Nutritive value of the winged bean (*Psophocarpus palustris* Desv.)

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1. The winged bean (*Psophocarpus palustris* Desv.) has been grown successfully for several seasons, on an experimental basis, in the forest belt of Ghana, where earlier attempts to grow the soya bean had proved unsatisfactory.

2. Although botanically different, the composition of the dry seeds was found to be very similar to that of the soya bean, containing 37·3 % protein, 18·1 % fat, 13·9 ppm thiamin and 1·8 ppm riboflavin. The oil of the seeds contained 125·9 mg tocopherol ($\gamma+\beta$) per 100 g. The amino acid composition of the protein was very similar to that of the soya bean, with methionine as the first-limiting amino acid. The content of unsaturated fatty acids and that of polyunsaturated essential fatty acids were satisfactory.

3. Active trypsin inhibitor found in the raw seeds could be destroyed satisfactorily by moist heat. No urease activity was detected.

4. The protein efficiency ratio (PER) and net protein utilization (NPU) of the beans determined with rats, were superior to those of groundnuts. The supplementary value of the protein was shown by mixing two parts of the winged bean and three parts of maize flour. When adjusted to either 10 % or 16 % protein, the PER values of these mixtures were similar to those of skim milk. At the 16 % protein level, addition of skim milk or 0·3 % DL-methionine to this mixture produced only an insignificant improvement in PER value.

5. The pleasant, sweet taste even when in the raw state is one of the advantages of the winged bean. Although, it is a climber, and should be staked, its cultivation on a small scale in selected areas of Ghana is recommended.

The winged bean (*Psophocarpus palustris* Desv.), also known as four-angled bean, Goa bean, asparagus pea, averrhoea bean, murukavarai in India or see-kok-tau in China, has received little attention hitherto as a possible source of vegetable protein for supplementary feeding of children, although its content of protein and fat is known to be similar to that of the soya bean. According to Nicholls, Sinclair & Jelliffe (1961), the dry seeds of the winged bean contain 33% of protein and 16% of fat. It is the immature pods that are mostly used, but the seeds are sometimes eaten alone.

The winged bean, which is mainly grown in the warmer parts of Asia, has also been grown successfully for several seasons in Ghana at the Agricultural Research Station (University of Ghana), situated in the forest area at Kade. It is a perennial, climbing plant, needing, in general, a good supply of nutrients and water, and firm support.

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It has produced a good crop repeatedly at the station, where earlier attempts to plant several varieties of soya bean had been disappointing. The green pods containing the young seeds are tender, snap readily, and make an excellent vegetable similar to French beans. After drying, the pods become woody and only the seeds remain edible. For more details of the cultivation of this species see Pospíšil & Černý (1967).

The study described here was undertaken in order to obtain more information on some of the components of the dry seeds and to assess their nutritive quality by measuring the protein efficiency ratio (PER) and net protein utilization (NPU) in rats. The information thus obtained should be of value in future feeding trials with children suffering from protein-calorie malnutrition, in which the seeds of the winged bean are used as a vegetable-protein substitute for milk.

EXPERIMENTAL

Analyses of the winged bean

The following analyses were performed at the Food Industry Research Institute, Czech Academy of Agriculture, Prague. Protein was determined by the biuret method of Dische (1930), and fat by precipitation after extraction according to Folch, Lees & Stanley (1957). The amino acid composition of the protein was measured according to Spackman, Stein & Moore (1958) with the automatic amino acid analyser developed by the Czechoslovak Academy of Sciences. The fatty acid composition of fat extract was determined by gas chromatography (using a Czechoslovak Chrom I gas chromatograph) after transesterification by methanol according to Anson & Northrop (1936–7). Tocopherols were determined by the method of Blattná, Manoušková & Davídek (1967) and thiamin and riboflavin by that of Černá & Kočová (1966).

The presence of trypsin inhibitor was demonstrated by following the course of proteolysis of casein in the presence of samples of winged beans, by spectrophotometric measurement of the release of tyrosine and tryptophan using Folin's reagent (Folin & Ciocalteu, 1927). The method of Sumner & Somers (1949) was used to test for urease.

Composition of diets

Dry winged bean seeds were soaked in water for 24 h. Their coats were removed and the seeds were steamed in an autoclave for 30 min at 100° to inactivate possible antinutrient factors. The seeds were then dried at 55–60° in a cabinet dryer and ground into flour. Groundnuts were processed in the same way; however, owing to their fat content, the final product was not a flour but a paste. Whole-maize flour obtained from the local market and skim-milk powder of good quality were also used.

A series of diets was prepared in which the protein content was adjusted to a 10% level for assessing NPU and to a 10 or 16% level for assessing PER.

Five different diets with a 10% level of protein were studied. The protein was derived from skim milk, winged beans, or groundnuts, as well as from mixtures composed of two parts of either winged beans or groundnuts, and three parts of maize. Cod-liver oil was added to all diets at a level of 1% and the total fat contents were adjusted to 15% by the addition of groundnut oil. All diets included 10% sucrose and cassava starch as required to make up the total carbohydrate to 60%, and 2% of a mineral mixture (Hegsted, Mills, Elvehjem & Hart, 1941). When needed, cellulose was added to adjust the total mixture to 100%. The nitrogen-free diet was made up of 14% groundnut oil, 20% sucrose, 50% cassava starch, 8% cellulose, 2% mineral mixture and 1% cod-liver oil. All diets containing 10% protein provided 415 kcal/100 g.

Another six diets were studied in which the protein level was adjusted to 16%. The protein was derived from skim milk or winged beans, as well as from mixtures of two parts of either winged beans or groundnuts, and three parts of maize. These diets were also supplemented with cod-liver oil (1%) and with groundnut oil to bring their total fat content to 17%. To make up the total carbohydrate to 50%, 10% sucrose and cassava starch were added. When necessary, cellulose was added to adjust the total to 100%. In one of the diets based on the winged bean and maize mixture, 10% skim-milk powder was substituted for part of this mixture so that the diet contained 3·6% milk protein and 12·4% vegetable protein. In another diet based on the winged bean and maize mixture 0·3% DL-methionine was incorporated. The calculated energy value of all diets containing 16% protein was 417 kcal/100 g.

Animal experiments

Groups of young growing albino rats, matched in respect of litter and of initial body-weight, were used to measure PER and NPU by the method of Miller & Bender (1955). The rats were placed in individual cages, six per group, when assessing PER, and four per group when measuring NPU. Food and water were provided *ad lib.* Consumption of food was recorded daily, and the rats were weighed twice a week. The experimental period lasted for 28 d for measurement of PER and 10 d for measurement of NPU.

RESULTS

Composition of the winged bean

The sample of dry skinned seeds which was analysed contained 37·3% protein, 18·1% fat, 25·2% carbohydrates, 9·7% moisture, 5·4% fibre and 4·3% ash. The calculated energy value was 410 kcal/100 g. The seeds contained 13·9 ppm thiamin and 1·8 ppm riboflavin. The oil of the seeds contained 125·9 mg tocopherol $(\gamma+\beta)$/100 g.

The amino acid composition of the fat-free dry matter of the skinned seeds is shown in Table 1. The content of tryptophan was not determined. Corresponding values for soya bean (Block & Weiss, 1956) are given for comparison.

The fatty acid composition of the fat is shown in Table 2. Corresponding values for soya bean according to the Drew Chemical Corp., Parsippany, N.J. (1970) are given for comparison.

The raw beans were found to contain an active factor inhibiting the activity of pancreatic trypsin. Destruction of this trypsin inhibitor could be achieved by application of moist heat (direct steam in an autoclave) for 10 min at 130°. The same effect was obtained by simply boiling for 30 min beans that had been previously soaked in water for 10 h. However, application of dry heat for 10 min did not destroy the trypsin inhibitor satisfactorily even at 175°. No activity of urease was detected in the raw specimen examined.

Table 1. *Amino acid composition (g amino acid/16 g N) of the protein of the winged bean compared with that of soya bean*

(All values are the means of two determinations)

Amino acid	Winged bean	Soya bean*
Arginine	6·5	7·0
Histidine	2·7	2·5
Lysine	8·0	6·6
Tyrosine	3·2	3·2
Tryptophan	ND	1·2
Phenylalanine	5·8	4·8
Cystine	1·6	1·2
Methionine	1·2	1·1
Serine	4·9	5·6
Threonine	4·3	3·9
Leucine	9·0	7·6
Isoleucine	4·9	5·8
Valine	4·9	5·2
Glutamic acid	15·3	18·5
Aspartic acid	11·5	8·3
Glycine	4·3	3·8
Alanine	4·3	4·5
Proline	6·9	5·4

ND, not determined.
* Values of Block & Weiss (1956).

Table 2. *Composition (% by weight) of the fatty acids in the fat extract of the winged bean seeds compared with that of soya bean*

Fatty acid	Winged bean	Soya bean*
14:0 Myristic acid	0·06	—
16:0 Palmitic acid	9·72	11·0
16:1 Palmitoleic acid	0·83	—
18:0 Stearic acid	5·69	4·0
18:1 Oleic acid	39·00	25·0
18:2 Linoleic acid	27·17	50·0
18:3 Linoleic acid	2·02	8·0
20:0 Arachidic acid		0·4
18:4 Parinaric acid	2·47	—
22:0 Behenic acid	13·38	0·3

* Values according to Drew Chemical Corp., Parsippany, NJ (1970).

PER *and* NPU *of the beans, measured with rats*

The results for the PER and NPU values of the winged bean as compared with those of skim milk and groundnuts, as well as of combinations of winged bean or groundnut with maize, are summarized in Table 3.

At the 10% level of protein both the PER and the NPU values of the winged bean were found to be superior to those of the groundnut (PER 2·14 *v.* 1·53 and NPU 55·0 *v.* 46·2 respectively). A statistically significant difference ($P < 0·01$) was also observed when comparing the winged bean–maize and groundnut–maize mixtures (PER 2·70 *v.* 1·92 and NPU 65·7 *v.* 54·7 respectively). Whereas the PER values for skim milk (3·04)

Table 3. *Protein efficiency ratio* (PER) *and net protein utilization* (NPU), *measured with rats* (*six/group for* PER *and four/group for* NPU), *of diets containing as the protein source skim milk or winged beans* (Psophocarpus palustris *Desv.*) (*alone, with maize, or with maize plus skim milk or methionine*) *or groundnuts* (*alone or with maize*)

Diet		Protein content of diet (%)								
No.	Source of protein	From winged bean	From groundnut	From maize	From skim milk	Total	Wt gain of rats (g)†	Protein intake of rats (g)	PER†	NPU
1	Skim milk	—	—	—	10·0	10·0	63·7 ± 10·2	20·92	3·04 ± 0·34	73·2
2	Winged bean	10·0	—	—	—	10·0	31·1 ± 7·6	14·52	2·14 ± 0·30	55·0
3	Groundnut	—	10·0	—	—	10·0	21·5 ± 3·3	17·07	1·53 ± 0·32	46·2
4	Winged bean + maize	7·3	—	2·7	—	10·0	49·8 ± 6·7	18·40	2·70 ± 0·20	65·7
5	Groundnut + maize	—	7·1	2·9	—	10·0	30·6 ± 6·5	15·92	1·92 ± 0·46	54·7
6	Skim milk	—	—	—	16·0	16·0	130·5 ± 28·7	54·86	2·37 ± 0·25	—
7	Winged bean	16·0	—	—	—	16·0	93·4 ± 14·0	46·64	2·00 ± 0·31	—
8	Winged bean + maize	11·7	—	4·3	—	16·0	90·0 ± 13·7	40·90	2·20 ± 0·21	—
9	Winged bean + maize + skim milk	9·1	—	3·3	3·6	16·0	94·3 ± 16·8	40·13	2·35 ± 0·27	—
10	Winged bean + maize + 0·3 % DL-methionine	11·7	—	4·3	—	16·0	105·2 ± 17·2	44·21	2·38 ± 0·40	—
11	Groundnut + maize	—	11·4	4·6	—	16·0	52·3 ± 6·9	28·70	1·82 ± 0·33	—

Significance of differences (evaluated by Student's t test) between PER values of diets

Diets	1 *v.* 2	1 *v.* 4	2 *v.* 4	4 *v.* 5	6 *v.* 8	6 *v.* 9	6 *v.* 10	7 *v.* 8	8 *v.* 9	8 *v.* 10	8 *v.* 11
Difference	**	NS	**	**	NS	NS	NS	**	NS	NS	**

NS, not significant; ** $P < 0.01$. † Mean values and standard deviations.

and for the winged bean (2·14) differed significantly ($P < 0·01$), the difference between the values for skim milk and for the winged bean–maize mixture (3·04 *v.* 2·70) was not significant.

At the 16% level of protein, the differences in the PER values for skim milk, for the unsupplemented winged bean–maize mixture, and for the mixtures containing supplements of either 10% skim-milk powder or 0·3% DL-methionine were not significant, the values being 2·37, 2·20, 2·35 and 2·38 respectively. The PER value of the winged bean–maize mixture (2·20), however, was significantly ($P < 0·01$) higher than that of the groundnut–maize mixture (1·82).

DISCUSSION

The results demonstrate the high nutritive quality of the winged bean seeds. Although botanically different, the winged bean resembles the soya bean in many respects. The protein and fat contents of both legumes are almost identical. As the amino acid composition of both proteins is very similar, it is not surprising that the NPU of the winged bean protein (55) is close to that of the soya bean (56), as given by FAO/WHO: Joint Expert Group on Protein Requirements (1965). Although the content of tryptophan was not determined, it is a reasonable assumption that methionine is the first-limiting amino acid, as it is for soya and other legumes. The high content of lysine can be expected to act favourably in supplementing cereal diets.

In the composition of the fat there was a relatively high content of unsaturated fatty acids and the content of polyunsaturated essential fatty acids was also favourable. The amount of 125·9 mg/100 g tocopherol in the oil of the winged bean seeds was higher than that found, for example, in soya-bean oil (50–90 mg/100 g) or in maize oil (60–90 mg/100 g). The content of thiamin was slightly higher, but that of riboflavin lower, than the corresponding values (11·0 ppm and 3·1 ppm respectively) given for the soya bean by Watt & Merrill (1963).

The nutritive quality, as assessed by the PER and NPU values, compared well with that of soya bean. The winged bean was definitely superior to the groundnut, which is at present the most important legume cultivated in Ghana. Mixing the winged bean and maize proteins resulted, as could be expected, in higher PER and NPU values. In the winged bean–maize mixtures, maize provided 27% of the total protein content of the diet, and winged bean 73%. We could not increase the proportion of maize, as this would make a mixture which, at the 16% protein level, would be too thick and bulky to be given as a milk substitute to young children. Because of the similarity between the proteins of the winged bean and the soya bean, increasing the proportion of maize to provide 40% of the total protein content in the diet would probably have an even better complementary effect, as has been reported by Bressani & Elías (1966), who used maize and defatted soya-bean flour.

The PER values for the winged bean–maize mixtures and for skim milk did not differ significantly, either at the 10% or at the 16% protein level. Substitution of skim-milk powder for part of the winged bean–maize mixture, or incorporation of 0·3% DL-methionine into the 16% protein diets, did not significantly increase the PER above that of the unsupplemented mixture. These results agree with those reported earlier by Bressani & Elías (1966), who tested the effect of supplementation of a soya bean–maize mixture with milk and with amino acids at a high level of dietary protein.

Although the winged bean resembles the soya bean in that it also contains an active trypsin inhibitor, which, in fact, can be found in many other legumes (Liener, 1962), it differs notably in that urease is completely absent. One advantage over the soya bean is the pleasant, sweet, nutty taste of the winged bean seeds, even in the raw state. This makes unnecessary any painstaking processing, such as prolonged fermentation (e.g. 'natto' and 'miso' in Japan, 'tempeh' in Indonesia) or by preparation of curd (e.g. 'tofu' in Japan), by precipitation of the bean 'milk', which are some of the ways in which soya bean has to be processed at the household level in some parts of Asia, when used direct from the field.

A disadvantage of growing the winged bean on a larger scale as a cash crop is that it has to be staked, and this is likely to increase the initial cost of cultivation. However, when grown by subsistence-level farmers in selected areas, even where earlier attempts to grow the soya bean have given unsatisfactory results, such as in the forest belt in Ghana, it could make a valuable contribution to the predominantly carbohydrate diet of the population, especially the young children.

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