consumption and antinutrient levels by a process that is simple and cheap, uncooked African yambean seeds were spontaneously fermented or subjected to lactic acid fermentation with *Lactobacillus plantarum*.

MATERIALS AND METHODS

Seeds of three varieties of African yambean, black, marble and white, were used for this study to ascertain varietal differences, if any, in the response of African yambeans to lactic acid fermentation. The seeds were cultivated and harvested in the same period (January/February 2000) in Edo State in the southern part of Nigeria. *L plantarum* was obtained from the laboratory of Prof Dr Holzapfel (Federal Research Centre for Nutrition and Foods, Karlsruhe, Germany) and cultivated in sealed test tubes containing De Mann, Rogosa and Sharpe (MRS) broth at 30 °C for 24 h. The suspension (10^8 cells ml^{-1}) was used for inoculation.

Fermentation

Fermentation was done essentially as described by Akinyele and Akinlosotu.[12] The seeds were washed and soaked in three times their volume of deionised water for 24 h. The seeds were then drained, thoroughly rinsed and ground to a slurry using a Waring-type blender (model MX32, Braun, Frankfurt/Main, Germany). Portions of 1 kg were inoculated with 10 ml of *L plantarum* suspension. The slurry was stirred and incubated at 30 °C in large sealed plastic containers for 48 h with occasional stirring. A non-inoculated batch was run simultaneously for spontaneous fermentation. Samples were taken at 0, 6, 12, 22, 28, 34 and 48 h, frozen at −20 °C, freeze-dried, reduced to a particle size of <0.5 mm (Cyclotec 1093, Tecator, Höganäs, Sweden) and stored at 4 °C.

Traditional cooking procedure

The dry seeds were boiled in about four times their volume of deionised water for 4 h. After draining, the 'soft' seeds were dried in an oven at 50 °C for about 18 h and further treated as described above.

Analytical methods

Proximates

AOAC methods 960.52[13] was used to calculate protein from N using the factor 6.25. The recovery of added glycine was 106–108%, the coefficient of variation being 2.14% ($n = 8$). Starch was determined enzymatically (assay kit 2335, Megazyme, Wicklow, Ireland). Average recovery was 97% for corn starch. AOAC method 920.39[13] was used for total lipids and AOAC method 923.03[13] for ash. Dietary fibre was determined using LMBG method §35.[14] *In vitro* protein digestibility was determined by the multienzyme technique of Hsu *et al*.[15]

Antinutrients

Trypsin inhibitor activity was determined by AACC method 71–10.[16] α-Amylase inhibitor activity was determined as described by Alonso *et al*[17] and Desphande *et al*.[18] One unit of enzyme activity was defined as 1 μmol reducing groups (calculated as maltose) min^{-1} liberated from soluble starch at 37 °C and pH 7.0. One unit of α-amylase activity inhibited was defined as one α-amylase inhibitory unit. The coefficient of variation was 8.04% ($n = 8$). Tannin was determined according to Price *et al*[19] and phytic acid essentially according to Wheeler and Ferrel.[20] Extraction efficacy was determined with 1.2 M HCl, 2.4 M HCl or 3% trichloroacetic acid (TCA), each containing 10% Na_2SO_4. The best recovery was with 1.2 M HCl. Extraction with 3% TCA was discontinued because of excessive foaming. Cyanogenic glycosides were determined as HCN equivalents using AOAC method 915.03B.[13]

Oligosaccharides

Soluble sugars were extracted using 80% v/v ethanol.[21] In order to optimise extraction, portions of white seed meal were extracted once for 30 min, once for 60 min, twice for 30 min and thrice for 30 min. Extracting twice gave a higher yield, the third extraction did not increase the yield significantly ($P < 0.05$). Extraction was therefore done twice. A 2 g sample (<0.5 mm) was extracted twice with 50 ml of 80% ethanol at 60 °C, centrifuged at 3000 × g for 10 min and the supernatants were vacuum evaporated. The residues were dissolved in 8 ml of doubly distilled water. The effects of various deproteinising agents on sugar yield were compared. All agents produced clear extracts.

Activated charcoal and acetonitrile gave lower yields than Carrez solution. Consequently, Carrez solution clearing was used for clean-up. The extract was deproteinised with 100 µl each of Carrez solution I and II,* centrifuged and the supernatant was filtered through a Sep-Pak C18 cartridge (Waters, Milford, MA, USA) which had been pre-wetted with 4 ml of methanol and 2 ml of water. A 2.5 ml aliquot was then made up to 10 ml with acetonitrile, centrifuged and the supernatant was used for analysis by HPLC as described by Muzquiz *et al*[21] and Oboh *et al*[22] with a modified mobile phase. A Spherisorb-5-NH2 column (250 mm × 4.6 mm id, Macherey and Nagel, Düren, Germany) was employed, using acetonitrile/water (1 ml min^{-1}) in two different proportions (75:25 w/w for sucrose and 60:40 w/w for oligosaccharides). Quantification was done on the basis of peak heights. External standards were used for calibration. A linear response was recorded in the range 0–4 mg ml^{-1} with a correlation coefficient of 0.999 for all standards. Recovery of the sugars tested was 85.6–113.6%. Coefficients of variation were 2.09% for raffinose, 0.88% for stachyose and 2.95% for verbascose ($n = 10$).

Statistics

Significance of difference was tested by analysis of variance and Tukey's HSD using SAS statistical software (SAS Institute Inc, Cary, NC, USA).

RESULTS AND DISCUSSION

Proximates

Small but statistically significant differences in some proximate contents were detected between the varieties (Table 1). The exceptions were the protein and ash contents of the black and marble varieties and the starch contents of the marble and white varieties, which were not significantly different. Protein was generally high, so was starch, whereas total lipid was negligibly low. Significant but minor differences ($P < 0.05$) were detected in the dietary fibre and lipid contents of the three varieties. These results underscore the possible role of African yambean seeds in combating protein/energy malnutrition, which is a problem in sub-Saharan Africa.

Table 1. Proximate composition (g kg^{-1}) of black, marble and white African yambean

Proximate	Black	Marble	White
Crude protein	224 ± 0.8a	221 ± 0.7a	254 ± 1.2b
Total starch	451 ± 14.8a	472 ± 3.6b	417 ± 23.9b
Total lipid	17.5 ± 0.7a	15.3 ± 0.0b	4.1 ± 0.0c
Ash	29.3 ± 0.3a	30.4 ± 0.4a	36.2 ± 1.2b
Dietary fibre	151 ± 4.6a	135 ± 1.7b	169 ± 6.6c

Results are given on a dry matter basis as mean ± standard deviation of triplicate determinations, except for dietary fibre (duplicate determinations). Values in a row with different letters are significantly different from each other ($P < 0.05$).

Dietary fibre was much higher than previously reported by other workers.[2,5,6,23] This seeming discrepancy may arise from the use of different analytical methods which detect different types of fibres (chemical digestion versus enzymatic/gravimetric method). As an example, El Adawy *et al*[24] reported 36 g kg^{-1} dietary fibre for common beans (*Phaseolus vulgaris*) using the chemical method,[25] while Manas *et al*[26] found 170.7 g kg^{-1} using the enzymatic/gravimetric method.[13] Considering starch, our results show that the seeds of African yambean are rich in both protein and starch. This means that the seeds are well equilibrated with regard to human nutrition (Table 1).

In the following, the potential of African yambean to contribute to an adequate protein supply is considered in more detail. According to WHO/FAO/UNO,[27] an adult man requires 0.75 g protein kg^{-1} body weight day^{-1}. This implies that a 70 kg man requires 52.5 g protein day^{-1}. If African yambean was the only source of protein, this man would have to consume 208–236 g of African yambeans to meet his daily protein requirement. To avoid severe health problems, a meal prepared by traditional cooking should not contain more than 200 g of seeds. If antinutrient content and digestibility were improved, the daily protein requirement could be met solely with African yambeans (about 230 g), assuming full bioavailability.

Antinutrients

In different seed varieties, antinutrients potentially reducing protein, starch and mineral availability occur at different levels. Statistically significant and partly marked differences ($P < 0.05$) were found between the varieties (Table 2). The values reported in this work for trypsin inhibitor activity and cyanogenic glycosides differ from those reported for an unspecified African yambean variety.[2,23] It is important to stress on the grounds of nutritive quality that interactions of phytate and tannin with protein can markedly affect protein availability, more so that tannin and phytate are heat-stable and make several minerals unavailable. Cyanogenic glycoside content was very high in white seeds (225 mg kg^{-1}, Table 2). In the other varieties, concentrations ranged from 37 to 40 mg kg^{-1}. The only result published for African yambean so far is 61 mg HCN equiv kg^{-1} in an unspecified variety.[23] Cyanogenic glycoside concentrations as high as found in our investigation are considered a serious health risk, bearing in mind that the lethal dose for an adult human is between 50 and 250 mg.[28] As for long-term exposure to cyanogenic glycosides, the occurrence of tropical ataxic neuropathy has been linked to the long-term consumption of improperly processed cyanogenic glycoside-rich foods.[29,30] Lima bean exceeds African yambean with regard to cyanogenic glycoside content.

* Carrez solution I: dissolve 23.8 g of zinc acetate trihydrate and 3 g of glacial acetic acid in water and dilute to a volume of 100 ml with water. Carrez solution II: dissolve 10.6 g of potassium ferrocyanide in water and dilute to a volume of 100 ml with distilled water.

Table 2. Antinutrients in seeds of black, marble and white African yambean

Antinutrient	Black	Marble	White
Trypsin inhibitor activity (TIU mg^{-1})	2.16 ± 0.01a	0.68 ± 0.01b	3.04 ± 0.05c
α-Amylase inhibitor activity (AIU g^{-1})	12.6 ± 1.01a	6.09 ± 0.86b	6.80 ± 0.54c
Tannin (mg g^{-1})	19.5 ± 0.09a	8.54 ± 0.06b	0.92 ± 0.04c
Phytic acid (mg g^{-1})	4.51 ± 0.05a	6.45 ± 0.06b	7.37 ± 0.05c
Cyanogenic glycosides (mg HCN kg^{-1})	37.0 ± 3.13a	40.1 ± 3.56a	225 ± 12.3b

Results are given on a dry matter basis as mean ± standard deviation of triplicate determinations. TIU, trypsin inhibitor unit; AIU, α-amylase inhibitor unit. Values in a row with different letters are significantly different from each other ($P < 0.05$).

Dibofori *et al*[31] reported 372 mg HCN equiv kg^{-1}, while Egbe and Akinyele[32] found a value as high as 420 mg kg^{-1}.

Lactic acid fermentation

African yambeans were fermented spontaneously and after inoculation with *L plantarum*. In both conditions an increase in volume of the samples was observed in the first few hours of fermentation, probably due to gas formation. Later the slurry's consistency changed towards 'fluid', probably owing to the solubilisation of nutrients and/or the release of water molecules during fermentation by the lactic acid bacteria. No major colour change was observed and the slurry retained its beany odour.

Proximates

Proximates changed little during fermentation, except total dietary fibre which decreased noticeably (Table 3). The minor increase in protein content during fermentation and cooking may be due to a concentration effect. Starch remained unchanged during lactic acid fermentation. The lactic acid bacteria may have used some dietary fibre components, such as cellulose and other non-digestible carbohydrates, as carbon source. Cooking resulted in some starch loss (Table 3). This may be due to amylose solubilisation during starch gelatinisation. Ash (ie minerals) and lipids were unchanged after fermentation (results not shown), whereas cooking resulted in an appreciable increase in the concentration of dietary fibre. These results correspond to those obtained by fermentation of *P vulgaris*.[33]

In vitro protein digestibility

This parameter can be used to estimate protein quality. *In vitro* protein digestibility (IVPD)[15] was almost the same in all raw seeds (Fig 1). Lactic acid fermentation resulted in no significant improvement in IVPD (Fig 1). By contrast, traditional cooking led to a small but significant improvement (Fig 1). The IVPD of raw African yambean protein reported here (70–73%) is in accord with previous results obtained by other techniques for African yambean[3] and other legumes.[33–36]

Antinutrients

The effectiveness of a processing method in improving a food's nutritional value can be inferred from the

Table 3. Protein and dietary fibre contents (g kg^{-1} dry matter) in raw, fermented and traditionally cooked seeds of black, marble and white African yambean

	Protein			Dietary fibre		
Treatment	Black	Marble	White	Black	Marble	White
Raw	224.0 ± 0.8a	221.0 ± 0.7a	253.5 ± 1.2a	151.2 ± 4.6a	135.3 ± 1.7a	169.3 ± 6.6a
Lactate fermented (48 h)	238.1 ± 1.5c	264.2 ± 4.4b	269.2 ± 4.1b	140.1 ± 6.1b	110.6 ± 2.2b	142.0 ± 1.6b
Non-inoculated (48 h)	236.3 ± 3.8c	237.7 ± 5.0c	280.5 ± 0.6c	92.9 ± 2.1c	138.9 ± 5.2a	126.1 ± 3.7c
Cooked (4 h)	255.9 ± 3.6d	243.7 ± 3.24c	278.3 ± 8.8c	169.1 ± 5.4d	168.6 ± 42.3c	173.8 ± 5.3a

Results are given as mean ± standard deviation ($n = 3$). Values in a column with different letters are significantly different from each other ($P < 0.05$).

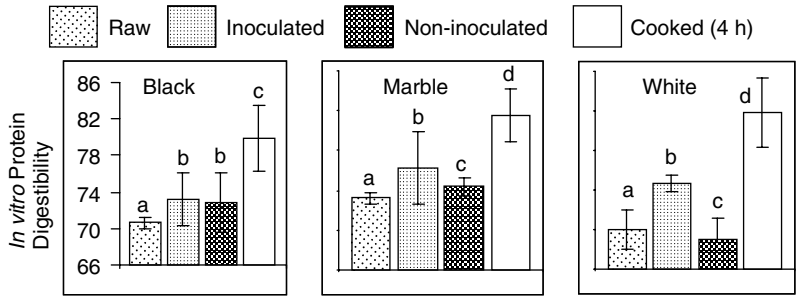

Figure 1. *In vitro* protein digestibility (%) of raw, lactic acid-fermented and cooked seeds of black, marble and white African yambean. Different letters within a variety denote significant differences ($P < 0.05$).

extent of retention of nutrients and of removal of antinutrients. Lactic acid fermentation affected the various antinutrients differently (Tables 4–10). Little or no trypsin inhibitor activity remained after fermentation (inoculated) of black, white or marble seeds (Table 4). The same was observed for α-amylase inhibitor activity (Table 5), though inactivation was less. Traditional cooking led to complete inactivation of both enzyme inhibitors, as reported for other legumes.[33,37] With respect to tannin, 50–60% reduction was achieved by lactic acid fermentation of black and marble seeds (Table 6). No tannin was detected in white seeds when fermented or cooked. The observed tannin reduction may be due to leaching or to the formation of insoluble tannin–protein complexes.[38,39] Contrary to our results, a tannin increase of 34% was reported during lactic acid fermentation of cowpea.[37] As for phytic acid, there was a significant reduction ($P < 0.05$) in black seeds as a result of lactic acid fermentation (Table 7). By contrast, phytic acid increased in marble seeds and remained almost constant in white seeds. Cooking for 4 h also led to no important phytic acid loss. The low level of phytic acid reduction during lactic acid fermentation of African yambeans is unique.[38,40] Ibrahim *et al*[37] and Kozlowska *et al*[41] reported a reduction by half in cowpea and lentils respectively. Granito *et al*[33] reported some reduction by lactic acid fermentation of total inositol phosphate in common beans. A lack of appreciable phytase activity in dry legume seeds has been reported.[42,43] Overall, lactic acid fermentation was differently, in part highly, effective in reducing a variety of antinutrients in African yambean seeds, except phytic acid.

Regarding cyanogenic glycosides, lactic acid fermentation resulted in nearly complete removal of the large amount of cyanogenic glycosides occurring in white seeds (Table 8). Traditional cooking for many hours was, however, also effective. The reduction in cyanogenic glycosides during fermentation may be attributed to bacterial glucosidase. For cassava

Table 4. Trypsin inhibitor activity in raw, fermented and cooked seeds of black, marble and white African yambean

	Black		Marble		White	
Treatment	Content (U mg^{-1} DM)	Retention (%)	Content (U mg^{-1} DM)	Retention (%)	Content (U mg^{-1} DM)	Retention (%)
Raw	2.16 ± 0.01a	100	0.68 ± 0.01a	100	3.04 ± 0.05a	100
Lactate fermented (48 h)	0.34 ± 0.05b	15.8	0.02 ± 0.00b	3.1	0.66 ± 0.03b	21.7
Non-inoculated (48 h)	0.40 ± 0.03b	18.7	ND	0	0.62 ± 0.06b	20.4
Cooked (4 h)	ND	0	ND	0	ND	0

Results are given as mean ± standard deviation ($n = 3$). Retention is percentage relative to content in raw beans. DM, dry matter; ND, not detected. Values in a column with different letters are significantly different from each other ($P < 0.05$).

Table 5. α-Amylase inhibitor activity in raw, fermented and cooked seeds of black, marble and white African yambean

	Black		Marble		White	
Treatment	Content (U g^{-1} DM)	Retention (%)	Content (U g^{-1} DM)	Retention (%)	Content (U g^{-1} DM)	Retention (%)
Raw	12.56 ± 1.01a	100	6.09 ± 0.86a	100	6.80 ± 0.54a	100
Lactate fermented (48 h)	6.42 ± 0.05b	51.1	2.12 ± 0.00b	34.8	2.89 ± 0.03b	42.5
Non-inoculated (48 h)	6.40 ± 0.03b	51.0	2.35 ± 0.06b	38.6	2.62 ± 0.06b	38.5
Cooked (4 h)	ND	0	ND	0	ND	0

Results are given as mean ± standard deviation ($n = 3$). Retention is percentage relative to content in raw beans. DM, dry matter; ND, not detected. Values in a column with different letters are significantly different from each other ($P < 0.05$).

Table 6. Tannin in raw, fermented and cooked seeds of black, marble and white African yambean

	Black		Marble		White	
Treatment	Content (mg g^{-1} DM)	Retention (%)	Content (mg g^{-1} DM)	Retention (%)	Content (mg g^{-1} DM)	Retention (%)
Raw	19.47 ± 0.09a	100	8.54 ± 0.06a	100	0.92 ± 0.04	100
Lactate fermented (48 h)	6.39 ± 0.12b	32.8	3.44 ± 0.04b	40.3	ND	0
Non-inoculated (48 h)	6.42 ± 0.10b	33.0	4.01 ± 0.05c	47.0	ND	0
Cooked (4 h)	14.73 ± 0.11c	75.6	3.79 ± 0.03b	44.4	ND	0

Results are given as mean ± standard deviation ($n = 3$). Retention is percentage relative to content in raw beans. DM, dry matter; ND, not detected. Values in a column with different letters are significantly different from each other ($P < 0.05$).

Table 7. Phytic acid in raw, fermented and cooked seeds of black, marble and white African yambean

	Black		Marble		White	
Treatment	Content (mg g^{-1} DM)	Retention (%)	Content (mg g^{-1} DM)	Retention (%)	Content (mg g^{-1} DM)	Retention (%)
Raw	4.51 ± 0.05a	100	6.45 ± 0.06a	100	7.37 ± 0.05a	100
Lactate fermented (48 h)	3.79 ± 0.05b	84.0	6.87 ± 0.02b	107	7.37 ± 0.02a	100
Non-inoculated (48 h)	3.24 ± 0.01c	71.8	7.17 ± 0.03b	111	6.69 ± 0.03b	90.8
Cooked (4 h)	3.45 ± 0.02d	76.5	5.58 ± 0.02c	86.5	6.64 ± 0.01b	90.1

Results are given as mean ± standard deviation ($n = 3$). Retention is percentage relative to content in raw beans. DM, dry matter. Values in a column with different letters are significantly different from each other ($P < 0.05$).

Table 8. Cyanogenic glycosides in raw, fermented and cooked seeds of White African yambean

Treatment	Content (mg HCN kg^{-1} DM)	Retention (%)
Raw	216.25 ± 18.21a	100
Lactate fermented (48 h)	34.54 ± 2.36b	16.0
Non-inoculated (48 h)	35.67 ± 4.87b	16.5
Cooked (4 h)	47.25 ± 4.34c	21.9

Results are given as mean ± standard deviation ($n = 3$). Retention is percentage relative to content in raw beans. DM, dry matter. Values with different letters are significantly different from each other ($P < 0.05$).

processing, lactic acid fermentation has been used previously to reduce cyanogenic glycosides.[44] It is thus conceivable that this type of fermentation can also reduce cyanogenic glycosides in African yambeans.

α-Galactosides were nearly completely removed by lactic acid fermentation from all seeds fermented spontaneously or with *L plantarum*, whereas the effect of cooking was negligible to moderate at best (Table 9). Similar results have been reported for cowpea and chickpea.[37,45] Depletion of oligosaccharides may be due to microbial α-galactosidase. The effective oligosaccharide removal by fermentation infers a much lower flatulence potential. The α-galactosides may be responsible also for the diarrhoea and cramps suffered by consumers. To estimate the flatulence potential of fermented or cooked African yambeans, gas formation was computed from α-galactoside content.[31,46] Table 10 shows that lactic acid fermentation effectively

Table 10. Flatulence potential (ml gas per 200 g dry matter) of a 200 g meal of black, marble or white African yambean seeds as affected by lactic acid fermentation and traditional cooking

Treatment	Black	Marble	White
Raw	350.4	366.0	247.2
Lactic acid fermentation (48 h)	26.4	20.4	34.8
Spontaneous fermentation (48 h)	52.8	16.8	63.6
Traditional cooking (4 h)	278.4	334.8	199.2

reduces flatus potential, whereas traditional cooking fails.

Energy requirements

Kerosene ($0.25 per litre) is the most important cooking fuel in Nigeria, followed by firewood. Assuming that 1 l of kerosene gives a cooking time of 1.25 h and that the fermented samples still require some form of heat treatment (30 min each) to become palatable, the kerosene requirements for lactic acid fermentation and traditional cooking were estimated. These conservative estimates show that the energy requirement for lactic acid fermentation is much lower than that for traditional cooking (Table 11). Lactic acid fermentation is therefore a highly economical and environmentally friendly processing method.

CONCLUSION

Antinutrients, except phytic acid, were significantly reduced in seeds of African yambean by lactic

Table 9. Oligosaccharides in raw, fermented and cooked seeds of black African yambean

	Sucrose					Total RFO	
Treatment	Content (g kg^{-1} DM)	Retention (%)	Raffinose content (g kg^{-1} DM)	Stachyose content (g kg^{-1} DM)	Verbascose content (g kg^{-1} DM)	Content (g kg^{-1} DM)	Retention (%)
Raw	12.2 ± 0.2a	100	6.0 ± 0.3a	21.7 ± 0.1a	1.5 ± 0.0a	29.2	100
Lactate fermented (24 h)	0.2 ± 0.0b	1.6	1.4 ± 0.5b	1.9 ± 0.4b	<0.1	3.3	11.1
Lactate fermented (48 h)	<0.1	0	1.1 ± 0.2c	0.8 ± 0.3c	0.3 ± 0.1b	2.2	7.5
Non-inoculated (24 h)	<0.1	0	3.1 ± 0.2d	5.1 ± 0.2d	0.6 ± 0.2b	8.8	31.8
Non-inoculated (48 h)	<0.1	0	1.2 ± 0.1c	2.0 ± 0.2b	1.2 ± 0.2c	4.4	15.1
Cooked (4 h)	8.0 ± 0.0c	65.6	2.2 ± 0.2e	19.5 ± 0.1e	1.5 ± 0.3a	23.2	79.5

Results are given as mean ± standard deviation ($n = 3$). Retention is percentage relative to content in raw beans. DM, dry matter; RFO, total raffinose family oligosaccharides. Values in a column with different letters are significantly different from each other ($P < 0.05$).

Table 11. Kerosene requirements for different processing treatments of 1 kg of African yambean seeds to yield a product 'ready to eat'

Treatment	Cooking time (h)	Kerosene (l)	Energy cost ($)
Traditional cooking	5	4	1
Lactic acid fermentation	0.5	0.4	0.10

acid fermentation with *L plantarum*. This process is therefore proposed as an effective energy-saving means for improving the nutritional quality of African yambean. In this perspective, fermentation clearly outscores the traditional cooking method. With respect to nutrient supply, about 200 g of fermented African yambeans would be enough to meet the WHO/FAO/UNO-recommended daily protein intake for a 70 kg adult male. With a starch content of over 400 g kg^{-1} in fermented African yambean seeds, these products can help to prevent protein/energy malnutrition, an evident or lurking illness that affects nearly half of the sub-Saharan African population.[47] Because of the considerable dietary fibre content of low-fat fermented African yambean products, these foods can help to cope with problems associated with western diets, such as obesity and certain kinds of cancer. It is important to emphasise that lactic acid fermentation does not require a high level of technology and so can easily be adopted in every household. Data on the hygiene status of the fermented products is required, however, before their use as regular foods can be recommended. Moreover, knowledge of the functional properties of lactic acid-fermented African yambean seeds required in order to conclude on the suitability of these products as additives to a variety of manufactured food products such as infant weaning foods.

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