Food Chemistry 36 (1990) 271–280

Some Aspects of the Biochemistry and Nutritive Value of African Yambean Seed (*Sphenostylis stenocarpa*)

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(Received 17 April 1989; revised version received and accepted 31 July 1989)

ABSTRACT

*The proximate and mineral compositions, amino acid profile and the quality of the protein of three varieties of African yambean (*Sphenostylis stenocarpa*) seed, in the raw, autoclaved and cooked forms, were assessed. The average crude protein, crude fibre and ash values of the raw yam bean were 23·3%, 4·9% and 3·9%, respectively. Mineral concentrations, on dry weight basis, were: 3·3–4·2 g kg^{-1} for P; 0·70–0·80 g kg^{-1} for Ca; 1·3–1·7 g kg^{-1} for Mg; 9·7–12·0 g kg^{-1} for K; 0·04–0·06 g kg^{-1} for Na; 27·8–46·2 mg kg^{-1} for Mn; 38·2–44·0 mg kg^{-1} for Zn; 52·0–63·0 mg kg^{-1} for Fe and 8·1–11·8 mg kg^{-1} for Cu. The amino acid composition of the protein indicated lysine, 7·38–8·09 g/16 gN; tryptophan, 1·21–1·26 g/16 gN and methionine + cystine, 3·08–3·45 g/16 gN to be above, or close to, the values recommended by FAO/WHO. Cooked yam bean seeds contained relatively lower amounts of the nutrient components determined. Significant differences ($P < 0·05$) between raw, autoclaved and cooked seeds were found for the protein quality indices. The findings are discussed in terms of the nutritional potential for this resource for man and livestock.*

INTRODUCTION

In the world's widening search for cheap sources of protein-rich foods, increasing attention has been focused on home-grown legume crops whose seeds contain relatively high amounts of proteins that can be used to improve the diets of the vast majority of the people. Among the locally grown legumes, the cowpea, groundnut and, to a lesser extent, soybean, are

Food Chemistry 0308-8146/90/$03·50

already popular in different parts of Nigeria as staple foods. There are several other important, but lesser known, legumes which are also consumed by the people.

The African yam bean (*Sphenostylis stenocarpa*), a climbing legume with exceptional ability for adaptation to lowland tropical conditions, is one of these lesser-known legumes. It is widely grown in southern Nigeria and produces a nutritious seed, as well as edible tubers. The ripe pods vary between 120 and 300 mm in length and contain from 10 to 30 seeds, with crude protein levels varying from 21 to 26% (Evans & Boulter, 1974).

Although the African yam bean represents a less expensive source of dietary protein among Nigerians of low economic status, very little is known about its nutritional potential. The present study was undertaken to determine the biochemical composition and nutritive quality of the protein of African yam bean.

MATERIALS AND METHODS

Origin, preparation and storage of samples

Three varieties of the African yam bean samples, viz: Sumunu-Iseyin I (purple), Sumunu-Iseyin II (grey) and Sumunu-Iseyin III (mottled) were obtained from local farmers around Iseyin and Shaki in Oyo State, Nigeria. A suitable quantity (2 kg) of each variety was subjected to autoclaving and cooking treatments. Preliminary investigations were carried out to establish cooking time for the individual varieties of beans, i.e. the time required to achieve no further increase in weight of the strained yam beans after holding in cold or boiling water, respectively. The cooking times ranged from 2·75 to 3·25 h (mean = 3 h) and, by then, the weight of the seeds had more than doubled.

Autoclaved seeds

The dry seeds were first milled in the raw form and then autoclaved at 105°C at 1·2 kg/cm^2 pressure for 30 min.

Cooked seeds

The dry seeds were added to boiling water (five times the volume of dry seeds), in a cooking pot and heated for their required cooking time. Cooked seeds were dried in a hot air oven at 55°C.

The raw and cooked seeds were milled in a Wiley press to pass through a

0·5 mm sieve and, along with the milled autoclaved samples, were separately stored in a sealed Kilner jar, labelled and kept in a deep freezer (−4°C) until required for feeding and chemical analysis.

Analytical procedure

All the analyses were done in duplicate and the results were expressed on a dry matter basis. The proximate compositions of the samples were determined by AOAC (1975) methods. Mineral contents were determined by, first wet-ashing the samples with a mixture of perchloric and nitric acids, followed by flaming in a Perkin–Elmer atomic absorption spectrophotometer 290, using different lamps. Phosphorus was determined colorimetrically by the phosphovanadomolybdate method (AOAC, 1975).

Amino acid analysis

The total amino acid composition was determined by the column chromatographic technique, using the automated Hitachi Perkin–Elmer amino acid analyser after hydrolysing 100 mg of each sample in a sealed tube *in vacuo* with 6N HCl at 110°C for 22 h. Tryptophan was determined chemically by the method of Miller (1967).

Biological evaluation of protein quality

Forty-four weanling male albino rats of the Wistar strain, weighing 50–55 g and approximately 4 weeks of age, were obtained from the University of Ibadan teaching and research farm rat colony. They were, thereafter, divided into eleven groups of four rats each on the basis of initial weight and litter origin. The rats were individually housed in perforated perspex cages with facilities for separate faecal and urinary collection.

The composition of the basal diet is shown in Table 1. The protein sources to be evaluated were added at the expense of maize starch to give 10% crude protein on a dry matter basis. Nutritional casein diet was used as the reference standard. One group of four rats was given the N-free basal diet, and the remaining ten groups were randomly allocated to the test and standard diets.

The rats were offered water and diets *ad libitum* for 10 days. Records were kept of the weight gains and total food intake. A 6-day (i.e. days 4–10) faecal and urine collection was made for rats during the trial. The urine from each cage was collected in small urine cups containing 3 cm^3 of 1·0M sulphuric acid as preservative, each day's collection being stored in screw-capped bottles at −4°C. Faecal samples were collected daily, bulked for each rat,

TABLE 1
Percentage Composition of the Basal Nitrogen-Free Diet given to the Rats

Ingredients	*Percentage*
Maize starch	65·0
Glucose	5·0
Cellulose	5·0
Sucrose	10·0
Groundnut oil	10·0
Mineral supplement[a]	4·0
Vitamin mixture[a]	1·0

[a] Miller (1963).

weighed, dried and stored. Duplicate samples of urine, faeces and diets were taken for nitrogen determination.

Based upon the nitrogen balance data, the following definitions of the methods of protein assessment were used:

Protein efficiency ratio (PER)

$$= \frac{\text{g gain in body weight}}{\text{g protein intake}} \quad \text{(NAS/NRC, 1963)}$$

Net protein ratio (NPR)

$$= \frac{\text{weight gain of test-protein group} + \text{weight loss of the N-free diet group}}{\text{protein intake}}$$

(Bender & Doell, 1957)

True digestibility of nitrogen (TD)

$$= \frac{I-(F-M)\times 100}{I} \quad \text{(Dreyer, 1968)}$$

Biological value (BV)

$$= \frac{I-(F-M)-(U-E)}{I-(F-M)} \quad \text{(Phillips } et\ al.\text{, 1981)}$$

Net protein utilisation (NPU)

$$= \frac{I-(F-M)-(U-E)\times 100}{I} \quad \text{(Phillips } et\ al.\text{, 1981)}$$

where I = nitrogen intake (mg);
F = nitrogen excreted in faeces (mg);
M = metabolic faecal nitrogen (from basal diet) (mg);
U = nitrogen excreted in urine (mg);
E = endogenous urinary nitrogen (from basal diet) (mg).

Statistical analysis

Data were subjected to the analysis of variance (Steel & Torrie, 1960), and significant differences between treatment means were determined by the multiple range test of Duncan (1955).

RESULTS AND DISCUSSION

Biochemical composition

The proximate chemical compositions of raw, autoclaved and cooked African yam bean seeds are presented in Table 2. Crude protein contents in the raw seeds of the three varieties ranged between 22 and 24%, and are therefore comparable to protein levels in cashew nut and bambara

TABLE 2
Proximate Composition of Raw and Processed African Yam Bean Varieties (% dry matter)

Yam bean varieties	*Dry matter*	*Crude protein ($N \times 6{\cdot}25$)*	*Crude fibre*	*Ether extract*	*Total ash*	*N-free extract*
Sumunu-Iseyin I (purple)						
Raw	89·4	23·8	4·7	2·4	3·8	65·3
Cooked	86·6	22·1	4·5	2·3	3·5	67·6
Autoclaved	88·7	23·6	4·6	2·6	3·8	65·4
Sumunu-Iseyin II (grey)						
Raw	90·4	23·4	4·9	2·8	4·2	64·7
Cooked	88·2	22·7	4·6	2·4	3·9	66·4
Autoclaved	89·8	23·5	5·1	2·9	4·1	64·4
Sumunu-Iseyin III (mottled)						
Raw	92·3	22·6	5·3	3·1	3·6	65·4
Cooked	90·0	20·9	4·9	2·6	2·9	68·7
Autoclaved	92·1	22·4	5·2	3·0	3·4	66·0

groundnut (21%), pigeon pea and lima bean (24%), groundnuts and cowpeas (25%), but much lower than that in soybean (38%) (Oyenuga, 1968). The levels of crude fibre, ether extract, total ash and N-free extract were similar in all the raw samples, while lower values were obtained for the cooked samples, thus indicating the loss of water-soluble nutrients during the process of cooking.

Mineral composition (Table 3) of the raw African yam bean showed slight varietal differences. Potassium was the most abundant macro-mineral, followed by phosphorus. Sodium and calcium levels were generally low in all the varieties. The values for calcium (Ca), magnesium (Mg), sodium (Na), phosphorus (P) and potassium (K) contents were 0·70–0·80 g kg^{-1}, 1·3–1·7 g kg^{-1}, 0·04–0·06 g kg^{-1}, 3·3–4·2 g kg^{-1} and 9·7–12·0 g kg^{-1}, respectively. The levels of micro minerals were, however, higher in Sumunu-Iseyin I (purple) than in Sumunu-Iseyin III (mottled). The latter contained 46·2 mg kg^{-1}, 40·1 mg kg^{-1}, 63·0 mg kg^{-1} and 11·8 mg kg^{-1} of manganese (Mn), zinc (Zn), iron (Fe) and copper (Cu), respectively. These results reveal African yam bean as a fairly good source of some essential minerals.

Bressani and Elias (1974) reported values of 0·10% for calcium and 0·30% for phosphorus in edible leguminous seeds, and they were classified as poor sources of these two essential minerals. The value reported for phosphorus in the present study showed that all varieties had their contents above 0·30%. However, the potential of any legume as a source of mineral elements

TABLE 3
Mineral Composition of Raw and Processed African Yam Bean Varieties

Yam bean varieties	*Macro-minerals ($g\,kg^{-1}$ dm)*					*Micro-minerals ($mg\,kg^{-1}$ dm)*			
	Ca	*P*	*Na*	*K*	*Mg*	*Mn*	*Zn*	*Fe*	*Cu*
Sumunu-Iseyin I (purple)									
Raw	0·80	4·2	0·05	11·7	1·7	46·2	40·1	63·0	11·8
Cooked	0·60	4·0	0·03	9·2	1·4	42·8	37·5	56·4	9·7
Autoclaved	0·71	3·9	0·06	10·4	1·5	46·3	41·0	60·2	10·1
Sumunu-Iseyin II (grey)									
Raw	0·70	3·5	0·04	12·0	1·6	27·8	44·0	52·0	8·6
Cooked	0·56	3·1	0·02	8·7	1·3	25·3	43·7	43·7	8·0
Autoclaved	0·70	3·4	0·03	10·8	1·5	27·4	44·3	49·9	9·3
Sumunu-Iseyin III (mottled)									
Raw	0·74	3·3	0·06	9·7	1·3	34·3	38·2	58·1	8·1
Cooked	0·61	3·0	0·04	5·8	1·0	31·7	35·4	44·5	7·7
Autoclaved	0·69	3·6	0·05	9·1	1·4	33·9	37·8	59·0	9·0

depends on the availability rather than the total content. It is known that the bioavailability of divalent minerals, especially calcium, phosphorus, magnesium and manganese, is adversely affected by phytic acid (Nwokolo & Bragg, 1977), and if the raw seed is rich in this acid, it could reduce, significantly, the overall availability of these minerals.

Cooked African yam bean contained lower percentages of minerals than raw beans. Decrease in mineral content of seeds after cooking was also observed by Meiners *et al.* (1976), and it is likely that the decrease was due to the leaching of minerals during the cooking process.

The amino acid composition of the three varieties of African yam bean and the FAO/WHO reference pattern are compared in Table 4. As reported by previous investigators (Oyenuga, 1966; Evans & Boulter, 1974), all the varieties studied were deficient primarily in methionine but rich in lysine, leucine and isoleucine. The Sumunu-Iseyin II (grey) seed lysine content of 8·09 g/16 g N was 2·7 times as high as in the groundnut (3·04 g/16 g N) and 1·3 times as high as in the soybean meal (6·22 g/16 g N) (Mba *et al.*, 1974). The

TABLE 4
Amino Acid Composition of the Protein of Raw African Yam Bean Varieties

Amino acid	*Amino acid (g/16 gN)*			
	Sumunu-Iseyin I (purple)	*Sumunu-Iseyin II (grey)*	*Sumunu Iseyin III (mottled)*	*FAO/WHO (1973)*
Essential				
Isoleucine	4·43	4·47	4·42	4·0
Leucine	7·45	7·61	7·80	7·0
Lysine	7·98	8·09	7·38	5·5
Methionine	1·17	1·08	1·18 }	3·5
Cystine	1·99	2·00	2·27 }	
Phenylalanine	5·43	5·53	5·72 }	6·0
Tyrosine	4·43	4·50	4·19 }	
Threonine	4·20	3·93	3·78	4·0
Tryptophan	1·26	1·21	1·24	1·0
Valine	5·48	5·72	4·97	5·0
Non-essential				
Aspartic acid	10·95	11·10	9·87	
Glutamic acid	14·02	14·18	13·80	
Alanine	4·40	4·60	4·21	
Arginine	5·88	6·39	5·35	
Glycine	4·23	4·46	4·10	
Histidine	4·00	4·33	4·08	
Proline	4·72	4·47	4·97	
Serine	5·83	4·96	6·48	

TABLE 5
Nutritive Value of Raw and Processed African Yam Bean Varieties together with Standard Casein Diet

Diets	*Weight gain in 10 days (g)*	*Food intake in 10 days (g)*	*Protein intake in 10 days (g)*	*PER*	*NPR*	*NPU (%)*	*BV (%)*	*Apparent digestibility (%)*	*True digestibility (%)*
Raw									
Sumunu-Iseyin I (purple)	−3·1	41·4	4·23	−0·73	1·37	17·5	29·2	56·4	59·1
Sumunu-Iseyin II (grey)	−3·9	40·5	4·14	−0·94	1·20	16·2	28·3	53·7	57·0
Sumunu-Iseyin III (mottled)	−3·4	42·0	4·29	−0·79	1·31	17·4	30·0	52·9	58·3
Mean	−3·5*	41·3*	4·22***	−0·82***	1·29**	17·0*	29·2*	54·3**	58·1**
SE of means	±0·82	±0·58	±0·07	±0·06	±1·05	±0·04	±0·09	±0·95	±0·50
Cooked									
Sumunu-Iseyin I (purple)	7·3	51·7	5·18	1·41	3·13	38·0	49·7	67·8	76·4
Sumunu-Iseyin II (grey)	6·9	50·1	5·04	1·40	3·12	36·5	48·8	66·9	75·7
Sumunu-Iseyin III (mottled)	7·7	53·2	5·35	1·44	3·26	40·7	51·3	69·1	79·5
Mean	7·3**	51·7**	5·19**	1·42**	3·17***	38·4**	49·9***	67·9***	77·2***
SE of means	±1·72	±1·01	±0·09	±0·02	±0·05	±1·42	±0·81	±1·01	±0·45
Autoclaved									
Sumunu-Iseyin I (purple)	8·2	50·6	5·29	1·55	3·32	39·2	50·2	69·4	78·5
Sumunu-Iseyin II (grey)	6·6	49·4	5·13	1·30	3·02	34·5	47·1	65·8	73·4
Sumunu-Iseyin III (mottled)	7·3	50·9	5·17	1·39	3·15	36·5	48·6	66·3	75·0
Mean	7·3**	50·3**	5·20**	1·41**	3·16***	36·7**	48·6**	67·1***	75·6***
SE of means	±1·04	±0·31	±0·03	±0·10	±0·07	±1·21	±0·97	±1·05	±0·97
Casein	18·7***	71·4***	7·28*	2·57*	4·20*	68·4***	72·0***	88·1*	95·2*

Mean values under a stated parameter with unlike superscripts were significantly different at the 0·05 level of probability based on Duncan's multiple range test (Duncan, 1955).

high content of this amino acid will likely increase the use of African yam bean as an important protein source for human diets and could also provide an alternative source of lysine to that of soybeans in livestock feeds.

Nutritive value

The results (Table 5) of the biological trial with rats showed that raw yam bean did not support growth and gave significantly ($P < 0{\cdot}05$) lower feed intake, protein intake, PER, NPR, NPU, BV, apparent digestibility and true digestibility values than did processed African yam bean and casein diets. This poor nutritive value could be ascribed to the occurrence of natural constituents which adversely affect protein utilisation. These include protease inhibitors, haemagglutinins, saponins, tannins and phytates (Kakade, 1974; Liener & Kakade, 1980), which are known to be present in legumes.

Heat treatment improved protein quality of the yam beans although protein efficiency and utilisation values obtained were rather low compared to the values obtained for casein ($P < 0{\cdot}05$). The comparatively lower nutritive values of autoclaved and cooked yam bean were partly due to methionine deficiency and partly to the anti-nutritional effects of factors not denatured by heat. Nevertheless, when African yam bean is consumed in combination with other cereal-based diets, as is normally done by some local communities in Nigeria, it could improve the dietary well-being of these people.

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