Single-Cell Protein Substitution in a Bread System: Rheological Properties and Product Quality[1]

T. A. VOLPE[2] and M. E. ZABIK, Department of Food Science and Human Nutrition, Michigan State University, East Lansing 48824

Cereal Chem. 58(5):441–443

ABSTRACT

The effects of substitution of 0, 3, 6, and 12% single cell yeast protein (SCP) were observed in a hard red spring wheat dough. Use of oxidants, a conditioner, a salt, and heating of the protein were evaluated as methods of reducing the deleterious effects of the SCP. SCP substitution at the 3% level yielded farinograph, extensigraph, and baking results similar to those of the untreated system. Addition of sodium stearoyl lactylate to the 3% SCP dough resulted in the most acceptable product according to sensory scores. High levels of SCP (6 and 12%) caused considerable decreases in dough quality, with the 12% SCP dough being very poor in performance. The 6 and 12% SCP doughs displayed particularly high farinograph absorptions, shortened farinograph stabilities, and decreased extensigraph resistence to extension and extensibilities. The quality of bread containing 6% SCP was fair and of the 12% SCP product, poor. Addition of oxidant or conditioner, individually or in combination with the salt or heat treatments, resulted in improved performance of the 6% SCP dough system.

In the United States, protein ingredients are often added to breads to improve the mechanical handling of the dough, enhance the flavor and texture, and supplement the protein quality of the product. Because wheat protein tends to be low in lysine, methionine, and tryptophan, which results in a protein of partially complete value the protein in unsupplemented wheat breads is only partially complete.

Typically, nonfat dry milk is the protein system of preference for use in bread production; however, fluctuation in availability and cost have resulted in a continuing search to locate functional alternate systems. Among those proteins investigated have been whey (McKenzie 1970), soy (Pollack and Geddes 1960), whey-soy blends, cottonseed, fababean, and other less conventional sources (Shehata 1969). Research on protein ingredient systems generally measures their functional bread-making properties and attempts to eliminate negative effects by formulation or process adjustment.

In this research, a commerically prepared baker's yeast single-cell protein (SCP) was studied in bread dough. Hard red spring wheat was supplemented at four levels with SCP. All variables were evaluated by farinograph, extensigraph, and bread baking to determine effects on rheological properties and product quality.

MATERIALS AND METHODS

The rheological properties and bread-baking character of a hard red spring wheat flour, Balancer 2831 (Table I), was evaluated using 0, 3, 6, and 12% substitution of flour weight with SCP (Table I). Five treatments were investigated at each level of SCP substitution: no additives, an oxidant—50 ppm potassium bromate/potassium iodate (3:1); a conditioner—0.5% sodium stearoyl-lactylate (SSL); 2% sodium chloride; and a 1.25-min microwave treatment of the dry SCP.

Farinograph and extensigraph measurements were made according to AACC procedures. Test weight of flour and water, determined by absorption, were selected from AACC farinograph table 54-28A.

The bread formula was: flour, 100%; yeast, 3.0%; salt, 1.5%; sugar, 5.0%; and water (24°C), 3.0% higher than farinograph absorptions (Table II). The bread was prepared by a straight dough method, fermented for 60 min at 30°C and 85% rh, degassed with a dough sheeter, scaled to 150 g, molded, proofed for 35 min at 30°C and 85% rh, and baked at 218°C for 20 min. The pH of the dough was determined by inserting electrodes directly into the dough immediately following preparation and at 10-min intervals throughout fermentation and 0, 16, and 35 min during proofing. Loaf volume was determined by rapeseed displacement. The quality of the bread was evaluated according to a descriptive matrix designed by Solle (1972).

Complete proximate analyses were conducted on breads with no additives. Moisture, ash, and lipid (as crude fat) were determined by AACC methods. Total nitrogen was determined using the micro-Kjeldahl method described by McKenzie (1970), and percent protein was calculated using the 5.7 conversion factor.

RESULTS AND DISCUSSION

Farinograph Studies

Yeast SCP has a water-binding capacity of 3 g of water per gram of SCP. With all variables, farinograph absorption increased as the level of SCP increased (Table III). In studies with defatted heat-treated soy flour, farinograph absorptions also increased with addition of soy flour up to 5% supplementation (Pollack and Geddes 1960). Use of oxidant, salt, and conditioners reduced the farinograph absorptions at all levels of SCP substitution when compared with those of the untreated controls. In the doughs without SCP, this trend was also observed except in the oxidant-treated system, which displayed a slight absorption increase (Table III).

TABLE I
Composition (%) of Hard Red Spring Wheat Flour and Yeast Single Cell Protein

Component	Hard Red Spring Wheat Flour	Yeast Single Cell Protein
Moisture	14.0	3.5
Protein	14.0	75.0
Fat	2.0	9.5
Ash	0.5	1.8
Carbohydrate	69.5	10.2

TABLE II
Percent Absorptions of Doughs Used in Bread-Baking Studies

	Level of SCP[a] Substitution (%)			
Treatment	0	3	6	12
No additive	68.6	72.7	86.9	95.2
$KBrO_3/KIO_3$	69.6	72.4	77.3	78.8
SSL[b]	66.4	71.5	76.4	87.3
NaCl	66.9	71.3	77.2	85.3
Microwave	···	72.3	75.5	76.3

[a]Yeast single cell protein.
[b]Sodium stearoyl lactylate.

[1]Published as Michigan Agricultural Experiment Station Journal Article 8914.
[2]Present address: Nabisco, Inc., Special Products Division, Fairlawn, NJ 07410.

0009-0352/81/05044103/$03.00/0
©1981 American Association of Cereal Chemists, Inc.

Increases in the protein content of a flour will also cause increases in farinograph arrival times. Although the SCP, increased the protein content, it did not display a constant effect on dough arrival time. For the untreated control doughs, increasing the level of SCP from 0 to 3 and 6% decreased arrivals from 1.9 to 1.5 min for both, whereas the 12% SCP dough had an increased arrival of 2.3 min. Compared to the 0% SCP systems, the addition of oxidant and salt to all doughs reduced arrival times and conditioner and heat treatment slightly increased arrival times for all doughs containing SCP.

The peak or dough development time is a measure of time required for a dough to reach maximum consistency or minimum mobility. A range of effects were noted for all treatments and levels of SCP substitution (Table III). In the control system, as the SCP increased from 0 to 6%, the peak time decreased. The 12% SCP dough peak occurred slightly later than that of the 6% SCP dough. This was also observed with the oxidant, salt, and heated systems. However, the peak times of the doughs containing SSL increased as SCP increased from 0 to 6% and decreased at the 12% level.

The farinograph peak and the mixing time for 186 samples of eight different winter wheat varieties displayed a correlation coefficient of +0.27 (Miller et al 1956). Another investigation showed that the time just before the farinograph peak was the point of optimum development for baking quality for dough made from that baking formula (Stamberg and Bailey 1938).

Peak times in this study ranged from 2.0 to 15.0 min. Full-formula doughs mixed to conform with shorter peak times were very underdeveloped, bucky, and stiff. Doughs mixed to late peak times tended to be overmixed, slack, and sticky. All bread was prepared using a constant 8-min mix that did not result in any overmixed doughs, and only the 0% SCP bread with salt treatment appeared undermixed.

The stability of a dough is an indicator of the flour's tolerance to mixing. Except for doughs containing oxidant, as the percent SCP in the dough increased, the stability decreased; the losses of stability were small between the 0 and 3% level but large at higher levels (Table III). With oxidant, the stability of the 3% SCP dough increased considerably over that of the 0% SCP dough but declined at 6 and 12% SCP.

The mixing characteristics of the dough were effected only slightly by substitution to the 3% SCP level, but 6 and 12% substitution showed increasingly negative effects. The higher levels of SCP diluted the gluten protein of the flour, resulting in a weakened dough with insufficient structural support. The SCP may also interfere in the chemical development of the gluten proteins of the dough.

The control and SSL systems at 0 and 3% SCP had farinograph curves with short development time and long stability characteristics. Salt-treated doughs had short-to-medium developments and long stability with 0, 3, and 6% SCP and medium stability with 12% SCP. Heat treatment of the SCP resulted in a medium peak time and medium stability for 3% SCP substitution but short stabilities at 6 and 12% SCP levels. The doughs containing oxidant displayed a long development and stability with 0% SCP but short development and long stability with 3% SCP. The 6 and 12% SCP levels had short development times and stabilities.

TABLE III
Farinograph Data[a] for Doughs Prepared from Flour Supplemented with 0, 3, 6, and 12% Single Cell Yeast Protein (SCP) Under Varied Treatments

Farinograph Measure	Treatment[b]	Level of SCP Substitution (%) 0	3	6	12
Absorption (%)	None	65.6	69.7	75.8	92.0
	Oxidant	66.6	69.4	74.3	83.9
	Salt	63.9	68.3	74.2	82.3
	Conditioner	63.4	68.5	73.4	84.3
	Heat	···	69.3	72.5	73.3
Arrival time (min)	None	1.9	1.5	1.5	2.3
	Oxidant	5.1	2.0	1.5	1.6
	Salt	3.1	2.1	1.8	2.5
	Conditioner	1.6	1.8	1.8	2.0
	Heat	···	3.0	3.0	3.1
Peak time (min)	None	6.1	3.0	2.5	2.9
	Oxidant	9.1	7.1	2.0	2.1
	Salt	15.0	15.0	4.0	5.3
	Conditioner	3.0	3.3	3.3	2.8
	Heat	···	5.6	5.1	5.3
Stability (min)	None	13.0	12.5	3.0	1.0
	Oxidant	9.1	12.5	2.0	0.8
	Salt	15.0	15.0	13.1	8.5
	Conditioner	13.3	10.3	2.0	2.1
	Heat	···	7.0	5.6	4.5

[a]Average of three replications.
[b]None = control; oxidant = $KBrO_3/KIO_3$ (3:1), 50 ppm; salt = NaCl, 2%; conditioner = sodium stearoyl lactylate, 0.5%; heat = microwave heat on dry SCP, 1.25 min.

TABLE IV
Means[a] of Measurements of Extensibility (mm) and Resistance to Extension (BU) for Doughs Made with Flour Supplemented with 0, 3, 6, and 12% Single Cell Yeast Protein (SCP) Under Varied Treatments

Treatment[b]	Time of Measurement (min)	0 mm	0 BU	3 mm	3 BU	6 mm	6 BU	12 mm	12 BU
None	45	237	570	235	426	211	316	137	307
	90	251	601	225	484	201	384	115	325
	135	256	700	210	465	193	416	103	315
Oxidant	45	240	846	245	616	207	516	132	490
	90	195	1001	217	787	181	660	121	524
	135	171	995	200	907	170	752	108	524
Salt	45	295	762	278	654	230	495	170	315
	90	275	937	257	724	216	579	142	341
	135	233	925	217	791	203	604	141	355
Conditioner	45	316	640	258	449	231	399	106	261
	90	295	667	263	490	207	421	126	270
	135	305	750	245	512	187	416	146	270
Heat	45			267	494	230	286	155	266
	90			247	504	208	336	142	285
	135			243	526	196	375	131	289

Level of SCP Substitution (%)

[a]Average of four replications.
[b]None = control; oxidant = $KBrO_3/KIO_3$ (3:1), 50 ppm; salt = NaCl, 2%; conditioner = sodium stearoyl lactylate, 0.5%; heat = microwave heat on dry SCP, 1.25 min.

Extensigraph Studies

The extensibility of a dough is a measure of the distance a dough can be stretched before it breaks or tears. Resistance to extension is

TABLE V
Mean[a] and Standard Error of Volume (cc) of Bread Prepared from Flour Supplemented with 0, 3, 6, and 12% Single Cell Yeast Protein (SCP) with Varied Treatments

Treatment[b]	Level of SCP Substitution (%) 0	3	6	12
None	473 ± 37	463 ± 30	349 ± 38	265 ± 21
Oxidant	498 ± 22	499 ± 33	435 ± 50	253 ± 12
Salt	411 ± 18	432 ± 30	381 ± 11	297 ± 26
Conditioner	495 ± 28	451 ± 7	406 ± 52	273 ± 56
Heat	···	488 ± 22	356 ± 22	228 ± 9

[a]Average of two loaves of each of four replications.
[b]None = control; oxidant = $KBrO_3/KIO_3$ (3:1), 50 ppm; salt = NaCl, 2%; conditioner = sodium stearoyl lactylate, 0.5%; heat = microwave heat on dry SCP, 1.25 min.

TABLE VI
Proximate Analysis[a] of Bread Prepared from Flour Supplemented with 0, 3, 6, and 12% Yeast Single Cell Protein (SCP)

	Level of SCP Substitution (%)			
Component	**0**	**3**	**6**	**12**
Moisture	39.26	40.60	42.36	45.49
Protein[b]	9.17	11.01	12.35	13.33
Fat	1.47	1.60	1.72	2.06
Ash	1.24	1.33	1.29	1.26
Carbohydrate (difference)	48.86	45.46	42.28	37.86

[a]Average of three replications.
[b]N × 5.7.

TABLE VII
Mean[a] and Standard Deviation of Sensory Evaluation[b] of Bread Prepared from Flour Supplemented with 0, 3, 6, and 12% Single Cell Yeast Protein (SCP) with Varied Treatments

	Level of SCP Substitution (%)			
Treatment[c]	**0**	**3**	**6**	**12**
None	68 ± 16	68 ± 12	99 ± 14	112 ± 18
Oxidant	74 ± 16	72 ± 16	89 ± 23	118 ± 11
Salt	71 ± 17	67 ± 11	86 ± 11	125 ± 16
Conditioner	72 ± 16	63 ± 15	89 ± 12	119 ± 14
Heat	···	70 ± 18	97 ± 17	126 ± 20

[a]Average of two loaves of each of four replications.
[b]The greater the number, the greater the deviation from a standard loaf of bread.
[c]None = control; oxidant = $KBrO_3/KIO_3$ (3:1), 50 ppm; salt = NaCl, 2%; conditioner = sodium stearoyl lactylate, 0.5%; heat = microwave heat on dry SCP, 1.25 min.

the inverse of the energy required to stretch or dislocate the structure. A soft, relaxed dough will yield a long and low extensigram, whereas a tight dough will result in a high narrow curve.

As indicated in Table IV, in all treatments except with oxidant, the dough's extensibility decreased as substitution increased. In the oxidant system, however, the extensibility for the 3% SCP dough increased above that of the 0% system for all three test times (45, 90, 135 min). The extensibility decreased with time for all SCP levels except the 0% control and for all treatments except the 0, 3, and 12% SCP doughs with SSL.

The resistance to extension decreased as the level of SCP substitution increased for all treatments (Table IV). In addition, resistance to extension increased with time except in the cases of the 3 and 12% SCP controls, the 0% SCP with oxidant, the 0% SCP with salt, and the 6% SCP with SSL variables.

Baking Study

SCP had a buffering effect on the pH of the dough during fermentation and proofing. The control dough had a final pH of 5.18. As the level of SCP increased, the final pH of the dough increased to 5.30, 5.43, and 5.45 for the 3, 6, and 12% SCP substitutions, respectively. Addition of oxidant, conditioner, and salt to the dough or heat treatment of the SCP had no effect on the final dough pH.

The volumes of breads containing 0, 3, 6, and 12% SCP are shown in Table V. Bread with 3% SCP had loaf volumes similiar to those of the 0% controls. Higher SCP levels yielded loaves with reduced volumes. Treatment of the 6% SCP dough did not help to improve volume. The use of conditioner, oxidant, or salt had no improving effect on breads containing 12% SCP. Heat treatment of the SCP before incorporation into the bread had no volume-improving effect at any level of SCP.

Research had shown that the use of full-fat soy decreased loaf volume (Bohn and Favor 1945), but later this effect was found to be overcome by increasing bromate concentrations in the bread formulas (Finney 1946). Pollack and Geddes (1960) reported that 1% unheated soy improved loaf volume but that higher levels were deleterious. With the SCP, oxidant performed as it does with soy to improve loaf volume. The salt treatment decreased loaf volume in the 0 and 3% SCP samples compared with that in the untreated breads. Increased resistance to extension for the salt variables indicates that loss of loaf volume may be related to the tightening of the gluten structure by the salt (Table IV).

Proximate analysis of the bread crumb showed tht the protein content of the bread increased as the SCP increased (Table VI). The 3% SCP bread contained 11.0% protein (as is basis). The 6 and 12% SCP breads contained 12.35 and 13.33% protein, respectively. The moisture content of the breads ranged from 39.26 to 45.49%. At the high moisture level of 45.49% for the 12% SCP bread, the crumb was very gummy and wet.

Sensory evaluation (Table VII) showed that the most acceptable product was the 3% SCP bread treated with SSL. The crumb color and grain of the 3% SCP-SSL bread were very good, yielding an acceptable product. Most of the 3% SCP breads scored either better or nearly as good as the 0% SCP breads in the treatment series.

Most of the 12% SCP bread scored higher than 100 in the sensory evaluation and were unacceptable. The 6% SCP control and heat-treated variables scored minimally acceptable and the 6% SCP-SSL, salt, and oxidant breads, fairly acceptable.

ACKNOWLEDGMENT

We thank Pillsbury Co. and Anheuser-Busch, Inc., for supplying materials used in this study.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved Methods of the AACC. Methods 08-01, 30-10, 54-10, 54-21B, and 54-28A, approved April 1961. The Association: St. Paul, MN.

BOHN, R. T., and FAVOR, H. H. 1945. Functional properties of soy as a bread ingredient. Cereal Chem. 22:296.

FINNEY, K. 1946. Loaf volume potentialities, buffering capacity and other baking properties of soy flour in blends with spring wheat flour. Cereal Chem. 23:96.

McKENZIE, H. A. 1970. Milk Proteins: Chemistry and Molecular Biology. Academic Press: New York.

MILLER, B. S., HAYES, B., and JOHNSON, J. A. 1956. Correlation of farinograph, mixograph, sedimentation and baking data for hard red winter wheat flour samples varying widely in quality. Cereal Chem. 33:277.

POLLACK, J., and GEDDES, W. F. 1960. Soy flour as a white bread ingredient. I. Preparation of raw and heat-treated soy flour and their effect on dough and bread. Cereal Chem. 37:19.

SHEHATA, N. 1969. The effect of supplementation with chickpea flour on the protein quality of wheat. Ph.D. thesis, Kansas State University, Manhattan.

SOLLE, H. 1972. A descriptive system of bread scoring. Bakers Dig. 46(5):55.

STAMBERG, O. E., and BAILEY, C. H. 1938. Relation of mixing speed to dough development. Cereal Chem. 15:739.

[Received September 7, 1979. Accepted March 10, 1981]