Nutritional Quality of Winged Bean Composite Breads[1]

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ABSTRACT

Chemical and nutritional qualities of baked products made with winged bean, triticale, and wheat are reported. The proximate composition of the composite breads containing 10–20% full-fat and defatted winged bean flour showed significant improvement in the total protein of both the triticale-and wheat-based products. When 15% defatted and full-fat winged bean was used, protein levels of triticale-based products improved as much as 78%, and wheat-based products improved as much as 57%. Growth of rats fed diets in which either defatted or full-fat winged bean was substituted improved significantly over those fed all-triticale or all-wheat diets. The protein efficiency ratios (PERs) and net protein utilizations (NPUs) of triticale-based, wheat-based, and triticale-wheat-based products containing 10–20% defatted and full-fat winged bean were also improved. The adjusted PER of the diets having 15% substitution of defatted winged bean compared well with the PER of the casein control diet, but their differences were significant. The PERs of the diets containing winged bean were significantly higher than the PERs of the 100% triticale and 100% wheat diets. The 100% defatted winged bean diet showed a PER of 2.14, comparable to the casein control diet, which had an adjusted PER of 2.5. The NPU results show that the composite diets appear much closer to the casein control diet in quality. Thus, there were no significant differences between the control diet, the diet combining 15 and 20% defatted winged bean with triticale-wheat, and the diet combining 20% full-fat winged bean with triticale-wheat. The NPU of the 100% defatted winged bean diet did not differ significantly from the NPU of the casein control diet at a 1% level of probability.

The winged bean (*Psophocarpus tetragonolobus* (L.) DC.), a twining perennial, is grown as an annual in many parts of the humid tropics, including Central and South America, the Caribbean, Africa, Oceania, and Asia. In most of these areas, where protein deficiency is high, the winged bean, with its high protein content, can play a major role in meeting the nutritional needs of the people.

Pulle et al (1975) reported that the consumption of bakery products appears to be increasing in the less developed tropical countries where the winged bean is native. These countries rely on imports of wheat from temperate countries to satisfy their flour needs for bakery products. This disadvantageous dependence on exporting countries for basic foodstuffs creates a serious problem; the balance of payment often cannot be met. The use of the winged bean in these wheat-importing countries, as a wheat substitute or for the development of composite breads with wheat or triticale, would alleviate dependence on other countries for wheat. Furthermore, the use of such composite breads could have a significant impact on the nutrition of the people who consume them.

The seeds of the winged bean compare favorably with those of soybean (*Glycine max*) in composition, nutritional value, and possibly in other aspects (Wong 1975). The winged bean averages about 50% protein and 22% fat (dry basis) (Okezie et al 1979). Individual seeds average about 37% protein (Nicholls et al 1961). The protein quality is comparable to that of soybean; the winged bean has as much lysine, methionine, and cystine as soybean. Wheat and triticale flours, although high in methionine content, are limiting in lysine.

Cerny et al (1971, 1973) and Pospisil et al (1971) reported nutritional studies with winged bean. Their studies involved the use of winged bean as a vegetable-protein substitute in the treatment of kwashiorkor in children and as a component of a food mixture with maize. According to the protein efficiency ratios (PERs) and the net protein utilizations (NPUs) of both studies, the plant is a potential source of high-quality protein for human consumption. No other reports have been published on the nutritional quality of baked products from winged bean, used alone or in combination with other materials.

Okezie et al (1980) reported that up to a 15% level of winged bean can be substituted in triticale- or wheat-based composites to provide rheological characteristics comparable to those of wheat, and with a 78% improvement in protein quantity over the wheat-based flour. The best improvement (93%) was made in the protein content of the composite flour obtained when the winged bean (20%), triticale, and wheat were used together. The physical properties of the various composite flours fluctuated when the three flours were used together.

Our study had two purposes. One was to determine the nutritional quality of composite breads made with the optimal quantity of winged bean flour as determined by previous investigators (Dobo et al 1981, Okezie et al 1980). The other was to verify whether the fluctuations in the rheological and baking properties of the composite flours between the 10, 15, and 20% substitutions observed in those previous studies would be reflected in the nutritional performance of the baked products when fed to animals.

MATERIALS AND METHODS

Raw Material Source and Preparation

The winged bean varieties used for the study were obtained from 27 Farms, Homestead, FL. The triticale variety was from the 1978 Alabama A&M University production line, and the wheat flour, Pillsbury's Best all-purpose flour, was purchased locally. The winged bean seeds were soaked for 30 hr, dehulled manually with the aid of a scarifier, and then dried at room temperature ($20 \pm 1°C$) for four to five days. The dried seeds were ground using a 60-mesh screen with a Fitzpatrick mill, model JT6 (Fitzpatrick, IL). Half of the flour was defatted using an azeotropic mixture of alcohol and hexane. The triticale was milled with a Brabender mill (60-mesh screen).

Preparation of Composite Flours

Table I shows the composite flour mixtures. Ten composite flours were used: defatted winged bean-triticale, defatted winged bean-wheat composites (both containing 15% winged bean each), and defatted winged bean-triticale-wheat composites with varying proportions of winged bean and triticale, and a constant proportion of wheat flour as developed by Okezie et al (1980). Similar composites were prepared using full-fat winged bean flour. Four other flours—defatted winged bean, full-fat winged bean, triticale, and wheat—were each prepared without mixture with any other flour.

Baking

Several loaves of bread were baked from each composite flour or blend using the straight-dough method (AACC 1962). The amount

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of water used was estimated from the farinograph absorption as recommended by Okezie et al (1980) and by feeling the dough texture during mixing in a Hobart mixer, model A-1207 (Hobart Manufacturing Co., Troy, OH). A total of 3 hr was allowed for the fermentation of each dough at 32 ± 1°C (80% rh). Baking times for doughs of composites D1–D12 ranged from 18 to 20 min, whereas those of flours D13 and D14 were approximately 24 min. The baking temperature was maintained at 193 ± 1°C in a Parlow oven. The breads were cut into crumbs and frozen to aid in their milling, which was done through a 10-mesh sieve in a Fitzpatrick mill.

Chemical Analysis

Proximate Compositions. The moisture, crude fat, crude fiber, crude protein, and ash of the winged bean, wheat, triticale flours, and baked breads were determined according to AOAC (1975) standard methods.

Amino Acids. The amino acids, with the exception of tryptophan and cystine, were quantitatively analyzed using the methods described by Moore et al (1963). Tryptophan was determined by the methods of Spies et al (1948, 1949).

Formulation of Experimental Diets

Through the use of standard AOAC method 43.183 (1975), a 10% protein diet was formulated from each composite bread. Casein was used for the positive control; a cornstarch or nonprotein diet served as the negative control. Vitamin-free, Berhart Tormarelli, modified salt mix, casein, vitamin mix, and cellulose, a non-nutritive fiber in the form of alphacel, were obtained from ICN Nutritional Biochemicals (Cleveland, OH). Cornstarch containing 75% amylopectin and 25% amylose was obtained from Sigma Chemical Company (St. Louis, MO), and corn oil (Kroger brand) was purchased locally. The ingredients were incorporated in each diet at varying proportions as shown in Table II. Starch was used to adjust the protein levels when needed. Each diet was subsequently tested for protein level.

Nutritional Quality Evaluation

Weanling male Wister rats about 21 days old were obtained from the Charles Rivers breeding laboratory (Wilmington, MA) and used in the feeding trial. On the first day of the three-day adaptation period, the rats were randomly distributed in single cages provided with automatic waterers. The feeders were equipped with wedges to minimize spillage. The cages were in an environmentally controlled room (23 ± 1°C; 50–60% rh) with uniform lighting 12 hr daily. The rats were fed on regular Purina Rat Chow throughout the adaptation period. After three days, feeding was discontinued, leaving the rats with free access to only water. After 6 hr, the rats were weighed. Seven rats in each group were randomized for group and weight distribution for individual cage assignment in a complete block design. Each rat was then started on the 10% protein diets. Each diet was fed ad libitum.

The weight gain of each rat was determined on the seventh day of each week for four weeks. Feed intake and amount of unconsumed diets were determined every two days. The trial was terminated after 28 days. On the final day, a 6-hr fast was imposed before the rats were weighed and then sacrificed using chloroform. The PERs described by Osborne et al (1919) and the NPUs described by Miller et al (1955) were calculated.

The data were subjected to analysis of variance and Duncan's multiple range tests (Duncan 1955) to separate the treatment means.

RESULTS AND DISCUSSION

Proximate Compositions

Table III shows the proximate composition of the different flours used to prepare the composite mixtures. The high oil content (22.87%) in the winged bean made grinding of the seeds difficult. Caking of the ground material was observed, and this tended to affect the yield and quality of the flour produced.

Table IV summarizes the proximate composition of the composite breads. It indicates improvement in the protein content of the triticale- and wheat-based products (D1, D2, D3, and D4) with 15% defatted and full-fat winged bean substitutions. The improvements resulted in increases (dry basis) of 62% for the triticale-based products, 44% for the wheat-based products, and

TABLE I
Composite Flour Mixtures

Product Identification Symbol	Winged Bean (%)	Triticale (%)	Wheat (%)
D1	15[a]	85	0
D2	15[a]	0	85
D3	15[b]	85	0
D4	15[b]	0	85
D5	100[a]	0	0
D6	100[b]	0	0
D7	10[a]	40	50
D8	15[a]	35	50
D9	20[a]	30	50
D10	10[b]	40	50
D11	15[b]	35	50
D12	20[b]	30	50
D13	0	100	0
D14	0	0	100

[a]Defatted.
[b]Full fat.

TABLE II
Composition of Experimental Diets (g/100 g)[a]

Diets	Ingredients (%)					
	Composite Breads	Corn Oil	Salt Mix	Vitamin Mix	Cellulose	Starch or Sucrose
D1	58.96	7.45	3.73	1.00	0.75	28.11
D2	58.31	7.44	3.85	1.00	0.91	28.49
D3	79.49	5.43	3.84	1.00	0.68	9.56
D4	78.49	5.01	3.92	1.00	0.60	10.98
D5	33.81	5.61	3.92	1.00	0.22	55.44
D6	36.89	2.94	3.94	1.00	0.49	54.74
D7	88.11	6.55	3.80	1.00	0.54	···
D8	79.68	6.50	3.85	1.00	0.53	8.44
D9	75.02	6.04	3.44	1.00	0.51	13.99
D10	88.59	5.31	3.80	1.00	0.57	···
D11	80.97	5.22	3.91	1.00	0.57	8.33
D12	75.76	4.75	3.86	1.00	0.55	14.08
D13	88.50	6.20	3.82	1.00	0.48	···
D14	87.87	6.49	4.02	1.00	0.62	···
D15	11.03[b]	7.99	4.75	1.00	1.00	74.23
D16	···	8.00	5.00	1.00	1.00	85.00

[a]Isonitrogenous.
[b]Vitamin-free casein.

TABLE III
Proximate Composition of Winged Bean, Triticale, and Wheat Used for Composite Flour (% dry matter)[a]

	Moisture (%)	Crude Fat (%)	Crude Fiber (%)	Crude Protein (%)	Ash (%)
Winged bean					
Full-fat flour	6.92	22.87	1.55	45.02[c]	4.10
Defatted flour	9.54	1.32	2.80	51.29[c]	4.62
Wheat	13.64	1.47	2.65	12.10[d]	0.43
Triticale[b]	12.13	1.00	2.30	11.50[d]	1.25

[a]Each value is the mean of two samples.
[b]Okezie and Dobo (1980).
[c]Crude protein = percent nitrogen × 6.25.
[d]Crude protein = percent nitrogen × 5.71.

67% for the triticale-wheat-based products. Statistical analysis showed that the protein values for the defatted and the full-fat winged bean substituted products were significantly different ($P < 0.01$) when compared to the sole diets of triticale or wheat. However, diets D1 and D2 and diets D3 and D4 with substitutions of 15% defatted and full-fat winged bean did not differ significantly.

The improved protein levels achieved in the triticale, wheat, and triticale-wheat-based composite breads, as shown in Table IV, agree with the findings reported by Okezie et al (1980) and Dobo et al (1981). The general effect, therefore, suggests that the low levels of 10, 15, and 20% of either defatted or full-fat winged bean flour substitutions in cereal-based products are desirable for improving the protein content of the products.

Amino Acids

Table V shows the amino acid profile of diets D1–D14. The total amino acid values of the triticale-, wheat-, and triticale-wheat-based diets (D1, D2, and D7–D12) with either defatted or full-fat winged bean flour were superior to the all-triticale diet (D13) and the all-wheat diet (D14). Additionally, the lysine levels of the composite diets (D1–D4 and D7–D12) indicated marked increases when compared to the all-triticale (D13) and the all-wheat (D14) diets.

The level of methionine was slightly improved in some diets, in others (D3, D4, and D12) they were reduced when compared to D14. However, the methionine level in D13 was higher than in all other diets except D11.

The amino acid improvements in the blends of winged bean and cereal diets indicate a potential usefulness of the winged bean flour as a supplement at levels of 10–20% to either triticale- or wheat-based products.

Nutritional Quality Evaluation

Although poor digestibility or impaired amino-acid bioavailability may affect nutritional value of a protein, the most important factor influencing protein quality in any bioassay with growing rats is the extent of the protein's limiting essential amino acid (Sammonds et al 1977). The growth rate of weanling rats under standardized conditions provides a reliable measure of the value of dietary protein (NAS 1963).

The weight gain (Table VI) of rats on diets D1–D5, D7–D10, D12, and D15 did not differ significantly from each other ($P > 0.1$). They were significantly higher, however, than the weight gain of rats on diets D6, D11, D13, and D14. Similarly, there was no significant difference in the efficiency of feed conversion to body weight in rats fed diets D1–D5, D7–D10, D12, and D15. However, these differed significantly from the feed intake efficiencies of rats on diets D11, D13, and D14. As expected, the rats fed the protein-free diet (D16) lost weight throughout the experimental period but did not show any other abnormalities.

The adjusted PERs and the NPUs of the composite diets D1–D12 may be compared to the PERs and NPUs of diets D13, D14, and D15. As shown in Table VI, the adjusted PER of the casein control diet (D15) is significantly higher than the PERs of all the test diets. On the other hand, the PERs of the composite diets D1–D12 are significantly better than those of the 100% triticale diet (D13) and the 100% wheat diet (D14). Although the PERs of diets D1, D5, D8, and D12 are not significantly different from each other, they differ significantly from those of diets D3, D4, D6, D7, D10, D11, D13, and D14. The PERs of diets D1, D4, D6, D7, D9, and D10 do not differ significantly.

The PERs of diets D7–D9 with defatted winged bean flour increased inconsistently. The diet with a substitution of 15% defatted winged bean (D8) has a higher PER than the 20% defatted winged bean diet (D9), but the difference is not statistically significant. The values of D8 and D9, however, are significantly higher than that of diet D7. Similar inconsistent increases in PERs

TABLE IV
Proximate Composition of the Composite Breads (percent dry matter)[a]

Product Identification Symbol	Moisture (%)	Crude Fat (%)	Crude Fiber (%)	Crude Protein (%)	Ash (%)
D1	32.7 de	0.98 j	0.59 g	18.7 de	2.17 e
D2	32.5 e	0.99 j	0.77 ef	18.9 de	2.03 fg
D3	5.4 h	4.80 ef	0.44 h	17.9 ef	2.28 d
D4	3.0 i	5.65 d	0.57 gh	17.6 ef	2.03 fg
D5	32.1 f	10.42 b	3.41 a	43.6 a	4.71 a
D6	32.1 f	20.23 a	2.04 b	39.9 b	4.25 b
D7	32.9 d	2.43 hi	0.77 ef	16.7 f	2.02 fg
D8	33.4 bc	2.82 h	0.88 de	18.9 de	2.16 e
D9	35.2 a	4.03 g	1.01 c	20.6 c	2.37 c
D10	33.6 b	4.46 fh	0.73 f	16.7 f	1.99 g
D11	35.4 a	5.29 de	0.82 def	19.1 cde	2.09 f
D12	33.3 c	6.43 c	0.90 cd	19.8 cd	2.25 d
D13	2.0 j	2.07 i	0.55 gh	11.5 h	1.25 h
D14	13.0 g	1.98 i	0.49 gh	13.1 g	1.28 h

[a] Each value is the mean of duplicate results. Means with the same letter are not significantly different from each other using Duncan's multiple range test at $P = 0.01$.

TABLE V
Amino Acid Composition of Winged Bean, Triticale, and Wheat Composite Breads[a]

Amino Acids[b]	Composite Breads													
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
Asparagine	527	489	404	369	895	909	572	554	620	488	553	488	260	210
Threonine	216	204	156	155	309	311	240	223	244	213	252	218	164	141
Serine	346	343	205	216	367	368	401	309	327	303	308	260	208	193
Glutamic acid	1,680	1,728	1,168	1,202	1,195	1,189	2,011	1,780	1,746	1,900	1,815	1,436	1,560	1,505
Proline	629	605	435	424	504	504	724	645	639	703	638	511	511	476
Glycine	226	219	162	162	277	281	257	239	253	235	234	197	167	143
Alanine	241	226	176	169	306	309	268	251	269	245	249	211	172	138
Valine	347	332	249	245	448	455	387	362	390	352	356	296	240	202
Methionine	70	73	55	53	74	69	72	77	77	74	83	63	82	66
Isoleucine	284	277	204	205	360	366	320	298	320	290	307	260	206	183
Leucine	516	513	370	376	690	693	597	557	598	542	534	454	249	316
Tyrosine	234	249	120	154	421	355	208	222	215	220	277	225	153	154
Phenylalanine	333	328	236	233	392	395	380	353	370	352	347	291	249	218
Histidine	168	166	125	126	231	234	191	179	193	170	174	150	149	101
Lysine	297	287	222	224	557	538	335	330	366	285	320	280	162	126
Arginine	315	317	210	226	517	479	332	328	346	311	352	292	207	178
Tryptophan	157	144	161	140	210	192	126	137	146	144	126	162	167	126
Total	6,586	6,500	4,568	4,679	7,753	7,647	7,421	6,844	7,119	6,827	6,925	5,794	4,946	4,476

[a] Milligrams of amino acid per gram of nitrogen.
[b] Cystine was not determined.

TABLE VI
Feed Consumption, Weight Change of Rats on the Experimental Diets, PER, and NPU Values[a]

Diets Identification Symbol	Protein Level (%)	Total Food Intake (g)	Total Protein Intake (g)	Total Weight Gain (g)	Efficiency of Feed Intake[b]	Observed PER	Adjusted PER	NPU
D1	10.25	461.51 def	47.30 cdef	83.68 bc	5.67 de	1.77 bc	1.81 bc	70.74 bcd
D2	10.35	421.74 efg	43.81 efg	96.62 abc	5.41 de	1.87 b	1.95 b	74.30 bcd
D3	10.34	517.63 abcd	53.52 abc	76.92 cd	6.65 cde	1.43 de	1.49 d	72.55 bcd
D4	10.28	521.91 abcd	53.65 abc	84.38 bc	6.48 cde	1.54 cd	1.61 cd	73.66 bcd
D5	10.40	387.44 g	40.29 g	82.99 bcd	4.69 de	2.06 b	2.14 b	86.23 ab
D6	10.03	412.49 fg	41.37 fg	63.96 de	7.17 cd	1.54 cd	1.60 cd	69.11 cd
D7	10.31	578.80 a	59.67 a	90.38 abc	6.54 cde	1.51 cd	1.58 cd	61.12 d
D8	10.44	554.69 ab	57.91 a	109.31 a	5.10 de	1.89 b	1.97 b	84.71 abc
D9	10.12	542.39 abc	54.89 ab	99.77 ab	5.46 de	1.82 bc	1.87 bc	84.51 abc
D10	10.00	510.14 bcd	51.01 bcd	78.15 cd	6.73 cde	1.53 cd	1.60 cd	70.69 bcd
D11	10.18	475.33 def	48.39 bcde	56.04 ef	8.66 c	1.15 e	1.16 e	66.67 d
D12	10.22	476.64 cdef	48.71 bcde	97.13 abc	4.91 de	1.99 b	2.08 b	84.52 abc
D13	10.19	487.25 cde	49.65 bcde	38.55 fg	12.78 b	0.78 f	0.81 f	37.37 e
D14	9.97	429.98 efg	44.29 defg	24.25 g	20.69 a	0.54 f	0.56 f	42.15 e
D15	10.28	429.70 efg	44.17 defg	106.08 a	4.02 e	2.46 a	2.50 a	96.63 a
D16	0.41	217.49 h	0.89	−47.85	...	...	...	...

[a]PER = Protein efficiency ratio; NPU = net protein utilization. Each value is the mean of seven results. Means with the same letter are not significantly different from each other, using Duncan's multiple range test at $P = 0.01$. The standard error of the mean for total food intake, total protein intake, total weight gain, efficiency of feed intake, and adjusted PER and NPU are plus or minus the following: 20.69, 2.14, 2.37, 6.27, 0.10, and 4.98, respectively.
[b]Grams of feed per gram of body weight.

of diets with full-fat winged bean flour are also observed, with the 10% substitution being significantly higher than the 15%, but significantly lower than the 20% full-fat winged bean substitution diet. These observations seem to conform to the rheological and baking qualities of the composite breads reported by Okezie et al (1980) and Dobo et al (1981). Thus, the results seem to suggest that bioavailability of nutrients of winged bean products is diminished when full-fat winged bean is substituted at the 15% level, but is improved either below or above this level. Why this occurs is not clear. It may be because of nutrient interactions occuring at a critical level of winged bean fat. This possibility and the mechanism of such interaction are worthy of further investigation.

The differences between the NPU of the casein control diet D15 and the NPUs of diets D5, D8, D9, and D12 are not significant. However, diet D15 differed significantly from the rest of the test diets ($P > 0.01$). Similarly, diets D5, D8, D9, and D12 have significantly higher NPUs than diets D6, D7, D11, D13, and D14. Although the NPUs of diets D1–D5, D8, D9, D10, and D12 do not differ significantly from each other, they are significantly different from diets D7, D11, D13, and D14.

Although the NPU of many of the test diets showed no significant difference from the NPU of the casein control diet, the PERs of those same test diets were significantly different from the PER of the control diet. Such differences may be related to the limitations associated with the PER as a protein quality evaluation method. One such limitation of the method is its failure to consider the need for tissue protein maintenance. As a result, the quality of poor dietary proteins is underestimated compared to better dietary proteins. The NPU method attempts to correct this basic weakness of the PER by considering the protein maintenance need. Thus, although the PER of the casein control diet is significantly different from the PERs of all the other diets, there is no significant difference between the NPU of the same casein control diet and the NPUs of many of the test diets. This dissimilarity may be attributed to the limitations of the PER method. The NPU method appears to be more accurate in determining the protein quality of a product than the PER method.

The results of the PER and NPU, however, show that mixing the winged bean flour with triticale or wheat flour or both yields a product with higher or improved nutritional quality when compared to the all-triticale or all-wheat diets.

CONCLUSION

The results indicate that supplementation of cereal-based products with up to 15 or 20% defatted or 10–15% full-fat winged bean flour with triticale or wheat yields bakery products of better nutritional quality than either wheat or triticale alone. The use of such new products, particularly in the less developed countries of Africa, Asia, and Latin America, would no doubt play a significant role in alleviating the protein malnutrition in countries to which winged bean is native. Furthermore, the application of winged bean in such acceptable and nutritionally high-quality baked products could reduce the dependence of these nonwheat-producing tropical countries on the wheat-producing countries for their bakery needs.

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