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Biochemical evaluation of some Nigerian legume seeds

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Two varieties each of bambara groundnut (*Voandzeia subterranea* (L.) Thouars), kidney bean (*Phaseolus vulgaris* L.), lima bean (*Phaseolus lunatus* L.), pigeon pea (*Cajanus Cajan* (L.) Millsp) and one variety of jack bean (*Canavalia ensiformis* (L) DC.) seeds grown in Nigeria were investigated for their proximate composition, mineral and amino acid contents, in the raw, cooked and autoclaved forms.

The crude protein of all raw legume seeds varied from 20·6 to 27·7%, crude fibre 3·2–9·5%, ether extract 1·3–6·7% and ash 3·0–4·8%. Potassium was the most abundant mineral, ranging from 9·9 g/kg in jack bean to 16·4 g/kg in lima bean TPL 88. Phosphorus was also appreciably high while sodium concentration was low. Iron contents were highest in kidney beans. The amino acid profile of the protein showed a consistent deficiency of methionine + cystine. Tryptophan was also limiting in pigeon peas while bambara groundnuts were borderline with regards to threonine. The lysine content of kidney bean pondo-6 was notably high compared with others. Cooked legume seeds contained relatively lower amounts of nutrient constituents assayed. The implications of these findings are fully discussed.

INTRODUCTION

Protein foods, particularly animal proteins, have continued to be in short supply in the diets consumed by a large segment of the population in developing countries. In many of these countries like Nigeria, traditional sources of animal proteins obtained from game or wild animals as well as the domestic production of animal products are prohibitively expensive. Legumes are some of the low-priced sources of protein-rich foods that have been important in alleviating protein malnutrition (Aykroyd *et al.*, 1982). Accordingly, the compositional evaluation of leguminous seeds such as soybean, cowpea, groundnut, chickpea and red gram have been carried out in different locations by many investigators (Mba *et al.*, 1974; Ologhobo and Fetuga, 1982, 1984; Newman *et al.*, 1987; Singh *et al.*, 1990).

Despite the large number of existing grain legumes in Nigeria, their consumption as staple foods has centred mainly on cowpea and groundnut. Several other locally available species like the bambara groundnut, kidney bean, lima bean, pigeon pea and jack bean which show remarkable adaptation to tropical conditions are less commonly used by the people. This is ostensibly due to lack of adequate information on their nutritional potentials. Recently, however, because of the severity of the protein deficit, together with the drive to exploit the full potentials of home-grown legume seed crops, considerable interest has been aroused on the utilization of these relatively neglected legume sources for human food and as livestock feed components.

This paper reports part of a series of systematic investigations undertaken to determine the biochemical composition of some legume seeds cultivated in Nigeria.

MATERIALS AND METHODS

Nine different kinds of legume seeds were used in this study. These included two varieties each of bambara groundnut (*Voandzeia subterranea* (L.) Thouars), kidney bean (*Phaseolus vulgaris* L.), lima bean (*Phaseolus lunatus* L.), pigeon pea (*Cajanus cajan* (L.) Millsp) and

Table 1. General appearance of the legume seeds analysed

Kind of legume	Seed colour	Seed coat-texture	Seed shape
Bambara groundnut (*Voandzeia subterranea*)			
KAB-3	Light brown; white hilum	Glossy	Round
Oturkpo local	Light brown with black strips; white hilum	Glossy	Round
Kidney bean (*Phaseolus vulgaris L.*)			
Pondo-6	Red with irregular white strips	Glossy	Very flat, kidney-shaped
Yara-1	White	Smooth	Flat kidney-shaped
Lima bean (*Phaseolus lunatus L.*)			
TPL 88	Red-brown	Glossy	Round-oval
TPL 249	White grey; black eyed	Glossy	Kidney-shaped
Pigeon pea (*Cajanus cajan (L.) Millsp*)			
Ex-Ibadan	Ash grey; light brown-eyed	Smooth	Round-oval
TUc 5537-1	Dark brown; black eyed	Smooth	Round-oval
Jack bean (*Canavalia ensiformis (L.) DC*)	White; dark brown-eyed	Glossy	Large, round-oval

one variety of jack bean (*Canavalia ensiformis* (L.) DC). The shape, colour and texture of these legumes are given in Table 1. The seeds were purchased from local markets located mainly in Iseyin and Offa, Nigeria. Legumes of each type were divided into three different batches of 1 kg. Two of such different batches were subjected to cooking and autoclaving treatments while the third batch was not treated. The procedures for both heat-treatments and preparation of raw, cooked and autoclaved samples were similar to those employed in a previous publication (Apata and Ologhobo, 1990).

Analytical procedure

Proximate analyses were carried out on air-dried samples according to standard methods (AOAC, 1984). The mineral constituents were determined by first wet-ashing 2 g each of the samples with a mixture of nitric acid, perchloric and sulphuric acids, followed by flaming in an atomic absorption spectrophotometer 290, using different lamps. Phosphorus was determined colorimetrically by the phosphovanadomolybdate method (AOAC, 1984).

Amino acid analysis

The amino acid compositions were determined by hydrolysing 100 mg of each sample with 10 ml of 6 N HCl in a sealed pyrex tube *in vacuo* at 110°C for 22 h, using the automated Hitachi Perkin-Elmer amino acid analyser. Cystine was determined as cysteic acid by the method of Moore (1963) while tryptophan was chemically determined by the method of Miller (1967). All the assays were performed in duplicate.

RESULTS AND DISCUSSION

Proximate chemical composition

The chemical compositions of raw, autoclaved and cooked legume seeds are presented in Table 2. The crude protein contents in the raw seeds ranged from 20·6% in bambara groundnut KAB-3 to 27·7% in jack bean. This range of protein levels did not differ appreciably from those previously reported for other varieties of bambara groundnut (Doku *et al.*, 1978), jack bean (Molina *et al.*, 1974), pigeon pea, lima bean (Luse, 1979) and several legume types including the cowpea, groundnut and lablab bean (Oke, 1967; Aletor and Aladetimi, 1989) but was lower than the soybean (Ologhobo and Fetuga, 1984). The remarkably high level of protein in the legumes under study underscores their importance as sources of this vital nutrient.

Ether extract gave a mean value of 3·1% which was rather low, thus limiting the contribution of the seeds as sources of edible oil. Jack bean contained much more crude fibre (9·5%) than the other leguminous seeds where values were in the range of 3·2–5·4%, indicating that the digestibility of associated nutrients in jack bean by monogastric animals is likely to be comparatively lower than in other seeds. The total ash contents of the seeds were in general agreement with those reported for other legumes (Platt, 1980).

The levels of proximate components in all the autoclaved samples were similar to values obtained for raw samples, while cooked samples has lower values possibly owing to the loss of water-soluble nutrients during the cooking process.

Mineral composition

The mineral contents of the raw and processed legume seeds are shown in Table 3. Of all the macro-minerals in the raw seeds potassium (K) was the most abundant, ranging from 9·9 g/kg in jack bean to 16·4 g/kg in lima bean TPL 88, followed by phosphorus (P) with values ranging from 2·4 g/kg in bambara groundnut KAB-3 to 4·6 g/kg in pigeon pea TUC 5537-1, and magnesium (Mg) between, 1·4 in jack bean and 2·2 g/kg in kidney bean pondo-6. Sodium (Na) and calcium (Ca) levels were generally low in all the legumes with mean values of 0·05 g/kg and 0·94 kg, respectively. Among the micro-minerals, manganese (Mn) concentrations ranged between 15·6 in jack bean and 26·5 mg/kg in kidney

Table 2. Proximate composition[a] of raw and processed legume seeds (% dry matter)

Kind of legume	Dry matter	Crude protein (N × 6·25)	Crude fibre	Ether extract	Total ash	N-free extract
Raw						
Bambara groundnut, KAB-3	91·1	20·6	3·2	6·7	3·5	66·0
Oturkpo local	92·4	21·4	3·4	6·4	3·8	65·0
Kidney bean, Pondo-6	92·5	21·8	4·0	1·4	4·6	68·2
Yara-1	93·3	22·4	4·5	1·9	4·2	67·0
Lima bean, TPL 88	92·3	22·5	5·4	1·3	3·9	66·9
TPL 249	92·8	23·7	4·5	2·6	4·8	64·4
Pigeon pea, Ex-Ibadan	91·6	22·3	4·8	2·8	3·9	66·2
TUc 5537-1	93·5	22·7	4·4	2·4	3·7	66·8
Jack bean	89·8	27·7	9·5	2·5	3·0	57·3
Mean	92·1	22·8	4·9	3·1	3·9	65·3
Standard deviation	1·30	1·84	1·76	1·80	0·51	2·92
Cooked						
Bambara groundnut, KAB-3	88·7	18·8	2·9	6·3	3·0	69·0
Oturkpo local	90·1	19·8	3·2	5·9	3·5	67·6
Kidney bean, Pondo-6	89·7	20·9	3·8	1·0	4·3	70·0
Yara-1	91·0	21·6	4·1	1·7	4·0	68·6
Lima bean, TPL 88	90·0	21·1	5·0	0·9	3·5	69·5
TPL 249	92·5	22·6	4·2	2·5	4·3	66·4
Pigeon pea Ex-Ibadan	87·0	21·1	4·4	1·9	2·9	69·7
TUc 5537-1	91·2	20·9	3·9	2·1	3·5	69·6
Jack bean	86·1	25·6	9·2	2·0	2·1	61·1
Mean	89·6	21·4	4·5	2·7	3·5	67·9
Standard deviation	2·03	1·75	1·64	1·76	0·67	2·45
Autoclaved						
Bambara groundnut, KAB-3	92·9	20·2	3·0	6·6	3·4	66·8
Oturkpo local	91·3	21·6	3·3	6·5	3·8	64·8
Kidney bean, Pondo-6	92·1	21·8	4·2	1·6	4·7	67·7
Yara-1	92·4	23·2	4·3	2·0	4·1	66·4
Lima bean, TPL 88	92·2	21·2	5·2	1·1	4·0	68·5
TPL 249	94·1	23·5	4·4	2·7	4·7	64·7
Pigeon pea, Ex-Ibadan	91·2	22·0	4·6	2·8	3·7	66·9
TUc 5537-1	93·0	22·4	4·2	2·3	3·9	67·2
Jack bean	89·4	27·9	9·7	2·6	2·8	57·0
Mean	92·1	22·6	4·8	3·2	3·8	65·6
Standard deviation	1·68	1·97	1·72	1·69	0·56	2·01

[a] Average of duplicate analysis.

bean Yara-1. The highest level of iron (Fe) was obtained in kidney bean pondo-6 (74·1 mg/kg). Pigeon pea (Ex-Ibadan) contained 38·3 and 12·4 mg/kg, respectively, of zinc (Zn) and copper (Cu).

The results show that these legume types would constitute a valuable source of some essential minerals and the values obtained are comparable with reports on other tropical legumes such as the African locust bean, groundnut (Oyenuga, 1968) and cowpea (Jagadi *et al.*, 1987). However, compared with the Mexican jack bean (D'mello *et al.*, 1985) and North American kidney bean (Meiners *et al.*, 1976), the levels for phosphorus, iron and manganese were higher in the current study. Such variation in the content of minerals for the same legume species may be related to genetic origin, geographical source and the level of soil fertility.

The low calcium contents, with correspondingly high phosphorus contents in all the raw seeds, reflect the disproportionate distribution of calcium and phosphorus that may affect their utilization for ideal growth and bone formation. This effect might even be worsened by the presence of phytate which has been shown to reduce the availability of calcium and phosphorus in these legume seeds (Apata and Ologhobo, 1989). Since the preparation of legume meals by some communities in Nigeria involves the addition and mixing of a variety of nutritious condiments, the existing imbalance ratio in the legumes could be offset.

The very low amounts of sodium in the legume seeds is good for health because of the relationship that low sodium diet has to hypertension in humans (Dahl, 1972).

All the cooked legumes had lower mineral concentrations than raw legumes. Aletor and Ojo (1989) have also observed a decrease in the mineral constituents of seeds after cooking, and it is likely that the decrease was due to leaching of minerals on account of the enhanced permeability of the seed coat by the process of cooking. Values for autoclaved legumes were only slightly different from the raw legumes; thus autoclaving appeared to have marginal effects on the mineral composition of these legumes.

Table 3. Mineral composition[a] of raw and processed legume seeds

	Macro-minerals (g/kg DM)					Micro-minerals (mg/kg DM)			
	Ca	P	Na	K	Mg	Mn	Zn	Fe	Cu
Raw									
Bambara groundnut, KAB-3	0·88	2·4	0·05	14·3	1·9	16·7	29·2	43·5	3·1
Oturkpo local	0·82	2·7	0·04	12·2	1·7	18·4	26·7	41·6	5·4
Kidney bean, Pondo-6	0·83	4·5	0·06	10·5	2·2	22·8	34·6	74·1	8·1
Yara-1	0·79	4·3	0·05	11·9	1·9	26·5	28·9	67·8	6·7
Lima bean, TPL 88	0·68	4·4	0·06	16·4	1·8	23·1	30·0	57·2	4·9
TPL 249	0·77	3·9	0·07	13·9	1·5	18·7	27·5	61·4	7·3
Pigeon pea, Ex-Ibadan	1·24	4·3	0·05	12·8	1·6	20·9	38·3	47·8	12·4
TUc 5537-1	1·13	4·6	0·04	15·0	2·0	17·2	35·6	55·3	11·7
Jack bean	1·32	3·4	0·07	9·9	1·4	15·6	27·0	48·7	7·8
Mean	0·94	3·8	0·05	13·0	1·6	20·0	30·9	55·3	7·5
Standard deviation	0·21	0·75	0·01	2·01	0·23	1·95	1·01	1·20	3·02
Cooked									
Bambara groundnut, KAB-3	0·79	2·2	0·04	11·7	1·5	14·9	26·5	48·1	2·2
Oturkpo local	0·75	2·1	0·03	12·4	1·2	15·7	27·4	38·5	4·7
Kidney bean, Pondo-6	0·80	4·1	0·04	7·8	1·9	21·0	32·1	69·3	7·7
Yara-1	0·65	3·9	0·02	9·0	1·4	22·9	25·6	64·4	5·9
Lima bean, TPL 88	0·59	4·2	0·04	12·9	1·7	21·5	26·8	50·6	4·7
TPL 249	0·64	3·2	0·04	10·0	1·0	16·3	25·9	57·4	6·8
Pigeon pea, Ex-Ibadan	1·12	4·1	0·03	11·1	1·7	19·4	35·4	44·3	10·0
TUc 5537-1	0·95	3·9	0·01	13·3	1·8	13·6	31·7	53·0	11·2
Jack bean	1·05	2·8	0·04	8·3	1·2	13·8	24·9	52·1	6·2
Mean	0·82	3·4	0·03	10·7	1·5	17·7	28·5	53·1	6·6
Standard deviation	0·19	0·78	0·01	1·95	0·25	1·64	0·73	1·40	2·64
Autoclaved									
Bambara groundnut, KAB-3	0·84	2·5	0·05	13·9	1·6	17·0	28·8	44·2	2·8
Oturkpo local	0·80	3·0	0·03	13·7	1·8	18·1	26·8	40·9	5·5
Kidney bean, Pondo-6	0·82	4·5	0·07	10·3	2·3	23·2	33·7	73·0	9·0
Yara-1	0·81	4·1	0·04	12·3	1·6	25·7	31·1	63·9	6·1
TPL 249	0·72	3·8	0·06	14·2	1·4	16·3	25·9	57·4	6·8
Lima bean, TPL 88	0·70	4·7	0·05	17·8	2·1	21·8	29·5	58·0	5·2
Pigeon pea, Ex-Ibadan	1·27	4·4	0·06	10·6	1·5	20·4	37·8	47·1	12·7
TUc 5537-1	1·12	4·2	0·03	14·7	2·1	16·8	36·2	57·2	9·4
Jack bean	1·20	3·3	0·07	9·7	1·3	15·2	27·9	49·6	8·1
Mean	0·92	3·9	0·05	13·2	1·7	19·3	30·8	54·6	7·3
Standard deviation	0·20	0·67	0·01	2·40	0·32	1·87	1·04	1·38	2·76

[a] Average of duplicate analysis.

Amino acid composition

Table 4 shows the total amino acid composition of the raw legume seeds and that of the FAO/WHO reference pattern. All seeds used in this study had relatively high non-essential and essential amino acids, with the exception of cystine and methionine. The methionine content of jack bean (1·47 g/16 g N) was slightly higher than that of other legume seeds. Threonine was particularly low in bambara groundnut KAB-3 (3·32 g/16 g N) while tryptophan appeared to be deficient in pigeon pean varieties but notably high in phenylalanine. Lysine levels ranged from 5·86 in pigeon pea TUC 5537-1 to 7·35 g/16 g N in kidney bean pondo-6.

The high content of lysine noted in these legumes supports the results of other investigators (Evans and Bendemer, 1967; Meredith and Thomas, 1982; Singh *et al.*, 1990), and the amount obtained for this amino acid in kidney bean pondo-6 is 2·4 times as high as in groundnut (3·04 g/16 g N) and 1·2 times as high as in the soybean meal (6·22 g/16 g N) (Mba *et al.*, 1974). Even the lowest value, as reported for a pigeon pea variety, exceeded the reference amino acid pattern. The importance of low-cost sources of plant protein high in lysine is readily understood when one views it against a background of its low content in cereals and cassava which form the bulk of the carbohydrate in the Nigerian diet. Cheap sources of lysine such as the legume seeds studied, are of primary importance to us for the successful feeding of our expanding population. This should be especially true if all of the lysine is available.

The observation of relatively low concentrations of methionine and cystine in legumes has been reported many times (Patwardhan, 1962; Owusu-Domfeh *et al.*, 1970; Apata and Ologhobo, 1990) and the consequent effects in the nutrition of humans and other monogastric animals have been reviewed by Millerd (1975). The data presented here also show that, apart from sulphur amino acids, which were in the shortest supply, tryptophan and threonine were second limiting in pigeon pea and bambara groundnut respectively. In practice, these deficiencies are unlikely to be serious

Table 4. Amino acid composition of the protein of raw legume seeds (g/16 g N)

Amino acids (g/16 g N)	Bambara groundnut		Kidney bean		Lima bean		Pigeon pea		Jack bean	FAO/ WHO (1973)	Mean
	KAB-3	Oturkpo local	Pondo-6	Yara-1	TPL 88	TPL 249	Ex-Ibadan	TUc55 37-1			
Essential											
Isoleucine	4·27	3·98	4·87	6·01	4·98	5·26	3·96	4·18	5·12	4·0	4·74(0·62)[a]
Leucine	7·82	7·59	8·63	8·38	8·71	8·37	8·04	7·43	9·07	7·0	8·23(0·56)
Lysine	6·57	6·83	7·35	6·71	6·67	6·90	6·82	5·86	6·56	5·5	6·70(0·46)
Methionine	1·38	1·29	1·19	1·32	1·38	1·24	1·37	1·42	1·47	3·5 (methionine + cystine)	1·34(0·11)
Cystine	1·51	1·40	1·06	1·18	1·05	0·98	1·24	1·06	0·89		1·15(0·38)
Tyrosine	3·61	3·37	3·97	4·46	3·42	4·02	3·73	3·97	4·15	6·0 (tyrosine + phenylalanine)	3·86(0·40)
Phenylalanine	5·69	5·25	5·75	5·26	7·31	6·46	8·62	8·11	5·97		6·49(1·18)
Threonine	3·32	3·78	4·56	5·07	4·28	4·45	4·12	3·84	4·37	4·0	4·20(0·46)
Tryptophan	1·31	1·19	1·44	1·12	1·21	1·03	0·86	0·94	1·02	1·0	1·12(0·17)
Valine	5·13	4·81	6·15	5·94	5·59	6·10	4·70	5·23	5·85	5·0	5·50(0·51)
Nonessential											
Aspartic acid	10·62	11·43	12·74	11·90	11·80	13·17	10·35	11·02	13·50	—	11·84(1·15)
Glutamic acid	17·01	16·60	13·85	14·26	19·10	15·90	17·32	16·48	14·81	—	16·15(1·64)
Alanine	4·29	4·74	4·37	4·61	4·98	6·20	6·17	5·45	4·95	—	5·08(0·67)
Arginine	6·43	7·16	6·25	5·56	7·31	6·24	6·48	7·20	6·90	2·0	6·61(0·51)
Glycine	3·64	3·82	5·11	4·26	6·10	5·13	4·15	3·86	4·63	—	4·52(0·70)
Histidine	3·17	2·94	2·64	3·20	2·53	3·01	3·08	3·19	4·56	2·4	3·15(0·67)
Proline	4·86	4·24	2·87	3·85	4·38	5·40	3·89	5·04	4·10	—	4·29(0·53)
Serine	5·07	5·26	5·16	4·39	5·71	6·88	4·58	4·43	7·01	—	5·39(0·90)

[a] Mean and standard deviation in parentheses.

limitations as relevant amino acid supplementation can be carried out when using these leguminous seeds, especially jack bean, in farm animal diets. Obviously, their utilization in this direction, as well as their increased use in human foods will go a long way in solving Nigeria's perennial protein-food shortage problem.

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