EFFECTS OF PROCESSING ON THE BAKING QUALITY OF WET ALKALINE PROCESS WHEAT PROTEIN CONCENTRATE[1]

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ABSTRACT

Baking studies were conducted with wheat protein concentrates prepared by a wet alkaline process (WAP-WPC). The acid (pH 5.0) or heat (85° C) precipitated WAP-WPC which were either freeze-, spray-, or drum-dried were included in pup loaves as 10 to 20% replacement of the flour by weight. With the addition of either 3% fat or 0.5% sodium stearoyl-2-lactylate (SSL) to loaves containing 10% WAP-WPC, the acid precipitates performed better than the heat precipitates, and drum-dried WAP-WPC performed better than spray-dried which, in turn, was superior to the freeze-dried protein concentrate. Loaves baked with 3% fat were either equivalent or superior to those which included 0.5% SSL. The specific loaf volumes of the loaves baked with 10% drum-dried WAP-WPC were $\geq$90% of that of the wheat flour control and higher than that of loaves which included 10% soy flour. Protein content of the loaves was increased by approximately 26, 41, and 57% when drum-dried WAP-WPC replaced 10, 15, and 20% of the flour, respectively.

The finite supply of available protein in a world with an ever increasing population is currently a major problem. Saunders *et al.* (1) have described a method in which a portion of the protein of wheat millrun[2] can be extracted with

[1]Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others which may also be suitable.
[2]Wheat millrun is the fraction of the kernel remaining after removal of flour during the conventional milling of wheat.

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mild alkali (pH 8.5). The procedure has since been reviewed and reported to the baking industry (2). The 5,000,000 tons of wheat millrun produced annually in the U.S. contain approximately 800,000 tons of protein which are used mainly as animal feed. The protein which is extracted from millrun by the wet alkaline process could be more efficiently utilized if it were consumed directly by humans. The extracted millrun residue, which contains approximately 13% protein (N × 5.7), may be fed to ruminants.

Wet alkaline process wheat protein concentrate (WAP-WPC) has good nutritional potential. The protein content (N × 5.7) varies from 51 to 55% when the majority of the starch is removed during the preparation process (3,4). The amino acid profile is favorable in that WAP-WPC contains 4 to 5 g lysine/16 g nitrogen (3). When fed to weanling rats, the protein efficiency ratio ranged from 1.8 to 2.0, and protein digestibility was $\geq$90% (5). WAP-WPC is also high in unsaturated fatty acids. From 78 to 80% of the total fatty acids are unsaturated with 52 to 59% being polyunsaturated. These fatty acids are moderately stable when stored under accelerated storage conditions (6).

Preliminary experiments indicated that WAP-WPC has good baking potential. Acceptable pup loaves were obtained when WAP-WPC prepared from wheat shorts was incorporated as 10% of the weight of the flour (1). The objective of this study was to evaluate the influence of preparation and drying methods on the baking quality of WAP-WPC.

MATERIALS AND METHODS

The WAP-WPC was prepared from millrun (Con Agra-Montana Inc.) by the wet alkaline process described by Saunders *et al.* (4). The protein concentrates used in this study had most of the starch removed during the preparation process, were acid (HCl pH 5.0) or heat (85° C) precipitated, and either freeze-, spray-, or

TABLE I
Straight-Dough Formula and Procedure

Ingredient	% of Flour or Blend[a]
Bread flour or flour-WAP-WPC[b] blend	100
Salt	2.0
Sugar	4.0
Shortening or	3.0 or
Dough conditioner[c]	0.5
Yeast	2.5
Potassium bromate	10 ppm

Method: Fermentation time, 1.75 hr, 87° F, 87% relative humidity; proof 55 min; bake 425° F 25 min. Immediately after baking bread was weighed and volume measured by rapeseed displacement method.

[a]14% moisture basis.
[b]Wet alkaline process wheat protein concentrate.
[c]Sodium stearoyl-2-lactylate.

drum-dried. Freeze-drying was conducted at 25° C in a modified Stokes vacuum oven. Spray-drying was carried out using a Bowen laboratory model conical-type dryer with inlet and outlet temperatures of 232° and 107° to 112° C, respectively. A steam-heated Buflovak double drum dryer with stainless-steel rolls 5 in. in diameter by 18 in. in length was used for drum-drying. The drum inlet temperature was 127° to 132° C. The freeze- and drum-dried WAP-WPC were ground to pass through a 20-mesh sieve.

Duplicate laboratory pup loaves (150 g dough/loaf) were prepared using the straight-dough process patterned after that used in government purchase specifications for soy-fortified flour (7). The basic formula and procedure are outlined in Table I. Acid and heat precipitated WAP-WPC which were freeze-, spray-, or drum-dried replaced 10% of the weight of the flour and were baked with either 3.0% fat or 0.5% sodium stearoyl-2-lactylate (SSL) added to the formula. In addition, the drum-dried WAP-WPC was baked at levels of 15 to 20% of the weight of flour, with the addition of 3.0% fat. The unbleached hard red winter wheat flour control contained 2.0% nitrogen and 12.5% moisture. In each of the experiments, duplicate loaves were baked with 10% defatted soy flour (Bakers Nutrisoy, Archer Daniels Midland Co., Decatur, Ill.). Loaves were evaluated on the basis of protein content, specific loaf volume, break and shred, grain, and texture.

Farinograms were obtained for wheat flour and mixtures containing 10% by weight replacement of WAP-WPC or soy flour. The AACC constant flour weight method 54-21 with 50 g total blend was used (8).

Proximate analyses were conducted according to AOAC procedures (9). Lipid content was determined by extraction with chloroform:methanol (2:1) (10). Starch was assayed by the enzymatic procedure of Saunders *et al.* (11). Total and reducing sugars were analyzed by the phenol-sulfuric acid and dinitrosalicylic acid methods (12,13), respectively. Amino acid analyses were conducted by the procedures described by Kohler and Palter (14). The protein content of all samples is expressed as N × 5.7.

TABLE II
Composition of Wet Alkaline Process Wheat Protein Concentrates Prepared from Wheat Millrun (Moisture free basis)

Method of Sample Preparation	Protein (N × 5.7) %	Lipid[a] %	Crude Fiber %	Starch %	Sugars Total %	Sugars Reducing %	Ash %
Acid Precipitation							
Freeze-dried	55.4	19.5	0.47	6.5	10.9	3.1	3.9
Spray-dried	55.4	18.4	0.51	8.1	8.2	1.5	4.1
Drum-dried	54.0	18.0	0.45	7.4	9.3	2.8	4.1
Heat Precipitation							
Freeze-dried	53.5	21.6	0.42	4.7	9.1	2.2	5.4
Spray-dried	52.3	20.7	0.48	5.5	7.2	0.6	5.3
Drum-dried	51.1	21.3	0.44	5.5	9.2	0.6	5.2

[a]Chloroform-methanol (2:1) extract.

TABLE III
Farinograph Data for Wheat Flour with 10% Wet Alkaline Process Wheat Protein Concentrate

Sample	Absorption %[a]	Time (min)	
		Arrival	Stability
Wheat flour control	59.0	1.5	9.0
Wheat with 10% soy flour	60.8	1.5	8.0
Wheat with 10% WAP-WPC[b]			
Acid precipitate			
Freeze-dried	59.0	1.0	17.5
Spray-dried	60.8	3.5	6.5
Drum-dried	59.0	1.5	8.5
Heat precipitate			
Freeze-dried	63.6	1.5	3.0
Spray-dried	62.2	2.0	8.5
Drum-dried	59.8	1.0	10.0

[a]Expressed on 14% flour moisture basis.
[b]Wet alkaline process wheat protein concentrates.

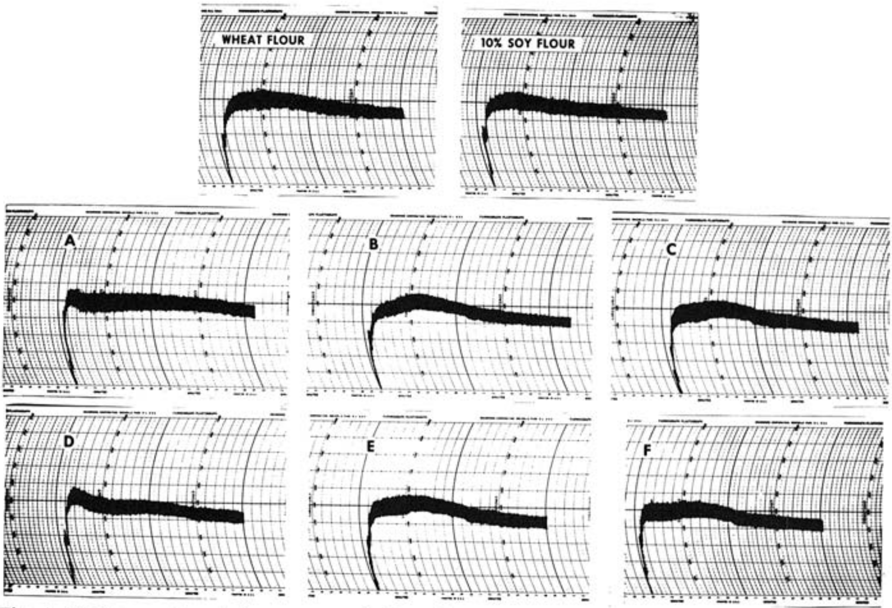

Fig. 1. Farinograph mixing curves of wheat flour and blends containing 10% wet alkaline process wheat protein concentrate (WAP-WPC) or soy flour. The WAP-WPC was precipitated and dried as follows: A through C, acid precipitated, A = freeze-dried, B = spray-dried, C = drum-dried; D through F, heat precipitated, D = freeze-dried, E = spray-dried, F = drum-dried.

RESULTS AND DISCUSSION

Composition of WAP-WPC

The protein content of WAP-WPC, prepared and dried by various methods, was quite similar and ranged from 51.1 to 55.4% (Table II). The acid precipitated WAP-WPC contained more starch and slightly less lipid and ash than did the heat precipitated protein concentrates. These slight compositional differences may be explained by variation in the quantity and composition of constituents which coprecipitate with the protein when it is isolated by acid or heat.

Dough-Mixing Properties

The farinograph absorption was not affected by replacing 10% of the wheat flour with freeze- or drum-dried, acid precipitated WAP-WPC (Table III). The heat precipitated WAP-WPC, especially those which were freeze- or spray-dried, enhanced the water absorption of the wheat flour-WAP-WPC blends. This may be partially due to the gelatinization of the starch component of WAP-WPC during the steam injection process. It is of interest to note that heat treatment of several oilseed flours increased the farinograph absorption of the final wheat flour-oilseed flour blends (15).

The mixing stability of the developed dough differed markedly among the various wheat flour-WAP-WPC mixtures (Table III). As indicated in Fig. 1, the

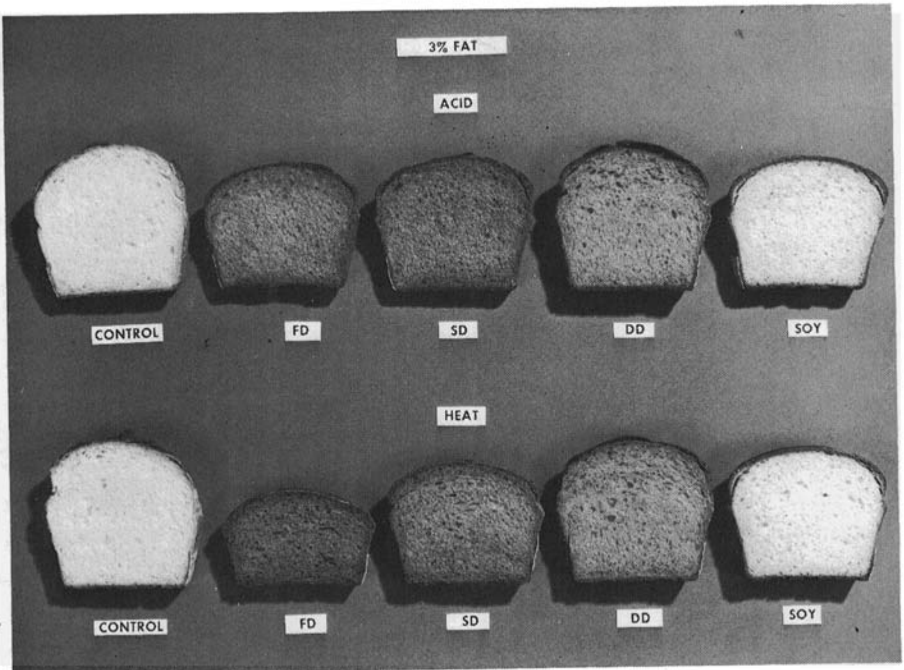

Fig. 2. Pup loaves baked using 3% fat in the formula. Acid or heat precipitated wet alkaline process wheat protein concentrate or soy flour included as 10% replacement of the flour by weight. FD = freeze-dried, SD = spray-dried, and DD = drum-dried.

farinograph mixing curves for the mixtures incorporating 10% freeze-dried protein concentrates (A and D) were typical with little, if any, peak development. Within the acid or heat precipitation treatments, the blends containing drum-dried WAP-WPC (C and F) were more stable than those including spray-dried preparations (B and E). The acid precipitated, freeze-dried WAP-WPC yields an unusual farinograph (A) so that accurate interpretation of the stability of the dough is difficult. Thus, these data appear to indicate that heat precipitation of WAP-WPC enhances farinograph absorption, and the blends containing drum-dried WAP-WPC and heat precipitated, spray-dried WAP-WPC exhibited the most promising dough stability.

Baking Properties

The baking performance of the WAP-WPC, prepared by various methods and incorporated as 10% of the flour, is apparent in Figs. 2 and 3. With both the acid and heat precipitated protein concentrates, the relative specific loaf volume of blends including WAP-WPC were, in order of decreasing volume: drum-dried > spray-dried > freeze-dried (Tables IV and V). Pooled variation from the mean of duplicate loaves baked from the same dough formulation was ±4.0, with the largest variation within a treatment being ±12.0. With either 3% fat or 0.5% SSL in the formula, the acid precipitated WAP-WPC used at the 10% level produced loaf volumes that were either equivalent or superior to those obtained with heat precipitated WAP-WPC (Figs. 2 and 3). The light brown color of the breads was

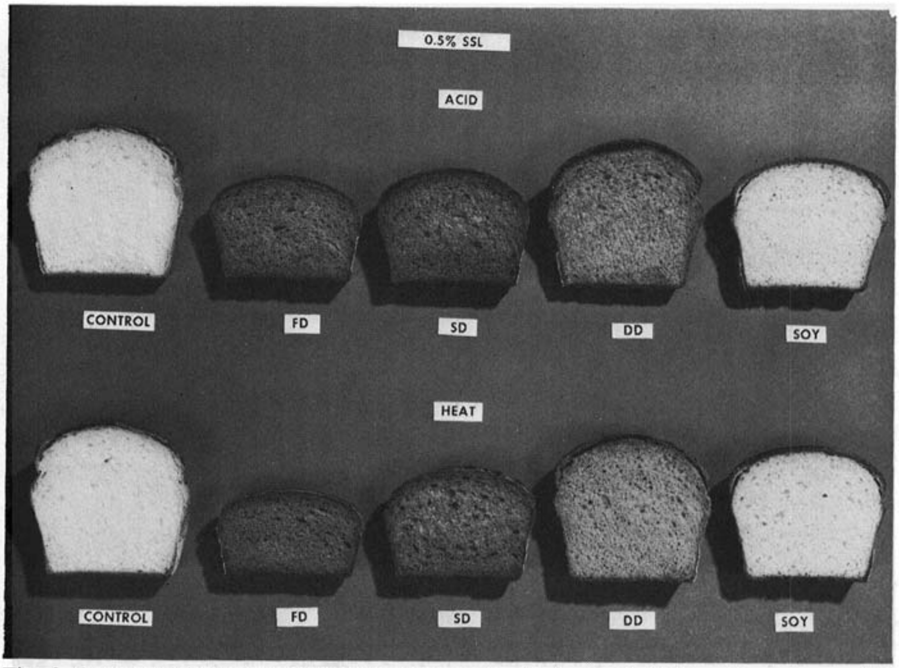

Fig. 3. Same as Fig. 2 except that pup loaves were baked with 0.5% sodium stearoyl-2-lactylate in the formula.

similar to whole wheat bread and was lightest when the volumes were high.

Both fat and SSL counteract the loaf-volume depressing effects of adding soy flour to wheat bread formulations (16). With WAP-WPC-flour blends, however, the functionality of both dough improvers was markedly influenced by both drying and precipitation methods. Fat at the 3.0% level was more effective than 0.5% SSL for improving the loaf volume of blends containing freeze- and spray-dried WAP-WPC.

The drum-dried WAP-WPC, which performed best at the 10% level, was incorporated as 15 and 20% of the flour with 3% fat in the formula. As anticipated, loaf volumes decreased and color increased with increasing concentrations of WAP-WPC (Fig. 4, Table IV). Subjective evaluation of the break and shred, grain, and texture of loaves baked with WAP-WPC at the various levels reflected the same trends observed in loaf volumes (Tables IV and V).

TABLE IV
Baking Characteristics of Breads Baked with Wet Alkaline Process Wheat Protein Concentrates (3.0% Fat added)

Sample	Protein (N × 5.7) %[a]	Mixing Time min	Loaf Volume cc	Specfic Loaf Volume cc/g	Break and Shred 5	Grain 15	Texture 15
Wheat control	13.34	6.0	695	5.63	3.25	12.0	13.0
10% Soy flour	16.93	5.5	628	5.02	2.75	13.0	13.0
10% WAP-WPC[b]							
Acid precipitate							
Freeze-dried	17.16	6.5	575	4.56	2.50	13.0	12.0
Spray-dried	17.44	6.5	613	4.92	2.50	12.5	13.0
Drum-dried	16.87	6.0	649	5.26	3.00	13.0	13.0
Heat precipitate							
Freeze-dried	17.16	6.5	395	3.04	0	10.0	9.0
Spray-dried	17.16	6.5	558	4.41	2.00	12.0	12.0
Drum-dried	16.76	6.0	644	5.17	3.00	13.0	13.25
15% WAP-WPC							
Acid Precipitate							
Drum-dried	18.81	6.5	580	4.64	2.25	12.5	12.5
Heat precipitate							
Drum-dried	18.70	6.5	600	4.84	2.50	12.5	12.5
20% WAP-WPC							
Acid precipitate							
Drum-dried	21.09	7.5	533	4.23	2.00	11.5	11.5
Heat precipitate							
Drum-dried	20.81	7.0	553	4.39	1.75	12.0	12.0

[a]Moisture-free basis.
[b]Wet alkaline process wheat protein concentrate.

TABLE V
Baking Characteristics of Breads Baked with Wet Alkaline Process Wheat Protein Concentrates (0.5% Sodium stearoyl-2-lactylate included)

Sample	Protein (N × 5.7) %[a]	Mixing Time min	Loaf Volume cc	Specific Loaf Volume cc/g	Break and Shred 5	Grain 15	Texture 15
Wheat control	13.34	6.0	698	5.79	3.25	13.0	13.0
10% Soy flour	16.93	6.0	633	5.10	2.75	13.0	12.5
10% WAP-WPC[b]							
Acid Precipitate							
Freeze-dried	17.16	6.0	458	3.56	0	9.0	9.0
Spray-dried	17.44	6.0	508	4.03	1.00	10.0	10.0
Drum-dried	16.87	6.0	718	5.89	3.50	12.5	13.0
Heat Precipitate							
Freeze-dried	17.16	6.0	350	2.69	0	8.0	8.0
Spray-dried	17.16	6.0	475	3.75	0	9.0	9.0
Drum-dried	16.76	6.0	668	5.35	3.00	13.0	13.0

[a]Moisture-free basis.
[b]Wet alkaline process wheat protein concentrate.

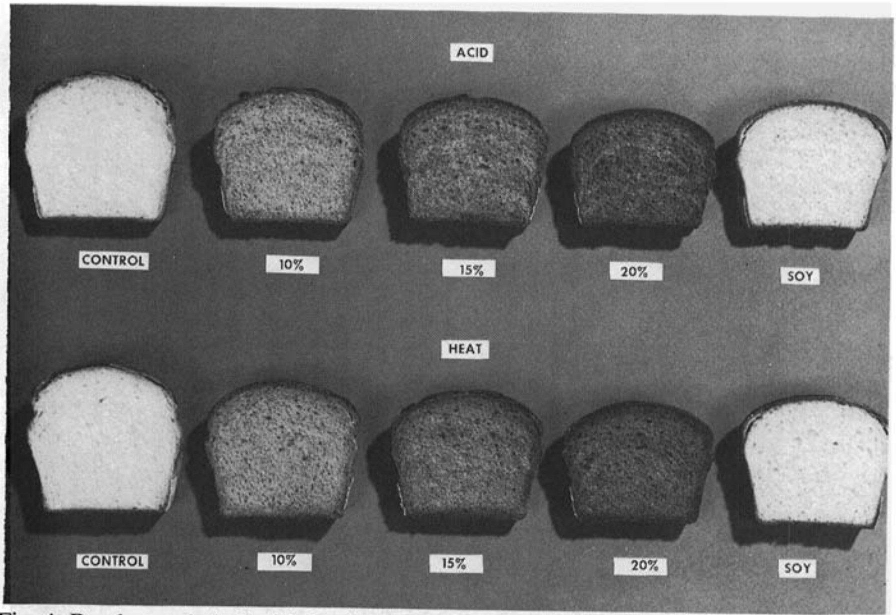

Fig. 4. Pup loaves baked with 3% fat. Drum-dried, acid or heat precipitated wet alkaline process wheat protein concentrate included at replacement levels of 10, 15, and 20% of the flour by weight. Soy flour included as 10% replacement of the flour.

On the basis of these data, it is apparent that the WAP-WPC which was heated to higher temperatures during the drying process had better baking properties. The freeze-dried WAP-WPC which was dried at 25° C showed little potential, whereas those which were spray-dried at outlet temperatures of 107° to 112° C and drum-dried at 127° to 132° C possessed good baking qualities. The conditions used for spray- and drum-drying appear to be severe enough to cause denaturation of wheat germ peroxidase and lipoxygenase (17). Thus, the high temperature drying of WAP-WPC may have inactivated one or more enzymes which could have interfered with CO_2 production and dough development. Temperature, however, may not be the only factor. The physical nature of the drum-dried WAP-WPC, which was markedly different from the fine powderlike spray-dried WAP-WPC, may also have some influence.

TABLE VI
Amino Acid Composition of Wheat Mill Fractions and Wet Alkaline Process Wheat Protein Concentrate

Amino Acid	FAO Provisional Pattern (1973)	Whole Wheat[a]	Patent Flour[a]	Millrun	Wheat Protein Concentrate Acid Precipitate Drum-dried	Wheat Protein Concentrate Heat Precipitate Drum-dried
		mg amino acid/g nitrogen				
Isoleucine	250	251	269	223	237	260
Leucine	440	409	424	405	423	473
Lysine	340	154	122	256	256	306
Methionine		118	123	114	129	134
Cystine		153	165	148	131	129
Methionine + Cystine	220	271	288	262	260	263
Phenylalanine		296	318	264	279	303
Tyrosine		181	194	183	181	206
Phenylalanine + Tyrosine	380	477	512	447	460	509
Threonine	250	176	167	268	227	253
Valine	310	306	286	318	345	351
Histidine		132	131	106	181	181
Arginine		276	226	427	532	520
Aspartic acid		297	245	461	449	508
Glutamic acid		1946	2211	1312	1273	1323
Serine		283	289	293	294	324
Proline		608	703	389	346	385
Glycine		244	212	356	351	362
Alanine		206	178	303	308	346
Amino acid score[b] (Chemical score)		45.3	35.9	75.3	75.3	90.0
% N recovered		95.0	97.5	91.2	92.9	97.3
% N in sample		3.00	2.68	3.01	9.47	8.98

[a]Based on data from Miladi *et al.* (20).
[b]FAO (1973) (Ref. 21).

With the exception of the drum-dried concentrates, acid precipitated WAP-WPC performed better in baking tests than those which were heat precipitated. Thus, heat precipitation by steam injection under the conditions described in this study had detrimental effects upon the baking quality of WAP-WPC. The higher temperatures used in drum-drying seemed to overcome these differences. The literature contains reports of variable effects of heat treatment of protein flours and concentrates prior to baking. The baking quality of sunflower and cottonseed flour was enhanced by dry heat treatment prior to baking, whereas that of sesame and peanut flour was slightly impaired (15). When concentrated raw skim milk (40% total solids) was preheated at 175° F for 10 min prior to being spray-dried, there was a definite improvement in the baking properties (18). Further studies are required to define the effects of various types of heat treatment upon the baking quality of protein concentrates and flours.

Protein Quantity and Quality

When WAP-WPC was substituted for 10% of the wheat flour, the protein content was increased by at least 25% over that of the wheat-flour control. The protein content of the baked loaves ranged between 16.8 and 17.4% (moisture free basis) (Table IV). When WAP-WPC was incorporated at levels of 15 and 20%, the baked loaves contained ≅18.8 and 21% protein, respectively. This represented an increase in protein of 41 and 57% over the control.

The quality of the protein would also be expected to improve on the basis of amino acid composition. The WAP-WPC contains at least twice as much lysine, and considerably more threonine, than does wheat flour (Table VI). Thus, WAP-WPC serves as an effective means of fortifying breads with protein and compares favorably with oilseed flours and dry milled WPC (16,19).

The baking quality and performance of WAP-WPC in 1-lb loaves as well as the biological value of the fortified, baked bread is currently under investigation and will be reported in a subsequent paper.

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