Development of a High-Temperature-Dried Soft Wheat Pasta Supplemented with Cowpea (*Vigna unguiculata* (L.) Walp). Cooking Quality, Color, and Sensory Evaluation

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ABSTRACT

High-temperature (HT) dried soft wheat pasta (SP) supplemented with 10, 20, and 30% cowpea meal (CM) was produced. Pasta with cowpea (CP) contained up to 30% more protein than did the SP. Ash reached a maximum of 1.3% in the 30% CP. After 10 min, the CP treatments' cooking loss decreased with additional CM, and the 30% CP had a cooked weight lower than that of the SP. CM addition improved pasta color scores and integrity during cooking, and breakage decreased during storage. No difference in acceptability was found between samples made with CP and 100% wheat. Results demonstrate that HT drying and CM addition can overcome some of the constraints of using soft wheat flour in pasta production.

As a wheat-derived staple food, pasta is second only to bread in world consumption (Mariani-Constantini 1988). Its nearly worldwide acceptance is attributed to its low cost, ease of preparation, versatility, sensory attributes, and long shelf life (Pagani 1986, Riley 1987). These factors may have been what led Helmut Maucher, chief executive of Nestle, to suggest that the future for feeding the world lies in pasta (Alpert and Smith 1989). However, this appears unrealistic when one considers that durum wheat (*Triticum durum*), the primary ingredient in "Italian style" pasta, contributes only 5% of the world's wheat production, and it generally trades at a higher price than does common wheat (*Triticum aestivum*) (Dick and Matsuo 1988). But, the comment by Maucher could be true if pasta could be produced from unconventional commodities.

Economically speaking, the use of soft wheat flour (SF) for pasta production could be advantageous; however, the poor sensory attributes and cooking quality of such products have dictated that durum semolina be used. As a result, research has focused on the use of semolina in Italian style pasta, and only limited attention has been given to improving nonconventional pasta quality.

Attempts to overcome the poor quality of nonconventional pasta have primarily relied on the use of additives and high-temperature drying (HT). For example, Chimrov et al (1981) reported that with the addition of sodium alginate and calcium gluconate, there was a decrease in soft wheat pasta's cooking loss, and its textural measurements were similar to those of hard wheat pasta. Haber et al (1978) found an increase in soft wheat farina pasta firmness when soybean or cottonseed meal was added. Soybean meal improved the soft wheat pasta color, while cottonseed compromised it. The most dramatic findings have come from studies on HT drying of nonconventional pasta: improved firmness, color intensity, and cooking quality have been reported (Dexter et al 1981, Wyland and D'Appolonia 1982, Resmini and Pagani 1983, Abecassis er al 1989).

The purpose of this study was to examine the potential of using cowpea as an additive, along with HT drying, to improve the quality of soft wheat flour pasta. This work has potential application in a country such as Brazil, whose population consumes, on average, 6 kg of pasta per person per year (Carvalho 1981). Furthermore, Brazil is the world's second largest producer of cowpea (Rachie 1985).

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MATERIALS AND METHODS

Material

Cowpea (*Vigna unguiculata* (L.) Walp, cv. California Blackeyed 5) was donated by Foundation Seed-California Crop Improvement Association, Davis, CA. Soft red winter wheat flour (SF) was provided by Cereal Food Processors Inc., Kansas City, KS, and a high-quality durum semolina (DS), sold for pasta production, was purchased from Pantanella Roma Imports of America, Tucson, AZ.

Cowpea Meal Production

Cowpea seed coats were knocked free from the cotyledons in a Bauer Brother's mill and separated in an Almaco seed cleaner. Decorticated cowpea was ground in a Vicking hammer mill. Cowpea meal (CM) consisted of the material that passed through a 20-mesh sieve but was retained on a 100-mesh sieve, thus simulating particle size of semolina (Vasiljevic and Banasik 1980).

Sample Preparation

The following pasta treatments were produced, in triplicate: 1) 100% durum semolina (DP); 2) 100% soft wheat flour (SP); 3) 90% SF flour, 10% CM (10% CP); 4) 80% SF, 20% CM (20% CP); 5) 70% SF, 30% CM (30% CP).

After 4 min of mixing at 32% moisture, the dough was extruded through a La Parmigiana laboratory-scale pasta extruder fitted with a brass macaroni die. A modification of the HT drying method described by Dexter et al (1984) was used (Table I). The final drying period was reduced from 6 to 2 hr. Rather than an environmental chamber, two baffled, forced-air ovens were used; 40°C drying was performed in an oven made by Chicago Surgical and Electric Company, and the 80°C drying was performed in a Market Forge oven (model M2200). At all times, samples were placed, one-layer thick, on wire shelves to ensure even air distribution. After cooling, samples were placed in plastic bags, which were stored in cardboard boxes and maintained at room temperature.

TABLE I
Pasta Drying Conditions

Time, hr	Temperature, °C	Drying Stage
0.5	25	Case hardening
1.0	40	Predrying
2.0	80	Drying
2.0	40	Final drying

Sample Composition

Raw materials and pasta were analyzed for protein, fat, ash, and moisture using the standard procedures of AOAC (1990). The micro-Kjeldahl method was used to determine crude protein. The nitrogen factor used for all 100% wheat samples was 5.75; 6.25 was used for the CM and the CP treatments. Crude fat determination was performed by extracting samples with hexane for 6 hr (AACC 1983). All analyses were performed in triplicate, once per treatment replicate, and reported on a dry weight basis. Chemicals used were all of analytical grade and were purchased from Sigma (St. Louis, MO).

Physical Measurements

AACC (1983) color evaluation methods were used. These included the use of a Hunterlab model D25-PC2 system (optical sensor, sensor interface unit, and computer), and a color score map. One year after production, duplicate measurements for L (darkness to lightness), a (green to red +), and b (blue to yellow +) were obtained from 50 g of sample from each treatment ground to 20 mesh. The pasta color score map, designed for the instrument cited above, was used to assign a score to each treatment. The scores were based on duplicate measurements of L and b values performed for each of the three replicates of each treatment.

With the intention of simulating the sometimes extreme handling and storage conditions found in a less developed country such as Brazil, storage bags were picked up and dropped 2 ft onto the floor, once per month. Degree of shattering was subjectively evaluated after a storage period of one year.

Optimum cooking time was established by boiling the pasta in distilled water until the center white core could no longer be seen when a small piece was crushed between two glass plates.

After 10 and 20 min of boiling samples in distilled water, cooked weight and cooking loss were determined in triplicate according to Vasiljevic and Banasik (1980) and Holliger (1963), respectively. Holliger's cooking loss method was modified as follows. After determining the cooked weight, each sample was dried in a forced-air oven at 110°C overnight. The dry weight of the samples, before and after cooking, was used to calculate the percentage of cooking loss. A cooking time of 10 min was chosen based on the optimum time found for the DP, and 20 min was used to simulate overcooking.

TABLE II
Pasta Acceptability and Optimum Cooking Time

Pasta	Acceptability[a]	Optimum Cooking Time (min)
100% Durum semolina (DP)	4.9	10
100% Soft wheat flour (SP)	4.7	7
90% SF + 10% CM (10% CP)[b]	4.5	7
80% SF + 10% CM (20% CP)	4.1	8
70% SF + 30% CM (30% CP)	4.0	8

[a] Means from the pasta sensory evaluation are not significantly different ($P < 0.05$).
[b] SF = Soft wheat flour; CM = cowpea meal; CP = pasta made from SF and CM.

Sensory Evaluation

Acceptability of the treatments was evaluated by a 25-member consumer panel, using a seven-point hedonic scale, in a standard sensory evaluation laboratory with fluorescent lighting. Panelists consisted of faculty and students of the University of Arizona, as well as students' family members, who responded to an advertisement soliciting sensory panelists familiar with the taste of cowpea. Before sampling, panel members received instructions and were allowed to view the questionnaire in an adjacent conference room. Demographic data collected included: age, sex, and country of origin.

The cooking process, standardized for all treatments, consisted of boiling 25 g of pasta in 950 ml of tap water containing 2 g of added NaCl and 15 g of butter. Each sample was cooked for its optimum cooking time (Table II), drained in a colander, and placed under a heat lamp until served.

Statistical Analysis

Analysis of variance and Duncan's multiple range test were performed using MSTAT (version 5), a statistical software program from Michigan State University.

RESULTS AND DISCUSSION

The cowpea decortication process resulted in a 72.3% yield, which is 2.7% less than what Ningsanond and Ooraikul (1989) reported after attempting to optimize a dry dehulling process using an abrasive dehuller and sieve. The CM appeared pale yellow in comparison to the white SF and amber yellow DS. Black pieces of hull became noticeable when 30% CM was mixed with SF. However, no mention of this was made by the sensory panel members.

Preliminary work using an Atlas home pasta machine (model 150) revealed that beyond 30% CM, the SF dough became too dry and crumbly to manipulate at 32% moisture, the level reported as ideal for durum pasta extrusion (Walsh et al 1971). However, at 30% or less CM supplementation and 32% moisture, there was no noticeable difference in the handling of the doughs; they all extruded with similar consistency and demonstrated no tearing during extrusion. Work by Nielsen et al (1980) found 30% to be the optimum water absorption level for a 33% pea and 67% hard red spring wheat flour dough, and a 20% soy protein concentrate and 80% hard red spring wheat flour dough. All samples were extruded at 32% moisture, because of how similar the doughs handled at 30% CM or less, and because previous work indicated that similar products had a water absorption near 32%.

Proximate composition of the raw material and the pasta products is shown in Table III. Addition of CM increased the

TABLE III
Proximate Composition of Raw Material and Pasta[a]

Treatments	Content, %				
	Moisture	Protein	Lipid	Ash	CHO[b]
Raw Material					
Durum semolina (DS)	10.77 ± 0.08	15.46 ± 0.26	1.16 ± 0.03	0.94 ± 0.04	71.67
Soft wheat flour (SF)	8.73 ± 0.05	10.72 ± 0.20	1.13 ± 0.04	0.64 ± 0.05	78.78
Cowpea meal (CM)	8.52 ± 0.10	23.08 ± 0.29	1.11 ± 0.01	3.37 ± 0.05	63.92
Pasta Products					
100% Durum semolina	9.74 ± 0.02	16.02 ± 0.35	0.38 ± 0.00	0.98 ± 0.04	72.88
100% Soft wheat flour	7.05 ± 0.15	10.94 ± 0.25	0.27 ± 0.02	0.65 ± 0.01	81.09
90% SF + 10% CM (10% CP)[c]	7.02 ± 0.11	11.30 ± 0.15	0.29 ± 0.00	0.79 ± 0.06	80.60
80% SF + 20% CM (20% CP)	8.19 ± 0.14	13.28 ± 0.01	0.34 ± 0.01	1.02 ± 0.03	77.17
70% SF + 30% CM (30% CP)	7.55 ± 0.04	14.22 ± 0.11	0.37 ± 0.01	1.28 ± 0.03	76.58

[a] Values are means ± standard deviation (triplicate samples).
[b] Carbohydrate (by difference).
[c] CP = Pasta made from SF and CM.

protein content of SP from 10.9 to 11.3, 13.3, and 14.2% in the 10, 20, and 30% CP, respectively. The SF contained 0.6% ash. Adding CM, with a 3.4% ash content, resulted in pasta ash values greater than the 100% SP. Moisture levels of the SP and CP treatments ranged from 7.0 to 8.2%, while the DP had 9.7% moisture.

Color measurement results are summarized in Table IV. Several trends were associated with greater cowpea supplementation. There was an increase in darkness, yellowness, and redness, as well as a decrease in greenness. The durum pasta's color score was 6, while the SP color score was 3.5. Supplementation of SF with 10 or 20% CM improved the pasta color score to 4.5; adding 30% CM brought the score to 5.0. Superior color scores for the CP compared to those of the SP were not a surprise. As noted earlier, upon visual examination, the CM displayed a slight yellow color compared to that of the SF. It was assumed that the CM contained more carotenoids than did the SF. However, a comparison could not be made; documentation on CM carotenoid content was not available in the literature. In addition to a difference in pigment content, color improvements found for the CP may also have been related to high-temperature exposure, combined with greater amounts of lysine and reducing sugars provided by the CM compared to those of the SF (Toepfer et al 1972, El Faki et al 1983). These conditions are known to promote the maillard reaction, which results in the formation of colored by-products (Hurrell et al 1979). Formation of maillard products during HT pasta drying has previously been reported (Acquistucci et al 1988).

Haber et al (1978) reported that the addition of soybean products to soft wheat created a pasta with color equal to or better than that of the soft wheat control. In a similar study, it was found that supplementing hard common wheat with field pea caused an increase in yellowness when compared to 100% hard wheat pasta (Nielsen et al 1980). Likewise, Hung et al (1991) reported that mixtures of lupin or chickpea flours with unbleached wheat flour resulted in greater yellow color and a concomitant increase in darkness. In contrast, supplementing durum pasta with a bean protein concentrate was reported to bleach the color, while soy concentrate isolate and grits had little effect (Hanna et al 1978). Thus, it appears that legume addition to common wheat has the potential to improve pasta color scores, but when combined with semolina, color measurements are compromised.

A poor color score found for the DP (far lower than 12, the maximum) can be attributed to the fact that the pasta was not extruded under a vacuum, a situation known to be related to poor pasta color (Banasik 1981). Additionally, assessment of the pasta color was performed one year after production, thus providing opportunity for carotenoid oxidation and a subsequent decrease in yellowness.

The characteristics of pasta cooked for 10 and 20 min are summarized in Table V. CP treatment cooked weights were the same as those of the SP, except with 30% legume addition, when a decrease in cooked weight was observed. As with most ingredients used in food processing, a level exists at which the ingredient added provides an optimum effect. However, at some point less than or greater than the optimum quantity, either the desired change in functionality does not occur or an unacceptable change results. Such a range of functionality generally must be determined empirically, because the mechanism behind the ingredient's functional property is not completely understood. A similar situation seems to have occured with the addition of CM to SF. At a certain level, somewhere between 20 and 30% CM, an effect on cooked weight occured; at levels below this, no effect could be measured. Albeit, at the higher end of the range of legume added in pasta, rather than at the lower end, Bahnassey and Khan (1986) also reported that only a specific range of supplementation was able to produce an effect. At 10 and 15% addition of a legume flour or legume concentrate to durum wheat, a lowering effect on cooked weight was noted by these authors, while increasing the amount to 25% resulted in no additional effect. The cooked weight results found for the present study are also consistent with the findings by Haber et al (1978). These authors found that adding soybean to SF resulted in decreased cooked weights when compared to an SP control. Similarly, addition of lupin or chickpea flours to unbleached wheat flour created a decrease in cooked weight (Hung et al 1991).

The question raised is: why does legume addition result in lower pasta cooked weights when legume flours display greater water absorption than wheat flour (Bahnassey and Khan 1986, Mustafa et al 1986)? Heat is known to cause protein molecules to unfold, exposing functional groups previously associated within the molecule to its external environment. Such an occurrence may increase legume protein surface hydrophobicity; thus, as Bahnassey and Khan (1986) have suggested, it decreases its water

TABLE IV
Hunter Color Measurement of Pasta

Pasta	Hunter Color Measurement[a] *L*	*a*	*b*	Color Score
100 % Durum semolina (DP)	52.7 ± 0.1 b	2.4 ± 0.1 b	18.3 ± 0.2 a	6.0
100% Soft wheat flour (SP)	55.1 ± 0.3 a	1.8 ± 0.1 c	12.6 ± 0.1 e	3.5
90% SF + 10% CM (10% CP)[b]	53.6 ± 0.4 b	2.2 ± 0.1 bc	15.0 ± 0.1 d	4.5
80% SF + 20% CM (20% CP)	50.2 ± 0.5 c	3.2 ± 0.2 a	16.2 ± 0.1 c	4.5
70% SF + 30% CM (30% CP)	49.0 ± 0.3 d	3.1 ± 0.0 a	17.5 ± 0.2 b	5.0

[a]Values are means ± standard deviation (duplicate samples). Within each column, values followed by the same letter are not significantly different ($P < 0.05$).
[b]CP = Pasta made from SF and CM.

TABLE V
Characteristics of Pasta Cooked for 10 and 20 Minutes[a]

Pasta	Cooked Weight, g		Cooking Loss, %	
	10 min	20 min	10 min	20 min
100% Durum semolina (DP	23.1 ± 0.3 c	29.4 ± 0.5 c	5.3 ± 0.3 e	7.3 ± 0.2 c
100% Soft wheat flour (SP)	29.5 ± 0.5 a	37.6 ± 0.3 a	10.0 ± 0.1 a	13.0 ± 0.4 a
90% SF + 10% CM (10% CP)[b]	29.4 ± 0.9 a	38.4 ± 0.6 a	9.2 ± 0.4 b	10.9 ± 0.3 b
80% SF ± 20% CM (20% CP)	29.4 ± 0.6 a	37.5 ± 0.8 a	8.6 ± 0.3 c	10.5 ± 0.4 b
70% SF + 30% CM (10% CP)	26.2 ± 0.5 b	35.2 ± 0.1 b	8.0 ± 0.2 d	10.5 ± 0.4 b

[a]Values are means ± standard deviation (triplicate samples). Within each column, values followed by the same letter are not significantly different ($P < 0.05$).
[b]CP = Pasta made from SF and CM.

binding capacity. In this study, we noted that the 30% CP displayed superior integrity during cooking when compared to the other treatments, except for DP. The most dramatic difference observed was between 30% CP and the SP. This may have been related to the higher percentage of protein in the 30% CP, which after undergoing some degree of denaturation, resulted in less water weight gain and subsequently less stress on the pasta.

Results from the cooking loss study are presented in Table V. After 10 min of cooking, increased amounts of CM resulted in less cooking loss. However, after 20 min, the loss was the same for all CP treatments but lower than that of the SP.

Legume supplementation of pasta by Bahnassey and Khan (1986) resulted in greater cooking loss when compared to a DP control. Traditional pasta drying was used for their study; that is, low-temperature long-time drying, as opposed to the present study, where an HT short-time drying method was utilized. High temperatures have been shown to increase the potential for associating or binding of lipid and starch with protein molecules, with the subsequent formation of more highly aggregated complexes (Wall and Huebner 1981). Dexter et al (1981) and Ibrahim and McDonald (1981) have demonstrated that temperatures within the 70–90°C range, as used in the present study, are sufficient to cause protein denaturation in durum pasta. Electron microscopy work done by Resmini and Pagani (1983) indicated that the ability of HT drying to denature SP protein results in its polymerization into a matrix with starch molecules dispersed throughout it. These researchers linked this phenomenon with the correlation they found between HT drying of SP and reduced cooking loss. These previous studies suggest, then, that the larger protein content in the CP, compared to that of the SP, may have provided a superior framework of denatured protein that was better able to trap starch molecules, preventing their loss during cooking, and thus ultimately decreasing the cooking loss.

The durum pasta's optimum cooking time of 10 min (Table II) was within the range of standard cooking times (10–12 min) used to evaluate DP (Cubadda 1986, Vasiljevic and Banasik 1980). A lower optimum cooking time of 7 min was found for the SP and 10% CP; the 20 and 30% CP required 8 min of cooking. Increased pasta cooking times accompanying legume fortification have previously been reported (Beslagic 1981, Bahnassey and Khan 1986). During pasta cooking, there is competition between starch and protein for water (Pagini 1986). It is known that when less protein surrounds starch granules, they swell and gelatinize faster (Grzybowski and Donnelly 1977). Thus, it is postulated that legume addition, along with its greater amount of protein, results in slower starch swelling and, subsequently, a longer time requirement for gelatinization to occur.

After a storage period of one year, the pasta was examined to determine the amount of shattering. All treatments displayed more than 50% shattering, except the DP and the 30% CP, which both showed no more than 10% shattering. Bahnassey and Khan (1986) reported a similar shattering problem with a legume-supplemented pasta. However, a continuation of this work by Duszkiewicz-Reinhard et al (1988) determined that the problem was caused by a low pasta moisture content, rather than an effect created by the use of legume flour.

Results from the sensory evaluation in the present study indicated that the pasta treatments were not perceived as different by the consumer panel (Table III). These findings may be explained, in part, by conclusions drawn from a pasta supplementation study by Hanna et al (1978), in which it was determined that a sensory panel is more sensitive to the supplementation material itself than to the amount added.

In the present study, panelists had a common characteristic that may also have affected the sensory study results. Over 30% of the evaluators were from areas of the world known to be regular consumers of cowpea, such as Brazil, Cape Verde, and Sierra Leone. Therefore, the panelists may not have found the CM flavor unacceptable when compared to the 100% wheat products, as has been the case in some products supplemented with a legume (Mustafa et al 1986, Hung et al 1991). Further validation of this can be found in several of the evaluators comments: "I like the flavor of beans" and "all the samples taste the same." A discussion by Vasiljevic and Banasik (1980) suggests that pasta quality is defined subjectively according to the eating habits and traditions of the consumer. The target markets for CP consist of people accustomed to the tastes of both cowpea and pasta, such as West Africans and Brazilians. CM supplementation, in relationship to pasta acceptability, may be of less importance to such consumers, as compared to others. Certainly, a study with a greater number of panelists would be needed to test this hypothesis.

CONCLUSIONS

SF is seldom used to produce Italian-style pasta because of its inferior quality when compared to DP. It might be expected then, in accordance with previous studies of pasta supplemented with legumes, that the addition of CM to SP would have little effect, or that it would further compromise its poor quality (Matsuo et al 1972, Haber et al 1978). However, in the present study, cowpea improved the color and cooking quality of HT-dried pasta made from SF, reduced the amount of shattering displayed after storage, and had no affect on consumer acceptability.

Further investigation is needed to examine the relationship between CP quality and dough moisture content, maximum drying temperature, length of HT exposure, and extrusion under vacuum. Also, texture analysis, in-country sensory work, and nutritional evaluation would be needed prior to commercial production of CP.

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