RHEOLOGICAL AND BAKING STUDIES OF LEGUME-WHEAT FLOUR BLENDS[1]

B. L. D'APPOLONIA[2], North Dakota State University, Fargo, ND 58102

ABSTRACT

Cereal Chem. 54(1): 53-63

Flour was obtained from faba beans, pinto beans, navy beans, mung beans, and lentils by dry milling. Pinto and navy bean flours were slightly grayish in color, while the remaining flours were varying degrees of yellowness. Rheological and baking properties of blends containing 5, 10, and 20% of the legume flours with a hard red spring wheat flour were investigated. As the legume flour level was increased, farinogram dough developing time and stability decreased. Incorporation of Emplex (sodium stearoyl-2-lactylate, SSL) increased dough strength. Extensigram data showed a reduction in the proportional number (R/E) as the percentage of legume flour in the blend was increased. Loaf volume of bread decreased as the level of legume flour was increased; however, incorporation of SSL produced acceptable bread at the 5 and 10% levels. A 2-hr fermentation with higher oxidation levels than the control flour produced the best bread for the various blends. Bread containing 5 or 10% legume flour showed a whiter crumb color compared to the control loaf.

Greater emphasis has been placed on the use of composite flour in bread-baking during the last 10–15 years. In general, composite flour refers to flour containing blends of wheat flour with nonwheat flours, although in some instances nonwheat materials have been used as a total substitute for wheat.

The studies have investigated not only the use of indigenous crops, such as cassava and other tuber crops, but also the use of cereals other than wheat, such as barley, sorghum, corn, and rice.

Besides investigating crops other than wheat in bread production, researchers have recently placed emphasis on the development of high-protein-type bread products. Because the literature on composite flours and protein supplementation is so extensive, it would be impossible to elucidate all of the studies. An up-to-date bibliography on composite flour technology has been published by the Tropical Products Institute (1).

The production of bread with composite flours or incorporation of high-protein additives in general requires the use of chemicals such as glyceryl monostearate (GMS), sodium stearoyl-2-lactylate (SSL), or other materials used as dough strengtheners.

The use of legume flours (particularly soy) to improve the nutritional value of bread has received considerable interest. Soy flour is a valuable additive not only because of its high protein content but also because of its higher lysine content compared to wheat flour. Several studies (2–5) have been conducted using soy flour in bread.

The production of high-protein bread from wheat-faba bean composite flours was studied by McConnell *et al.* (6). They found that the addition of faba bean flour to hard red spring (HRS) wheat flour at the rate of 10, 20, 30, and 40%

[1]Presented at the 60th Annual Meeting, Kansas City, Mo., Oct. 1975. Published with the approval of the Director of the Agricultural Experiment Station, North Dakota State University, Fargo, as Journal Series No. 676.

[2]Associate Professor, Department of Cereal Chemistry and Technology.

resulted in a progressive decrease in loaf volume and a deterioration in crumb grain, even in the presence of a dough conditioner such as SSL. These difficulties could be overcome and protein levels markedly increased by using faba bean concentrate prepared by air classification in place of faba bean flour.

The purpose of this investigation was to study primarily the physical dough properties and baking potential of various legume flours blended at different levels with a common lot of HRS wheat flour.

MATERIALS AND METHODS

Samples

Legumes. Five legumes were used and included mung bean (*Phaseolus aureus*), faba bean (*Vicia faba*), navy bean (*P. vulgaris*), pinto bean (*P. vulgaris*), and lentil (*Lens esculenta*). The pinto beans and lentils were grown in North Dakota, the navy beans in Michigan, the faba beans in Manitoba, and the mung beans in Oklahoma.

Wheat. A composite of HRS wheat varieties grown in North Dakota was used to obtain the flour for blending purposes.

Milling of Legumes

The various legumes were milled according to the procedure described by Watson *et al.* (7) with minor modifications. The samples were passed initially through the first-break rolls of an Allis-Chalmers experimental mill. Passage through the first break primarily cracked the hull. The material was then passed through the second-break rolls of the same mill, thereby producing a meal-type product which was sieved through a U.S. No. 25 sieve using a Strand Shaker to separate much of the hull from the endosperm. The meal was then passed through the reduction rolls of a Buhler Laboratory experimental mill. The flour obtained from the three reduction rolls was combined and used for preparing the blends with the HRS wheat flour.

Milling of HRS Wheat

The HRS wheat was milled on a Pilot Miag mill (8). The flour contained 13.6% protein (14.0% mb) and was used in the unbleached, unmalted state.

Preparation of Blends

Blends containing 5, 10, and 20% of each legume flour with the HRS wheat flour were prepared. The blends were used for all analyses, including investigation of their physical dough properties and baking performance.

Water-Retention Capacity

The water-retention capacity of the legume-wheat flour blends (LWFB) was conducted on 5-g samples. The sample was placed in a 30-ml tared centrifuge tube, 10 ml distilled water added, the mixture slurried with a glass rod, and the tube placed in a water bath at 25°C. A few drops of octanol were added to prevent foaming. The suspension was hand-stirred with a glass rod every 10 min, and the flour adhering to the sides of the tubes was scraped to prevent drying. The tubes containing the flour-water slurry were kept in the bath for exactly 30 min, then removed and centrifuged for 10 min at 750 × *g*. The supernatant was decanted and the tubes left to drain for 10 min on a paper towel to remove excess moisture. The sample was weighed and the water-retention capacity determined from the amount of water retained.

Pasting Properties

The pasting properties of the LWFB were investigated with the Brabender Amylograph®. Flour (50 g db) was suspended in 350 ml amylograph buffer solution by agitating in a Waring Blendor at low speed for 1 min. The suspension was poured into the amylograph bowl and the blender rinsed with 100 ml of buffer solution. The slurry was heated uniformly from 25° to 95°C, held for 15 min at 95°C, and then cooled uniformly to 50°C. Pasting temperature, peak height, peak temperature, 15 min-height, and setback were obtained from the amylograph curve.

The flour pasting properties were also investigated in the presence of 1.0 g Emplex (SSL) Patco Products, 3947 Broadway, Kansas City, Mo. The SSL was added slowly during agitation of the flour-water slurry in the Waring Blendor.

Physical Dough Properties

The farinograph and extensigraph were used to determine the physical dough properties of the different LWFB with and without the incorporation of SSL. For the farinograph studies, the 50-g bowl with a 50-g sample was used, and with the extensigraph a 100-g sample was used. For both tests, 0.25 g of SSL was used.

Baking Studies

The various LWFB were baked according to the conventional straight-dough procedure and 100 g of flour. The effects of fermentation time, oxidation requirements (potassium bromate), and SSL were investigated. Farinogram absorption and mixing time were used as indicators of these two parameters for bread-baking. Mixing was performed in a National 100-200 g mixer (National

TABLE I
Protein and Ash Content of Various Legumes[a]

Legume	100% Legume	Legume Flour	
	Protein %	Protein %	Ash %
Mung bean	22.9	23.8	3.07
Lentil	23.4	24.2	2.59
Faba bean	25.9	28.9	3.50
Navy bean	20.7	20.6	3.57
Pinto bean	19.2	19.5	3.12

[a]Results expressed on a 14.0% moisture basis. Protein = N × 6.25.

Mfg. Co., Lincoln, Nebr.). The baking formula used was as follows:

Flour	100 g (14% mb)
Salt	2%
Sugar	5%
Shortening	3%
Compressed yeast	3%
Potassium bromate	Variable
SSL	Bread with SSL contained 1%
Water	Variable

Defatted Legume Flours

The effect of defatting the legume flours on bread-baking properties was investigated. The legume flour was extracted by stirring the flour with petroleum ether (1:2 w/v) for 20 min. The slurry was filtered through a Büchner funnel and the residue re-extracted with petroleum ether as above, followed by filtration and extraction of the residue a third time. The extracted flour was allowed to air-dry overnight, or until the odor of solvent was absent.

Taste Panel Evaluation

Bread produced from the 10% LWFB was evaluated by a taste panel using the triangle test, in which two samples were the control (100% wheat-flour bread) and the third was the 10% legume-wheat flour bread under test. The panel of 15—20 individuals judged the bread for mastication (mouth-feel and chewing performance) and for taste and aroma.

For mastication the panel was asked to rate the bread in the triangle test as: 1, satisfactory; 2, gummy, doughy; 3, tough; and 4, other (indicate). The panel was also asked to rate the bread for taste and aroma as: 1, pleasant taste; 2, bland, tasteless; 3, bitter taste; and 4, other (indicate).

Other Determinations

Moisture, ash, and protein contents were determined by standard AACC procedures (9).

RESULTS AND DISCUSSION

Analytical Data

The data in Table I show the protein and ash contents of the various legumes. Protein content of the mung and faba beans and lentils was higher in the milled flour than in the 100% legume, whereas the navy and pinto beans had essentially the same values for the 100% ground bean and the milled flour. The faba bean flour contained the highest protein content.

The pinto and navy bean flours were grayish in appearance and the other legume flours were varying degrees of yellowness. The legume flours had high ash contents when compared to the ash content of patent flour, which is generally between 0.38 and 0.48. Ash content cannot be used as an indicator of milling efficiency of legumes as with wheat (7).

Water-Retention Capacity

The data in Table II show the water-retention capacity values obtained for the various LWFB and the HRS wheat-flour control. The pinto bean-wheat flour blends gave the highest values of the various LWFB, followed by the navy bean-wheat flour samples. The water-binding capacity values increased as the percentage level of pinto, navy, or mung bean flour in the blend was increased. The water-binding capacity values of the 100% navy and pinto bean flours were 91.6 and 99.4%, respectively, whereas the mung bean, lentil bean, and faba bean flours had values of 65.0, 71.0, and 55.3%, respectively. Therefore, it would appear that the pinto and navy bean flours were better able to retain water than the other legume flours.

Pasting Properties

Data on the pasting properties of the LWFB and control flour in the absence and presence of SSL are shown in Table III. In the presence of SSL, the swelling of the starch was restricted and thus the initial temperature of pasting and peak temperature were delayed. The peak height and 15-min height in all cases were higher with the inclusion of SSL than in its absence. With or without the inclusion of SSL, the peak height and 15-min height were highest for the 5% legume-flour blend for all legumes. These values decreased as the percentage of legume flour in the blend was increased, with the exception of the navy bean and pinto bean without SSL. In general, without the incorporation of SSL, a decrease in setback was noted as the level of legume flour in the blend was increased, whereas with SSL greater variations were noted in setback values among the different legume flours. Without SSL, the lentil-containing blends had the highest peak heights of the different legumes. With SSL, peak heights were more nearly the same; however, the 15-min height for the navy bean-

TABLE II

Water-Retention Capacity Values of Legume-Wheat Flour Blends

	Water-Retention Capacity			
Source	**5%**	**10%**	**20%**	**100%**
Control (HRS wheat flour)	...	...	...	67.2
Mung bean	63.9	64.7	68.9	65.0
Lentil	63.3	63.8	62.6	71.0
Faba bean	66.7	65.4	63.6	55.3
Navy bean	65.5	69.5	72.9	91.6
Pinto bean	71.6	76.1	81.6	99.4

TABLE III
Pasting Properties of Legume-Wheat Flour Blends

Source	Blend %	Initial Pasting Temperature, °C		Peak Temperature[a], °C		Peak Height B.U.		15-min Height B.U.		Setback B.U.	
		No SSL	2% SSL	No SSL	2% SSL	No SSL	2% SSL	No SSL	2% SSL	No SSL	2% SSL
Control (HRS wheat flour)	...	67.0	88.0	95.0	95.0 (2.5 min)	470	630	340	480	310	>520
Mung bean	5	65.5	79.0	94.5	95.0 (7.5 min)	520	710	375	660	415	>340
	10	68.5	82.0	93.5	95.0 (7.5 min)	510	660	340	600	420	300
	20	71.5	80.5	93.5	95.0 (4.0 min)	490	660	310	510	380	350
Lentil	5	65.5	83.5	95.0 (0.5 min)	95.0 (2.5 min)	590	730	440	575	310	>425
	10	67.0	77.5	94.5	95.0 (4.0 min)	560	680	420	570	230	130
	20	67.0	74.5	93.5	95.0 (2.5 min)	510	640	350	470	190	200
Faba bean	5	75.0	83.5	94.5	95.0 (6.0 min)	520	720	370	640	280	140
	10	67.0	82.0	95.0	95.0 (6.0 min)	500	700	350	560	330	290
	20	68.5	79.0	93.5	95.0 (2.5 min)	480	610	325	435	145	−10
Navy bean	5	68.5	76.0	95.0 (0.5 min)	95.0 (7.0 min)	530	735	420	720	450	>280
	10	71.5	80.5	93.5	95.0 (7.0 min)	460	640	320	640	370	10
	20	73.0	79.0	95.0	95.0 (5.0 min)	500	600	400	540	360	−70
Pinto bean	5	68.5	73.0	95.0	95.0 (4.0 min)	500	720	385	610	205	−20
	10	68.5	77.5	94.5	95.0 (4.0 min)	440	680	340	600	140	30
	20	67.0	79.0	94.0	95.0 (5.5 min)	460	600	370	550	170	140

[a]Time in parentheses is the number of minutes after the temperature first reached 95°C.

containing blends was considerably higher than for the other legumes.

Although not investigated, the differences noted in peak height, 15-min height, and setback with the incorporation of the legume flour to the HRS wheat flour may be of importance to crumb firming.

Physical Dough Testing

Table IV shows the farinograph data of the control wheat flour and the various LWFB with and without the incorporation of SSL. Absorption of the mung bean and lentil flour blends decreased as the percentage of legume flour in the blend was increased. The navy and pinto bean flour blends without incorporating SSL had a higher farinogram absorption than the control. The higher farinogram absorption values of these two LWFB compared to the other samples are in agreement with the water-binding capacity results.

Dough developing time of the LWFB was less than that of the control flour; however, no extreme differences were noted in developing time for the three blends of a particular legume. The stability in all cases decreased as the percentage of legume flour in the blend increased, indicating an overall weakening of the dough.

Addition of 0.50% SSL based on the flour weight decreased farinogram absorption for some of the LWFB. Also apparent was the higher absorption of the navy and pinto bean-wheat flour blends, particularly at the 20% level, compared to the other LWFB. SSL increased the farinogram developing time

TABLE IV
Farinograph Data of Legume-Wheat Flour Blends

		Absorption, %		Dough Developing Time, min		Stability, min	
Source	**Blend %**	**No SSL**	**0.50% SSL**	**No SSL**	**0.50% SSL**	**No SSL**	**0.50% SSL**
Control (HRS wheat flour)	...	62.0	62.4	9.5	15.0+	15.0	20.0+
Mung bean	5	59.8	59.4	5.5	5.0	12.0	18.2
	10	59.2	59.2	5.5	6.0	8.6	15.8
	20	58.0	58.2	6.0	8.0	6.3	9.7
Lentil	5	62.4	61.3	5.5	6.0	8.7	17.0
	10	61.6	59.7	5.0	6.0	7.8	11.0
	20	59.6	60.3	4.0	5.5	4.2	7.6
Faba bean	5	62.0	61.0	5.5	9.0	9.5	20.0
	10	62.9	62.2	6.5	8.0	6.0	12.5
	20	61.4	60.7	5.5	7.5	4.0	7.0
Navy bean	5	65.4	62.1	5.5	7.5	9.2	13.3
	10	64.0	62.0	5.5	5.5	5.6	11.5
	20	63.5	63.0	5.5	5.5	5.0	8.0
Pinto bean	5	62.4	62.7	6.5	10.0	9.0	18.0
	10	63.2	64.0	7.0	8.0	7.5	14.5
	20	64.0	64.0	6.0	8.5	4.0	9.0

compared to the corresponding farinogram without SSL. In all cases, the addition of SSL increased the stability of a particular blend, indicating an increase in dough tolerance to mixing.

Table V shows the proportional numbers calculated from the extensigrams for the different LWFB with and without the incorporation of SSL. A reduction in the proportional number (R/E) occurred as the percentage of legume flour in the blend was increased. The greater the proportional number, the "shorter" the dough. The 5 and 10% pinto bean-wheat flour blends had the highest proportional numbers after the 45-min rest period. Particularly noteworthy are the large proportional values for the 5 and 10% faba bean-wheat flour blends at the 180-min rest period with or without the incorporation of SSL.

Baking Studies

A total of 350 loaves of bread were made using the various legume flours to study different fermentation times, oxidation levels, dough strengthener amounts, and amount of legume flour with HRS wheat flour.

The baking results presented in Table VI are those obtained using a 2-hr fermentation, 10 and 30 ppm $KBrO_3$ for the control flour and various LWFB, respectively, and with and without the incorporation of 1% SSL. Baking

TABLE V
Extensigraph Data of Legume-Wheat Flour Blends

		Proportional Number[a]			
		No SSL		0.25 g SSL	
Source	Blend %	45-min Rest	180-min Rest	45-min Rest	180-min Rest
Control (HRS wheat flour)	...	0.39	0.58	0.37	0.52
Mung bean	5	0.29	0.61	0.31	0.84
	10	0.20	0.68	0.23	0.77
	20	0.19	0.49	0.21	0.50
Lentil	5	0.24	0.66	0.28	0.69
	10	0.20	0.48	0.27	0.74
	20	0.16	0.23	0.09	0.21
Faba bean	5	0.27	1.50	0.24	1.47
	10	0.17	0.75	0.16	0.94
	20	0.10	0.16	0.07	0.24
Navy bean	5	0.29	0.62	0.23	0.57
	10	0.17	0.41	0.16	0.50
	20	0.12	0.27	0.11	0.31
Pinto bean	5	0.34	0.62	0.42	0.61
	10	0.32	0.67	0.33	0.71
	20	0.17	0.52	0.23	0.59

[a] $\frac{\text{Resistance to Extension}}{\text{Extensibility}}$

TABLE VI
Baking Data on Legume-Wheat Flour Blends

Source	Blend %	Baking Absorption %		Specific Volume[a] cc/g		Crust Color[b]		Crumb Color[b]		Grain[b]	
		No SSL	1% SSL	No SSL	1% SSL	No SSL	1% SSL	No SSL	1% SSL	No SSL	1% SSL
Control (HRS wheat flour)	...	60.7	60.7	6.18	6.76	10.0	10.0	8.5	9.0	10.0	10.0
Mung bean	5	59.7	59.7	6.24	6.74	10.0	10.0	9.5	10.0	9.0	9.5
	10	58.7	58.7	5.79	5.99	8.5	8.5	9.0	9.5	8.5	9.0
	20	52.7	52.7	4.82	5.16	7.0	7.0	7.0	7.5	7.0	7.5
Lentil	5	59.7	59.7	5.96	6.60	10.0	10.0	9.5	10.0	9.0	9.5
	10	58.7	58.7	5.92	6.08	9.0	9.0	9.0	9.5	8.5	9.0
	20	54.7	54.7	4.95	5.33	7.5	7.5	7.0	8.0	7.5	8.0
Faba bean	5	57.7	57.7	6.02	6.88	10.0	10.0	9.0	9.5	8.0	7.5
	10	55.7	55.7	5.71	6.06	8.5	8.5	8.5	9.0	7.0	7.5
	20	51.7	51.7	4.61	4.85	7.5	7.5	7.5	8.0	6.5	7.0
Navy bean	5	60.7	60.7	6.42	6.97	10.0	10.0	9.5	10.0+	10.0	10.0+
	10	59.7	59.7	5.73	6.25	9.0	9.0	9.5	10.0	9.5	9.5
	20	56.7	56.7	4.71	5.13	7.5	7.5	8.5	9.0	7.0	8.0
Pinto bean	5	59.7	59.7	6.00	6.36	10.0	10.0	9.5	10.0	9.5	9.5
	10	58.7	58.7	5.46	5.83	9.0	9.0	9.5	10.0	9.0	9.0
	20	54.7	54.7	4.53	4.82	7.5	7.5	8.5	9.0	7.0	7.5

[a]Specific volumes represent an average of duplicate bakes.
[b]Values are based on a score of 1–10 with 10 being the best score.

absorption of all the LWFB decreased as the amount of legume flour in the blend was increased. However, for the bread containing the navy bean flour, baking absorption was somewhat higher than that containing the other legume flours. Best bread-baking results were obtained using a 2-hr fermentation period and 30 ppm of $KBrO_3$ for the LWFB. The incorporation of 1% SSL increased the loaf volume of the bread produced from all samples. As the level of legume flour in the blend was increased, the crust color of the bread became increasingly darker. The 20% blend level of the mung-bean flour bread produced the darkest crust color of the various samples. This was due to the higher sugar content in mung bean. A whiter crumb color was noted with the 5 and 10% legume flour bread over the control bread. This was of interest since the legume flours obtained from faba bean, mung bean, and lentil had varying degrees of yellowness while the pinto and navy bean flours were grayish in appearance. One could conclude that perhaps a lipoxygenase-type enzyme in the legume flour was responsible for the improving effect on crumb color. The addition of 1% SSL improved the crumb color of the corresponding loaf containing no SSL. In most instances, the grain of the legume-wheat flour bread was improved with the inclusion of SSL. The bread containing the 5 and 10% navy bean flour produced the best grain and internal appearance of the various legume flour-containing breads.

The bread baked from the blends prepared from the legume flours extracted with petroleum ether produced results similar to those obtained with the blends prepared from the unextracted legume flours.

Taste Panel Evaluation

Taste panel information indicated that at the 10% level the wheat-mung bean bread was the most satisfactory of the legume-wheat flour breads for taste and aroma.

Eighty per cent of the panel of 15 rated the mung bean bread as having a pleasant taste, while the remainder rated it as bland and tasteless. With the 10% navy bean or lentil bread, 67% of the panel rated it as having a pleasant taste. The breads containing 10% pinto bean or faba bean flour were rated the poorest in taste and aroma compared to the bread containing the other legume flours. Only 38 and 40% of the panel rated the pinto bean bread and faba bean bread, respectively, as having a pleasant taste.

The 10% pinto bean bread gave the highest rating for mastication of the different legume-containing breads and was more acceptable than the control bread. The lentil-containing bread was rated the poorest in the mastication test.

This study has shown that certain differences exist among legumes when blended with HRS wheat flour on physical dough properties and bread-baking. A weakening of the dough as indicated by the farinograph and extensigraph data was verified with the baking results. In general, acceptable bread could be produced at the 5 or 10% level of legume flour with the incorporation of 1% SSL.

Acknowledgments

The author gratefully acknowledges the technical assistance of Truman Olson for milling the legumes and Rachel Nelson for performing the physical dough and baking studies.

Literature Cited

1. DENDY, D. A. V., KASASIAN, R., BENT, A., CLARKE, P. A., and JAMES, A. W. Composite flour technology bibliography (2nd ed.). Trop. Products Inst.: London (1975).
2. TSEN, C. C., HOOVER, W. J., and PHILLIPS, D. High-protein breads. Use of sodium stearoyl-2-lactylate and calcium stearoyl-2-lactylate in their production. Baker's Dig. 45(2): 20 (1971).
3. TSEN, C. C., and TANG, R. T. K-State process for making high protein breads. I. Soy flour bread. Baker's Dig. 45(5): 26 (1971).
4. MARNETT, L. F., TENNEY, R. J., and BARRY, V. D. Methods of producing soy-fortified breads. Cereal Sci. Today 18: 38 (1973).
5. TSEN, C. C., and HOOVER, W. J. High-protein bread from wheat flour fortified with full-fat soy flour. Cereal Chem. 50: 7 (1973).
6. McCONNELL, L. M., SIMMONDS, D. H., and BUSHUK, W. High-protein bread from wheat-faba bean composite flours. Cereal Sci. Today 19: 517 (1974).
7. WATSON, J. W., McEWEN, T. J., and BUSHUK, W. Note on dry milling of fababeans. Cereal Chem. 52: 272 (1975).
8. SHUEY, W. C., and GILLIS, K. A. Evaluating wheat quality on a laboratory scale commercial mill. Northwest. Miller 275: 8 (1968).
9. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved methods of the AACC. Method 44-15A, approved April 1967; Method 08-01, approved April 1961; and Method 46-10 approved April 1961. The Association: St. Paul, Minn.

[Received November 7, 1975. Accepted March 30, 1976]