BREAD-BAKING PROPERTIES OF COTTONSEED PROTEIN CONCENTRATES PREPARED FROM SOLVENT-EXTRACTED GLANDLESS COTTONSEED FLOUR[1]

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ABSTRACT

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Spray- or freeze-drying pH of cottonseed protein concentrates, prepared from solvent-extracted glandless cottonseed flour, significantly affected their baking properties. Five pH levels (4.5, 5.5, 6.5, 7.5, and 8.5) adjusted with NaOH and $Ca(OH)_2$ were examined for spray-drying. Two pH levels (4.5 and 6.5) were compared for freeze-drying. Parent glandless cottonseed flour and commercial soy flour were included for comparative purposes. Each protein source was blended with wheat flour (14% protein on dry weight basis) to produce blends with 17.5% protein. This increased bread protein (N × 6.25) by 30% as compared to bread baked with 100% wheat flour (*i.e.*, from 10 to 13% on as-is basis). Brabender Farinograph® absorption, peak time, and stability increased as the spray- or freeze-drying pH was increased. Acceptable bread could be baked with cottonseed protein concentrate spray- or freeze-dried near neutral pH. It was similar in quality to bread baked with glandless cottonseed flour and commercial soy flour. Low pH adversely affected the baking properties of both spray- and freeze-dried concentrate. Calcium ions at any pH level reduced the loaf volume significantly. Change in pH of cottonseed protein concentrate at the dough-mixing stage had no effect on its baking properties.

The fortification of human food with oilseed proteins is expanding rapidly. Much of the success has been achieved with soy protein products, but cottonseed and peanut protein products have also been included in human foods at least experimentally. Cottonseed flour has been used in a wide variety of food products. Cottonseed protein concentrates (CSPC) prepared from solvent-

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extracted flour can vary significantly in baking characteristics (1). For instance, Lawhon *et al.* (1) demonstrated that solvent-extracted CSPC prepared from glandless cottonseed flour (GCSF) and spray-dried at acid pH had significantly poorer baking properties than a comparable concentrate spray-dried near neutral pH.

The objectives of the work reported here are 1) to study the baking properties of CSPC, spray-dried at different pH levels; 2) to compare the influence of Ca^{++} and Na^{+} on the baking properties of CSPC; and 3) to determine the effect of freeze- *vs.* spray-drying on the baking properties of CSPC. Parent GCSF and commercial soy flour (SF) were included for comparison.

The ultimate goal was to optimize a process for cottonseed protein concentrate that would have optimum properties for use in fortification of baked products.

MATERIALS AND METHODS

Preparation of Cottonseed Protein Concentrate

Lawhon *et al.* (1) described the processing of CSPC at the pilot-plant scale. A simplified schematic diagram of the process is presented in Fig. 1. After the solid residue (CSPC) was recovered, it was divided into seven lots. Five lots were spray-dried after pH was adjusted to 4.5, 5.5, 6.5, 7.5, and 8.5 with 1*N* NaOH. Hereafter, these products are referred to as CSPC 4.5 Na, CSPC 5.5 Na, CSPC 6.5 Na, CSPC 7.5 Na, and CSPC 8.5 Na. The two remaining lots of CSPC were freeze-dried after adjusting the pH to 4.5 and 6.5 with 1*N* NaOH.

In another processing run, CSPC was divided into five portions and spray-dried after the pH was adjusted to 4.5, 5.5, 6.5, 7.5, and 8.5 with 1*N* $Ca(OH)_2$. Hereafter, these products are referred to as CSPC 4.5 Ca, CSPC 5.5 Ca, CSPC 6.5 Ca, CSPC 7.5 Ca, and CSPC 8.5 Ca.

The spray dryer was an Anhydro Spray Dryer Type III, No. 2, which is a flat-

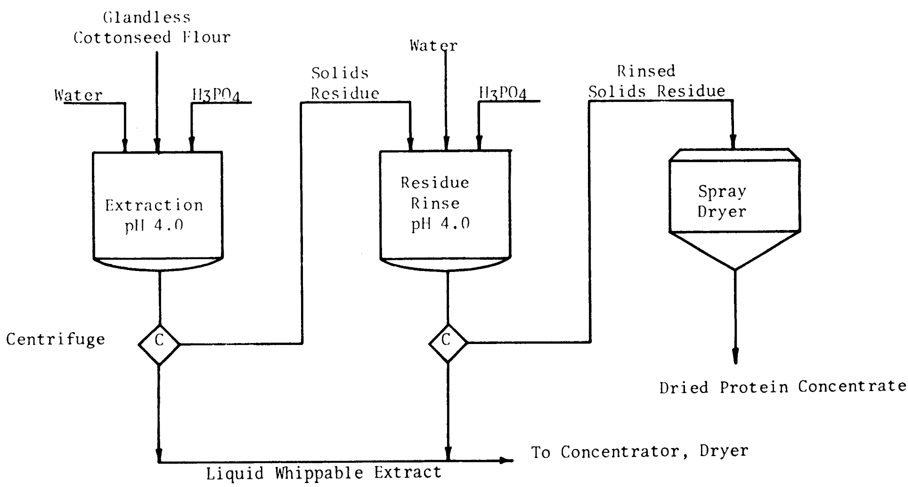

Fig. 1. Procedure used to prepare cottonseed protein concentrate.

bottom dryer with centrifugal atomization for feed. Inlet air temperature was held at 150° C. Outlet air temperature was 82° to 93° C during drying.

Analytical Methods

All CSPC products, GCSF, and SF were analyzed for protein (N × 6.25), moisture, and ash (2). Wheat flour was analyzed for protein (N × 5.7) and moisture (3). Nitrogen solubility profiles were obtained for concentrates representing each group as described by Lawhon *et al.* (1). The 'L' value of a Hunterlab Digital Color and Color Difference Meter, Model D25D, was used as a measure of color intensity for all the protein sources, the wheat flour, and the bread crumb and crust colors.

Amino acid analysis of CSPC 4.5 Na, CSPC 6.5 Na, CSPC 4.5 Ca, and CSPC 7.5 Ca, and the GCSF were by the procedure of Spackman *et al.* (4). Tryptophan was determined by the method of Kohler and Palter (5). Cystine was determined using a modification of the procedure by Schram *et al.* (6).

PHYSICAL DOUGH AND BAKING PROPERTIES

Dough-Mixing Properties

Strength and stability of dough were determined with a Brabender Farinograph according to standard AACC procedure (3). Water absorption was the amount of water required to center the curve on a 500 Brabender Unit line.

Baking Procedure

Pound loaves were baked using each flour blend with a short-time dough system as described by Khan *et al.* (7). Sodium stearoyl-2-lactylate was used at the 1% level.

Loaf volume was measured immediately after baking by the rapeseed displacement method. The bread was weighed and stored overnight. The crumb grain score, crumb and crust color, and pH of the crumb and dough were measured 18 hr later. pH of the dough and bread crumb was measured according to AACC procedure (3).

Experimental Design

In the first series of experiments, each oilseed product was mixed with wheat flour to produce a blend with 17.5% protein (N × 6.25) on a 14% moisture basis. A total of 15 flour blends was studied in a randomized complete block design. All blends were baked on the same day and the whole bake was replicated three times.

In a second experimental series, CSPC 5.5 Na was divided into three lots and these lots were adjusted with 1*N* NaOH to pH values of 6.5, 7.5, and 8.5 at the dough-mixing stage. Each lot was baked and the baking performance was compared to the original CSPC 5.5 Na. In the same manner, CSPC 8.5 Na was divided into four lots and these lots were adjusted with 1*N* HCl to pH values of 7.5, 6.5, 5.5, and 4.5 at the dough-mixing stage. The baking performance of each lot was then compared to the original CSPC 8.5 Na. Each lot was combined with the appropriate amount of wheat flour to produce blends with 17.5% protein. All blends were baked on the same day, and the whole bake was replicated on each of two different days. A total of 13 blends was studied in a randomized complete block design.

Analysis of variance was calculated for loaf volume and crumb grain score. Significant differences between two means were calculated by Fisher's Least Significant Difference (LSD) method.

RESULTS AND DISCUSSION

Proximate analyses of all the CSPC's, GCSF, SF, and wheat flour are presented in Table I. At equivalent pH levels (adjusted with NaOH), the protein content of freeze-dried concentrate was higher than that of the spray-dried material. Ash content increased and color of the concentrate became darker as the pH of the concentrate prior to spray- or freeze-drying increased. Increase in ash content of CSPC was due to the larger amounts of alkali required to raise the pH to higher levels. The freeze-dried concentrates were lighter in color than corresponding spray-dried concentrates at the same pH level. The concentrates prepared with $Ca(OH)_2$ were lighter than those prepared with NaOH.
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Nitrogen solubility profiles of CSPC prepared with NaOH are shown in Fig. 2. These differed significantly from those of CSPC prepared using $Ca(OH)_2$. But

TABLE I
Proximate Analyses of Cottonseed Protein Concentrates Spray- or Freeze-Dried at Different pH Levels, Glandless Cottonseed Flour (GCSF), Commercial Soy Flour (SF), and Wheat Flour

Drying Method	Alkali	pH Level	Moisture %	Protein[a] %[b]	Ash %[b]	Color[c]	Amount of Oilseed Source/100 g of Blend[b] g
Spray	NaOH	4.5	4.7	64.2	5.7	78	8.9
		5.5	5.0	63.9	7.1	79	9.0
		6.5	5.1	63.8	7.0	75	9.0
		7.5	4.6	63.8	7.2	65	8.9
		8.5	5.5	62.9	7.6	57	9.2
	$Ca(OH)_2$	4.5	6.5	63.6	5.8	84	9.2
		5.5	7.0	63.6	6.5	83	9.2
		6.5	7.5	62.7	6.7	78	9.4
		7.5	7.5	60.9	7.1	74	9.7
		8.5	7.2	62.3	7.3	71	9.4
Freeze	NaOH	4.5	1.5	66.1	5.2	85	8.3
		6.5	1.7	65.6	7.3	78	8.4
Controls							
Wheat flour			12.7	12.4	...	90	...
GCSF			6.9	54.3	5.6	88	11.2
SF			6.9	48.0	4.6	87	13.2

[a]Protein = N × 6.25 for oilseed products; N × 5 for wheat flour.
[b]Expressed at 14% moisture basis.
[c]'L' value of Hunter's Color Difference Meter.

nitrogen solubility profiles were not significantly related to the baking properties of the CSPC products.

The essential amino acid compositions of selected CSPC and GCSF are presented in Table II. There was no difference in the essential amino acid pattern between CSPC Na and CSPC Ca. The available lysine content of CSPC was less than that of GCSF.

Physical Dough and Baking Properties

Mixing properties of all the concentrates and the control flours are presented in Table III. The farinograph absorption, peak time, and stability of the dough increased with increase in spray-drying pH. The increase in dough stability could be due to the higher ash content of the CSPC.

The baking properties of all the concentrates and control flours are presented in Table IV. Breads baked with the spray-dried concentrates are shown in Fig. 3.

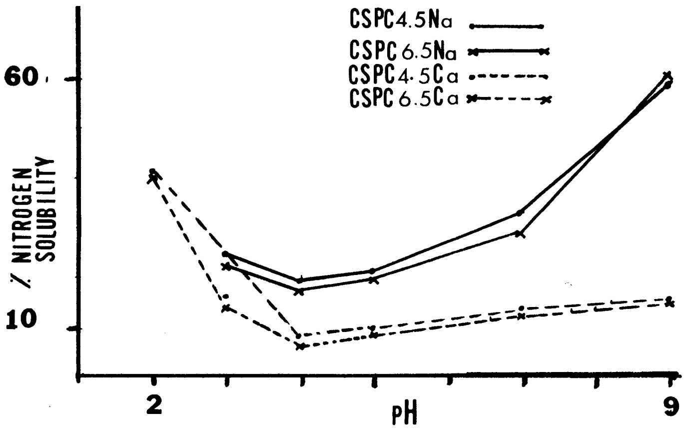

Fig. 2. Nitrogen solubility profiles of cottonseed protein concentrates as a function of pH.

TABLE II
Essential Amino Acid Compositions of Cottonseed Protein Concentrates (CSPC) Spray-Dried at Two pH Levels and Glandless Cottonseed Flour (GCSF)

	g Amino Acid/100 g Protein				
Amino Acid	CSPC 4.5 Na	CSPC 6.5 Na	CSPC 4.5 Ca	CSPC 7.5 Ca	GCSF
Lysine	3.6[a]	4.0	3.7	3.6	4.0
Cystine	1.9	2.1	2.1	1.8	2.4
Methionine	1.8	1.5	1.3	1.3	1.4
Valine	4.9	4.9	4.4	4.5	4.5
Leucine	6.4	6.2	6.0	6.2	6.0
Isoleucine	3.4	3.2	3.2	3.2	3.1
Tryptophan	1.4	1.5	0.6	0.6	1.5
Threonine	3.2	3.1	2.8	2.9	3.2
Phenylalanine	6.3	6.2	6.1	5.9	6.0
Tyrosine	3.4	3.4	3.1	2.9	3.3
Available lysine	3.1	3.1	...	...	3.8

[a]Average of four replicate analyses.

TABLE III
Mixing Properties of Cottonseed Protein Concentrates, Spray- or Freeze-Dried at Different pH Levels; Glandless Cottonseed Flour (GCSF); and Commercial Soy Flour (SF)

Drying Method	Alkali	pH Level	Water Absorption[a] %	Peak Time min	Stability min
Spray	NaOH	4.5	64.6	5.0	7.5
		5.5	64.9	5.0	7.0
		6.5	64.0	6.0	16.0
		7.5	67.9	9.0	14.0
		8.5	69.9	10.0	15.0
	$Ca(OH)_2$	4.5	64.5	5.0	8.5
		5.5	67.5	5.0	7.5
		6.5	68.4	5.0	13.0
		7.5	68.3	6.0	13.5
		8.5	69.2	7.0	10.0
Freeze	NaOH	4.5	67.0	5.0	9.0
		6.5	65.4	7.0	12.0
Controls					
Wheat flour			63.0	7.0	15.5
GCSF			64.2	4.5	5.5
SF			63.5	5.5	7.0

[a]Expressed on a 14% moisture basis.

TABLE IV
Baking Properties of Cottonseed Protein Concentrates, Spray- or Freeze-Dried at Different pH Levels; Glandless Cottonseed Flour (GCSF); and Commercial Soy Flour (SF)

Drying Method	Alkali	pH Level	Loaf Volume cc	Crumb Grain Score %	Crust Color[a]	Crumb Color[a]	pH of Dough	pH of Crumb
Spray	NaOH	4.5	2442	53	26	71	5.1	4.8
		5.5	2433	50	25	70	5.2	5.1
		6.5	2775	70	27	72	5.5	5.5
		7.5	2825	70	27	72	5.8	5.9
		8.5	2790	60	28	71	5.9	6.1
	$Ca(OH)_2$	4.5	2463	43	28	71	5.3	5.2
		5.5	2400	56	28	71	5.5	5.6
		6.5	2408	53	29	70	5.6	5.6
		7.5	2200	53	28	68	5.9	6.0
		8.5	2367	57	28	68	5.9	6.1
Freeze	NaOH	4.5	2350	40	28	73	4.9	4.8
		6.5	2735	67	25	70	5.6	5.5
Controls								
Wheat flour			3192	80	29	82	5.3	5.5
GCSF			2875	77	24	76	5.6	5.6
SF			2825	73	24	74	5.6	5.7
LSD (0.05)			140	15				

[a]'L' value of Hunter's Color Difference Meter.

Acidic pH adversely affected the baking properties of spray-dried concentrate. Acceptable bread could be baked with CSPC spray-dried near neutral pH. It was similar in quality to the bread baked with GCSF or SF. pH adjustment with $Ca(OH)_2$ significantly reduced the loaf volume and bread crumb grain score. But the dough-handling and mixing properties of doughs with CSPC Na were not different from those that contained CSPC Ca. The bread baked with freeze-dried CSPC is shown in Fig. 4. Freeze-drying of CSPC did not alter its baking properties. At equivalent pH levels, bread baked with freeze-dried concentrates had the same loaf volume as those with spray-dried concentrates.

Crust and crumb colors of the bread baked with the CSPC were not affected by the freeze- or spray-drying pH. The higher sugar content of GCSF and SF had contributed to the dark crust color.

The pH of the dough and the bread crumb was not affected by spray- or freeze-drying pH. This could be due to the buffering action of yeast during fermentation (8,9).

The change in pH of the CSPC at the dough-mixing stage did not change its baking properties. The baking properties of bread baked by altering pH of CSPC 5.5 Na and CSPC 8.5 Na at the dough-mixing stage are presented in Table V. There was no significant difference between loaf volumes of breads containing CSPC 5.5 Na and those baked by adjusting the pH of CSPC 5.5 Na at the dough-

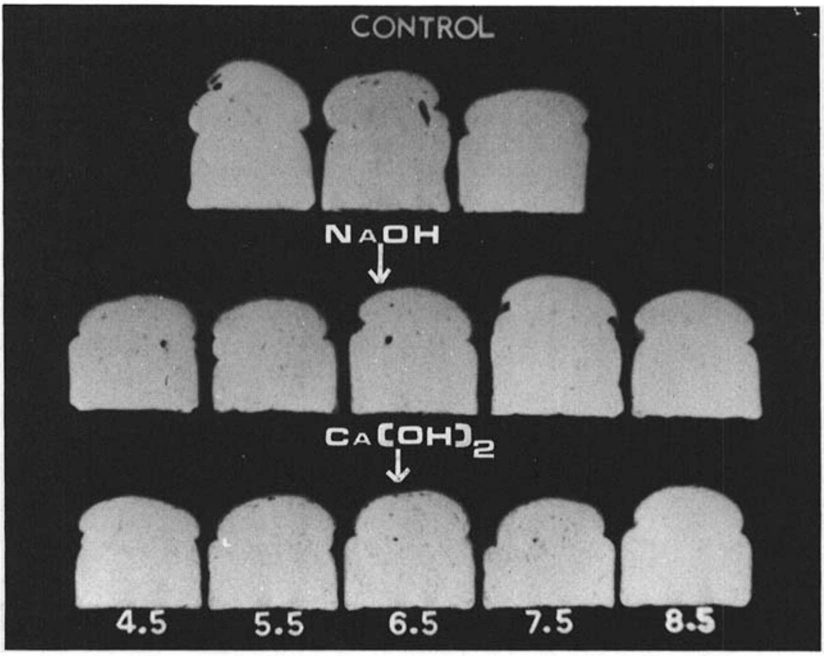

Fig. 3. Pound loaves of bread baked by short-time dough procedure with cottonseed protein concentrate spray-dried at pH levels of 4.5, 5.5, 6.5, 7.5, and 8.5, adjusted with NaOH and $Ca(OH)_2$. Control: Bread baked with 100% wheat flour, 13% commercial soy flour, and 11% glandless cottonseed flour.

mixing stage. Similar results were observed when pH of CSPC 8.5 Na was adjusted at the dough-mixing stage. These results suggest that the spray-drying pH had affected the functional properties of the CSPC. The acidic spray-drying pH had affected the compatibility of CSPC with wheat gluten, which resulted in its poor baking properties.

SUMMARY

Baking properties of cottonseed protein concentrates, spray- or freeze-dried at different pH levels, were evaluated with a short-time dough system. Enough of each protein product was added to raise the bread protein by 30% as compared to bread baked with 100% wheat flour (*i.e.*, from 10 to 13% on an as-is basis).

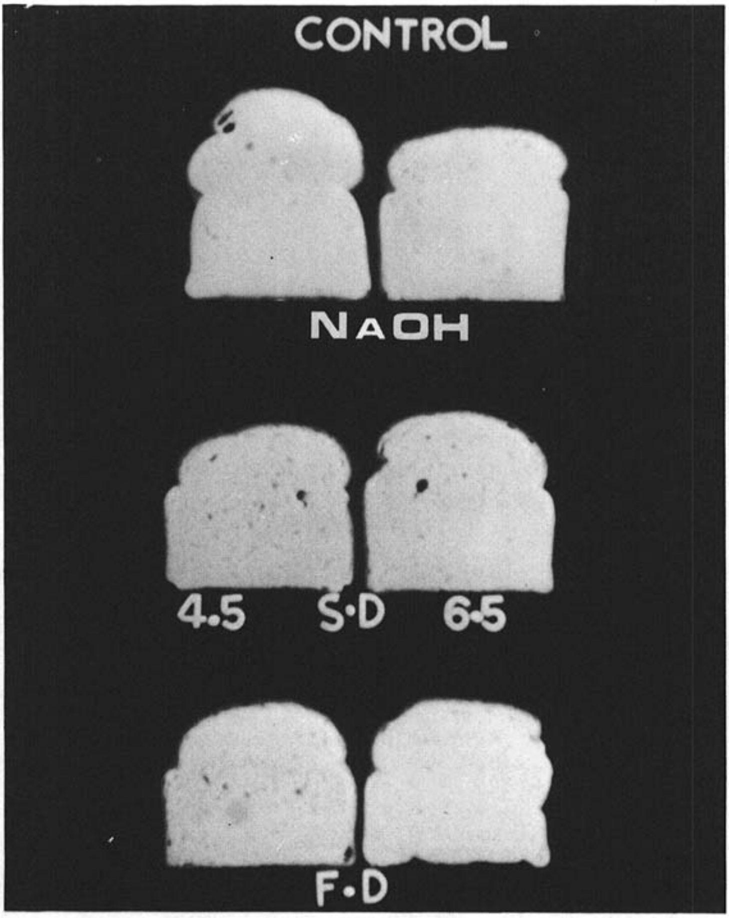

Fig. 4. Pound loaves of bread baked by short-time dough procedure with cottonseed protein concentrate spray-dried (S.D.) and freeze-dried (F.D.) at pH levels of 4.5 and 6.5. Control: Bread baked with 100% wheat flour and 11% glandless cottonseed flour.

TABLE V
Baking Properties of Cottonseed Protein Concentrates (CSPC 5.5 Na, CSPC 8.5 Na) with the pH Adjusted at Dough-Mixing Stage

Alkali	pH Prior to Spray-Drying	pH Adjusted during Dough-Mixing	Loaf Volume cc	Crust Color[a]	Crumb Color[a]	pH of Crumb
NaOH	5.5	...	2588	28	71	5.3
		6.5	2625	29	70	5.7
		7.5	2638	31	72	5.8
		8.5	2538	31	71	6.0
	8.5	...	2775	30	70	6.1
		7.5	2750	30	71	6.0
		6.5	2788	29	71	5.6
		5.5	2800	31	71	5.5
		4.5	2813	29	71	5.1
	4.5	...	2600	31	70	4.9
	6.5	...	2725	32	71	5.5
	7.5	...	2975	30	72	5.9
Controls						
Wheat flour			3208	29	78	5.3
LSD (0.05)			139			

[a]"L' value of Hunter's Color Difference Meter.

Acceptable loaves were obtained with blends containing cottonseed protein concentrate spray- or freeze-dried at near neutral pH adjusted with NaOH. They were similar in quality to the bread baked with parent glandless cottonseed flour or commercial soy flour. pH adjustment with $Ca(OH)_2$ had an adverse effect on the baking performance of cottonseed protein concentrate. Change in pH of CSPC during the dough-mixing stage did not influence its baking properties.

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