Soy Enrichment of *Chapaties* Made from Wheat and Nonwheat Flours[1]

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ABSTRACT

Cereal Chem. 61(5): 435–438

The *chapati* is a thin, steam-leavened bread that is the staple food of many semiarid nations. Because the *chapati* comprises a substantial part of the diet in these nations, it should be made as nutritionally complete as possible. *Chapaties* prepared with various blends of cereal flours were enriched with soy flour so that their nutritional quality would be improved. A reproducible method for preparing nonwheat *chapaties* was developed. *Chapaties* that puffed satisfactorily were prepared from the following blends: whole wheat-soy; grain sorghum-soy; corn-soy; proso millet-soy; and pearl millet-soy. A whole-wheat *chapati* was used as a control. The protein quality and quantity of the *chapaties* and the digestibility of the proteins present were improved when they were prepared with a soy flour blend. The blend was adjusted to have 5.5 g of lysine for every 100 g of protein in the composite flour. The corn-soy blend had the highest calculated protein-efficiency ratio—2.15—as compared with 1.41 for the unblended corn. In all cases, calculated protein-efficiency ratios were improved by being blended with soy flour.

The *chapati* is a thin, steam-leavened bread that is the staple food of India and West Pakistan. It is also commonly eaten in parts of Africa, Mongolia, and China. The bread is prepared from very basic ingredients (whole-grain flour and water) and cooked at high temperatures. One method of cooking *chapaties* calls for placing them on the walls of a tendour, which is a simple oven with mud walls (Aziz and Bhatti 1962). They may also be prepared on flat iron plates over an open flame (Chaudhri and Muller 1970). The *chapaties* are traditionally served with side dishes such as vegetables, meat, and milk. They are often made in the morning and carried to the fields for lunch. They are usually stacked in a pile, wrapped in cloth, and stored in baskets (Murty and Subramanian 1982).

Because *chapaties* comprise a major portion of the diet of the people of these nations, the impact of their nutritional quality is great (Chaudhry 1967). Most *chapaties* are made from whole wheat (Kent 1975), which, like most cereal grains, is low in certain essential amino acids. The *chapati* should be made as nutritionally complete as possible if the dietary requirements of the people are to be met.

Because the cereal grains are typically first limiting in lysine, they can be enriched by being blended with a legume product such as soy flour, which contains higher levels of lysine. Steinke and Hopkins (1983) have found that specific combinations of vegetable and legume products optimize the amino-acid balance of the blended product. In a similar way, *chapaties* made with cereal grains can be made to fulfill more of the dietary requirements than *chapaties* that are not enriched. To demonstrate the value of added soya protein,

[1]Published as paper number 7338, Journal Series, Nebraska Agricultural Experiment Station.
This work was supported in part by the Nebraska Soybean Development, Utilization, and Marketing Board.

Mathew and Raut (1981) conducted a study on children admitted to hospital wards for protein-calorie malnutrition (PCM). The patients were given soya milk, and their response was monitored. The researchers found that normal body weight could be obtained within 120 days, depending on the severity of the PCM.

Some work has been done to develop procedures for preparing *chapaties* with flours other than wheat, such as pearl millet (Olewnik et al 1984). Other procedures have been developed for preparing *chapaties* by replacing part of the wheat flour with a nonglutinous flour and adding a soy supplement (Ebeler and Walker 1983). However, we were unable to find any references to methods that had been developed specifically for the preparation of *chapaties* made by replacing all of the wheat flour and adding a soy supplement.

The objectives of this work were to determine whether *chapaties* could be prepared by totally replacing the traditional whole-wheat flour with another cereal flour, and to improve the protein quality of the *chapaties* by blending the cereal flours with soy flour.

MATERIALS AND METHODS

Chapaties were prepared with five cereal-legume composite flours: whole wheat-soy, red-grain sorghum-soy, corn-soy, proso millet-soy, and pearl millet-soy. A *chapati* prepared from whole wheat was used as a control.

The whole-wheat flour was a commercially milled hard red winter wheat flour purchased locally. The corn flour was a commercially milled product obtained from Crete Mills, Crete, NE. The soy flour used was toasted Nutrisoy obtained from Archer Daniels Midland in Decatur, IL, and the red-grain sorghum flour was obtained from Grain Products Inc., Dodge City, KS. Whole-grain millet flours were prepared in the laboratory using the Udy sample mill. The average particle size was determined for each of the flours, using the Fisher Subsieve Sizer.

The *chapaties* were prepared by modifying the laboratory procedure developed by Ebeler and Walker (1983) for preparing wheat-based *chapaties*. The level of soy used in each composite

TABLE I
Comparison of Protein Characteristics Before and After Blending

Flour or Blend	Grams Lysine (per 16 g of N)	Lysine Level (% of FAO)[a]	Percent Protein[b]	Percent Digestibility[c]	Calculated Protein Efficiency Ratio
Soy	7.07	111	52.70	85.72	1.95
Whole wheat	2.91	43	15.19[c]	77.20	1.59
Whole wheat-soy	5.50	81	27.59	80.02	1.91
Sorghum	2.05	28	7.45	73.76	0.54
Sorghum-soy	5.50	77	18.17	76.60	1.75
Corn	3.00	43	6.64	73.76	1.41
Corn-soy	5.50	77	14.34	75.76	2.15
Proso millet	1.24	18	11.57	78.05	0.49
Proso millet-soy	5.50	82	26.93	80.92	1.93
Pearl millet	2.62	36	10.90	75.12	0.73
Pearl millet-soy	5.50	78	22.40	77.53	1.94

[a] Adjusted for digestibility.
[b] Moisture-free basis. Percent protein = percent nitrogen × 6.25 for nonwheat flours. For wheat, percent protein = percent nitrogen × 5.7.
[c] In-vitro digestibility.

TABLE II
Proximate Compositions

Flour	Moisture (%)	Protein (%)[a,b]	Ash[a] (%)	Lipids[a] (%)	Particle Size (μm)
Soy	8.63	52.70	6.00	1.50	13.1
Whole wheat	10.40	15.19	1.56	1.49	25.5
Sorghum	12.85	7.45	1.13	0.86	27.3
Corn	11.25	6.64	1.02	2.95	24.3
Proso millet	13.64	11.57	3.90	3.80	26.9
Pearl millet	9.44	10.90	1.50	6.37	24.7

[a] Moisture-free basis.
[b] Percent protein = percent nitrogen × 6.25 for nonwheat flour. For wheat, percent protein = percent nitrogen × 5.7.

TABLE III
***Chapati* Baking Parameters**

Flour	Flour[a] Mass (g)	Percent Absorption (14% mb)	Total Water Added (ml)	Cooking Time	Percent Puffing
Whole wheat	33.60	64	23.80	4 min, 15 sec	100
Whole wheat	22.62	68	25.43	4 min, 14 sec	100
Soy	10.76				
Sorghum	26.06	105	37.60	5 min, 05 sec	80
Soy	8.09				
Corn	28.11	106	38.35	5 min, 00 sec	80
Soy	5.64				
Proso millet	21.38	96	34.48	4 min, 50 sec	90
Soy	12.74				
Pearl millet	24.03	97	35.80	5 min, 10 sec	60
Soy	9.12				

[a] As-is basis (35.00 g of flour on 14% mb).

flour was determined so that 100 g of protein in the blend contained 5.5 g of lysine (FAO-WHO 1973). The lysine, protein, and moisture contents were used to calculate the appropriate ratios of cereal to soy flour (Tables I and II).

For the four composite flours that did not contain wheat, the dough was partially pregelatinized to develop a consistency sufficient to hold the *chapati* dough together during sheeting. The partial gelatinization was determined subjectively by how well it formed a dough that could be handled easily. The water (Table III) was added to the cereal component of the composite flour and was placed in a 650-W microwave oven at 30% power for 1 min and 20 sec. After the dough was pregelatinized, it was prepared in the same manner as the wheat-containing *chapaties*. The *chapaties* were then baked for approximately 5 min (Table III) in a convection oven at 232°C (450°F). To obtain uniform puffing, they were turned after 1, 2, and 2.5 min.

Although *chapaties* are not traditionally prepared in convection ovens, there is a similarity between the type of heat produced by a convection oven and that produced by a tendour. Olewnik et al (1984) developed a simulated tendour that included an enclosed, heated chamber. This kind of oven represents the way *chapaties* are often prepared in their native countries. However, the purpose of this work was to develop a reproducible method for preparing *chapaties* in the laboratory. Attempts to produce a uniform *chapati* were made using a hot plate, but the reproducibility and acceptability of these *chapaties* were lower than those made in the convection oven.

Traditionally, *chapati* doughs are allowed to rest for 1 hr before they are cooked. This presumably improves the hydration of the proteins and starches and allows the dough to develop more completely (Knight 1965). This technique was tried for this project but was discontinued because no significant improvements in the dough or *chapati* quality were found.

When the *chapaties* were evaluated, the following characteristics were considered to be desirable (Mason and Hoseney 1980): minimal thickness, puffing throughout, centering of cleft between upper and lower surfaces, flexibility, tan to golden-brown surface color, uniformity of texture and color, adequate internal cooking, and chewy texture. Each *chapati* was subjectively evaluated by being compared with the whole wheat *chapati* because it met most of the desirable characteristics of a good *chapati*. This is only a model, however. The characteristics that make a *chapati* acceptable vary from region to region and from culture to culture.

The protein quality of the flours and their blends was determined by chemical analysis. The proteins in each composite flour were evaluated by C-PER. This method was derived from the PER method, in which the efficiency of proteins is determined by comparing the amount of weight a laboratory rat gains for each gram of protein it consumes. The C-PER method was developed to predict this ratio based on amino acid content (Table IV) and in-vitro digestibility (Table I) (Hsu et al 1978). The amino-acid analysis was based on three hydrolysates: acid hydrolysis; performic-acid oxidation and acid hydrolysis; and alkaline hydrolysis (Satterlee et al 1982).

RESULTS AND DISCUSSION

Chapaties made from blends that did not contain wheat were difficult to work with because the dough did not have the rubbery consistency necessary for easy manipulation. This consistency developed readily in the doughs containing wheat flours because gluten was present. In the nonwheat flours, this rubbery consistency was simulated by partially pregelatinizing the starch of the nonwheat cereal component of the composite flour.

The whole wheat-soy combination produced the best *chapati*, based upon subjective standards. It puffed the highest and had characteristics most similar to those of the whole-wheat *chapati*. The *chapati* made from the proso millet flour puffed about 90% as high as the whole-wheat *chapati*, whereas both the corn-soy and the sorghum-soy composites produced *chapaties* that puffed about 80% as high as the whole-wheat *chapati*. The *chapati* made with the pearl millet-soy composite flour puffed only about 60% as high as the whole-wheat control (Table III).

The whole wheat-soy composite produced a *chapati* that tasted very similar to the plain whole-wheat *chapati*. The presence of soy was not easily detectable. The sorghum and both of the millet composites produced *chapaties* that had a grainy mouthfeel and left an aftertaste. The *chapati* made with corn and soy did not leave an aftertaste and had a smoother mouthfeel. All sensory evaluations were informal observations made by the authors.

The sorghum and proso millet flours had the largest average particle size of all the flours. The whole wheat, pearl millet, and corn flours had similar particle sizes, whereas the soy flour was approximately one half the average particle size of the cereal flours (Table II).

The C-PERs of the sorghum and both of the millet flours were very low before blending. After blending, the values were increased up to 300% (Table I). Both the quality and quantity of the protein present in these three flours were improved greatly by blending with soy to balance the protein with respect to the FAO suggested level for lysine. The blend with the highest C-PER was the corn-soy blend. The protein quality in this blend was very high because the amino acids present in the two proteins complemented each other. The corn protein contained high levels of methionine and cystine (112% of FAO recommended levels) and low levels of lysine (43% of FAO recommended level) and tryptophan (48% of FAO recommended level). The soy protein contained a surplus of lysine (111% of FAO recommended level) and tryptophan (111% of FAO recommended level) and a deficit of methionine and cystine.

Before each of the flours was blended with soy and balanced for the FAO recommended level for lysine, less than one half of the lysine required for efficient protein synthesis was available. After blending, the composite flours contained at least 75% of the recommended level of lysine. In theory, this value would have been 100%, but because the proteins were not completely digestible, not all of the amino acids were available (Table I).

Not only was the protein quality improved, the quantity was increased also. The amount of protein in each flour increased approximately twofold by being blended with soy. The wheat-soy,

TABLE IV
Amino Acid Composition[a]

Flour or Blend	Lys	M + C	Thr	Iso	Leu	Val	P + T	Trypt	Asp	Pro	Cys	Amm
Soy	7.07	2.76	4.28	4.46	8.02	4.79	9.26	1.24	13.00	3.82	1.61	2.20
Whole wheat	2.91	4.16	3.19	3.03	7.51	4.47	8.52	1.22	6.57	9.09	2.23	2.91
Whole wheat-soy	5.50	3.29	3.87	3.92	7.83	4.67	8.98	1.23	10.57	5.81	1.84	2.47
Red sorghum	2.05	2.85	3.22	3.86	13.57	4.82	8.61	1.14	6.56	8.24	2.18	2.93
Red sorghum-soy	5.50	2.79	3.95	4.27	9.76	4.80	9.06	1.21	10.99	5.20	1.79	2.43
Corn	3.00	5.08	3.53	3.12	13.19	5.09	8.93	0.60	6.62	8.94	2.55	2.43
Corn-soy	5.50	3.65	3.99	3.94	10.01	4.91	9.13	0.99	10.54	5.79	1.97	2.28
Proso millet	1.24	4.38	2.91	3.90	13.05	4.36	9.39	1.33	5.80	6.92	1.60	3.15
Proso millet-soy	5.50	3.20	3.91	4.31	9.37	4.67	9.29	1.26	11.06	4.65	1.61	2.46
Pearl millet	2.62	4.58	3.73	4.23	10.54	5.36	8.20	1.89	7.83	6.37	2.23	2.99
Pearl millet-soy	5.50	3.40	4.09	4.38	8.91	4.99	8.89	1.47	11.18	4.72	1.83	2.48

[a]Grams of amino acid per 16 g of N.

proso millet-soy, and pearl millet-soy blends contained particularly high levels of protein (at least 20%).

CONCLUSIONS

The addition of the high-protein soy flour improved the protein quality and quantity of each of the five composite flours. In all cases, the digestibility of the proteins was improved by the presence of the soy flour. Since they were more digestible than the cereal proteins, the added soy proteins increased the average digestibility of the sample. The corn-soy blend had particularly high protein quality because the amino acids in the proteins of the two flours tended to complement one another.

Digestibility is a very important factor in determining protein efficiency and the amount of each amino acid available for protein synthesis. The composite flour proteins were balanced for the FAO recommended level for lysine (5.5 g of lysine per 100 g of protein), but this amount was based on the ideal condition that the proteins were completely digestible. Since the digestibility of the proteins determined how much amino acid was available, efforts should be made either to improve the digestibilities of the cereal flours or to balance the proteins for a higher level of lysine than that recommended by FAO.

Each of the five cereal-legume combinations was used to prepare acceptable *chapaties*. Because *chapaties* are already commonly prepared from wheat, sorghum, and millet flours, there is great potential for the acceptance of soy-enriched *chapaties* made with each of these flours. The *chapati* made with whole wheat enriched with soy had an advantage in that the techniques and ingredients used to prepare it were not significantly different from those required for the traditional whole-wheat *chapati*. This ease in preparation could improve its acceptability. The acceptability of the *chapaties* made with both of the millet flours could be improved if the grittiness were reduced. With a different milling process, these flours might be made finer, leaving a smoother mouthfeel.

ACKNOWLEDGMENTS

The authors wish to thank Greg Godwin for the protein digestibilities and the amino-acid analysis, and Susan Ebeler for the protein, ash, and fat determinations.

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[Received October 31, 1983. Accepted May 30, 1984]