Nutritional and Organoleptic Evaluation of Wheat Breads Supplemented with Pigeon Pea (*Cajanus cajan*) Flour[1]

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ABSTRACT

In an attempt to introduce nutritious products through the creative use of indigenous foods, a study was conducted to determine the physical, sensory, and nutritional characteristics of all-purpose wheat flour breads supplemented with pigeon pea (*Cajanus cajan*) flour at the 0, 5, 10, 15, and 25% levels. Proximate composition (protein, fat, moisture, ash, carbohydrate, and fiber) was determined for all breads. Available lysine, phytate, zinc, and the phytate/zinc molar ratios were also determined. As an increased quantity of pigeon pea flour was substituted for the all-purpose wheat flour in these experimental breads, acceptance by a taste panel remained favorable with no significant differences among the means of the characteristics measured in all breads ($P < 0.05$). An increase in pigeon pea flour from 0 to 25% increased protein content (from 9.19 to 13.0%), lysine (from 0.3 to 171.0 mg lysine/16 g N), and zinc (from 5.26 to 5.80 μg/g). However, there were increases in phytate (1.6–2.5 mg/g) and the phytate/zinc molar ratios (30–43) as well. These molar ratios may provide an estimate of the bioavailability of zinc from the breads.

Diets limited in protein and calories are common for a large percentage of the population in developing countries. As a result, researchers have increasingly focused on improving the diet in countries where malnutrition is widespread. Wheat is the major calorie source for 70% of the populations of the near and middle east when eaten in the form of bread or other baked products (Browe et al 1961). Wheat is an excellent food, and in various forms may enhance nutritional intakes in all vulnerable groups.

Supplementation of wheat with inexpensive staples such as cereals or legumes has resulted in products of high nutritional value (Sheheta and Freyer 1970). Pigeon pea (*Cajanus cajan*), a legume containing 19.2% protein, is widely used as a source of protein combined with rice (Caribbean Food and Nutrition Institute 1974). However, pigeon pea flour has not been extensively investigated for use as a food supplement. This study was undertaken to determine the acceptability and nutritional quality of breads supplemented with increasing levels of pigeon pea flour.

MATERIALS AND METHODS

Pigeon peas (packaged by Goya Inc., Secaucus, NJ 07094) were purchased from a local grocery store. The peas were processed into flour by the method outlined by Gayle (1983). The dried peas were boiled for 1 min, then soaked for 1 hr and dehulled. The dehulled kernels were blended in a Waring blendor to a slurry, placed on a tray lined with aluminum foil, and dried in an oven (75° C) for 8 hr. After drying, the flour was blended, sifted to a grain size twice that of the all-purpose flour, and stored in an air-tight container at room temperature until used.

The following formula was used to prepare the breads: 15 g of granulated sugar, 1 g of salt, 22 g of margarine, 7.5 g of yeast (active dry), 113 g of whole milk (heated), 50 g of whole egg, and 270 g of flour. The sugar, salt, and fat mixture was placed in a mixing bowl; one-half of the hot milk was added, and the mixture was blended to a uniform consistency. After cooling the mixture to 27° C, the yeast (dissolved in the remaining warm milk), egg, and flour were added to the mixture, and the moderately soft dough was mixed at low speed in a Hobart mixer (5 kg capacity) until smooth and satiny. The dough was turned into a lightly greased bowl, turned over, and the top of the dough was also greased. The bowl was placed in a 27° C oven, and the dough was allowed to rise until doubled in bulk. After approximately 2 hr, the dough was punched down, kneaded, shaped into loaves, placed in greased 9 × 5 × 2½ in. loaf pans and allowed to rise again until doubled in size. The raised loaves were placed in a preheated (210° C) oven and baked for approximately 20 min (West et al 1985).

Five different breads were prepared with pigeon pea flour blended with all-purpose flour in the following combinations: a) 100% all-purpose wheat flour (0% pigeon pea flour); b) 5% pigeon pea, 95% wheat; c) 10% pigeon pea, 90% wheat; d) 15% pigeon pea, 85% wheat; and e) 25% pigeon pea, 75% wheat. All ingredients except the flour remained constant. After baking, the loaves were permitted to cool to 27° C, arranged on a plastic-covered display table, and photographed under normal lighting conditions.

A taste panel of 25 persons was selected randomly from African, American, and West Indian university students. All of the members were experienced taste panelists as a result of completing a required food science course. They evaluated the breads according to a published format (Morr and Irmiter 1985). Although cubicles to separate the panelists were not available, the scoring was completed in a professional manner with no conversation between panelists during the scoring process. All five breads were presented to the panelists at one session and the order of presentation was randomized to avoid confounding the panel results. The breads were scored once by each panelist in the belief that, with 25 taste panelists, a sufficient number of evaluations would be made. The panel used sensory evaluations based on a 5-point hedonic scale: 1, very poor; 2, poor; 3, fair; 4, good; and 5, excellent. Each bread was evaluated for appearance, crust, flavor, texture, overall eating quality, and acceptability.

Proximate composition of the five breads was determined (repeat analyses performed in duplicate) using the following methods of the Association of Official Analytical Chemists (1984): moisture, 7.007; ash, 7.009; protein, 47.021; and fat, 14.019. Total carbohydrate content was determined by difference. The analytical values for protein were compared with values for protein in USDA Handbook No. 8 (1963).

Phytate analyses were performed in triplicate by the modified ion-exchange method of Harland and Oberleas (1977). Dried, powdered bread samples were wet digested with nitric/perchloric acids. Zinc analyses of the solubilized digestates were performed in triplicate by atomic absorption spectrophotometry (Perkin-Elmer Corp. 1973). National Bureau of Standards orchard leaves were used to assure proper analytical techniques.

The phytate/zinc molar ratios were calculated by dividing the millimoles of phytate by the millimoles of zinc for each level of pigeon pea flour that was incorporated into the breads (Oberleas and Harland 1981).

Protein quality of the breads was determined in triplicate by estimating (in vitro) the available lysine using the method of Carpenter (1960). Statistical analysis of the data was performed using the Statistical Analytical System (Barr et al 1979) and the Statistical Package for the Social Sciences (Nie et al 1975). The data were subjected to one-way analysis of variance, the *t* test, linear

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regression, and Pearson's correlation coefficient. When ANOVA showed significant differences, the application of a t test revealed the extent of the differences.

RESULTS

Table I shows the mean scores for the five breads. Overall eating quality and acceptability correlated positively with slice appearance ($r = 0.52-0.78$), crust ($r = 0.59-0.72$), flavor ($r = 0.72-0.91$), and texture ($r = 0.73-0.92$) for the five experimental loaves ($P < 0.001$).

Table II shows the proximate composition of the breads. Protein values increased from 9.19 to 13.0%, ash from 0.89 to 1.19%, and moisture from 29.00 to 31.00% as the percentage of pigeon pea flour in the breads was increased. Conversely, fat and carbohydrate-fiber percentages declined as pigeon pea flour was increased.

Phytate concentrations of the breads increased significantly with higher levels of pigeon pea flour (Table III). Zinc also increased as the percentage of pigeon pea flour increased. These differences were not consistently significant because some of the standard errors were large. While this increase in zinc content was only 0.54 μg/g, or 10% of the initial zinc content, the phytate level increased 0.9 mg/g, 56% of its initial content. Phytate/zinc molar ratios ranging from 30 to 43 were obtained for the five breads (Table III).

The amount of available lysine in the breads was significantly increased as substitutions of pigeon pea flour for wheat flour became larger ($P < 0.01$) (Table IV). Available lysine (mg/16 g N) increased from 0.3 ± 0.02 to 171.0 ± 14.89 at the highest level of substitution.

There were no differences in the scores for sensory evaluation of the breads ($P > 0.05$). As the amount of pigeon pea flour in the formulation increased, the breads became slightly more squat and compact, the grain became more dense, and the resiliency to finger pressure decreased. These characteristics, however, did not detract from the overall acceptability of the breads.

TABLE I
Taste Panel Mean Scores for Breads[a]

Flour[b]	Slice Appearance	Crust	Flavor	Texture	Overall Eating Quality Acceptability
0% PPF, 100% WF	4.28	4.36	3.84	4.08	4.08
	±0.15	±0.13	±0.21	±0.21	±0.20
5% PPF, 95% WF	4.32	4.28	3.96	4.00	4.04
	±0.20	±0.20	±0.21	±0.22	±0.23
10% PPF, 90% WF	3.84	3.92	3.76	3.84	3.80
	±0.20	±0.20	±0.20	±0.20	±0.20
15% PPF, 85% WF	4.44	3.96	3.62	3.86	3.92
	±0.14	±0.13	±0.25	±0.20	±0.20
25% PPF, 75% WF	4.12	4.04	3.70	3.68	3.88
	±0.13	±0.15	±0.21	±0.20	±0.20

[a]Sample size = 25. All values represent mean ± SE.
[b]PPF = pigeon pea flour, WF = wheat flour.

TABLE II
Proximate Composition of Breads (g/100 g)[a]

	Pigeon Pea Flour/Wheat Flour (% w/w)				
Component	0/100	5/95	10/90	15/85	25/75
Protein	9.19	11.50	12.10	12.60	13.40
	(10.60)[b]	(11.96)	(12.32)	(12.56)	(13.33)
Fat	5.93	5.90	5.84	5.12	5.00
Ash	0.89	0.96	1.05	1.07	1.19
Moisture	29.00	29.20	29.50	30.50	31.00
Carbohydrate-fiber	52.98	52.44	51.51	50.71	50.59

[a]All values represent four determinations (analyses of duplicates, repeated once).
[b]Protein values in parentheses are calculated from USDA Handbook No. 8 (1963).

DISCUSSION

These experiments show the possibility of using pigeon pea flour as a supplement to all-purpose wheat flour without any impairment in the overall eating quality and acceptability of the breads. This finding is very important to the first author, who plans to set up a pilot plant in Jamaica to produce breads made of the indigenous food, pigeon pea flour. The peas are commonly consumed, but pigeon peas as flour have not been tested as a marketable commodity. If an acceptable product can be made and sold, it will enhance the protein quality of the Jamaican diet. Supplementation of commonly used staples with pigeon pea flour may therefore enhance the nutritional content of wheat-based products that are consumed in developing countries where malnutrition is prevalent. Despite the fact that the nutritive value of bread is low (FAO 1970), the amino acid balance can be improved by the addition of plant proteins in concentrated forms or by the addition of lysine (Rosenberg and Rohdenburg 1952).

Because the pigeon pea flour contributed a slightly yellowish-gray color to the dough, care was taken to bake all of the loaves to the same degree of brownness as well as doneness. As a result there were slight differences in overall baking times.

Although there was great variability in the scoring of the loaves and bread slices, this may be a normal phenomenon when one considers the various kinds of breads which an individual may eat and like. We have many breads available to us, and will choose certain breads just because they are different. This would hopefully be the fate of these pigeon pea breads when introduced into the Jamaican food supply.

Positive correlations between appearance and eating quality reinforce the belief that these breads might first be chosen because of their appearance, but chosen the second time because of their flavor and overall acceptability.

According to Davies and Olpin (1979), a phytate/zinc molar ratio greater than 10 may produce zinc deficiency in rats, and ratios above 20 may be associated with clinical evidence of zinc deficiency (Oberleas and Harland 1981). In the study reported here, the phytate/zinc molar ratios of all the breads were high (30–43), although in agreement with high ratios previously found in breads such as rye (58) (Oberleas and Harland 1981) and the phytate/zinc molar ratio found in the all-purpose wheat flour itself (40).

TABLE III
Zinc and Phytate Content of Breads[a]

Sample No.	PPF[b] (%)	WF[c] (%)	Zinc (μg/g)	Phytate (mg/g)	Phytate/Zinc Molar Ratio
1	0	100	5.26 ± 0.170 a	1.6 ± 0.003 a	30
2	5	95	5.30 ± 0.002 b	1.7 ± 0.010 b	32
3	10	90	5.50 ± 0.007 c	1.9 ± 0.009 c	34
4	15	85	5.60 ± 0.071 a	2.0 ± 0.011 d	35
5	25	75	5.80 ± 0.070 a	2.5 ± 0.016 e	43

[a]Values represent mean ± SE. Means followed by unlike letters are significantly different ($P < 0.01$), as determined by t test. All determinations were performed in triplicate.
[b]PPF = pigeon pea flour.
[c]WF = wheat flour.

TABLE IV
Available Lysine in Breads[a]

Sample No.	PPF[b] (%)	WF[c] (%)	mg Lysine/16 g N
1	0	100	0.3 ± 0.02 a
2	5	95	72.0 ± 1.42 b
3	10	90	103.0 ± 1.42 c
4	15	85	131.0 ± 7.80 d
5	25	75	171.0 ± 14.89 d

[a]Values represent mean ± SE. Means followed by unlike letters are significantly different ($P < 0.01$), as determined by t test. All values represent four determinations (analyses of duplicates, repeated once).
[b]PPF = pigeon pea flour.
[c]WF = wheat flour.

Recent research by Sandstrom and Cederblad (1980) and Shah and Belonge (1984) showed that, in man, the amount of zinc absorbed from protein meals of legume source was dependent more on the total amount of zinc in the meal than on the presence of dietary phytic acid or calcium. Thus, protein-rich foods may make an important contribution to the overall diet when the zinc intake is sufficient to compensate for those foods containing a high phytate/zinc molar ratio.

Marsh (1982) observed that when rats were fed diets containing pigeon pea flour as the sole protein source there was no significant increase in growth even when the diets were supplemented with methionine. However, the authors did not consider the fact that the high phytate/zinc molar ratio in pigeon pea flour could precipitate symptoms of zinc deficiency, such as growth impairment.

It might be possible to reduce the phytate content of the experimental breads by increasing the amount of leavening, or by increasing the fermentation period of the breads (Harland and Harland 1980); however, this was not tested.

Although proteins from cereals and legumes are better sources of zinc compared with the relatively low concentration supplied by protein from tuberous foods (Mbofung et al 1984), the incidence of marginal zinc deficiency might occur among segments of the population in which the consumption of cereals, legumes, tuberous foods, and vegetables is high (Atimno et al 1982). Recent data from research with humans suggest that if soybean is the major protein source in the diet, a level of 15 mg of zinc may not be adequate to meet the daily requirement for humans (Cossack and Prasad 1983).

The quality of protein in this study was evaluated by the availability of lysine. High values for available lysine in the pigeon pea supplemented breads indicated that pigeon peas could meet the adult requirement of this amino acid. Lysine is also a requirement for growing children. Carpenter (1960) observed that there was a high correlation between available lysine and the biological value of protein. Sheheta and Freyer (1970) observed that supplementing wheat flour with 10 or 20% chick-pea flour produced a significantly higher protein efficiency ratio in rats compared with unsupplemented wheat flour because of the contribution of lysine from the chick-peas.

In summary, pigeon pea flour (*Cajanus cajan*) was substituted for wheat flour in breads at the 0, 5, 10, 15, and 25% levels. All breads were equally acceptable to the taste panel. The total protein, available lysine, and zinc content increased, and the fat content decreased as the percentage of pigeon pea flour was increased in the breads. However, the phytate and the phytate/zinc molar ratios increased to levels that have been shown to produce symptoms of zinc deficiency. When the contribution of zinc from other foods in a daily diet can be increased to compensate for the high phytate and low zinc, these breads may very well add flavor, texture, and variety to ordinary meals. Moreover, this experiment illustrates the creative use of an indigenous food which may enhance the nutritional quality of the diet.

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