Preparation and Properties of Soy-Fortified Cereal Weaning Foods[1]

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Cereal Chem. 56(6):548-551

ABSTRACT

Dehydrated cereal-based weaning foods fortified with whole soybeans were produced by a relatively simple process (ie, blanching, grinding, cooking, and drum-drying). Addition of low amounts of sodium bicarbonate to grind-water improved flavor of the final product. Gelation of soy-cereal mixtures prior to drum-drying improved drying characteristics and organoleptic properties. Addition of soybeans overcame lysine deficiency of cereals and increased protein content of soy-cereal mixtures. Processing conditions had relatively little effect on protein quality. Optimum nutritional quality was obtained when soybeans formed 25 to 30% of the soy-cereal mixture. Organoleptic tests indicated that 20% soybeans could be incorporated before scores were significantly lowered.

Cereals are traditionally used as a major source of food in many less-developed countries of the world with over half the protein in the diet obtained from cereals. Most cereals, however, have some limitations due both to their low protein content and to limitations in some essential amino acids such as lysine. There is a particular need for high-quality weaning foods in less-developed countries and much effort has been focused on methods for producing nutritious foods from plant sources (Bressani 1975, Horan 1974, Milner 1969).

Many legumes and oilseeds are high in both protein and lysine; soybeans in particular have received much attention in recent years and a variety of soy-cereal blends have been developed with varying degrees of success (Anderson et al 1971, Bookwalter et al 1971, Ferrier et al 1975). Of all the forms the final product may take, a dry food in the form of flakes or a powder would be particularly amenable to easy production, packaging, storage, and distribution. Drum-drying or roller-drying was chosen in this particular project since it is a simple and fairly common technology for less-developed countries. To ensure the highest protein quality and good organoleptic properties, soybeans and cereals were blended in

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0009-0352/79/000089$3.00/0

various ratios and tested for optimum nutritional quality. The particular processing variables that would maximize desirable organoleptic qualities were also optimized.

MATERIALS AND METHODS

Preparation of Soy-Cereal Powders

Soybeans were of the Bonus (1975) variety and unless otherwise mentioned, used with hulls. Whole corn from the 1975 crop was obtained from Farmer City Grain Co-operative, Farmer City, IL. Parboiled rice (Uncle Ben's, Laredo, TX) was purchased from a retail store. Prior to use, the corn and rice were ground to a flour in a Mikropul hammer mill equipped with a 60-mesh screen.

Soybeans were blanched by dropping into boiling tap water (1:10 bean-to-water ratio) with vigorous stirring to maximize heat transfer. After 20 min of boiling, beans were drained and blanch water discarded. The beans were then ground with three parts by weight of softened water containing sodium bicarbonate ($NaHCO_3$) (one of the variables investigated in this study). For laboratory bench-scale studies, a 1-gal Waring Blendor was used for 1 min at low speed and 2 min at high speed. For pilot scale studies, a Reitz mill equipped with a 0.023-in. screen was used; the soy slurry was passed through the mill twice. Cereal flour, in the amount necessary to give the required soy-cereal ratio (another variable), was added and mixed thoroughly. If the soy-cereal mixture were to be pre-gelled, it was brought to gelation temperature in a steam kettle with vigorous stirring. If pre-gelled, the mixture, adjusted to 16–20% solids, was then ground again in the Reitz mill. In either case, the soy-cereal mixture was dried by pouring directly between the two rolls of the drum dryer (Blaw Knox, 6 × 7-5/8-in. rolls). Steam at 40 psig was used to heat the drums, and drum speeds were adjusted to 2–4 rpm to produce thin continuous sheets with about 5% residual moisture. The sheets were then crumbled by hand, passed through a 16-mesh screen, and stored either in plastic bags or No. 10 plain tin cans at 34°F. All subsequent analytical and organoleptic tests were conducted within two weeks. At least two separate batches of the soy-cereal mixture with each variable were made and evaluated separately.

Analytical Methods

Moisture, fat, protein, ash, amino acids, and fiber content were determined according to methods of the AOAC (1970). Consistency was measured on a Bostwick consistometer (Central Scientific Company, Chicago), an instrument commonly used to measure consistency of tomato products. Water absorption data were obtained on a Bauman apparatus (Bauman 1967), using dehydrated soy-cereal samples that had been further ground in a Wiley mill to 100 mesh. Unless otherwise mentioned, all data reported are means of at least two replicate determinations.

Nutritional Evaluation

The samples were ground and incorporated into rat diets. The rat assay was conducted by Raltech, St. Louis, MO, according to AOAC methods (1970), except that all diets contained 1.91% fiber. The protein efficiency ratio (PER) data were adjusted to a casein standard of 2.50.

Organoleptic Evaluation

Organoleptic properties studied were flavor (an evaluation of the intensity of the characteristic flavor of the cereal), off-flavor (bitterness, soapiness, rancidity), texture (smoothness and softness), hang-up (sticking of particles to throat when swallowing), and color. To avoid any bias due to differences in water absorption, the soy-cereal powders were rehydrated to a paste with sufficient tap water to produce a flow rate of 10 cm in 30 sec on the consistometer. The taste panel was drawn from a pool of 10 members with previous experience in judging soy or cereal products. A 1 to 9 point hedonic scale and triangle preference tests were used. Data were analyzed statistically using Duncan's multiple range test or Tukey's ω-procedure.

RESULTS AND DISCUSSION

Soybean Treatment

Nelson et al (1976) previously have shown that the two major problems associated with soybeans—"painty" off-flavors and trypsin inhibitors—can be effectively overcome by the heat treatment used. No studies were conducted on the effect of soaking prior to grinding or blanching. There are conflicting reports about the value of presoaking the soybeans. Presoaking the beans softened them and resulted in better texture when soybeans were processed into a soy beverage (Nelson et al 1976) or into a dal (Spata et al 1974). However, Ferrier et al (1975) reported no beneficial effect on organoleptic scores of soaking prior to blanching with soy-banana weaning foods. The blanching process was found to hydrate and soften the beans sufficiently for our purposes and hence the presoaking step was eliminated. The soybeans were not dehulled in order to minimize the number of unit operations.

Effect of Bicarbonate

Bourne et al (1976) and Nelson et al (1976) have suggested that sodium ions in the product resulted in a distinct improvement in flavor and texture. Addition of $NaHCO_3$ to the water during grinding of soybeans and cereals most improved flavor of reconstituted 30:70 soy/corn mixtures at a level of 0.05% $NaHCO_3$ (Table I). Higher levels resulted in off-flavors most frequently described as "soapiness," probably because of residual bicarbonate or to the interaction of sodium ions and fatty acids in samples. A distinct darkening of the product at the 0.5% $NaHCO_3$ level, similar to that observed with soy-banana weaning foods (Ferrier et al 1975), was observed for the soy-corn product. Nelson et al (1976) used the higher (0.5%) concentration of $NaHCO_3$ during blanching for the preparation of soy milk but in their process, the blanch water was discarded prior to further processing and hence there was little residual off-flavor. Lower levels have to be used in dehydrated soy-cereal preparations since the bicarbonate would still be present in the final product.

Pregelation

After mixing soybeans and cereal flours together, the blends were either finely ground directly in the Reitz mill or were gelled prior to grinding by slowly heating to gelation temperatures (63–68°C). Table II shows that pregelation of soy-corn significantly softened the final product and reduced the hang-up phenomenon. This effect was also noticed with the soy-rice mixtures where triangle tests revealed that almost all panelists

TABLE I
Effect of Sodium Bicarbonate ($NaHCO_3$) on Flavor of 30:70 Soy/Corn

% $NaHCO_3$	Final Concentration of $NaHCO_3$ (mg/g Product)	Flavor Score[a]
0	0	5.0 b
0.05	2.5	7.3 c
0.10	5.0	5.6 b
0.50	25.0	1.6 d

[a] 1 = High off-flavor, 9 = no off-flavor. Number of panelists = 8. Numbers with different letters are significantly different at the 1% level.

TABLE II
Effect of Pregelation on Flavor Scores of 30:70 Soy/Corn (No Bicarbonate Used)

Treatment	Softness[a]	Hang-up[b]
Gelled	6.5 c	5.2 e
Ungelled	4.2 d	4.7 f

[a] 1 = Hard, 9 = very soft. Number of panelists = 8.
[b] 1 = High hang-up, 9 = no hang-up. Number of panelists = 9. Numbers with different letters are significantly different at the 5% level.

could notice differences in texture due to pregelation, although only half indicated a preference for the gelled sample (Table III).

Pregelation, however, had effects other than organoleptic. It prevented the cereals from settling out from the mixtures and resulted in a more uniform feed to the Reitz mill and drum dryer. Pregelled samples tended to form stronger, more continuous sheets as it came off the drum dryer, a phenomenon also observed by Kon et al (1974). Obviously the samples would partially gel when in contact with the hot drums of the dryer, but these results indicate a separate gelation step has desirable benefits on the organoleptic properties.

Pregelation increased water absorption for all soy-cereal mixtures, either with or without added bicarbonate (Table IV). Water absorption data on the Baumann apparatus are typical of equilibration processes of cereal products, in that water was absorbed in an asymptotic manner before reaching a maximum. Increased water binding due to pregelation has been related to the extent of starch damage during processing (Chilton and Collison 1974). Increasing the cereal content of the mixtures increased water absorption, reflecting the increased starch content similar to that

TABLE III
Triangle Tests on Effect of Pregelation on Flavor Scores of 30:70 Soy/Rice

Sodium Bicarbonate	0	0.05%
Number of panelists	7	7
Correctly identifying odd sample	6	6
Preferred gelled sample	3	3

TABLE IV
Water Absorption Characteristics of 30:70 Soy/Cereals as Determined by the Baumann Apparatus

Sample	Sodium Bicarbonate Level (%)	Pregelled	Equilibration Moisture Content (ml/g Solid)	Equilibration Time (min)
Soy-corn	0	No	3.5	3.1
	0	Yes	4.1	3.3
	0.05	No	3.8	5.0
	0.05	Yes	4.3	5.5
Soy-rice	0	No	3.5	10.0
	0	Yes	3.6	9.0
	0.05	No	3.8	8.0
	0.05	Yes	4.2	6.0

TABLE V
Comparison of Theoretical and Experimental Amino Acid Profiles (mg/g Protein) and Nutritional Quality of Soy-Corn Blends

Amino Acid	FAO Standard[c]	20:80 Soy/Corn Theor.	20:80 Soy/Corn Exptl.	33:67 Soy/Corn Theor.	33:67 Soy/Corn Exptl.
Isoleucine	43.2	42.0	40.5	45.8	42.0
Leucine	48.8	96.0	94.3	106.0	86.6
Lysine	43.2	48.2	47.6	56.2	54.6
Methionine	22.0	16.4	10.9	15.6	9.5
Phenylalanine	29.6	49.0	47.8	49.4	49.1
Tyrosine	28.0	36.8	22.5	35.9	21.9
Threonine	28.8	39.2	36.2	40.0	36.0
Tryptophan	14.4	10.5	...	11.6	...
Valine	43.2	49.9	46.9	48.7	46.4
Histidine	...	29.6	28.0	28.4	27.4
% Protein	...	15.2	14.85	18.91	19.40
% Fat	...	4.8	4.88	6.8	6.82
PER[a]	...	...	2.27	...	2.31
Calories[b] per 100 g.	...	340	...	350	...

[a] Protein efficiency ratio of casein = 2.50.
[b] Calculated assuming 40% digestibility of soybean carbohydrate and 100% for all other constituents.
[c] From Food and Agriculture Organization (1968).

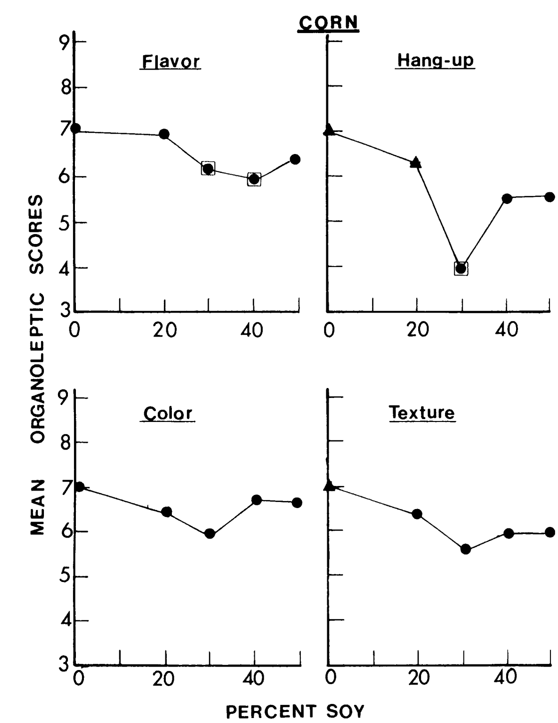

Fig. 1. Effect of adding soybeans on organoleptic scores of soy-corn mixtures. Data points with similar symbols have scores statistically similar to each other at the 10% level.

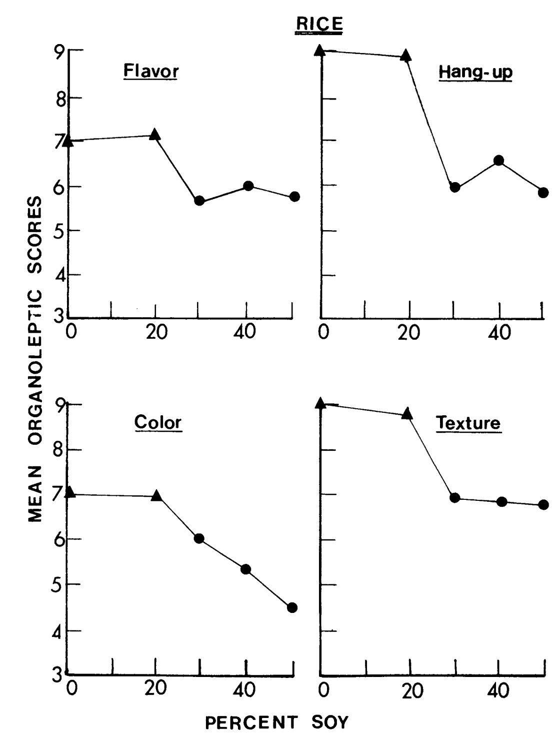

Fig. 2. Effect of adding soybeans on organoleptic scores of soy-rice mixtures. Data points with similar symbols have scores statistically similar to each other at the 10% level.

observed in semolina-corn-soy mixtures (Molina et al 1976). Two effects shown in Table IV presently are not well understood—the increase in water absorption in the presence of $NaHCO_3$ and the increase in equilibration (complete hydration) time when soy-corn was pregelled, a phenomenon contrary to what is expected when products are "instantized" by pregelation.

Water absorptive capacities measured on the Bauman apparatus are useful since they indicate the maximum amount of water that could be added before "weeping" occurred. In addition, tests done on the consistometer confirm that more water had to be added to the pregelled product to maintain a uniform consistency. Excessive gelation may result in weaning foods too thick to be fed to infants easily. If too much water is needed to achieve a satisfactory consistency, it would reduce the net intake of protein and calories per portion consumed. Our studies indicate only an additional 10–15% water is needed, although Kon et al (1974) found that as much as 25% more water is needed to obtain the same consistency as the ungelled product.

Optimum Soy-Cereal Ratios

Two factors were considered in optimizing the ratio of soy to cereal—nutritional and organoleptic qualities. Bressani (1975) concluded that adding soybeans to comprise 50% of the protein of the mixture had the maximum protein quality. A preliminary estimate of the protein quality of a blend was obtained by calculation, using the weighted contribution of each amino acid of the cereal and the soybean to the blend. Table V shows that a fairly close approximation between these theoretical and experimental values is obtained, and hence such calculations were used to help formulate the optimum soy-cereal blend. For example, a minimum of 15% soybeans is needed in soy-corn mixtures to overcome the lysine deficiency, and a 22:78 ratio to overcome the isoleucine deficiency. A ratio of 33:67 soy/corn (Table V) and 30:70 soy/rice (not shown) exhibited the best protein quality. The PER of the blends was much higher than their individual components (0.7 for corn and 2.0 for soybeans) and similar to that obtained with other soy-corn blends (Bookwalter et al 1971, Bressani 1975, Graham and Baertl 1974). Similarity between theoretical and experimental values for most amino acids indicates little thermal damage during processing; the exceptions are tyrosine and methionine, which is surprising since both amino acids have been shown to be stable during drum drying (Onayemi and Potter 1976, Shemer et al 1973).

Organoleptic Evaluation

Soy-cereal mixtures of various ratios were prepared with 0.05% $NaHCO_3$; the mixtures were gelled prior to drum-drying and reconstituted as mentioned in Materials and Methods. As seen in Figs. 1 and 2, there is a general decline in relative organoleptic scores with increasing soy content. As much as 20% soy could be added to cereals before panelists noticed a loss in the characteristic flavor of the cereal. Similar limits have been observed by Bookwalter et al (1971). Soy had no significant effect on color of soy-corn, but did produce a distinct darkening above 20% in soy-rice mixtures. The most serious effect was on hang-up, a phenomenon where the particles stick to the throat when swallowing. It was significant ($P < 0.01$) at any level above 20% soy. This could be due to the presence of the hulls, since a correlation was found between increasing fiber content and hang-up. In separate trials (not shown here), use of dehulled soybeans partially alleviated this problem, but it was still noticeable and objectionable at high soy-cereal ratios.

CONCLUSIONS

Soy-fortified cereal mixtures suitable for use as weaning foods can be produced using relatively simple technology. Protein quality appeared to be optimum when the soy/cereal ratio was about 30:70. Organoleptic properties, however, suffered a serious drop at this level and a maximum of 20% soybeans in corn and rice mixtures is recommended, which results in a 15 g protein, 340 calorie (100 g basis) food.

ACKNOWLEDGMENT

This research was partially supported by the International Soybean Program, contract AID/CM/ta-G-73-49, University of Illinois, Urbana.

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[Received October 25, 1978. Accepted May 29, 1979]