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Nutritional evaluation of a high-temperature dried soft wheat pasta supplemented with cowpea (*Vigna unguiculata (L) Walp)*

Christine J. Bergman [1], *Daisy G. Gualberto* [2] *and Charles W. Weber* [3]

University of Arizona, Tucson, Arizona, United States

SUMMARY. The objective of this study was to determine the nutritional quality of the pasta described above. The work was unique in the following aspects: 1) the drying process was a nonconventional method, consisting of a high-temperature short-time (HTST) process; 2) the nutritional quality of the wheat pasta was improved by the cowpea supplementation. Cowpea was especially chosen due to it being a staple food in the diet of the people in Northeast Brazil. Benefits attributed to the HTST drying process include a reduction in bacterial counts, shorter processing time and less energy consumption. In addition, there are reports in the literature of improved pasta firmness, color intensity, and cooking characteristics, when non *Trticum durum* materials plus drying are used. The pasta produced in this work was made using 100 % soft wheat flour (SP), and soft wheat flour (SF) mixed supplemented with 10, 20 and 30 % dehulled cowpea meal (CM); refered to as 10, 20 and 30 % SP, respectively. The methods utilized in this project included: AACC methods for proximate analyses and trypsin inhibitor activity determination, atomic absorption spectrophotometry for mineral determination, a dye binding procedure for measuring available lysine, HPLC for amino acid quantification,, FAO/WHO amino acid scoring patterns for chemical scores and AOAC for protein digestibility. The protein content of the pastas supplemented with CM ranged from 11.3 to 14.2 %, while the 100 % SF pasta (SP) contained 10.9 %. CM supplementation resulted in 52 to 113 % more total lysine, and 26 to 82 % more available lysisne in the CM pasta compared to the SP. Chemical scores for SP were 45 and 59 % for preschool and school-age children, respectively. Adding 30 % CM to SP improved the above chemical scores to 89 and 100+, respectively. However, the addition of CM compromised the *in vitro* protein digestibility of SP from 4 to 6 %. The addition fo 30 % CM provided the SP with greater calcium (Ca), iron (Fe), zinc (Zn) and copper (Cu): 44, 49, 91 and 402 % respectively. Cooking the CM pasta resulted in a 50 to 90% retention of mineral content, with the greatest loss being for Cu. In the cooked 30 % CM pasta, the contents of Fe, Zn and Cu were, respectively, 50, 67 and 243 % greater than their content in the cooked SP. Of the cooked pasta, the only one displaying trypsin inhibitor activity was the 30 % CM pasta, which had 0.8 TIU.

RESUMEN. Evaluación nutricional de una pasta de harina de trigo secada a alta temperatura y suplementada con frijol (judía de vaca) (*Vigna unguiculata (L) Walp*). El objetivo de este estudio fue determinar la calidad nutricional de dicha pasta. El trabajo fue único en los siguientes aspectos: 1) El proceso de secado fue hecho bajo un método no convencional, dicho proceso consistió en secar la pasta a alta temperatura y en corto tiempo; 2) la calidad nutricional de la pasta de harina fue mejorada con un suplemento de frijol. El frijol fue selectivamente escogido por ser un cultivo común y que forma parte de la dieta en los habitantes del noroeste de Brasil. Otros beneficios atribuidos al proceso de secado utilizado en este estudio son reducción de contaminación de bacterias de la pasta. Bajo un punto de vista industrial, este proceso podría representar una reducción en el tiempo de procesamiento, una disminución en el consumo de energía y una reducción en los costos de producción. Adicionalmente, la literatura reporta un mejoramiento de la pasta de harina en varios aspectos, cuando otras harinas diferentes a *Triticum durum* son usadas y posteriormente secadas. Dichos aspectos son firmeza, intensidad de color, y características de cocimiento. La pasta producida en este estudio fue hecha usando 100% de harina de trigo y harina de trigo suplementada con 10, 20 y 30 % de harina de frijol. Los métodos utilizados en este estudio fueron: AACC, para la inhibición de la actividad de la tripsina; espectrofotometría de absorción atómica, para la determinación de minerales; colorimetría, para la estimación de la lisina disponible; HPLC, para la cuantificación de amino ácidos; FAO/WHO, para las determinaciones de escores químicos, y AOAC, para la evaluación de la digestibilidad de la proteína. El contenido de proteína de las pastas suplementadas con harina de frijol fue entre 11.3 y 14.2 %, mientras que la pasta de harina de trigo al 100 % presentó sólo 10.9 % de contenido proteico. La pasta de harina suplementada con frijol resultó de 52 a 113 % con más lisina total, y de 26 a 82 % con más lisina disponible, comparativamente con la harinas de trigo. Los escores químicos de la harina de trigo fueron 45 % para niños de edad pre-escolar y 59 % para niños en la primaria. Estos escores químicos fueron mejorados, cuando a la harina de trigo, se le adicionó 30 % de harina de frijol, dichos resultados fueron 89 % para pre-escolares y 100+ para niños de primaria. Sin embargo, el suplemento de harina de frijol redujo de un 4 a 6 % la digestibilidad *in vitro* de las proteínas presentes en la harina de trigo. La suplementación de harina de trigo con 30 % de harina de frijol incrementó el contenido de calcio, hierro, zinc y cobre en un 44, 49, 91 y 402 % respectivamente. En dicho tipo de pasta, estos minerales fueron retenidos de un 50 a 90 % cuando la harina de frijol fue cocida, siendo la mayor pérdida de cobre. Cuando las pastas fueron cocidas, el contenido de hierro, zinc y cobre resultó mayor en un 50, 67 y 243 %, respectivamente, en la harina suplementada con 30 % de harina de frijol comparativamente con la harina de trigo. De todas las pastas cocidas, únicamente la que fue suplementada con 30 % de harina de frijol mostró inhibición de la actividad de la tripsina, con 0.8 unidades internacionales de tripsina.

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[1] Post-doctoral position with the United States Department of Agriculture/ Agriculture Research Service/Soft Wheat Quality Laboratory.

[2] Post-doctoral position with the United States Department of Agriculture/ Ohio Agricultural Research and Development Center/Soft Wheat Quality Laboratory.

[3] Full Professor. University of Arizona, Nutrition and Food Science Department. Tucson, USA.

INTRODUCTION

Although pasta is losing its inexpensive and filling «reputation» in western countries, many areas of the developing world continue to view pasta in this way. However, in order to reach and maintain this low cost status for foods, such as pasta, governments of many less developed countries have felt compelled to: first, use large amounts of hard currency to import wheat, and second, subsidize this grain at the point of consumption (1,2).

Nutritionally, unfortified pasta provides consumers with kilocalories, but offers little in terms of vitamins or minerales. Additionally, pasta is not considered an adequate protein source for children, or young adults, due to its limiting essential amino acid lysine (Lys).

Attempting to reduce developing countries reliance on wheat imports, while improving pasta's nutritional quality, several studies have evaluated the use of locally grown crops in pasta formulation. In terms of product quality, encouraging results have been reported using soybean (3), lupin (4), pea (5), other legumes (6) and chickepea (7), while products of lesser quality have been produced using rape seed (8), and corn gluten meal (9).

Recent improvements in the genetics of *Vigna unguiculata* (L) Walp, better known as cowpea or blackeyed pea, have resulted in a greater production within its traditional growing regions in the tropics, and brought about its introduction to previously unsuitable regions (10). Currently, cowpea is an important source of protein in less developed regions, such as in Northeast Brazil and West Africa. Value added products have been suggested as a means to increase the market for cowpea in the regions mentioned above as well as in the United States (11, 12, 13). In addition, such products could help overcome the constraints to icreased consumption created both by storage-induced textural defects and laborious methods used in the production of home made cowpea based foods (14, 15).

Drying is considered to be the most critical and difficult step in pasta production. High temperature (HT) drying has received limited research attention yet it is widely used in industry. Similar stages compared to conventional drying methods are used, along with temperatures above 70 °C (16). The suggested benefits of HT drying include reduction in bacterial counts, drying time, labor and maintenance requirements, thus, pasta production costs are reduced (17). In addition, several authors claim improvements in firmness, color intensity, and cooking characteristics when low quality durum wheat or nondurum materials are used (18, 19).

Like most legumes, cowpea contains a variety of antinutritonal factors, which may result in adverse physiological response if they are not removed, or their activity reduced during processing. Dehulling has been reported to reduce the amount of stachyose and raffinose in cowpeas, while almost eliminating its tannin content (20, 21). The amount of lectins in cowpea has been reported to be low compared to other legumes, while its phytic acid content has been found at levels similar to that in durum semolina flour (22, 23). Previous work indicates that cowpea also contains moderate levels of trypsin inhibitor, which displays reduced activity when exposed to moist heat, while dry heat has been shown to be less effective in reducing the inhibitor's activity (24, 25).

A high-temperature (HT) dried pasta supplemented with cowpea developed by Bergman et al (26), thus may be compromised in it's nutritonal quality, due to trypsin inhibitor activity, as it is produced by a dry heat process. Other potential shortcomings of that product are the detrimental affect of the HT drying porcess on Lys availability (27, 28), and mineral loss during cooking, due to leaching into the cooking water. The objective of this study was to examine the nutritional quality of HT dried pasta products, made from soft wheat, and supplemented with cowpea.

MATERIAL AND METHODS

Material: Cowpea (*Vigna unguiculata* (L). Walp, cv. California Blackeyed #5) was donated by Foundation Seed- California Crop Improvement Association, Davis, California. The soft wheat flour was provided by Cereal Food Processors, Inc., Kansas City, Kansas, and the durum semolina was purchased from Pantanella Roma Imports of America, Tucson, Arizona. Chemicals were of analytical grade and were purchased from Sigma, Saint Louis, Missouri.

Pasta production: According to Bergman et al (26), cowpeas were dehulled and ground, and the pasta was extruded and HT dried. The following pasta treatments were produced: 1) 100 % durum semolina (DP); 2) 100 % soft wheat flour (SP); 3) 90 % soft wheat flour, 10 % cowpea meal (10 % CP); 4) 80 % soft wheat flour, 20 % cowpea meal (20 % CP); and 5) 70 % soft wheat flour, 30 % cowpea meal (30 % CP).

Sample composition: Proximate composition and acid detergent fiber were performed, in triplicate, using the AACC methods (29). Atwaters' energy conversion factors, of 4 kcal/g for protein and carbohydrate, and 9 kcal/g for fat, were used to estimate the kilocalorie content of the pasta treatments (30).

Mineral determination: Samples (in triplicate) were wet ashed, using HNO_3 and HClO Ashed samples were evaluated for their Ca, Cu, Fe and Zn contents, using a Hitachi Polarized Zeeman Atomic Absorption Spectrophotometer (model 180-70). Linear regression, using spectroscopy absorbance values for mineral standars, was used to determine sample mineral concentrations. Bovine liver, from the National Standards Bureau, was also analyzed to evaluate the methods' accuracy. Calculation of mineral retention, after cooking, was performed using the following equation (31):

% True Retention= [(mineral content per g of cooked pasta x g of pasta after cooking) /
(mineral content per g of uncooked pasta x g of uncooked pasta)] x100

Available lysine: The available Lys content of both, the raw materials and the pasta samples cooked for 10 minutes, was measured (in triplicate), using a drye binding procedure (32).

Amino acid determination: Each sample was analyzed (in duplicate), both in the presence and absence of sodium thioglycolate. Sodium thioglycolate was used to preserve methionine. In the absence of sodium thioglycolate, a performic acid oxidation step was carried out in order to measure cystine, as cysteic acid. Samples were hydrolized with 6 N HCl in an autoclave, for 18 h, at 121 °C, 15 psi (33). They were then evaporated to dryness using a rotary evaporator, dissolved in 0.1 N HCl, and filtered through Whatman N° 5 filter paper. Amino acids were derivatized with fluorescent o-phthaladehyde, and an internal standard of amino butric acid was added to each sample run (34, 35). Quantificatin of amino acids was performed using HPLC (Spectra-Physics, model 8000B), with a Rp-18, 3μ spherical column. Tryptophan contents were estimated by calculating the mean of eight values, reported for cowpea, and five values, reported for wheat flour (36, 37, 38).

Chemical score (Amino Acid Score): The chemical score was calculated by expressing the limiting essential amino acid (EAA) in the treatments, as a percentage of the same EAA in the FAO/WHO amino acid scoring patterns, for preschool children (2-5 years), school children (10-12 years), and adults (38). ***In vitro* protein digestibility:** Digestibility was measured (in duplicate), by using an *in vitro* protein digestion method (39).

Trypsin inhibitor activity: Trypsin inhibitor activity (TIA) was measured (in triplicate), using defatted samples and the AACC method (29).

Statistical analysis: Data were evaluated by analysis of variance, with t test (LSD), using the statiscal analysis system (SAS) computer program (40).

RESULTS AND DISCUSSION

Proximate composition of pasta: The proximate analysis of the raw material and supplemented pastas is shown in Table 1. Beginning at 20 % supplementation, the protein content of the pasta entered the range of protein (11.5- 13 %) generally considered necessary for durum semolina to produce good quality pasta (41).

TABLE 1
Proximate composition of raw material and pasta*

Treatments Content (%) Raw material	Moisture	Protein	Lipid	Ash	CHO**
Durum semolina (DS)	10.77	15.46	1.16	0.94	71.67
Soft wheat flour (SF)	8.73	10.72	1.13	0.64	78.78
Cowpea meal (CM)	8.52	23.08	1.11	3.37	63.92
Pasta products					
100 % Durum semolina (DP)	9.74	16.02	0.38	0.98	72.88
100 % Soft wheat flour (SP)	7.05	10.94	0.27	0.65	81.09
90 % SF + 10 % CM (10 % CP)	7.02	11.30	0.29	0.79	80.60
80 % SF + 20 % CM (20 % CP)	8.19	13.28	0.34	1.02	77.17
70 % SF + 30 % CM (30 % CP)	7.55	14.22	0.37	1.28	76.58

* Values are means of three replicates, reported on a dry weight basis

** CHO= Carbohydrate

Crude fat values were lower in the pasta than in its raw ingredients. This was likely due to the formation of complexes between lipid and starch, or protein, which are known to occur when wheat is hydrated, and mixed. For example, Youngs et al (42) found that 91.5 % of the lipid, in durum semolina, was bound after the material had been mixed with water, and centrifuged. Thus, the low fat content of the pasta treatments were not unexpected, as hexane, a non-polar solvent was used which is unable to extract those complexes.

In terms of energy content, cowpea has been reported to provide 3.9 kcal/g (43), while wheat flours are reported to contain 4.0 kcal/g (44). As a result of these similar values, the kcal content of the CP, calculated using Atwaters factors, did not vary, compared to DP and SP.

The acid detergent fiber (ADF) content of the raw samples were found to be: 0.44 % (DS), 0.34 % (SF), and 3.40 % (CM). The amount of ADF found in the pasta products was: 0.46 % (DP), 0.35 % (SP), 0.56 % (10 % CP), 0.84 % (20 % CP), and 1.13 % (30 % CP). As expected, the ADF content of the pasta products increased with greater CM addition.

Mineral content: The contents of the minerals Ca, Cu, Fe and Zn in the raw material are shown in Table 2. CM contained levels of those minerals comparable to values reported previously, except for Fe (43, 45). The large value found for Fe may stem from contamination from milling equipment. Compared to DS and SF, CM had the highest contents of Ca, Cu, and Fe, and the least amount of Zn. The mineral content of DS and SF, did not differ significantly from each other, except for Zn, where DS showed a higher content. Mineral contents found for the SF and DS, in this study, were in agreement with findings in the lieterature (46, 47).

TABLE 2
The content of selected minerals in raw materials (PPM)*,**

Samples	Calcium	Copper	Iron	Zinc
Cowpea meal (CM)	444.6a	13.4 a	81.7a	3.8c
Durum semolina (DS)	184.8b	2.1b	39.4b	11.1a
Soft wheat flour (SF)	197.6b	0.7b	37.4b	7.0b

* Values are means of replicates, reported on a dry weight basis. Within each column, values followed by the same letter are not significantly different ($P<0.05$).

** ppm= parts per million

The mineral content of the pasta are shown in Table 3 (Ca and Cu contents) and Table 4 (Fe and Zn contents). CM supplementation at the 20 and 30 % level resulted in the cooked pasta having higher quantities of Ca, Cu, Fe and Zn compared to the SP. The mineral content of the pasta treatments was also evaluated in terms of percent true retention (Tables 3 and 4), a method which takes into consideration the loss of solids accompanying cooking (31). In the present study, all treatment had Ca and Zn retentions comparable to the durum pastas examined by Ranhotra et al (46) and Albrecht et al (48). However, the percent retention values for Fe, in all treatments, were lower than values reported in the literature (46), and higher than the ones reported by Albrecht et al (48). Cu retention, in the present study, ranged from 50 to 79 %, while the comparison studies cited above, reported values of 12 and 97 % respectively. The primary difference existing between the methods used in these studies was in the rinsing of the cooked pasta. Ranhotra et al (46) followed typical commercial package cooking instructions, which seldom includes rinsing the cooked pasta. In contrast, the pasta evaluated in the present study, and by Albrecht et al (48), were rinsed after cooking. Because the rinsed pasta, in both cases, had lower retention values than the material, which was not rinsed, Cu may have migrated to the pasta surface during cooking, and was then washed off during the rinsing process.

TABLE 3
Mineral content of pasta before and after cooking and percent retention*

Pasta	Calcium Uncooked (ppm)**	Calcium Cooked (ppm)	Calcium Retention (%)	Copper Uncooked (ppm)	Copper Cooked (ppm)	Copper Retention (%)
Durum semolina (DP)	205.1c	229.2b	106	2.4bc	2.0b	79
Soft wheat flour (SP)	193.7c	186.4c	87	1.0d	0.7d	63
90%SF + 10%CM (10% CP)	259.3b	239.8b	91	1.8cd	1.0c	50
80%SF + 20%CM (20% CP)	252.8b	246.2b	89	3.0b	1.8b	55
70%SF + 30%CM (30% CP)	278.8a	290.9a	96	4.0a	2.4a	55

* Values are means of two replicates, reported on a dry weight basis. Within each column, values followed by the same letter are not significantly different ($P<0.05$). SF= Soft wheat flour; CM= Cowpea meal; CP= Pasta made from soft wheat and cowpea.

** ppm= parts per million.

TABLE 4
Iron and zinc content of pasta before and after cooking and percent retention*

Pasta	Iron Uncooked (ppm)**	Iron Cooked (ppm)	Iron Retention (%)	Zinc Uncooked (ppm)	Zinc Cooked (ppm)	Zinc Retention (%)
Durum semolina (DP)	61.0d	38.5d	60	12.5b	11.1b	84
Soft wheat flour (SP)	81.6a	53.2b	59	7.6d	7.6c	90
90%SF + 10%CM (10% CP)	60.8d	42.9c	64	9.2c	8.2c	81
80%SF + 20%CM (20% CP)	69.8c	56.5a	74	12.0b	10.4b	80
70%SF + 30%CM (30% CP)	79.1b	58.0a	67	14.6a	12.7a	80

* Values are means of two replicates, reported on a dry weight basis. Within each column, values followed by the same letter are not significantly different ($P<0.05$). SF= Soft wheat flour; CM= Cowpea meal; CP= Pasta made from SF and CM

** ppm= parts per million.

Esssential amino acids: The EAA content of the raw material is shown in Table 5, and of the cooked pasta in Table 6. Results, for the raw material, were in agreement with findings in the literature, except for an apparent discrepancy in the wheat tyrosine (Tyr) values (49,50). In the present study, SF and DS contained 50 % more Tyr compared to the levels reported in the studies cited above. However, the Tyr content found in hard wheat (51), was greater than the levels found, in the DS and SF, in the present study. Finley (52) reported a 43 % difference in levels of Tyr, in soybeans, depending on the conditions of hydrolysis. It has been reported that Tyr content, in wheat, have limited variability between classes (53). Thus, differences in the methodology used among previous studies and the present work, rather than genotypic differences, may explain the variations between Tyr values reported here, and in the literature. There was a significant difference in the amino acid content among the raw materials ($P<0.05$). CM was found to have the highest levels of His and Lys. SF had the highest content of Met, followed by DS, and CM. Finally in terms of Cys content, the three materials differed significantly, with SF having highest Cys content, followed by DS, and CM.

TABLE 5
Essential amino acid (EAA) content of raw matrials (g/16g N)*, **

EAA	Cowpea meal (CM)	Durum semolina (DS)	Soft wheat flour (SF)
His	3.28a	2.12b	2.20b
Ile	4.15a	3.63c	3.93b
Leu	7.53a	6.78b	7.51a
Lys	7.18a	2.22b	2.42b
Met	1.20c	1.34b	1.54a
Cys	0.72c	1.92b	2.23a
Phe	5.06a	4.54b	5.03a
Tyr	2.90b	2.62c	3.14a
Thr	3.17a	2.10c	2.42b
Trp***	1.09	1.03	1.03
Val	4.80a	3.97c	4.59b

* Values are means of two replicates, reported on a dry weight basis. Within each column, values followed by the same letter are not significantly different ($P<0.05$).

** EAA= Essential amino acids. Histidine, isoleucine, leucine, lysine, methionine, cysteine, phenylalanine, tyrosine, threonine, tryptophane, and valine.

*** Tryptophan values represent the mean of literature values for 8 cowpea cultivars and 5 wheat flours (36).

TABLA 6
Essential amino acid (EAA) content of cooked pasta (g/16g N)*,**

EAA***	DP	SP	90% SF+ 10% CM	80% SF+ 20% CM	70% SF+ 30% CM
His	2.09cd	2.01d	3.24bc	2.50b	2.80a
Ile	3.79a	3.60a	3.85a	4.01a	4.25a
Leu	7.20a	6.79a	7.25a	7.45a	7.89a
Lys	2.72c	2.60c	3.68bc	4.51ab	5.53a
Met	1.49a	1.50a	1.51a	1.49a	1.51a
Cys	1.61a	2.07a	1.74a	1.28a	1.31a
Phe	5.28a	4.99a	5.29a	5.45a	5.64a
Tyr	2.83a	2.80a	3.01a	3.10a	3.20a
Thr	2.28c	2.25c	2.67b	2.85ab	3.01a
Trp****	1.03	1.03	1.04	1.04	1.05
Val	4.16cd	4.13d	4.47bc	4.70b	4.91a

* Values are means of replicates, reported on a dry weight basis. Within each column, values followed by the same letter are not significantly different ($P<0.05$).

** DP= 100 % Durum semolina pasta, SP=100 % soft wheat flour pasta, SF= soft wheat flour, CM= cowpea meal.

*** Histidine, isoleucine, leucine, lysine, methionine, cysteine, phenylalanine, tyrosine, threonine, tryptophan and valine.

**** Tryptophan values represent the mean of literature values for 8 cowpea cultivars and 5 wheat flours (36).

Dexter et al (27) demonstrated that amino acid levels in pasta are not significantly affected by pasta drying. Taking this into consideration, the cooked pasta in the present study was chosen to be evaluated for its amino acid content. A greater amount of the EAA's, His, Lys, Thr and Val were found in the supplemented pasta compared to the DP and SP treatments. The other EAA were not found to be signifcantly different between treatments. However, the levels of Met and Cys, in CM, were less than in the SF and DS treatments.

Consequently, sulfur amino acid levels, in the pasta, were compromised by cowpea supplementation.

Total and available lysine: The total and available Lys contents of the raw material are shown in Table 7, while the contents in the cooked pasta are presented in Table 8. The total Lys content of 7.18 g/16g N found for CM, in this study, agrees with findings by Hurrel et al (32), who reported a value of 6.62 g/16 g N for dehulled cowpea. The addition of 20 and 30 % CM increased the total Lys content of the SP from 2.60 g/16 g N to 4.51 and 5.53 g/16 g N, respectively. Increased available Lys was also achieved with cowpea supplementation. Addition of 30 % CM boosted the level by 82 % resulting in an available Lys content of 4.37 g/16 g N. Lys is the essential amino acid of most concern in pasta, because high temperature during processing have been reported to reduce its availability, thus aggravating it's limiting amino acid statuus (28). High processing temperatures, low water content, and significant levels of reducing sugars are all factors which promote reduction in Lys availability. Those conditions favor the Maillard reaction, which occurs between reducing sugars and free amino groups of proteins, thereby decreasing Lys availability, and ultimately, protein digestibility (54,55). Dexter et al (16) have shown that with a relatively high water content and a small amount of reducing sugars, decreases in available Lys, in pasta, are directly related to the drying temperature and length of product exposure to heat (27).

TABLE 7

Total and available lysine contents of raw materials*

Sample	Lysine content g/16g N Total	 Available
Raw material		
Durum semolina (DS)	2.32b	2.30b
Soft wheat flour (SF)	2.42b	2.39b
Cowpea meal (CM)	7.18a	6.90a

* Values are means of two replicates, reported on a dry weight basis. Within each column, values followed by the same letter are not significantly different ($P<0.05$).

TABLE 8

Total and available lysine contents of cooked pasta*

Sample**	Lysine content g/16g N Total	 Available
Pasta		
100% Durum semolina (DP)	2.72c	2.47b
100 % Soft wheat flour (SP)	2.60c	2.40b
90 % SF + 10% CM (10%CP)	3.68bc	3.03b
80% SF + 20% CM (20% CP)	4.51ab	3.36ab
70% SF + 30% CM (30% CP)	5.53a	4.37a

* Values are means of two replicates, reported on a dry weight basis. Within each column, values followed by the same letter are not significantly different ($P<0.05$).

** SF= Soft wheat flour; CM=Cowpea meal; CP= Pasta made from SF and CM.

A study evaluating the effect of HT drying on available Lys, in semolina pasta, reported a loss of 32 %, after 5 h of drying at 85 °C(28). Dexter et al (27) reported the available Lys loss, in semolina pasta, to be 9.4 % after a drying cycle consisting of one h at 40 °C, 2 h at 85 °C, and 6 h at 40 °C. In the present study, the percent of total Lys, in the pasta treatments, which was available, decreased from 6 to 24 % in relationship to the raw materials. The percent of total Lys, which was available in the DP and SP were 91 and 92 %, respectively. Lower values of 82, 75 and 79 % were found for the percent of available Lys compared to the total Lys, in the 10, 20 and 30 % CM supplemented pastas. This difference between the 100 % wheat treatments and the CP might, in part, be explained by the fact that cowpea possesses approximately three times more reducing sugar than wheat (56,57). Thus, exposing the CP treatments to HT drying may have created conditions, which favored more the Maillard reaction.

Chemical Score: Several methods for evaluating protein quality have been developed to try to decrease the time and cost of performing animal studies. A simple technique known as chemical score, or amino acid score, reports the percentage of a product's lowest occurring EAA, compared to the content of the same EAA in a reference protein (38). Chemical scores for cooked pasta, as compared to amino acid needs of young children, adolescents, and adults are listed in Table 9. Based on their chemical to amino acid needs of same EAA in a reference protein (38). Chemical scores for cooked pasta, as compared to maino acid needs of young children, adolscents, and adults are listed in Table 9. Based on their themical scores, SP and DP would not be considered good protein sources for preschool or school children, as their scores fell within the range of 45 to 62. However, at 20 % supplementation and above, CM dramatically improved the SP's chemical score for school children. Adding 30 % cowpea brought the limiting amino acid score of SP, for preschool children, from 45 to 89. Although this increase was a substantial improvement, it was not enough for it to be considered equivalent to an «ideal protein» source for preschoolers.

TABLE 9

Pasta chemical scores for children and adults*

Pasta sample*	Chemical Score (%)*** Preschool child (2-5 yrs)	 School child (10-12 yrs)	 Adult
100% Durum semolina (DP)	47	62	100+
100% Soft wheat flour (SP)	45	59	100+
90% SF + 10%CM (10% CP)	63	84	100+
80% SF + 20% CM (20% CP)	78	100+	100+
70% SF + 30% CM (30% CP)	89	100+	100+

* Scoring patterns of amino acid levels are those suggested by FAO/WHO (1985)

** SF= Soft wheat flour; CM=Cowpea meal; CP= Pasta made from SF and CM.

*** The limiting amino acid was lysine, except for 30% CP, for preschool child, it was threonine.

TABLE 10

In vitro protein digestibility of raw materials and cooked samples

Samples*	Digestibility (%)**
Raw material	
Durum semolina (DS)	89.10a
Soft wheat flour (SF)	85.21c
Cowpea meal (CM)	74.80g
Pasta Products	
100% Durum Semolina (DP)	87.56b
100% Soft Wheat Flour (DP)	84.63c
90 % SF + 10% CM (10% CP)	81.04d
80% SF + 20% CM (20% CP)	79.50e
70% SF + 30% CM (30% CP)	78.17f

* SF= Soft wheat flour; CM=Cowpea meal; CP= Pasta made from SF and CM.

** Values are means of two replicates, reported on a dry weight basis. Within the column, values followed by same letters are not significantly different ($P<0.05$).

Tabla 11

Effect of cooking on trypsin inhibitor activity***

Samples	TIU***	
	Uncooked	Cooked
Raw material		
Durum semolina (DS)	trace	—
Soft wheat flour (SF)	trace	—
Cowpea meal (CM)	14.8a	—
Pasta Products****		
100% Durum semolina (DP)	trace	trace
100% Soft wheat flour (SP)	trace	trace
90 % SF + 10% CM (10% CP)	1.3d	trace
80% SF + 20% CM (20% CP)	2.9c	trace
70% SF + 30% CM (30% CP)	3.3b	0.8a

* Values are means of three replicates, reported on a dry weight basis. Within each column, values follwed by the different letters are significantly different.

** Trace= values too low to fall within the 40 % to 60 % inhibition range required to calculate accurate trypsin inhibitor activity values.

*** TIU= Trypsin inhibitor unit

**** SF= Soft wheat flour; CM=Cowpea meal; CP= Pasta made from SF and CM.

***In vitro* digestibility:** Protein quality is a function of a foods' protein digestibility, as well as its essential amino acid content. The *in vitro* protein digestibility (IVPD) method used in this study has been reported to be able to distinguish between as little as 1 % differences in the protein digestibility of several processed cowpea products (58). Table 10 presents the *in vitro* protein digestibility results of the raw materials and cooked pasta samples from the present study. The IVPD of the raw cowpea was found to be 74.8 %, which is similar to the value of 77.8 % reported by Phillips and Baker (58), and within the range of 75 % to 80 % reported for varooius cowpea cultivars, by Onigbinde and Akinyele (20). Furthermore, the IVPD value of 89.1 % for durum semolina, is comparable to previously reported data for this commodity: 85.4 % (59) and 87.6 % (9).

The IVPD of uncooked and cooked pasta were not significantly different, thus only the values for the cooked treatments are reported. As CM supplementation increased, IVPD scores for the supplemented pasta decreased. Reduced durum semolina digestibility, after pasta drying has previously been related to simultaneous losses of available Lys (59). In the present study, the cowpea treatments (Table 7) had 75 to 82 % of their total Lys avaliable, while the raw materials had close to 100 %. Therefore, the presence of indigestible Lys complexes, along with the additional fiber provided by the cowpea, may have related to the lower IVPD, which accompanied CM supplementation (60).

Trypsin inhibitor activity (TIA): TIA values for raw matrials, uncooked and cooked pasta are listed in Table 11. The value of 14.8 obtained for CM, in this study, is less than the range of 15.6 to 31.2 reported by Ogun et al (25), and higher than the value of 12.20 reported by Elkowicz and Sosulski (24). Activities for SP, DP, 10 % CP and 20 % CP were too low to fall within the 40 to 60 % inhibition range required to calculate and were thus reported as trace. Sing and Chauhan (61) reported a value of nil for the TIA of cooked noodles made from durum, while Bahnassegy et al (6) reported 0.8 TIU in uncooked durum semolina pasta.

The TIA method requieres that «one ml of extract inhibits 40-60 % of the standard trypsin solution» (29). Fifty ml of 0.01 N NaOH are generally used to extract one g of sample. In the present study, this method was utilized, but still several samples did not demonstrate TIA activity. Only after increasing the amount of sample extracted to two g did the SP, DP, 10 % CP, and 20 % CP, after cooking demonstrate TIA. The CP treatments had TIU values from 1.3 to 3.3. At the point of consumption, that is, after cooking, the CP's TIA ranged from trace to 0.8 TIU. Therefore, TIA in CP should not be considered as posing a potentianl health risk.

CONCLUSION

Considering total protein, EAA content, and available Lys the supplemented products were all nutritionally superior to the SP. Additionally, trypsin inihibitor activity was found to be of little consequence. However, the protein in the CP pasta was less digestible that one in the 100 % wheat pastas.

Te use of response surface methodology (RSM) has proven effective in iptimizing HT dried pasta quality (62). Future work to improve CP might include the use of RSM to determine the optimum SF and CM combination and processing conditions which will maximize the nutritional quality, sensory properties and cooking quality of CP.

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