Wheat and Composite Flour *Chapaties*: Effects of Soy Flour and Sucrose-Ester Emulsifiers[1]

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ABSTRACT

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Chapaties, which are thin, steam-leavened breads often made from sorghum or millets, represent a major portion of the diet for people in the semiarid tropics. A simple laboratory method was developed to measure the effect of the addition of soy flour and emulsifiers upon *chapaties* baked from wheat, sorghum, pearl and proso millets, corn, and soy flours obtained from commercial sources and from those produced in U-D and Brabender Quadrumat Jr. mills. Various flours and their blends were judged subjectively for dough handling and puffing characteristics, and *chapti* color was determined with a Hunter color difference meter. The Instron testing machine was used to measure tenderness. A simple response surface methodology technique was used to interpret experimental results. Visual scores and Instron shear-force values decreased approximately linearly with percent nonwheat flour. Sucrose-ester emulsifiers did not improve dough-handling characteristics or tenderness of the finished product.

Chapaties are a steam-leavened bread product common to India, Pakistan, and parts of Africa. They are typically, made from *atta*, a whole wheat meal, mixed with water to form a dough (Kent 1975). The dough is rolled thin and cooked on a hot surface or baked in a mud oven (Kent 1975) to produce a puffed ball (Chaudhri 1970). All or a part of the wheat flour may be replaced with sorghum or millet flours. Because these flours do not contain gluten, however, the *chapaties* may lose their extensibility. When high levels of sorghum or millet flours are used, special care must be taken to form *chapaties* that puff easily and are pliable.

Sorghum or millet alone are not good sources of nutritionally balanced protein. The protein content of sorghum may vary from 6 to 12%; protein content of pearl millet is slightly higher, varying from 10 to 14% (Hoseney et al 1981). The protein efficiency ratios (PERS) for both sorghum and millet are low, ranging from 0.5 to 1.8 (Hoseney et al 1981). Like most other cereal grains, sorghum and millet are limiting in lysine; therefore, supplementing these grains with the limiting amino acid can improve the protein value (Hoseney et al 1981). For these reasons and because *chapaties* are a major part of many Indian diets, much interest has been placed in improving their nutritional quality.

Sorghum-legume combinations form potentially good protein sources. Hoseney et al (1981) reported that children fed sorghum-legume combinations daily for more than a year grew well and did not show signs of deficiency. Effects on *chapati* quality of other protein sources such as fish protein concentrates (FPC) and cottonseed flour were also studied (Archer 1970).

Because the replacement flours are often detrimental to *chapati* quality, an emulsifier may be used to improve puffing quality, dough handling, and pliability. The effects of the food emulsifiers sodium stearoyl-2-lactylate (SSL) and glycerol monostearate (GMS) on *chapati* texture have been studied (Swaranjeet et al 1982). For more than 10 years, the fatty-acid esters of sucrose have been studied for their effect in baked foods (Chung et al 1981). Breyer et al (1983) indicated that the esters can restore bread loaf volume when up to 15–20% of the wheat flour is replaced with

sorghum. Bread tenderness can be improved, and cookie spread factor can be controlled by using sucrose esters. These esters have potential in other food systems, but limited work has been done in this area.

Food-grade sucrose esters are now manufactured commercially in Japan by Dai-Ichi-Kogyo Seiyaku Co., Ltd. of Kyoto. The process is patented and licensed by the Department of Economic Development in the state of Nebraska, and licenses are available for use in this and other countries. The esters are presently produced as a series, with hydrophile-lipophile balance (HLB) values ranging from about 1 to 15. This series is a result of varying the degree of substitution of stearic and palmitic acids on the sucrose molecule (Osipow et al 1972). The esters are pending FDA approval as food additives, but are expected to be allowed at levels up to 1.0%.

The first objective of this research was to develop a simple, reproducible laboratory method for making *chapaties* of good quality. Mason and Hoseney (1980) listed the following as desirable characteristics. The *chapati* should be flexible and have a soft, silky appearance. Mouthfeel should be smooth and not gritty, and the *chapati* should be easily chewed. The *chapati* should be uniform in diameter, well puffed on both sides, and well baked inside. The effects of replacement flours on these *chapati* characteristics can be measured by both subjective and instrumental methods.

Our second objective was to increase the nutritional quality of the *chapati*. A commercial soy flour could be blended with the sorghum, corn, or millet replacement flour based upon the amino acid balance for the soy-sorghum, soy-millet, or soy-corn blend. The resulting *chapaties* could then be evaluated subjectively for pliability, color, and flavor, and objectively for tenderness.

The third objective was to determine whether the sucrose-ester emulsifiers can counteract the deleterious effects of the replacement flours. Sucrose esters have been shown to be beneficial in bread and cookies, but little has been published about their action in other food systems.

MATERIALS AND METHODS

Flours

A commercial brand of whole wheat flour containing 13.0% protein (N × 6.25) and 1.0% fat was used for all samples.

Two types of sorghum flour were prepared in our laboratory from a commercially grown red sorghum. Sorghum tempered for 8 hr to 17% moisture produced an acceptable "white" flour in the Brabender Quadrumat Jr. laboratory mill. A separate 60-mesh U.S. Standard sieve (Strand Shaker) gave a flour of approximately 60% extraction. The U-D sample mill with a 1-mm screen was used to prepare a whole grain flour. No tempering or sifting was used to prepare this flour.

Pearl millet flours from a composite variety sample were prepared in approximately the same manner as the sorghum flours. The Brabender mill was used to produce a more refined flour tempered 1½ hr; 2% added moisture; 60-mesh sieve). The U-D sample mill was used to produce a whole grain flour and a whole grain proso millet flour.

A commercial corn flour (Crete Mills, Crete, NE) and a defatted, toasted soy flour (ADM, Decatur, IL) were also used.

The proximate composition of each flour (as determined by standard AACC methods) is listed in Table I.

Flour blends were prepared to balance the amino-acid ratios of each flour blend based upon the FAO pattern (FAO/WHO 1973).

Sucrose Esters

Sucrose esters with HLB values ranging from 1 to 15 were obtained from Dai-Ichi-Kogyo Seiyaku Co., Ltd. of Kyoto, Japan. The emulsifiers were added at levels of 0.5, 1.0, and 2.0% of the total flour weight.

Chapati Preparation

Thirty-five grams of flour (14% mb) were mixed with water in a 35-g National pin mixer. Mix time and absorption were determined by the mixograph method (AACC 1962). Absorption of 64% was found to be optimal within the ranges of flours studied. The dough

was divided into two 25-g portions. Each portion was first shaped into a smooth ball and then rolled out on a floured surface to an approximate thickness of ¹/₁₆-in. The thickness was controlled by placing metal gauge strips ¹/₁₆-in. thick on either side of a flat aluminum cookie sheet. The dough was then either cooked on a hot cast-iron skillet for 2–3 min until puffed (turned every 30 sec) or baked in a Sharp electric convection oven at 232°C for 2 min. The temperature of the cast-iron skillet was controlled manually and monitored with a surface thermometer. It was very difficult to regulate the temperature by this method. Temperatures were tried in the range of 200–250°C, but they could not be maintained within less than a 10°C range for any particular series of tests. There were considerable problems with burning and nonreproducibility when the samples were prepared by the cast-iron skillet method. Therefore, the convection oven method was adopted for all repeated experimental data. Although *chapaties* are not traditionally baked in an electric convection oven, this method was more suited to laboratory evaluation because it gave a uniform, reproducible sample, and the products were still similar to those baked on a hot surface.

Evaluation of *Chapati* Quality

The dough handling and puffing characteristics of each *chapati* were evaluated subjectively and reported on a 10-point scale. A control *chapati* that rolled out smoothly and puffed completely was assigned a 10. A score of 0 was given if the dough did not hold together at all, and 1 if it could be rolled out but did not puff. Intermediate values were then assigned to the various samples.

The Instron Universal Testing machine was used to objectively measure shear force and toughness of the *chapaties*. (Toughness is the work required to cause a rupture in a material.) A shear-press apparatus with a 2.54 cm-diameter plunger (Fig. 1) and an Instron crosshead speed of 1 cm/min were standard for all trials.

Peak force (grams of force required to shear) and deformation to peak shear force (centimeters of deformation) data were recorded for all *chapaties* (Fig. 2). The deformation to peak shear force was used as an indication of the toughness of the *chapati*.

Color was determined by the Hunter color difference meter. The

TABLE I
Proximate Composition of Flours[a]

Flour	Protein, %[b]	Ash, %	Fat, %
Whole wheat	15.2	1.6	1.5
Brabender sorghum	7.4	1.1	0.9
U-D sorghum	9.9	1.6	2.7
Brabender pearl millet	8.4	0.5	2.8
U-D pearl millet	10.9	1.5	6.4
Proso millet	11.6	3.9	3.8
Corn flour	6.6	1.0	2.9
Toasted nutrisoy	52.7	6.0	1.5

[a] Moisture-free basis.
[b] N × 6.25.

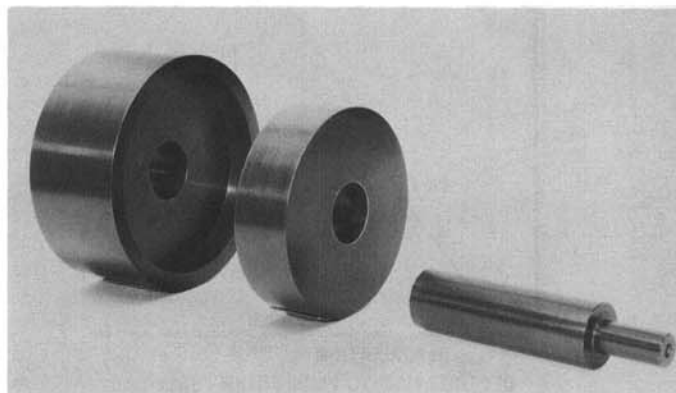**Fig. 1.** Instron shear-press apparatus.

"L, a, b" scales were used to give measurements of the light dark, red–blue, and yellow–green indices. Each day the instrument was zeroed with a white machine reference. The inside color of the *chapati* was measured so that any residual flour from the rolling-out process did not affect the results (Hunterlab).

The flavor and mouthfeel of *chapaties* containing corn, sorghum, millet, soy, and wheat blends were evaluated by two Indian students familiar with *chapaties*. A multiple-comparison test was used (Larmond 1977). The students were asked to compare the samples to a reference *chapati* made from 100% whole wheat and to rank the texture (mouthfeel), flavor, and overall quality. Additional comments were encouraged. With only two participants, it was not expected that the results would be used to provide definitive or statistically significant data. The information was used only as a check on the other tests to ensure that the resulting *chapaties* were in fact reasonable facsimilies of those consumed in India.

Protein Quality

AOAC method 43.C10 (Satterlee et al) was used to determine the computed protein efficiency ratio (C-PER) for each flour and blend (Table II).

Statistical Analysis

A simple response surface methodology (RSM) program was used to analyze all data. An Apple II+ computer was used, and two or three independent variables could be analyzed, depending upon the data. Predicted responses and contour maps were obtained for all data sets (Walker et al 1983).[2] Graphs were prepared using the empirical equations obtained from the RSM program.

[2] C. E. Walker and A. M. Parkhurst. 1983. Response Surface Analysis of Bake-Lab Data with a Personal Computer. Presented at the 1983 AACC Annual Meeting, Kansas City, MO.

TABLE II
Protein Quality as Determined by C-PER

Flour or Blend	C-PER[a]
Whole wheat flour	1.42
Sorghum flour (Brabender)	0.54
Pearl millet flour (Brabender)	0.73
Corn flour	1.41
Toasted soy flour	1.95
Sorghum-soy blend (0:66:1)	1.87
Millet-soy blend (0.52:1)	1.97
Corn-soy blend (0.48:1)	1.97
Sorghum-corn-soy blend (0.26:0.29:1)	1.84

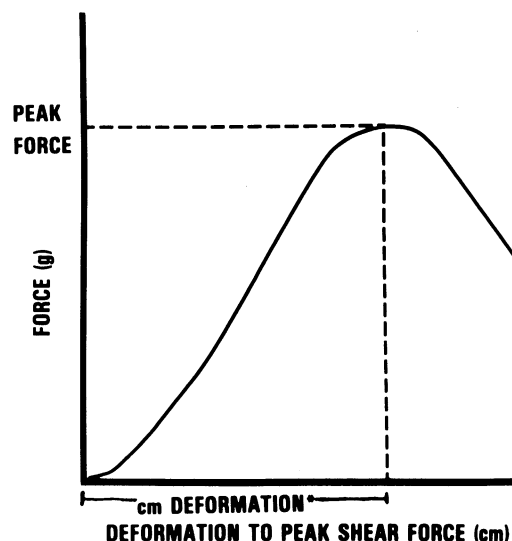[a] Values given are for the flour blend only, not for the finished *chapati*.

RESULTS AND DISCUSSION

Effects of Replacement Flours

Effects on Subjective Score. Approximately 50–80% of the wheat flour could be replaced with other cereal grains to produce an acceptable *chapati*. (A score of 4 was the approximate minimum for an acceptable *chapati*.) Pearl millet could be used up to a level of 70–80%, whereas only a 50% replacement was acceptable with proso millet. The type of milling and absorption levels, within the ranges studied, seemed to have no significant effect upon *chapati* score. A linear relationship between score and percent replacement flour was observed in most cases (Fig. 3). At high levels of replacement (75–100%), it became very difficult to form a dough that would hold its shape and roll out easily, regardless of the absorption level used. Mason and Hoseney (1980) used boiling water to mix the dough in order to gelatinize the starch. This method was not utilized for this research but might have increased the *chapati* handling quality.

Effects on Shear Force. Instron values for force required to shear showed that for all substitute flours the force initially decreased as increasing amounts of nonwheat flour were used. The product may be weaker structured because of the dilution of the wheat gluten. At 40–50% replacement, the force began to increase dramatically (Fig. 4). At this point the *chapati* did not puff completely, but formed a flat, hard, rigid structure. As a result, the shear force increased. An increase in absorption resulted in a decreased shear force due to the increased hydration and moisture content.

Effects on Toughness. By determining centimeters of deformation (Fig. 2), a measurement of *chapati* toughness was obtained. The toughness of the *chapati*, regardless of flour type, decreased approximately linearly as the percent of replacement flour increased (Fig. 5). This was apparently due to the dilution of the gluten structure as nonglutenous cereal grains replaced the whole wheat flour. In some instances, especially with the more refined flours such as that obtained from the Brabender, higher water absorption seemed to have an improving effect at the high levels of replacement flour. Because a whole wheat *chapati* has a high deformation value, it is assumed that values comparable to the control are more desirable.

Effects on Color. The redness-blueness "a" value, as determined by the Hunter color difference meter for each of the various flour

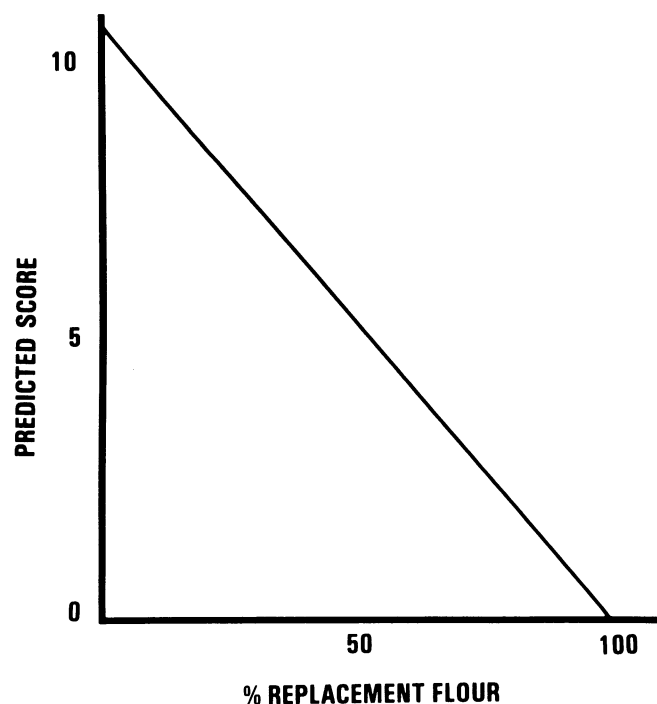**Fig. 2.** Typical Instron curve.

Fig. 3. Effects of nonwheat replacement flours on *chapati* score, as predicted by response surface methodology.

types, is shown in Tables III and IV. As the percent of flour replacement increased, the color shifted toward gray.

Effects of Soy Blends and Emulsifiers

Effects on Subjective Score. In general, the subjective score decreased as percentage of replacement blend increased, as observed earlier. By adding emulsifers, however, it was possible to obtain a score as high as the control had, even though up to 40% of the whole wheat flour had been replaced with the cereal-soy flour blends. There was a greater emulsifying effect at lower blend levels; higher HLB emulsifiers resulted in a slightly higher score (Fig. 6).

Effects on Peak Force. In general, the shear force decreased at the higher HLB values. This was especially true for the corn flour blends (Fig. 7). Generally, at the higher levels of emulsifier and replacement blend, a decreased force was observed (Fig. 8), but at low blend levels a lower level of emulsifier also decreased the force. This type of relationship could be seen on the RSM plots, where a saddle-shaped configuration was observed. In all cases, HLB value appeared to have a greater effect than the emulsifier level; therefore 0.5% emulsifier may be all that is required to decrease shear force.

Effects on Toughness. The relationship between deformation (toughness) and percent blend is approximately linear with toughness decreasing as percent blend increases. There was little or no emulsifier effect within the ranges studied (Fig. 9). The three-component blends were an exception, however. They tended to develop a maximum toughness at 20–40% blend and then began to decrease (Fig. 10). *Chapati* toughness increased at higher HLB values. This increased toughness is assumed to be more desirable because it is more comparable to the control value.

Effects on Flavor. Two Indian students evaluated the color, texture, and flavor of *chapaties* made with corn, sorghum, and soy flour blends as compared to a whole wheat control. In general, the *chapaties* were as acceptable as or slightly better than the control in

TABLE III
Color "a"[a] for *Chapaties* (Determined by Hunter Color Difference Meter)[b] with Single Replacement Flours

| Percent Replace-ment | Replacement Flour | | | | | |
	Corn	Brabender Pearl Millet	U-D Pearl Millet	U-D Proso Millet	Brabender Sorghum	U-D Sorghum
0	7.6	7.6	7.6	7.6	7.6	7.6
10	8.0	7.4	6.9	7.0	7.8	6.6
30	8.3	6.2	5.7	5.2	8.1	6.8
50	7.3	5.1	4.7	3.7	7.4	6.7
75	4.2	3.8	3.6	2.3	5.2	6.0
100	−0.8	2.7	2.9	1.4	1.4	4.7

[a] Intermediate values predicted by response surface methodology program.
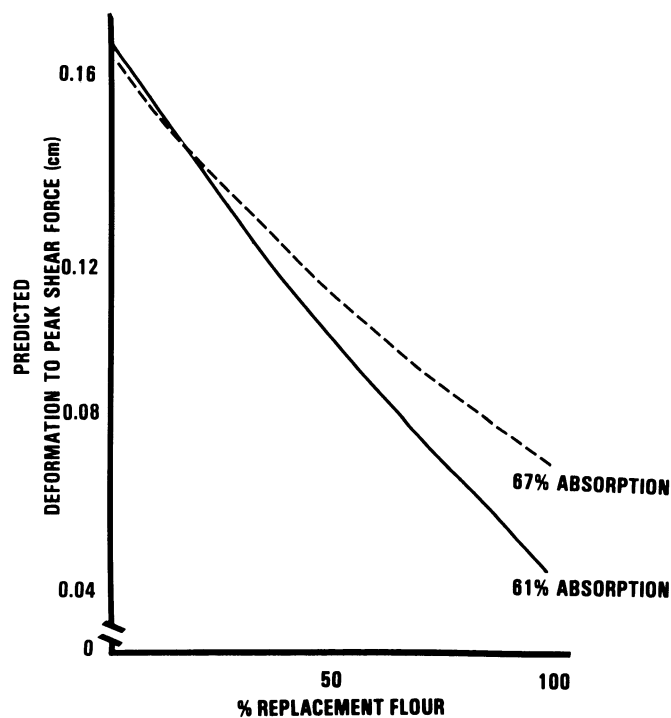[b] Color "a" is a measure of redness if positive, gray if 0, and greenness if negative.

Fig. 5. Effects of nonwheat replacement flours and absorption on Instron deformation to peak shear force (Brabender sorghum flour) as predicted by response surface methodology.
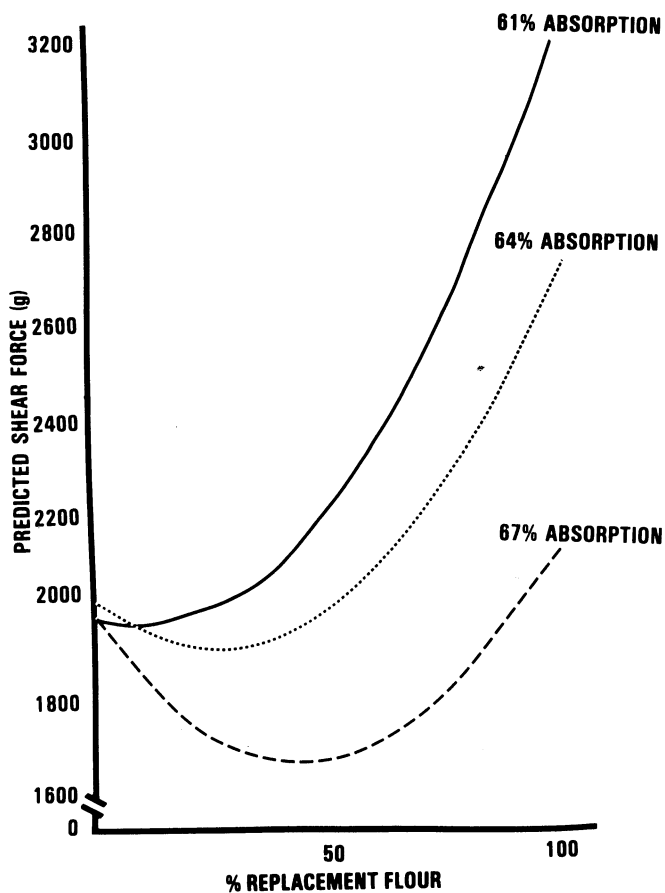

Fig. 4. Effects of nonwheat replacement flours and absorption on Instron peak shear force (U-D proso millet flour) as predicted by response surface methodology.
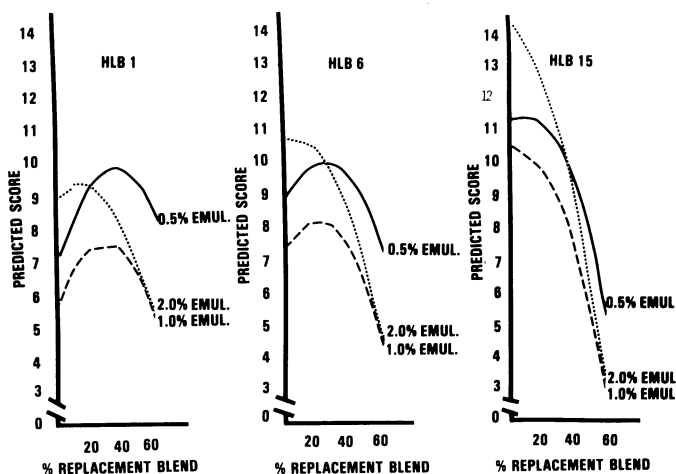

Fig. 6. Effects of nonwheat replacement blends and emulsifier hydrophile-lipophile balance on *chapati* score (corn-soy blend) as predicted by response surface methodology.
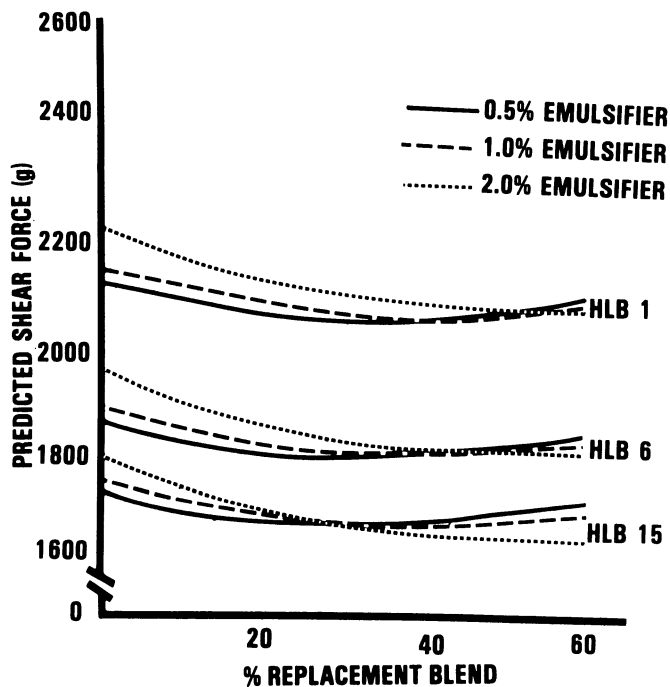
Fig. 7. Effects of nonwheat replacement blends and emulsifier hydrophile-lipophile balance on Instron peak shear force (corn-soy blend) as predicted by response surface methodology.
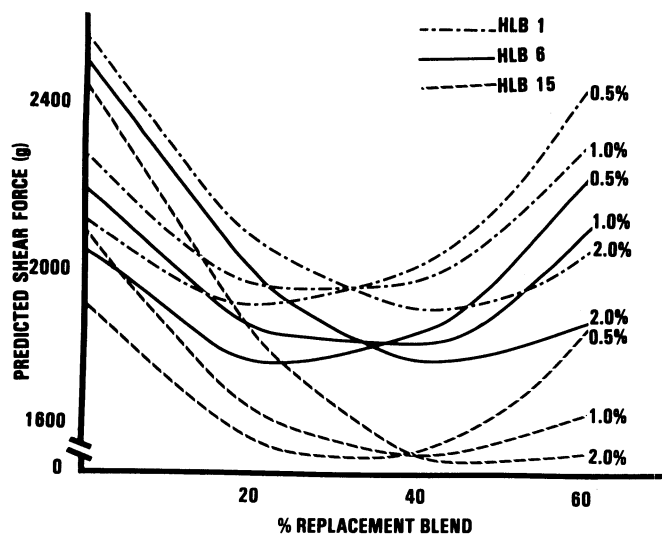

Fig. 8. Effects of nonwheat replacement blends and emulsifier hydrophile-lipophile balance and level on Instron peak shear force (sorghum-soy blend) as predicted by response surface methodology.

all categories, even when up to 60% of the wheat flour was replaced. The most common comment was that the control *chapati* was slightly undercooked. A longer baking time is recommended for future work in this area.

No statistical conclusions can be made based only on two judges, but the information obtained was valuable because it gave an idea of the acceptability of the products and indicated where further work needs to be done.

Effects on Protein Quality. The protein quality of the sorghum and pearl millet flours was improved by blending with soy flour (Table II). In all cases the C-PER of the blends alone was higher than the whole wheat flour C-PER, though no statistical treatment was possible. Previous evidence has shown that mild cooking treatments, such as those used in the preparation of *chapaties*, improve the nutritional value of the wheat flour, though this is not yet universally accepted (Kasarda et al 1971). Based upon this, the C-PER values of the cooked *chapaties* may be higher than for the
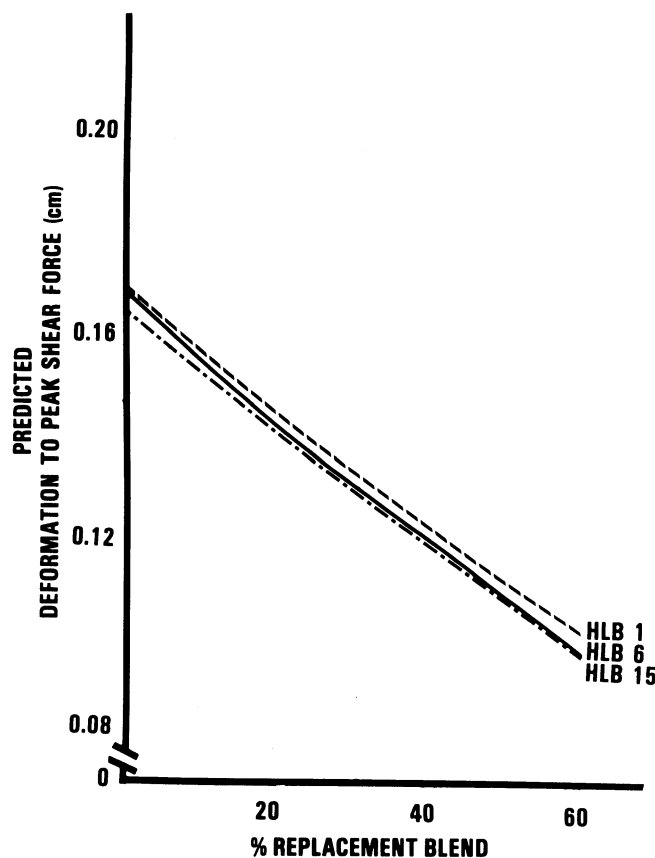

Fig. 9. Effects of nonwheat replacement flour blends and emulsifier hydrophile-lipophile balance on Instron deformation to peak shear force (pearl millet-soy blend) as predicted by response surface methodology.

TABLE IV
Color "a"[a] for *Chapaties* (Determined by Hunter Color Difference Meter)[b] with Flour Replacement Blends

	Replacement Blend			
Percent Replacement	Sorghum-Soy (0.66:1)	Corn-Soy (0.52:1)	Millet-Soy (0.48:1)	Sorghum-Corn-Soy (0.26:0.29:1)
0	7.6	7.6	7.6	7.6
20	7.7	6.7	6.8	6.5
40	6.6	6.7	5.8	6.3
60	7.0	5.9	5.0	5.7

[a] Intermediate values predicted by response surface methodology.
[b] Color "a" is a measure of redness if positive, greenness if negative, and gray if zero.
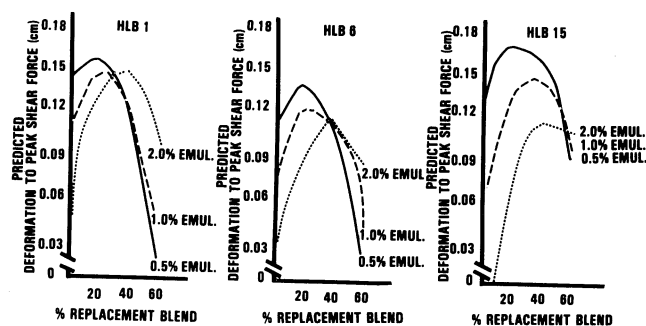

Fig. 10. Effects of nonwheat replacement blends and emulsifier hydrophile-lipophile balance and level on Instron deformation to peak shear force (corn-sorghum-soy blend) as predicted by response surface methodology.

Flour or Blend	Hunter Lab Color "a"			Score			Force			Deformation		
	R	R^2	SE	R	R^2	SE	R	R^2	SE	R	R^2	SE
Brabender sorghum	0.94	0.88	0.51	0.98	0.96	0.94	0.92	0.84	1.35	0.98	0.96	0.84
U-D sorghum	0.90	0.80	0.64	0.96	0.93	0.94	0.78	0.62	1.10	0.99	0.98	0.57
Brabender pearl millet	0.98	0.96	0.32	0.97	0.94	1.19	0.75	0.56	1.27	0.97	0.94	0.71
U-D pearl millet	0.97	0.94	0.46	0.97	0.95	0.64	0.86	0.73	1.32	0.98	0.97	0.68
Proso millet	0.99	0.98	0.36	0.98	0.97	0.83	0.91	0.84	1.26	0.97	0.94	1.05
Corn	0.95	0.90	0.54	0.98	0.96	0.94	0.88	0.78	1.05	0.98	0.97	0.65
Sorghum-soy (0.66:1)	0.87	0.76	0.53	0.96	0.92	0.97	0.92	0.84	1.02	0.98	0.97	0.59
Corn-soy (0.52:1)	0.91	0.84	0.28	0.95	0.90	0.71	0.86	0.75	1.35	0.99	0.98	0.004
Millet-soy (0.48:1)	0.97	0.94	0.32	0.93	0.86	0.76	0.88	0.78	1.23	0.98	0.95	0.63
Sorghum-corn-soy (0.26:0.29:1)	0.88	0.78	0.38	0.98	0.97	0.44	0.85	0.72	1.17	0.93	0.86	1.56

flours alone. Further work should be done in this area before definite conclusions can be made, as this work (Kasarda et al 1971) was based only upon wheat and not upon blends of wheat with other grains.

CONCLUSIONS

A simple reproducible method for the laboratory preparation of *chapaties* was developed. This method uses instruments available to most cereal technology laboratories and gives products similar to those obtained through traditional Indian methods. Results of the statistical analysis of data from this method (Table V) indicated very high multiple regression coefficients and low standard errors.

Replacement of 50–80% of the wheat flour with other cereal grains could be achieved, and an acceptable *chapati* could still be produced. Initial sensory evaluations indicated that up to 60% of the whole wheat flour could be replaced with the soy-cereal blend to produce a *chapati* as acceptable as the control.

The type of milling had little effect on the *chapati*; however, flours obtained by other methods may yield different results. The toughness and shear force decreased at the higher absorption levels.

When emulsifiers were present in the system it was possible to get scores as high as the control when up to 40% of the whole wheat flour had been replaced with nonglutenous flours. High HLB emulsifiers tended to decrease the shear force and increase the toughness, comparable to that of the control.

In all cases the protein quality of the *chapati* was improved when soy flour was added to balance the amino-acid ratios.

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