Effects of Dehulling on Functional Properties of Dry Bean (*Phaseolus vulgaris* L.) Flours[1,2]

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ABSTRACT

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Effects of dehulling on certain functional properties of flours of 10 different cultivars of dry beans (*Phaseolus vulgaris* L.) were investigated. Dehulling improved the water and oil absorption capacities of bean flours by 3–39% and 10–44%, respectively. Foaming and emulsion capacities of bean flours increased as a result of dehulling. Foams and emulsions of dehulled bean flours were, however, less stable than those of whole bean flours. Foaming properties of bean flours were dependent on pH and concentration. Seed coat removal improved gelling properties of most cultivars investigated. Among the cultivars studied, small white beans showed excellent water absorption, gelling, and emulsion properties. Black beauty and cranberry flours gave the maximum increase in whipping volume, whereas foams prepared from dark red kidney beans were the most stable. The seed coat appears to play an important role in foam and emulsion stability of bean flours.

The popularity of formulated convenience foods places greater emphasis on the reliability of functional properties of protein ingredients. Novel protein sources must be functionally reliable if they are to be used in foods. Several potential food proteins (oilseed, microbial, leaf) are presently underutilized (Kinsella and Shetty 1979). Dry bean is one source of food proteins with a significant potential for food applications.

Functionality is defined as "any property of a food or food ingredient, besides the nutritional ones, that affects its utilization" (Pour-El 1981). Most properties of biological products that lead to their industrial utilization are functional. Research on the nutritional and functional properties of oilseed proteins, particularly soybean proteins, has resulted in their extensive utilization in processed foods such as sausage-type meats and meat products, coffee whiteners, beverages, marshmallows, whipped toppings, and bakery products (Dubois and Hoover 1981, Kinsella 1979, Waggle et al 1981). Soybean proteins have well known limitations such as beany and off flavors that restrict the acceptability of foods containing soy preparations, and thus the application of soy proteins (Kinsella 1979). Additional sources of seed proteins may provide the desired range of functional and nutritional characteristics.

Many processes used for extracting and preparing seed proteins cause denaturation, loss of solubility, and decrease in functional potential. Suitable modifications to improve functional properties of proteins by physical treatment (Kinsella 1979, McWatters and Heaton 1974, Neucere 1972, Schwenke et al 1981, Wu and Inglett 1974), partial hydrolysis by use of acid, alkali, or enzymes (Beuchat et al 1975, Hermansson et al 1974, Sekul et al 1978, Zakaria and McFeeters 1978), chemical modification (Beuchat 1977, Canella et al 1979, Childs and Park 1976), and chemical derivatization (Feeney 1977) have been reported in the literature. The effects of dehulling and the role of seed coat carbohydrates in functional properties of legume proteins have not been studied to great extent. We describe the effects of removal of seed coat on water and oil absorption, gelation, foaming, and emulsion properties of 10 cultivars of dry beans (*Phaseolus vulgaris* L.) commonly grown in the United States.

MATERIALS AND METHODS

Mature dry beans (*Phaseolus vulgaris* L.) of pinto, sanilac, cranberry, viva pink, small red, Great Northern, dark red kidney, light red kidney, black beauty, and small white cultivars, grown and harvested in 1980, were purchased from Roger Brothers Seed Co., Twin Falls, ID. Unless mentioned otherwise, all chemicals used were of reagent grade.

Preparation of Whole Bean Flour

Whole dry beans were ground to a 60-mesh flour in a Udy Cyclone Mill (Tecator, Inc., Boulder, CO).

Preparation of Dehulled Bean Flour

Beans were soaked in distilled water (1:5, w/v, bean to water ratio) for 12 hr at room temperature (21° C). Seed coats were then removed manually and dried in an air oven at 50° C for 24 hr to determine the hull contents. The dehulled beans were freeze-dried along with the soak water and ground to obtain a 60-mesh flour in a Udy Cyclone Mill.

Analytical Procedures

Proximate analyses for moisture, protein (N × 6.25), fat, and ash contents were performed using AOAC (1975) methods. The total carbohydrate content was determined by difference.

Oil and Water Absorption

Oil (Crisco Vegetable Cooking Oil, Procter and Gamble, Cincinnati, OH) and water absorption capacities were determined by the method of Beuchat (1977). A 1-g sample was mixed with 10 ml of distilled water or oil for 30 sec in a mixer (Vari-Whirl, set on "fast" speed). The samples were then allowed to stand at room temperature (21° C) for 30 min, centrifuged at 5,000 × *g* for 30 min, and the volume of the supernatant measured in a 10-ml graduated cylinder. Density of water was assumed to be 1 g/ml and that of oil 0.88 g/ml.

Gelation

Least-gelation concentrations of whole and dehulled bean flours were determined by the method of Coffmann and Garcia (1977) with slight modifications. Appropriate sample suspensions of 2, 4, 6, 8, 10, 12, 14, and 16% (w/v) were prepared in 5 ml of distilled water. The test tubes containing these suspensions were then heated for 1 hr in a boiling water bath followed by rapid cooling under running cold tap water. The test tubes were then further cooled for 2 hr at 4° C. The least-gelation concentration was determined as that of the sample that did not fall down or slip from the inverted test tube.

Foaming Properties

Foaming capacity and stability of whole and dehulled bean flours were studied according to the method of Coffmann and Garcia (1977). A 1-g sample was whipped with 100 ml of distilled water for 5 min in a Waring Blendor at "HI" speed setting and then poured in a 250-ml graduated cylinder. The total and foam volumes were recorded at intervals of 0.0, 0.5, 1.0, 1.5, and 2.0 hr at room

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TABLE I
Proximate Composition of Whole and Dehulled Bean Flours[a]

Cultivar	Moisture		Protein		Fat		Ash		Carbohydrates	
	WBF[b]	DBF	WBF	DBF	WBF	DBF	WBF	DBF	WBF	DBF
Pinto	12.79	18.29	18.12	20.87	1.65	1.91	4.05	4.33	76.18	72.89
Sanilac	11.61	16.35	18.98	22.36	1.65	2.35	4.28	4.17	75.09	71.12
Cranberry	12.71	15.47	23.43	26.55	1.09	2.07	4.22	4.43	71.26	66.95
Viva pink	12.69	11.67	21.30	22.16	1.06	2.06	4.41	4.35	73.23	71.43
Small red	13.12	14.06	22.45	25.16	1.43	2.00	4.15	4.13	71.97	68.71
Great Northern	12.50	18.82	23.01	23.21	1.63	2.31	4.29	4.39	71.07	70.09
Dark red kidney	13.22	10.35	20.32	22.94	1.58	1.73	4.42	4.52	73.68	70.81
Light red kidney	10.52	14.82	20.89	25.32	1.52	1.98	4.39	4.73	73.20	67.97
Black beauty	10.41	15.93	22.87	24.47	1.86	2.71	4.48	4.76	70.79	68.06
Small white	13.03	14.74	19.73	20.98	1.99	3.26	3.94	3.85	74.34	71.91

[a] Mean of triplicate determinations on a dry-weight basis.
[b] WBF = whole bean flour, DBF = dehulled bean flour.

temperature (21° C). Volume increase (percent) was calculated according to the following equation:

$$\text{Volume increase (\%)} = \frac{\begin{array}{c}\text{Volume after}\\ \text{whipping (ml)}\end{array} - \begin{array}{c}\text{Volume before}\\ \text{whipping (ml)}\end{array}}{\text{Volume before whipping (ml)}} \times 100$$

Specific volumes of foams were determined as an index of air uptake during whipping. Weights were taken before and after whipping and the specific volume calculated according to the method of Baldwin and Sinthavalai (1974):

$$\text{Specific volume} = \frac{\text{Volume after whipping (ml)}}{\text{Weight after whipping (g).}}$$

To study the effects of concentration on foamability, 1, 2, 3, 4, 5, 7, and 10% (w/v) aqueous dispersions were used. Effects of concentration were evaluated only for whole bean flours.

A 2% (w/v) aqueous dispersion was employed to study the effects of pH on foaming capacity of whole and dehulled bean flours because it gave a noticeable increase in volume. The pH was adjusted to a desired value by using 0.1*N* HCl or 0.1*N* NaOH or both before the dispersions were whipped.

Emulsion Properties

Emulsifying activity (EA) and emulsion stability (ES) were used as indices of emulsifying properties and were evaluated by the method of Yasumatsu et al (1972) with slight modifications. A 7% (w/v, db) aqueous dispersion of the flours was prepared. Twenty milliliters of the dispersion was mixed with 20 ml of Crisco Vegetable Cooking Oil and blended in a Sorvall omni-mixer (Ivan Sorvall, Inc., Newtown, CT) for 5 min at a speed setting of 6. An aliquot was centrifuged at 3,000 × *g* for 5 min. EA was expressed as the percentage of the total mixture that remained emulsified after centrifugation.

ES was evaluated by recentrifugation following heating at 80° C for 30 min in a water bath.

All experiments were conducted at room temperature (21° C), at least in duplicate, and means were reported on a dry-weight basis.

Statistical Analyses

Data were analyzed by analysis of variance procedures of the Statistical Analysis System (SAS 1979). Least significant differences were used for multiple mean comparison tests.

RESULTS AND DISCUSSION

Proximate Composition and Hull Content

Proximate analyses data of whole and dehulled bean flours are shown in Table I. The protein contents of whole bean flours ranged from 18.12% in pinto to 23.43% in cranberry. Removal of seed coats increased the protein content of all the cultivars. In most cases, oil and ash content also increased on dehulling. Variations in oil and ash content, however, were relatively small among the 10 legumes investigated. The total carbohydrates in the whole and dehulled bean flours were above 65% of dry weight and constituted the highest amount of the total seed weight. The differences in composition of the major constituents of the 10 legumes ranged within narrow limits. Because all the cultivars were of *Phaseolus vulgaris* L., great compositional differences were not expected, especially among crops from the same year and location. Sgarbieri et al (1979) also observed minimal differences in gross composition among four varieties of common bean (*Phaseolus vulgaris*).

TABLE II
Hull Contents of Dry Beans

Cultivar	Hulls (%)
Pinto	8.2
Sanilac	8.7
Cranberry	6.9
Viva pink	8.0
Small red	8.1
Great Northern	9.1
Dark red kidney	9.0
Light red kidney	9.8
Black beauty	8.6
Small white	8.9

The hull contents of dry beans ranged from 6.9 to 9.8% of the dry weight of the seed (Table II). Available literature data suggest that the seed coat fraction apparently is a characteristic of the species. Singh et al (1968) reported the wide range of 8.05–17.11% for the seed coat fraction of several Indian pulses. Garcia and Palmer (1980) observed that the hulls constituted 15.9% of the total dry weight of the seed in winged bean cultivar TPT-2. Both these studies (Garcia and Palmer 1980, Singh et al 1968) also indicate that, except for crude fiber and calcium, the seed coat fraction contributes very little to the food value of legumes.

Water and Oil Absorption

Water and oil absorption capacities of whole and dehulled bean flours are summarized in Table III. Small white flour (whole and dehulled) was exceptionally high in water absorption, whereas black beauty flours had the lowest water absorption capacities. The values for the remaining eight cultivars ranged from 1.66 to 2.03 g/g in whole bean flours and from 1.73 to 2.49 g/g in dehulled bean flours. Dehulling improved the water absorption capacity of all the cultivars investigated. The extent of improvement, however, greatly differed. The increase in water absorption after dehulling was marginal for pinto, sanilac, and cranberry cultivars (less than 10% increase over the original water absorption capacity). Maximum improvement was observed for light red kidney (38.6%) and Great Northern (32.2%), with others showing moderately to highly increased water absorption. Except for Great Northern bean, our values for whole and dehulled bean flours were higher than those reported by Sosulski et al (1976a) for dehulled seed flours of 10 legumes of different genera. These authors reported a range from 92% for mung bean (*Vigna radiata*) flour to 270% for the Great Northern bean (*Phaseolus vulgaris*). Sanilac pea bean, the only other legume belonging to the *Phaseolus vulgaris* group in their study, had a 125% water absorption capacity, which was less than that observed for dehulled sanilac flour in the present investigation (1.98 g/g). Water absorption values for dehulled flours of the 10 legume cultivars in the present study were comparable to those of dehulled soy flour (2.4 g/g) as reported by Sosulski and Fleming (1977) but exceeded those reported for peanut flour (less than 1 g/g, Beuchat 1977, Beuchat et al 1975) and sunflower flour (107.1%, Lin et al 1974). The higher water absorption of dehulled flours might have been due to their protein content, which was higher than that in the corresponding whole bean flours (Table I). Increased water absorptions by soy products (flours, concentrates, and isolates) with increased protein contents were reported by Fleming et al (1974). In most cases using a similar test procedure (one having excess water), a greater water absorption was noted for protein isolates than for concentrates, possibly indicating a relationship between water absorption and protein content (Fleming et al 1974, Hutton 1975, Lin et al 1974, Wang and Kinsella 1976). Water absorption of a particular sample, however, need not be parallel to its protein content. Lin et al (1974) observed that all sunflower products had lower water absorptions than did soy products, although their protein contents were similar. Thus, protein content appears to be primarily responsible only for water absorption; other food components may also have an influence. Water absorption variations among the 10 cultivars may be related to the nature and type of proteins differing among the cultivars. Hydrophilic properties of proteins are related to such polar groups as carbonyl, hydroxyl, amino, carboxyl, and sulfhydryl. Water-binding capacity varies with the number and type of polar groups (Kuntz 1971). The differences in water absorption capacities among the 10 cultivars may reflect this fact. The higher water-absorption capacities of the dehulled legume flours investigated may be important to properties such as swelling, solubility, viscosity, and gelation.

TABLE III
Water and Oil Absorption Capacity
of Whole and Dehulled Bean Flours[a]

Cultivar	Water Absorption Capacity (g/g)			Oil Absorption Capacity (g/g)		
	WBF[b]	DBF	Percent Increase	WBF	DBF	Percent Increase
Pinto	1.81	1.86	2.8	1.32	1.59	20.5
Sanilac	1.82	1.98	8.8	1.05	1.51	43.8
Cranberry	1.66	1.73	4.2	1.19	1.45	21.8
Viva pink	2.03	2.49	22.7	1.19	1.47	23.5
Small red	1.96	2.17	10.7	1.16	1.44	24.1
Great Northern	1.77	2.34	32.2	1.26	1.39	10.3
Dark red kidney	1.92	2.43	26.6	1.30	1.46	12.3
Light red kidney	1.66	2.30	38.6	1.14	1.34	17.5
Black beauty	1.43	1.66	16.1	1.07	1.43	33.6
Small white	3.76	4.36	16.0	1.12	1.48	32.1
LSD ($P = 0.05$)[c]	0.116			0.206		

[a] Mean of triplicate determinations on a dry-weight basis.
[b] WBF = whole bean flour, DBF = dehulled bean flour.
[c] Least significant difference. Ratios of the means within or between the cultivars exceeding this value are significantly different.

TABLE IV
Least Gelation Concentrations of Whole and Dehulled Bean Flours[a]

Cultivar	Least Gelation Concentration (%, w/v)	
	Whole Bean Flour	Dehulled Bean Flour
Pinto	12	12
Sanilac	14	12
Cranberry	12	12
Viva pink	10	10
Small red	10	8
Great Northern	12	12
Dark red kidney	12	10
Light red kidney	14	10
Black beauty	12	10
Small white	10	8

[a] Mean of triplicate determinations.

Oil absorption characteristics varied within the narrow limits of 1.05–1.32 g/g for whole bean flours and from 1.34–1.59 g/g for dehulled bean flours (Table III). All the cultivars investigated had lower oil absorption than water absorption, regardless of the dehulling treatment. Maximum increase in oil absorption after dehulling was recorded for sanilac ($\sim$44% increase over the original oil absorption). For other cultivars, oil absorption improved by 10–34% after dehulling. Oil absorption by dehulled flours of the 10 legumes averaged higher than that reported by Sosulski et al (1976a) and Sosulski and Youngs (1979) for several legume flours, including soy and lupin. Oil absorption values greater than those observed in the present investigation, however, were reported for peanut flour (1.8–2.0 g/g) by Beuchat (1977) and Beuchat et al (1975), rapeseed flour (2.35–3.62 g/g) by Sosulski et al (1976b), and sunflower flour (2.2 g/g) by Sosulski and Fleming (1977). Oil absorption is mainly attributed to the physical entrapment of oil and is related to the number of nonpolar side chains on proteins that bind hydrocarbon chains of fats (Kinsella 1979, Lin et al 1974). The lower oil absorption of the legume flours as compared to their water absorption values suggests that the major proteins in these cultivars are predominantly hydrophilic.

Gelation

Dehulling improved the gelation properties of all cultivars excepting pinto, cranberry, viva pink, and Great Northern (Table IV). For the whole and dehulled bean flours, least gelation concentrations differed marginally, with ranges of 10–14% (w/v) and 8–12% (w/v), respectively. According to Schmidt (1981), gelation may be defined as a protein aggregation phenomenon in which polymer-polymer and polymer-solvent interactions and attractive and repulsive forces are so balanced that a tertiary network or matrix is formed. Such a matrix is capable of immobilizing or trapping large amounts of water. Factors that affect gelation properties include protein concentration, other protein components in a complex food system, nonprotein components, pH, ionic and reducing agents, and heat treatment conditions (Schmidt 1981). Improved gelling abilities as a result of dehulling may be attributed to the higher protein content of the dehulled flours and the removal of the seed coat fractions. Gelation involves the formation of a continuous network that exhibits order. Higher protein may enhance the rate at which such a network is formed. The seed coat fractions containing complex carbohydrates might interfere in the formation of such a continuous network of molecules to form gels. A higher protein concentration thus may be required to overcome their interference with gel formation. Schmidt et al (1978) reported that dialysis of a whey protein concentrate (WPC) system to minimize ash and lactose improved its gelation properties. Gels formed by the WPC after dialysis were more translucent, stronger, more cohesive, less springy, more gummy, and more chewy than were gels formed from nondialyzed WPC. More information, however, is needed on the effects of food components other than the protein on protein gelling properties before predictions regarding the gelling behavior of a given protein in a complex food system can be made.

Foaming Properties

Dehulling improved both the total and foam volumes of the bean flours (Table V). Volume increase on whipping of 1% aqueous dispersions of the whole and dehulled bean flours ranged from 15 to 29% and from 21 to 33%, respectively. Among the whole bean flours, the maximum increase in volume was recorded for cranberry and black beauty, whereas small white had the lowest foaming capacity. After dehulling, however, small white showed the greatest improvement in foaming capacity, registering a 33% increase in volume.

The specific volumes of the foams were determined as indicators of air uptake during whipping. Except for pinto, cranberry, and black beauty, dehulling increased the specific volume of foams, indicating better foaming and air uptake during whipping. The lower air uptake during whipping of dehulled pinto flour was accompanied by a decrease in its foam volume. Specific volume of a foam (volume per unit mass) for a given set of conditions is an indication of air uptake only and is not necessarily a measure of foam quality and stability.

Foam stability results are given in Table VI. Although the total volumes at the end of 2 hr at room temperature (21° C) were usually lower for dehulled bean flours, significant differences ($P = 0.05$) in foam stabilities of the whole and dehulled bean flowers were observed only for Great Northern and dark red kidney cultivars. Except for sanilac, cranberry, light red kidney, and small white cultivars, however, foam volumes at the end of 2 hr were

TABLE V

Foaming Properties of Whole and Dehulled Bean Flours[a]

	Volume After Whipping (ml)				**Percent Volume Increase**		**Specific Volume (ml/g)**	
	Total volume		**Foam Volume**					
Cultivar	**WBF**[b]	**DBF**	**WBF**	**DBF**	**WBF**	**DBF**	**WBF**	**DBF**
Pinto	117	121	30	26	17	21	1.29	1.26
Sanilac	124	127	33	34	24	27	1.30	1.31
Cranberry	129	129	37	38	29	29	1.35	1.33
Viva pink	123	129	36	41	23	29	1.34	1.36
Small red	121	127	34	39	21	27	1.33	1.33
Great Northern	121	127	30	35	21	27	1.27	1.31
Dark red kidney	125	133	33	43	25	33	1.31	1.38
Light red kidney	121	128	31	41	21	28	1.29	1.36
Black beauty	129	130	39	39	29	30	1.37	1.35
Small white	115	133	21	41	15	33	1.21	1.39
LSD ($P = 0.05$)[c]	3.55		3.90		3.55		0.039	

[a] Mean of triplicate determinations.

[b] WBF = whole bean flour, DBF = dehulled bean flour.

[c] Least significant difference. Ratios of two means within or between the cultivars exceeding this value are significant.

TABLE VI

Foam Stability of Whole and Dehulled Bean Flours[a]

	Volume at Room Temperature (21° C) After Minutes										**Decrease over 2 hr (%)**	
	0		**30**		**60**		**90**		**120**			
Cultivar	**Total**	**Foam**	**Total**	**Foam**	**Total**	**Foam**	**Total**	**Foam**	**Total**	**Foam**	**Total**	**Foam**
Pinto												
WBF[b]	117	30	113	23	110	20	107	16	105	14	10.3	53.3
DBF	121	26	113	16	108	11	106	8	105	7	13.2	73.1
Sanilac												
WBF	124	33	116	21	113	18	110	15	107	12	13.7	63.6
DBF	127	34	122	26	117	21	113	16	110	13	13.4	61.8
Cranberry												
WBF	129	37	122	27	116	21	112	17	109	13	15.5	64.9
DBF	129	38	117	22	111	16	109	13	107	11	17.1	71.1
Viva pink												
WBF	123	36	117	26	112	21	109	18	106	15	12.2	58.3
DBF	129	41	119	25	110	16	107	13	105	11	18.6	73.2
Small red												
WBF	121	34	116	26	112	22	109	18	107	16	11.6	52.9
DBF	127	39	118	24	111	16	108	13	106	11	15.0	71.8
Great Northern												
WBF	121	30	118	23	117	22	114	19	111	16	8.3	46.7
DBF	127	35	121	25	110	14	107	11	103	7	18.9	80.0
Dark red kidney												
WBF	125	33	120	25	117	21	116	21	115	20	8.0	39.4
DBF	133	43	120	25	115	20	112	17	110	15	17.3	65.1
Light red kidney												
WBF	121	31	118	25	113	20	113	20	109	15	9.9	51.6
DBF	128	41	120	27	115	22	111	18	109	15	14.8	63.4
Black beauty												
WBF	129	39	123	29	118	24	113	20	111	17	14.0	56.4
DBF	130	39	117	20	111	14	109	12	107	9	17.7	76.9
Small white												
WBF	115	21	113	18	111	16	108	12	106	10	7.8	52.4
DBF	133	41	119	24	111	15	107	11	105	10	19.5	75.6
LSD ($P = 0.05$)[c]	3.55	3.90							4.06	3.54		

[a] Mean of triplicate determinations.

[b] WBF = whole bean flour, DBF = dehulled bean flour.

[c] Least significant difference. Ratios of two means within or between cultivars exceeding this value are significant.

significantly lower for dehulled bean flours. Only sanilac showed improved foam stability after dehulling. The decrease in total volumes over 2 hr were 7.8–15.5% for whole bean flours and 13.2–19.5% for dehulled bean flours. The decrease in foam volumes was much greater and were 39.4–63.6% and 61.8–80.0% for whole and dehulled bean flours, respectively. Sosulski et al (1976a) observed a decrease of 18.2–38.6% in foam volumes of 10 legume flours over 2 hr. Soybean retained a higher foam volume over the 2-hr period than did any other legume flour.

The differences in foaming capacity of the 10 legume flours may be due primarily to differences in the amounts and types of proteins involved and the relative abilities of these proteins to denature, precipitate, and lower the surface tension at the air-liquid interface of the foam. The primary factors involved in foam formation are surface tension, viscosity, and the character of the protein film that is formed at the surface of the liquid (Kinsella 1979). Stable foams occur when low surface tension and high viscosity occur at the surface of the colloidal solution, forming a tough, amorphous, solid surface film. The high average foam stability of the whole bean flours might have been due to the complex carbohydrates in their seed coats. Because of their hydrophilic nature, these carbohydrates probably help to increase the viscosity at the surface of the colloidal solution, thereby preventing coalescence of gas bubbles and causing high foam stability.

Foaming capacities of the whole bean flours were greatly improved by increasing the concentration of the flour in aqueous dispersions (Table VII). At 10% (w/v) solids concentration, the foaming capacity ranged from 56 to 90% and may be attributed to the increased protein contents of the test samples with increasing concentration. An increase in foaming capacity and stability of glandless cottonseed flour was reported by Cherry and McWatters (1981) when they increased the flour concentration from 2 to 6% in suspensions at natural pH (about 6.5). These authors observed a decrease in both foaming capacity and stability, however, beyond 6% concentration of the flour. The improvement in foaming properties with increased flour concentration was largely attributed to the increased protein concentration.

TABLE VII

Effects of Concentration on Foaming Capacity of Whole Bean Flours[a]

	Percent Increase in Volume After Whipping						
	Concentration (%, w/v)						
Cultivar	1	2	3	4	5	7	10
Pinto	17	44	56	60	64	70	80
Sanilac	24	48	50	58	62	70	78
Cranberry	29	42	54	60	70	74	90
Viva pink	23	46	52	60	64	70	70
Small red	21	50	56	58	60	68	72
Great Northern	21	44	52	58	58	62	62
Dark red kidney	25	46	58	62	66	68	76
Light red kidney	21	46	60	64	72	82	82
Black beauty	29	54	56	60	62	72	74
Small white	15	48	50	52	54	54	56

LSD[b] ($P = 005$) = 3.33

[a] Mean of duplicate determinations.

[b] Least significant difference. Ratios of two means within or between the cultivars exceeding this value are significant.

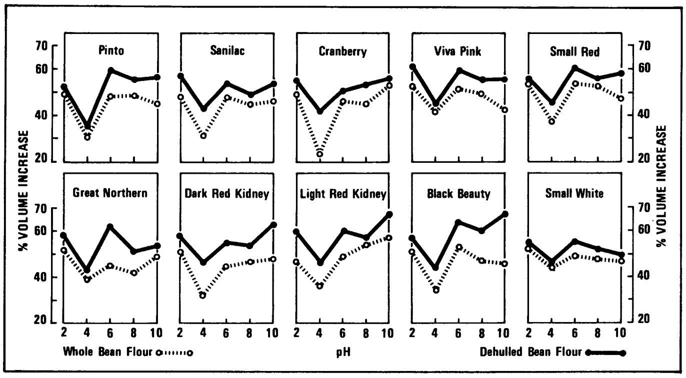

Fig. 1. Effects of pH on foaming capacity of whole and dehulled bean flours.

Foaming capacities of whole and dehulled bean flours were pH-dependent (Fig. 1). The trend at different pH levels varied with the cultivar. At all pH values investigated, dehulled flours had a greater increase in volume than did the corresponding whole bean flours. At pH 4.0, the apparent isoelectric pH of bean proteins, minimal foaming was observed for all cultivars. Invariably, the greatest increase in volume on whipping of 2% aqueous dispersions of both whole and dehulled bean flours was observed at pH 2.0, 6.0, or 10.0, depending on the cultivar. Cherry and McWatters (1981) reported a similar trend (higher foaming at about pH 2.0 and above 8.0) for glandless cottonseed flour. They attributed the optimum foaming properties of glandless cottonseed flour at pH 1.5 and 11.5 to the dissociated proteins and increased solubility of major storage globulins at these pH values. Such pH dependence of foaming characteristics was also reported for soy and sunflower proteins (Lin et al 1974), succinylated and acetylated sunflower proteins (Canella et al 1979), and peanut protein (Sekul et al 1978).

Emulsion Properties

Emulsion properties of the whole and dehulled bean flours are summarized in Table VIII. EA varied from 60.54 to 88.51% for whole bean flours and from 64.24 to 94.20% for dehulled flours. Dehulling significantly improved the EA in all except the dark red kidney cultivar. In both groups, small white had maximum EA, whereas cranberry had the lowest. Emulsions of these two cultivars were also the most and the least stable, respectively, in both groups. Dehulling reduced ES of all the cultivars investigated. Significant reductions, however, were observed only for cranberry, viva pink, dark red kidney, light red kidney, and small white cultivars. The emulsions of whole bean flours recorded over 90% stability after they were heated at 80° C for 30 min. The increased EA after dehulling of legume seeds may be ascribed partly to more protein being in the suspensions of dehulled bean flours for a given amount of oil. Lah and Cheryan (1980) evaluated the emulsion properties of a soy isolate (Promine-D) and a full-fat soy protein product prepared by ultrafiltration using a method similar to ours. They reported EA as 90.0 and 82.0% and ES as 86.5 and 82.8%, respectively, for these two products at a pH of 6.7. Among the 10 legumes, only small white showed similar emulsion properties. McWatters and Cherry (1977) reported that the emulsion, foaming, and thickening properties of cowpeas may be influenced by their high carbohydrate content (about 60%, db). These authors stated that the starch component may interact with protein and other

TABLE VIII

Emulsifying Activity and Stability of Whole and Dehulled Bean Flours[a]

	Emulsifying Activity(%)		Emulsion Stability[b]	
Cultivar	WBF[c]	DBF	WFB	DBF
Pinto	63.80	68.57	90.52	89.82
Sanilac	64.62	70.28	95.50	93.64
Cranberry	60.54	64.24	88.85	85.17
Viva pink	76.19	77.82	92.78	87.61
Small red	71.22	75.70	95.13	93.05
Great Northern	71.74	83.46	93.21	90.57
Dark red kidney	71.38	72.69	94.30	90.55
Light red kidney	65.47	70.48	93.10	89.66
Black beauty	69.96	73.05	90.52	89.17
Small white	88.51	94.20	97.07	93.09
LSD[d] ($P = 0.05$)	1.48		2.82	

[a] Mean of four determinations.

[b] Percent of original emulsifying activity after heating at 80° C for 30 min.

[c] WBF = whole bean flour, DBF = dehulled bean flour.

[d] Least significant difference. Ratios of two means within or between the cultivars exceeding this value are significant.

components in the system. Our results also suggest that functional properties apparently cannot be solely attributed to the proteins and other food components such as carbohydrates, and lipids may also contribute appreciably, possibly through protein-carbohydrate and protein-lipid interactions.

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