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Research article

Supplementation of corn (*Zea mays* L.) starch – wheat (*Triticum aestivum* L.) extruded product with pigeon pea [*Cajanus cajan* (L.)] flour

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Abstract

The effect of adding decorticated pigeon pea [*Cajanus cajan* (L.)] flour (DPPF) in ratios of 5%, 10% and 15% to wheat (*Triticum aestivum* L.)flour and corn (*Zea mays* L.) starch on extruded product was studied. Blend of wheat flour and corn starch (control) and blends after addition of different levels of DPPF were analyzed for chemical composition before processing to detect the effect of processing (extrusion) and supplementation on nutritional value. That is, moisture content was found 7.0% for all blends, ash content was in a range of 0.54 – 0.85%, whereas fat content was found 1.07% for all blends. However, protein and carbohydrates content were increased by the addition of DPPF in a range of 6.01 – 9.01% and 82.07 – 85.38%, respectively. Moreover, the analyses for calcium (Ca), magnesium (Mg) and phosphorus (P) revealed a significant increase with the addition of DPPF.

Results of *in vitro* protein digestibility for blends supplemented with DPPF were significantly increased (26.15%) by adding 10% DPPF compared to the control (23.50%). However, this content was decreased (23.65%) by the addition of 15% DPPF as compared to 10% recipe.

Moisture content of extruded sample fortified with DPPF before frying ranged between 11.57 – 11.58%. while fried extruded samples were 4.0% ash content ranged between 2.15 – 3.45%. Fat content levels for the samples between 23.37 – 23.65%. Nevertheless, protein content was increased by 5.44% and up to 7.49% in the control and the fortified samples, respectively. However, carbohydrates were reduced (61.41 – 65.04%).

Significant increase in minerals content (Ca, Mg and P) in samples by increasing the ratios of DPPF.

In vitro protein digestibility was increased in the 5% and 10% DPPF recipe and decreased in 15% DPPF recipe as compared to the control.

Levels of essential amino acids rose in extruded samples fortified with 5% compared to control. The protein quality has improved and lysine score increased from 51.225 in control to 105.90 in 5% DPPF.
Extruded samples supplemented with DPPF significantly increased volume (expansion ratio) and the highest level was 357 in fortification with 5% DPPF. In corporation of DPPF in extruded samples beyond 10% had a negative effect on volume.
The organoleptic test reflects that the fortification with 5% DPPF was found superior in taste, crispness and general acceptability.

Key words: Corn – extrusion – fortification - pigeon pea – starch – supplementation - wheat.

Introduction

Legumes are of prime importance in human and animal nutrition, due to their high protein content 20-50% (Singh *et al*., 2004). Grain legumes are also a rich source of vitamins especially the B-complex, and minerals such as calcium and iron.

The increased costs and limited supplies of animal proteins, have necessitated contemporary research efforts geared towards the study of food properties and potential utilization of protein from locally available food crops, especially from under-utilized or relatively neglected high protein oilseeds and legumes (Enujiugha and Ayodele-Oni, 2003). The enrichment of cereal-based foods with oilseeds and legume proteins has received considerable attention. Attempts to increase the utilization of legumes have employed a wide range of processing techniques such as germination, dehulling, cooking, roasting, autoclaving, fermentation and extrusion cooking (Wang *et al*., 1997).

Recently, extrusion cooking has become one of the most popular technologies in food processing. It is a low cost, high temperature short time (HTST) process, used worldwide for processing of a number of food products (Frame, 1994; Harper, 1981 and Smith and Singh, 1996). Cereals have excellent expansion properties because of their high starch content and are well suited to thermal extrusion (Singh *et al* 1994 and Singh *et al*., 1998). Remarkable progress has been made in the utilization of new protein sources, such as oilseeds, leguminous seed and single cell proteins (Kinsella, 1978). Among legumes, pea has a very important position and is an important source of nutrients particularly proteins and essential amino acids. The blending of peas with cereals can complement each other so that protein in the resulting product more nearly resembles that of a complete or balanced protein.

The objective of this study was to improve the protein content of wheat flour with rich source (pigeon pea) and to give a balanced amino acid profile for making extruded product.

Materials and methods

Blends and samples preparation

The blends were prepared by adding 1.5kg of wheat flour and 1kg corn (Z. mays) starch(control sample) (describe how you prepared it), then decorticated pigeon pea flour was added in the ratios 5%,10% and 15%. Samples were prepared by adding tab water till well wetted, extruded by a machine model DLG 90 single screw, then cut into regular shapes, dried under shade for 18 hours at 30ºC and then fried.

Chemical composition

Moisture, ash, crude protein, fat and carbohydrates were determined for samples (before and after frying) according to AACC (2000) method.

Calcium , Magnesium and Phosphorus

Ca , Mg and P determined according to Chapman and Pratt (1961) using CE 202 Ultraviolet spectrophotometer.

In vitro protein digestibility with pepsin

The *in vitro* protein digestibility was determined for samples (before and after frying) by the method of Maliwal (1983) as modified by Manjula and John (1991).

Amino acids profile

Amino acids were determined using HPLC.

Physical tests

Volume of extruded samples

Twenty grams of each sample weighed, then put in a measuring cylinder (500 ml), then the volume was readed.

Sensory evaluation:

Extruded samples were assessed organoleptically by the ranking test according to the procedure described by Ihekoronye and Ngoddy (1985).

Statistical analysis procedure

Data generated was subjected to statistical Package for Social Science (SPSS). Means were tested by analysis of variance (ANOVA), then were separated using Duncan's Multiple Range Test (DMRT) according to Mead and Gurnow (1983).

Results and discussion

Proximate composition of blends

Table (1) shows the results of proximate composition of blends with 5%, 10% and 15% decorticated pigeon pea (*C. cajan*).

The moisture content of control sample as 7.0%, incorporation of decorticated pigeon pea flour (DPPF) has no significant effect in moisture content. Results gave 7.0% at 5, 10 and 15% substitution of pigeon pea flour. These results are less than the results reported by Zeleny (1971) and Pyler (1973) who showed that the moisture content of wheat flour was 8-14% and 13.0%, respectively.

The ash content of control sample illustrated in Table (1) was 0.54%. This result is in a good agreement with Zeleny (1971) who reported that the ash content of wheat flour is 0.52-0.55%. Addition of decorticated Pigeon pea flour (DPPF) caused significant increase in ash content, showing values 0.61, 0.68 and 0.85% at 5, 10 and 15%, respectively. That is, the pigeon pea contains 3.73% ash as reported by Hassan (2007).

The fat content was 1.07% for the control and all blends 5, 10 and 15% DPPF. These results were lower than that obtained by Hassan (2007) who reported fat content of wheat flour as 1.33% (Table 1).

The protein content of the test samples is shown in Table (1) as 6.01%. This value was lower than the value reported by Giami *et al*. (2005) and Haldore *et al*. (1982) who gave that the protein content of wheat flour as 11.3 and 10-16%, respectively. This decrease may be due to the addition of corn starch because there is negative relationship between starch and protein content. Incorporation of DPPF caused significant increase in protein content. Results were 6.86, 7.73 and 9.01% for 5, 10 and 15%, respectively. This positive effect is attributed t o the enrichment of pigeon pea in protein content, which recorded a range between 18.5 and 26.3% with a mean value of 21.5% (Hulse, 1977).

Carbohydrates content of samples ranged between 82.07 to 85.38%. The highest value was observed in the control, whereas fortification with 15% DPPF gave the lowest value (Table 1).

The mineral content of blends , Calcium (Ca) content of the control was 0.0200% with an increase on fortification with 5, 10 and 15% DPPF to 0.0213, 0.0243 and 0.0310%, respectively (Table, 1). While, increasing of DPPF level in blends increased magnesium (Mg) content from 0.0100% for 5% DPPF to 0.0165% for 15% DPPF compared with control (0.0080%). Phosphorous (P) content was 0.00095, 0.00098, 0.00115 and 0.00139 for control, 5 10 and 15% DPPF, respectively (Table, 1). From these results, it is observable that minerals increased with increasing of DPPF, that may be due to the high content of minerals in pigeon pea, and the highest value was obtained in the blend containing 15% DPPF.

Moisture content of extruded samples after drying

Results in Table (2) show the moisture content of extruded samples after drying and before frying. The moisture content was 11.57% for control and 5% DPPF and 11.58% for 10% and 15% DPPF.

Proximate composition of extruded samples after frying

Table (3) shows the results of proximate composition of extruded samples after frying. Moisture content of extruded samples illustrated in Table (3) as 4% for all samples after frying. This result was lower than the moisture content of samples before frying (11.57-11.58%), and that may be attributed to the very high temperature of frying oil, which has driven some of the moisture.

The ash content was reported as 2.15, 3.24, 3.34 and 3.45 for control, 5, 10 and 15% DPPF, respectively.

The fat content was obtained in Table (3) ranged between 23.37 - 23.65% for the samples. These high values of fat may be attributed to frying treatment where samples absorbed high quantity of oil.

The protein content of extruded samples after frying was 5.44% for control. Addition of DPPF by 5, 10 and 15% caused a significant increase in protein content by 6.65, 7.07 and 7.49%, respectively.

Carbohydrates ranged between 61.41 to 65.04% for the samples.

Minerals content

Table (3) shows the mineral content of extruded samples after frying. Calcium (Ca) content was found to be 0.0203% in control sample. Incorporation of decorticated pigeon pea flour resulted in an increase to 0.0227%,0.0251% and 0.0263% for 5,10 and 15% DPPF. Increasing levels of DPPF in extruded samples resulted in an increase in magnesium (Mg) content. Values obtained ranged from 0.0161 to 0.0221% for the samples. Phosphorous (P) content was increased gradually with increasing levels of DPPF. The value of P was 0.00223% for control sample, whereas higher value was obtained for 15% as 0.00308%.

***In vitro* protein digestibility**

In vitro protein digestibility of blends and extruded samples are illustrated in Table (4). The values increase for blends with addition of DPPF from 23.50% for control to 26.15% for 10% DPPF. Incorporation with 15% DPPF decreased *in vitro* protein digestibility.Extrusion cooking has enhanced *in vitro* protein digestibility, these values ranged between 23.63 and 26.30% and the value was decreased in addition of 15% DPPF. Incorporation of DPPF up to 10% increased *in vitro* protein digestibility for blends and extruded samples.The results agree with Bishnoi and Khetarpaul (1993) and Chau and Cheung (1997) who reported that the extrusion cooking produced a more significant improvement of *in vitro* protein digestibility and *in vitro* starch digestibility in faba and kidney beans.

Amino acids content of samples after frying

Table (5) show the contents of amino acids for samples after frying in mg/100 g. Tryptophan is an essential amino acid, but it was not determined as it is not stable in acid hydrolysis. All amino acids were increased in fortification with 5% decorticated pigeon pea flour than the control, especially lysine. It was increased from 51.225 mg/100 g in control to 105.900 mg/100 g for 5% fortified with DPPF. These results are in a good agreement with Abdallah (2002) who found that the fortification of wheat flour with faba bean increased lysine, therionine, leucine and isoleucine in bread.Pigeon pea protein is a rich source of lysine, but is usually deficient in sulphur-containing amino acids, methionine and cystine, it thus supplements the essential amino acids in cereals (Gopalan *et al*., 1971). Lysine-deficiency is considered as a major nutritional problem in wheat protein, this problem could be solved either through direct addition of lysine or supplementation by legumes (Jansen, 1970 and Dendy, 1995).

Physical tests

Volume of extruded samples

The effect of decorticated pigeon pea flour on extruded product samples volume is shown in Table (6).The addition of decorticated pigeon pea up to 10% significantly ($P \leq 0.05$) increased the volume of samples compared to control. The volume decreased when added 15% decorticated pigeon pea flour.This result is in agreement with that obtained by Hassan (2007) who found that the replacement of wheat flour by pigeon pea up to 10% increased the specific volume of bread. Singh *et al*. (2005) claimed that the expansion ratio of extrudates decreased with increase in the level of pea grits in feed material.

Sensory evaluation of extruded samples

Results of sensory evaluation of extruded samples containing decorticated pigeon pea flour are presented in Table (7). The results showed significant ($P \leq 0.05$) differences among the samples in taste, colour, crispness and flavuor. General acceptability showed no differences among the control and 5% decorticated pigeon pea flour.

In general, all samples gave high scores in all sensory characteristics, and the best one was that fortified with 5% decorticated pigeon pea flour.

Conclusions

From the results obtained in this study, it can be concluded that:The supplementation of wheat flour and corn starch with DPPF has improved the nutritional value of blends and extruded product. Scores of limiting essential amino acids have been improved in extruded product supplemented with 5% decorticated pigeon pea flour. Wheat flour and corn starch with 5% DPPF produced extruded product of the highest volume (expansion ratio), and the best in quality and general acceptability.

Table (1): Proximate composition and some minerals of the blends

Samples	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	CHO (%)	Ca (%)	Mg (%)	P (%)
B_c	7.0±0.00^a	0.54±0.00^e	1.07±0.00^f	6.01±0.01^g	85.38±1.01^a	0.0200^a	0.0080^a	0.00095^a
B_5	7.0±0.00^a	0.61±1.73^c	1.07±0.00^f	6.86±0.01^e	84.46±1.01^b	0.0213^b	0.0100^b	0.00098^b
B_{10}	7.0±0.00^a	0.68±1.73^c	1.07±0.00^f	7.73±0.01^b	83.52±0.01^c	0.0243^c	0.0143^c	0.00115^c
B_{15}	7.0±0.00^a	0.85±.0.00^d	1.07±0.00^f	9.01±0.01^a	82.07±0.01^d	0.0310^d	0.0165^d	0.00139^d

Any two mean±S.D values within each column having different superscript letters differ significantly ($P \leq 0.05$).

Blends:

B_c : Blend of wheat flour and corn starch (control).

B_5 : Blend of wheat flour and corn starch with 5% DPPF.

B_{10} : Blend of wheat flour and corn starch with 10% DPPF.

B_{15} : Blend of wheat flour and corn starch with 15% DPPF.

Table (2): Moisture content (%) of extruded samples after drying and before frying

Samples	Moisture content (%)
X_c	11.57±0.02^b
X_5	11.57±0.02^b
X_{10}	11.58±0.00^b
X_{15}	11.58±0.01^b

Any two mean±S.D values having different superscript letters differ significantly (P≤0.05).

Xc: Extruded sample (control)

$X_{5:}$ Extruded sample with 5% DPPF

X_{10}: Extruded sample with 10% DPPF

X_{15}: Extruded sample with 15% DPPF

Table (3): Proximate composition of extruded samples after frying

Samples	Moisture(%)	Ash (%)	Fat (%)	Protein (%)	CHO (%)	Ca (%)	Mg (%)	P (%)
X_c	4.0 ± 0.00^{b}	2.15 ± 0.00^{b}	23.37 ± 0.29^{d}	5.44 ± 0.01^{i}	65.04 ± 00.08^{e}	0.0203^{e}	0.0120^{e}	0.0223^{e}
X_5	4.0 ± 0.00^{b}	3.24 ± 0.00^{b}	23.58 ± 0.35^{d}	6.65 ± 0.01^{f}	62.53 ± 0.36^{f}	0.0227^{f}	0.0161^{f}	0.0235^{f}
X_{10}	4.0 ± 0.00^{b}	3.34 ± 0.00^{b}	23.44 ± 0.17^{c}	7.07 ± 0.01^{d}	62.15 ± 0.18^{g}	0.0251^{g}	0.0185^{g}	0.0269^{g}
X_{15}	4.0 ± 0.00^{b}	3.45 ± 0.00^{b}	23.65 ± 0.29^{e}	7.49 ± 0.01^{c}	61.41 ± 0.30^{ef}	0.0263^{i}	0.0221^{i}	0.0308^{i}

Any two mean±S.D values within each column having different superscript letters differ significantly ($P\leq0.05$)

Xc: Extruded sample (control)

X_5: Extruded sample with 5% DPPF

X_{10}: Extruded sample with 10% DPPF

X_{15}: Extruded sample with 15% DPPF

Table (4): *In vitro* protein digestibility of blends and extruded samples

Sample	Protein digestibility %
B_c	23.50[a]
B_5	23.55[b]
B_{10}	26.15[c]
B_{15}	23.65[d]
X_c	23.63[i]
X_5	23.70[j]
X_{10}	26.30[ef]
X_{15}	23.70[h]

Bc : Blend of wheat flour and corn starch (control).

B_5 : Blend of wheat flour and corn starch with 5% DPPF.

B_{10} : Blend of wheat flour and corn starch with 10% DPPF.

B_{15} : Blend of wheat flour and corn starch with 15% DPPF.

Xc: Extruded sample (control)

X_5: Extruded sample with 5% DPPF

X_{10}: Extruded sample with 10% DPPF

X_{15}: Extruded sample with 15% DPPF

Table (5): Amino acid content of samples after frying (mg /100 gm)

Amino acid	X_c	X_5
Aspartic acid	150.700	250.325
Threonine	108.450	153.563
Serine	131.844	192.65
Glutamic acid	732.500	1106.675
Glycine	123.088	175.925
Alanine	195.363	274.863
Cystine	-	-
Valine	227.038	305.525
Methionine	54.875	72.613
Isoleucine	205.288	266.300
Leucine	356.088	473.350
Tyrosine	-	-
Phenylalanine	181.825	270.575
Histidine	82.063	125.475
Lysine	51.225	105.900
Ammonia	658.500	1010.325

Xc: Extruded sample (control)

X_5: Extruded sample with 5% DPPF

Table (6): Volume of fried extruded samples

Samples	Volume (cc^3)
X_c	$317±5.77^{bcd}$
X_5	$357±11.55^{a}$
X_{10}	$337±20.82^{abc}$
X_{15}	$310±5.77^{d}$

Any two mean±S.D values having different superscript letters differ significantly (P≤0.05).

Xc: Extruded sample (control)

X_5: Extruded sample with 5% DPPF

X_{10}: Extruded sample with 10% DPPF

X_{15}: Extruded sample with 15% DPPF

Table (7): Sensory evaluation of fried extruded samples

Samples	Taste	Colour	Crispness	Flavour	General acceptability
X_c	$7.8±0.43^{ab}$	$8.2±1.05^{a}$	$8.0±1.18^{ab}$	$7.8±1.12^{a}$	$8.1±0.86^{a}$
X_5	$8.3±1.06^{a}$	$8.3±0.58^{a}$	$8.4±0.72^{a}$	$7.9±0.77^{a}$	$8.3±1.06^{a}$
X_{10}	$6.4±1.24^{c}$	$6.4±0.99^{b}$	$6.9±0.83^{bcd}$	$6.4±1.18^{b}$	$6.2±1.01^{b}$
X_{15}	$5.7±1.06^{c}$	$5.9±1.06^{b}$	$5.9±1.13^{d}$	$5.8±1.86^{b}$	$4.6±1.68^{c}$

Any two mean±S.D values within each column having different superscript letters differ significantly (P≤0.05).

Xc: Extruded sample (control)

X_5: Extruded sample with 5% DPPF

X_{10}: Extruded sample with 10% DPPF

X_{15}: Extruded sample with 15% DPPF

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