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Food safety and security: Fermentation as a tool to improve the nutritional value of African yambean

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Summary
African yambean is highly resistant to environmental stress and can produce acceptable yields even under unfavourable conditions. However, adverse health effects and the 4 to 6 hour cooking time hinder extension. Can alternative processing downsize these shortcomings?
Fermentation with lactic acid bacteria and the tempeh fungus *Rhizopus oligosporus* was probed. Protein digestibility was similar as if cooked for 4 h. Undesired compounds, notably oligosaccharides and cyanogenic glycosides, were markedly reduced or absent. Both processes are proposed for household and industrial uses.

Introduction
Protein malnutrition is persistent in Africa partly because animal protein is unaffordable to the majority of the population. Interest is therefore rising in low-cost, protein-rich plant foods as supplements. Legumes are rich in protein and can produce high yields without any nitrogen fertilization.

Figure 1: Seeds of three varieties of African yambean and soybean for comparisons

African yambean (*Sphenostylis stenocarpa*) land races are cultivated in West Africa for its seeds. Considerable yields are possible with this crop even on the acidic and leached sandy soils of the humid lowland tropics. The crop is little susceptible to pests and diseases and can cope with harsh climatic conditions.

The chemical composition of African yambean (AYB) has been addressed previously (AGUNBIADE ET AL, 1999; AKINTAYO ET AL, 1999; APATA ET AL, 1990; APATA ET AL, 1997). Protein content is lower than that of soybean (25 % *vs.* 38%), the proportion of most essential amino acids corresponds to the WHO/FAO recommendation. Despite these assets, African yambean production is declining in Nigeria for at least two reasons. Firstly, an extremely long cooking time is required to render the beans palatable. The very high consumption of costly fuel or fire wood constitutes a heavy burden for men and the environment. Secondly, despite extensive cooking, the beans can provoke acute and chronic health effects indicating too high an antinutrient level. Nigerians were questioned about health effects (AZEKE, 2003). In the order of frequency, flatulence, stomach cramps, diarrhoea, and dizziness were reported. It has been shown that a cooking time as long as 12 – 14 h is required to abolish the spasmogenic effect (AZEKE, 2003). This finding demonstrates that the traditional method leaves much to be desired: the beans are boiled in water for about 5 h (consumer questioning, see ref. (AZEKE, 2003) after soaking in water and tedious manual removal of the seed coat. The final product is a very filling and lasting yellowish cake-like food. The aforementioned nuisances or health effects are, however, critical.

An attempt to improve by fermentation the nutritional quality was made (OGBONNA ET AL, 2001). The method is flawed by the 8 to 10 hr cooking time required before fermentation: neither time nor energy saving is achieved. Another input requirement of novel methods to be developed is applicability in households and small scale industries.

Materials and Methods

Seeds of three varieties of African yambean were from a nigerian farmer. *Lactobacillus plantarum* was obtained from Prof. Dr. Holzapfel (Federal Research Centre for Nutrition and Food, Karlsruhe, Germany) whose support of this work is gratefully acknowledged. Suspensions with 10^8 cells mL^{-1} were used.

Lactic acid fermentation was done essentially after ref. (AKINYELE ET AL,.1991). *Rhizopus*-fermentation (tempeh) was done using untreated or mechanically dehulled seeds (Schule GmbH, Germany). *Rhizopus oligosporus* spore suspension was made to 10^6 spores/mL. Fermentation was done as traditionally with soya beans. In brief, dehulled African yambean seeds were soaked and cooked for 30 min in water, inoculated in ambient conditions, mixed and packed into perforated plastic bags, Incubation was at 30°C for 48 h. Alternatively, 1 % citric acid was used instead of water.

Analyses. Starch was determined enzymatically (Megazyme, Wicklow, Ireland). Other methods were: ash (AOAC OFFICIAL METHODS OF ANALYSIS, 1999), dietary fibre ("German Official Collection of Analytical Procedures"§ 35 LMBG, 1997), trypsin inhibitor (AACC METHOD, 1995), α-amylase (ALONSO ET Al, 2000, DESPHANDE ET AL, 1982) tannin (PRICE ET AL, 1978), phytic acid (WHEELER ET AL, 1971), cyanogenic glycosides (AOAC OFFICIAL METHODS OF ANALYSIS, 1999), soluble sugars by HPLC (MUNZQUIZ ET AL, 1992, OBOH ET AL, 2000) . "Flatus potential" was estimated after ref. CALLOWAY ET AL, 1968). Statistics were done with SAS statistical software (SAS Institute Inc., Cary, NC, USA)

Results and conclusions

This section is threefold: raw seed characterization (i) with regard to undesired compounds and nutritional value. Fermentations (ii), and characterization (iii) of the fermented products.

Protein and starch content was 22 – 25 g 100 g^{-1}, or 42 – 47 g 100 g^{-1}, respectively. Antinutrient contents were: α-amylase inhibitor (6 – 13 U g^{-1}), saponin (2 – 4 mg kg^{-1}), trypsin inhibitor (0.7 – 3.0 TIU mg^{-1}), total and soluble oxalate (21 – 35 and 3 – 6 mg 100 g^{-1}, respectively), tannin (0.9 – 20 mg g^{-1}), phytic acid (4.5 – 7.3 mg g^{-1}) and α-galactosides (2.3 – 3.4 g 100 g^{-1}). Cyanogenic glycoside was very high in the white seeds (225 mg kg^{-1}). These results demonstrate that significant differences exist in the antinutrient contents of the three varieties ($p<0.05$), especially for cyanogenic glycosides.

Table 1 shows the effect of traditional cooking (in water) on the removal of α-galactosides from seeds of African yambean and other species. Traditional cooking is effective in this respect for certain bean species but inappropriate for African yambeans.

Table 1: Efficacy of cooking in water to reduce α-galactosides from African yambean and other legume species. The traditionally recommended cooking time is given in parentheses.

	African yambean (4 h)	Cow pea* (45 min)	Faba bean** (60 min)	Lentil** (60 min)	White bean** (60 min)
Proportion of α-galactosides removed (%)	17.5	100	42.0	46.3	47.2

* (IBRAHIM ET AL, 2002), **(ABDEL-GAWAD ET AL, (1993)

Lactic acid fermentation of ground seeds using *Lactobacillus plantarum* and tempeh-type solid substrate fermentation using *Rhizopus oligosporus* were probed. The effects on nutritional quality were compared with that of traditional cooking for 4 hours.

Fermentation with *Lactobacillus plantarum* resulted in an improvement of the nutritional quality: protein was increased by 6 – 20 %, dietary fiber was decreased correspondingly. *In vitro* protein digestibility was slightly increased ($P>0.05$). The flatulence causing α-galactosides, and the potentially highly toxic cyanogenic glycosides, were reduced by about 85%. Lactic acid fermentation was clearly more effective than the traditional cooking in reducing the flatulence potential (oligosaccharides). The reduction in trypsin and α-amylase inhibitor activities and tannin was marked. Significant phytic acid reduction was observed only with the black seeds.

Fermentation with *Rhizopus oligosporus* resulted in nearly complete removal of the α-galactosides, *i. e*., the flatulence potential dropped to almost nil (Table 2). Cyanogenic glycoside content in white seeds fell to about 50 %, which is however still relatively high a level (104 mg kg^{-1}). Enzyme inhibitor activity was absent, tannin content dropped to 20 % or nil. Phytic acid reduction was also near complete with black and marble seeds but less effective with white seeds. Fungal growth was visibly inhibited with white seeds.

Table 2: Flatulence potential (ml gas 200 g-1) of AfricanYambean using different methods of processing

Processing	Flatus potential
Raw beans	350
Rhizopus-fermentation	6
Lactic acid fermentation	26
Cooking for 4 hours	278

A modified tempeh procedure using 1 % citric acid was introduced. This tempeh was hygienically excellent. Fungal growth with the white variety was greatly improved, and no cyanogenic glycosides were detected (Table 3). Unfortunately, oligosaccharide content was not decreased significantly with the modified procedure. Yet both tempeh procedures were clearly more effective in improving nutritional quality than was traditional cooking.

Table 3: Cyanogenic glycosides in African yambean (white seeds) using different methods of processing

Processing	Cyanogenic glycosides
	(mg HCN equiv. kg)$^{-1}$)
Raw beans	225 ± 12
Dehulled beans	105± 6
Rhizopus-fermentation	Not detected
Cooking for 4 hours	47± 4

Energy requirements were estimated by calculations. With both lactic acid and *Rhizopus*-fermentation (tempeh), energy requirement was a mere 13 and 25 % of that of traditional cooking (Table 4).
In conclusion, fermentation can substantially improve the nutritional quality of African yambean and, at the same time, provide important economical and environmental benefits. Both processes are proposed for application in the household or in small-scale industries.

Table 4: Energy consumption to make a palatable food from 1 kg African yambeans using the traditional cooking method compared with lactic acid fermentation or Rhizopus-fermentation.

Processing	Recommended cooking time	Kerosene consumption	Energy cost
	(h)	(liter)	(euro)
Traditional cooking	5	4	1,0
Rhizopus-fermentation	1	0.8	0.2
Lactic acid-fermentation	0.5	0.4	0.1

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