Steamed Bread. I. Chinese Steamed Bread Formulation and Interactions[1]

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ABSTRACT

Cereal Chem. 67(5):471–475

The characteristics of traditional soft Chinese steamed bread were studied with various combinations of formula ingredients and fermentation proofing procedures. Properties sought and followed were a large volume with a soft, moist, and uniformly fine-textured crumb, and a smooth semiglossy and white surface. Those properties were significantly affected by dough water absorption, sugar-yeast combinations, and corresponding fermentation and proof times. A response surface methodology program was used to determine the best combinations of sugar, yeast, and fermentation and proof time to give the highest quality steamed bread. An optimum formula was found with 8% sugar and either 1.0% instant active dry yeast or 1.5% fresh baker's yeast with a 3.5-hr fermentation, 58-min proofing, and 10-min steaming. Protein quantity as well as quality had a significant effect on the quality of steamed bread produced. Weak soft wheats benefited from increases in protein content. Wheat cultivar, class, and year or location were found to influence steamed bread quality. Breads of equally satisfactory quality were made using either a sponge-dough or a straight-dough procedure and with a dough leavened by either fresh or instant active dry yeast.

Steamed bread is a major use of wheat in the People's Republic of China (PRC) and provides an important item in the diet of consumers in many other Southeast Asian countries. While the PRC grows large quantities of wheat to supply much of its needs, it also is a major wheat importer. The other countries in that region with a Chinese dietary tradition are similarly major importers of wheat. The requirements of flour to make high-quality steamed breads are poorly defined. On-sight visits of flour mills and bakeries revealed large variations in flours produced and resulting baked product quality (Rubenthaler et al 1987). The PRC produces both hard red (winter and spring) and soft wheats, which are commonly blended to produce two basic flours with ash contents of 0.60 and 0.85%. Steamed breads produced in northern China, where the wheat source is largely hard red spring wheat, are distinctly different in texture than breads produced in Southern China from lower protein hard red and soft red winter wheat flours. Wet gluten content is commonly used as a flour quality indicator, and varies from 24 to 40%.

The formula for steamed bread is simply flour, water, salt, and yeast, and may sometimes include sugar and/or shortening. Traditionally, the bread is produced from a starter "mother dough," in place of yeast, to make a sour-type bread. Much of the bread in rural China is still produced this way. Steamed bread is commonly made in a sponge-dough system, with fermentation times of 3–4 hr. It is prepared in a variety of shapes and often filled with meats, vegetables, or a sweet bean paste prior to steaming. Common to all forms, characteristics sought in steamed bread are a smooth semi glossy finish, white color inside and out, a soft, moist, and uniform crumb texture, and a large specific volume.

Very little is known about the suitability of Pacific Northwest soft white wheat flour for the production of Chinese steamed bread. A previous study (Faridi and Rubenthaler 1983) indicated significant varietal differences among soft white and club wheats of medium to low flour strengths in addition to large effects from protein content (in the range 8–12%). The higher the protein within a cultivar, the better the steamed bread quality. Preston et al (1986) studied the effects of flour extraction rates of Canadian wheats on the performance of steamed bread. They prepared rather stiff doughs from 1,000 g of high-protein flour and 590 ml of water in the GRL mixer, rested them for 30 min, divided the dough into 140-g pieces, and proofed them a relatively short time (30 min) prior to steaming. Lower extraction patent flours generally outperformed the standard straight grade flours in volume and texture.

In light of the disadvantages of the additional handling and remixing required in the traditional sponge-dough system, we investigated the development of a straight dough formula and procedure that would produce steamed bread comparable to sponge-dough bread. Objectives for formulation included using "instant active dry yeast" to further standardize the test procedure by eliminating the variability in the activity of fresh cake yeast that occurs from batch to batch and with aging. Procedures were studied to optimize yeast and sugar levels with fermentation and proof time to give the best volume, texture, and overall score. The influences of extraction and flour protein quantity and quality on steamed bread were studied for a number of flours varying widely in protein contents and source.

MATERIALS AND METHODS

A commercial (Fisher Mills, Seattle, WA) soft wheat flour marketed under the name White Spear was used in all the basic experiments involving formula ingredients and procedure interactions. This commercial unbleached soft wheat flour had a protein content of 8.3% (N × 5.7, 14% mb) and ash of 0.40% (14% mb). The flour was milled from a soft white winter (SWW) mix and had an optimum water absorption of 54.5% and a mixograph dough development time of 2.7 min.

Flours used in a study of optimum versus fixed absorption were from the hard red winter cultivar Weston grown at Connell, WA, in 1988; a commercial hard red spring mill mix obtained from Centennial Mills, Spokane, WA, in 1988; a composite flour used as a bread-baking standard at the U.S. Department of Agriculture, Agricultural Research Service, Western Wheat Quality Laboratory, Pullman, WA; and a commercial soft wheat cookie flour obtained from Fisher Mills, Seattle, WA. These flours varied in protein content from 8.1 to 13.3% and in water absorption from 54 to 65%.

Other flours used in the study of the influence of protein content and quality for steamed bread making were a series (six) of the SWW cultivar Nugaines that varied in protein from 6.4 to 9.3%; two club wheats (Tres and Crew) and two SWW wheats (Stephens and Daws) grown in nurseries at both Lind and Pullman, WA, in 1987 and 1988, which ranged in protein from 9.0 to 15.6%; and seven commercial export cargo subsamples obtained by the Washington Wheat Commission, Spokane, WA, in 1988, which included three SWW wheats that varied in protein from 6.8 to 8.2%, a club wheat at 7.0%, an eastern soft red winter (SRW) at 9.3%, a French SRW with 8.7%, and an Australian standard white with 9.4% protein when milled to a flour extraction of

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72%. The six cargo samples were milled by the USDA, ARS, Western Wheat Quality Laboratory on their Miag Multomat to 72, 76, and 82% extractions.

Flour moisture, protein, ash, water absorption, and dough mixing properties (mixograph) were determined by AACC methods (AACC 1983). Results are expressed on 14% mb; protein was calculated as N $\times$ 5.7%. All determinations including baking tests were made at least in duplicate.

Yeast

Yeasts used in the study were fresh baker's yeast cakes obtained from Fleischmann/Standard Brands Inc., Sumner, WA, and an instant active dry yeast from Red Star (Universal Foods, Milwaukee, WI).

Baking Procedure

Unless stated otherwise, all doughs were mixed with water to optimum consistency in a National (National Mfg., Div. of TMCO, Inc., Lincoln, NE) mixer using 160 g of flour; fermented and proofed at 30°C and 95% rh; rolled out, molded, and divided into seven pieces with equipment described by Faridi and Rubenthaler (1983); placed on a steam tray for proofing, and steamed for 10 min in a model 3005, Market Forge Ultra Steamer (Market Forge Company, Everett, MA).

Bread Score Measurements

The bread was cooled for 5 min, then weighed. The volume of the combined seven pieces was determined within 15 min after steaming by rapeseed displacement. As an indicator of crumb softness, a rheological value was measured using a Fudoh rheometer (model J, Fudoh Company Inc., Tokyo, Japan) fitted with a disk probe of 1 cm^2 and an automatic-stop accessory adjusted to permit 1-cm penetration of the bread. Data was in grams of force taken at the 1-cm compression point. The bread was sliced horizontally to remove the top and to expose the crumb at 2.54 cm from the bottom of the bun. Penetrations were measured in all seven buns and the readings averaged. Values increase as firmness increases.

Visual scoring was done on a numerical basis of 1 to 10, where 1 is excellent. Factors scored were the following four traditional characteristics: "crust" whiteness and shine; "crust" smoothness; crumb color; and crumb texture and uniformity. Bread score was the average of scores for those four factors.

Response Surface Methodology

To study the interaction of the multiple variables of yeast and sugar concentrations with fermentation and proof time, a response surface methodology (RSM) computer program was used (McKesson Corporation, Dublin, CA, copyright 1984) similar to that followed by Ylimaki et al (1988). Three-dimensional plots were obtained using the RSM generated Taylor expansion equations in an SAS Graph program (SAS 1985a).

Statistics

Multiple correlation coefficients, percent of variation, and analysis of variance were provided by the RSM program, or calculated with the general linear models procedure of SAS (SAS 1985b), or both.

TABLE I
Response Surface Methodology Model

Ingredient	Variable Level: Low (−1)[a]	Center Point (0)[a]	High (1)[a]
Sugar, %	4	6	8
Yeast, %	1.0	1.5	2.0
Fermentation time, hr	2.5	3.0	3.5

[a] Response surface methodology variable concentration code.

TABLE II
Observed and Predicted Results for Steamed Bread Volume and Texture Random Response Surface Methodology Levels Used to Develop the Taylor Expansion Equations

Sequence	Variable Levels: Sugar (%)	Yeast (%)	Time (hr)	Volume (ml): OB[a]	CA[a]	Texture (g/cm^2): OB[a]	CA[a]
1	8.0	2.0	3.0	730	754	52	53
2	6.0	1.5	3.0	830	798	55	58
3	8.0	1.5	3.5	850	833	56	61
4	4.0	1.5	3.5	755	757	58	59
5	6.0	1.5	3.0	800	798	62	58
6	4.0	1.5	2.5	670	687	78	73
7	6.0	1.5	3.0	765	798	58	58
8	8.0	1.0	3.0	700	695	69	65
9	6.0	2.0	2.5	730	708	53	54
10	6.0	1.0	3.5	715	737	58	58
11	6.0	2.0	3.5	835	828	67	62
12	4.0	1.0	3.0	660	636	69	69
13	6.0	1.0	2.5	610	617	75	81
14	4.0	2.0	3.0	755	760	53	58
15	8.0	1.5	2.5	665	663	63	62
Multiple correlation coefficient				0.96		0.90	
% explained by model				92.96		81.03	
% by 1st order (linear)				66.81		44.27	
% by 2nd order (quadratic)				21.08		6.78	
% by interaction effects				5.07		29.98	
% experimental error				3.01		2.61	
% unexplained				4.03		16.36	
Standard deviation				32.52		3.51	
SEE				31.38		5.98	

[a] OB = Observed, CA = calculated (predicted).

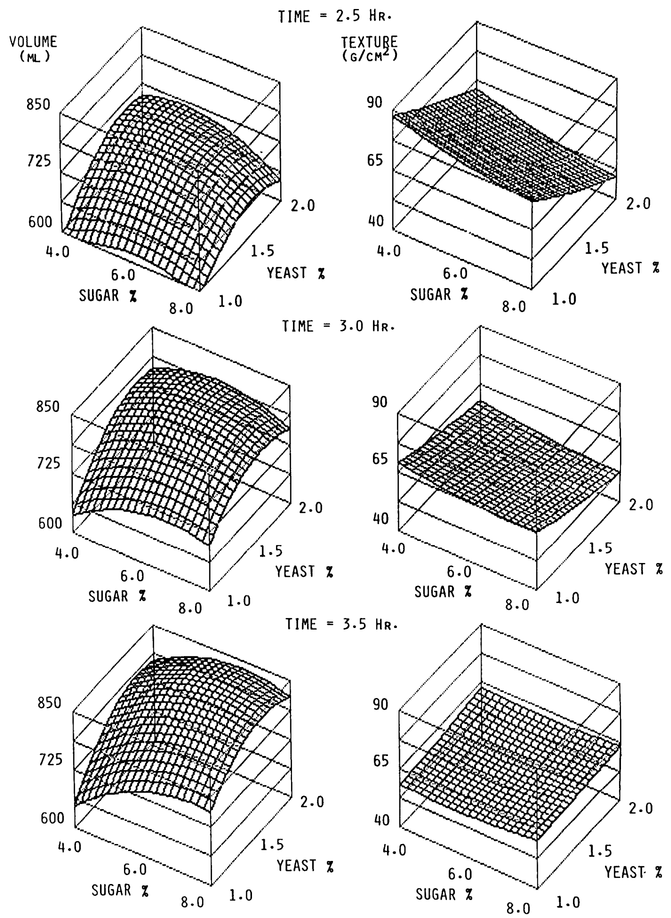

Fig. 1. Response surface three-dimensional plots of the effects and interactions of sugar (4, 6, and 8%), yeast (1.0, 1.5, and 2.0%), and fermentation time (2.5, 3.0, and 3.5 hr) on steamed bread volume (left) and texture (right) measured in milliliters and grams of force per square centimeter, respectively.

RESULTS AND DISCUSSION

To further standardize the test procedure of Faridi and Rubenthaler (1983) for steamed bread, an understanding of the interaction of formula ingredients and their optimum amounts to give maximum response to the major characteristics was needed. To determine the interactions and optimum levels of sugar, yeast, and fermentation time that give the best combination of volume and crumb texture, the RSM procedure was followed.

Preliminary baking tests indicated the best sugar level was at about 6%, compressed yeast at about 1.5%, and fermentation time at 3 hr. From this we derived the model setup for the RSM shown in Table I. The program requires equal concentration levels below and above the center point of each variable, coded as −1, 0, and +1, respectively. The three-variable procedure randomly picks 13 combinations of the variables plus 2 replicates. The combinations selected along with the baking results and calculated values for bread volume and texture are shown in Table II. The multiple correlation coefficients, percentage of variation explained and unexplained by the model, standard deviation, and standard error of estimate (SEE) are also included in the table. A consistently better bread volume was obtained at 6% sugar regardless of the yeast level or fermentation time. The texture was better with 8% sugar but became much less differentiated with sugar level as fermentation time increased and improved at the longer fermentation time (3.5 hr). This is shown in Table II, and more clearly in the three-dimensional plots in Figure 1. The largest volume with the softest crumb structure was obtained with 6% sugar, 1.5% yeast, and 3.5 hr of fermentation time.

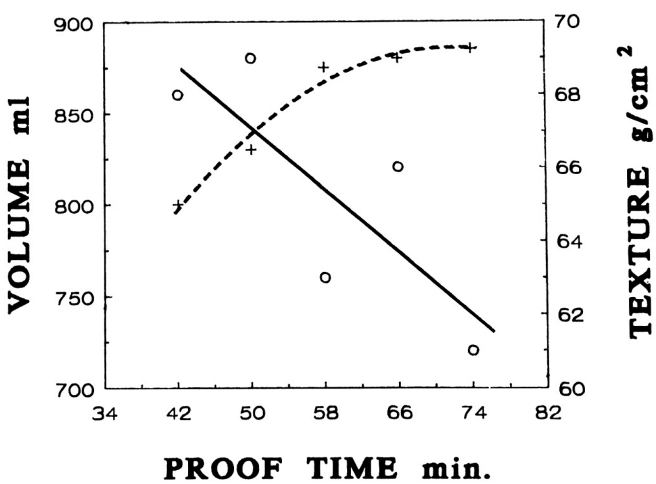

Fig. 2. A plot of the effects on steamed bread volume (+) and texture (○) of varying proof times.

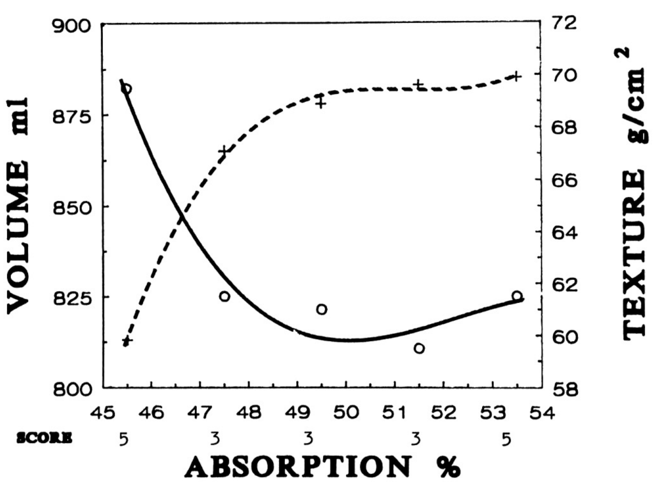

Fig. 3. A plot of the effects on steamed bread volume (+), crumb texture (○), and score of varying dough water absorptions.

Other studied variables were responses to proof time and water absorption. Both bread volume and texture improved with proof time (fermentation time held constant at 3 hr) up to about 58 min with little change at longer proof times (Fig. 2). Variations in dough water absorption gave similar dramatic changes in volume and texture softness (Figs. 3 and 4). This was observed particularly at the drier, stiffer levels where 3–4% more water increased the volume by about 70 ml and softened the crumb by 10 g/cm^2 of compression force (about 16%) as illustrated in Figure 3. Bread crumb scores were also lower when doughs were either over or under hydrated (Fig. 3). The influence of adequate dough water on bread volume and particularly on crumb structure is illustrated in Figure 4.

Baking trials were made with the "base flour," White Spear, and with four other flours using a fixed water absorption of 50% as reported by Lukow et al (1990) and with an optimum absorption. The steamed breads produced with the fixed low absorption were significantly poorer than those with optimum water (Table III). The volumes were $\geq$350 cm^3 lower for the two stronger flours (Weston, hard red winter, and Commercial, hard red spring) and 141–172 cm^3 less for the other three weaker flours, indicating a significantly different response between the stronger hard and weaker soft wheat flours. The differentiation between the five flours was much less when using the low, fixed absorption. As previously observed, the crumb grains and textures were correspondingly poorer in the dry doughs.

To further standardize the test procedure, the variability in the activity of fresh yeast from batch to batch and from that which takes place during aging was eliminated by the use of instant active dry yeast. The data in Figure 5 illustrate the interaction of volume and texture in steamed bread with a yeast series ranging from 0.25 to 1.4% in the sponge-dough system. As yeast level increased, the volume and the softness increased, with little improvement at yeast levels above 1.0%. The yeast series was also tested in the straight-dough system with similar results (not shown). Breads produced with 1.0% active dry yeast were nearly identical to those with 1.5% fresh yeast (Table IV). The bread volume, weight, textural score, and standard deviations using both yeast systems were quite close, indicating the yeasts could be interchanged in making steamed bread.

Comparisons of steamed breads from a flour series of protein contents from 6.4 to 9.3% produced from the SWW wheat cultivar Nugaines revealed a strong relationship between protein content and bread volume and texture (r = 0.92 and 0.86, respectively; Fig. 6.). However, the relationship did not hold from cultivar to cultivar or across classes of wheat. As shown in Table V, for seven commercial lots of soft wheats from the 1988 crop, results varied considerably in volume and texture among wheats of various sources and of different classes at similiar protein levels. In four of the seven cases the volume was improved at the 76% flour extraction level over the 72% level. Five of the seven also had improved texture properties with the 76% extraction flour.

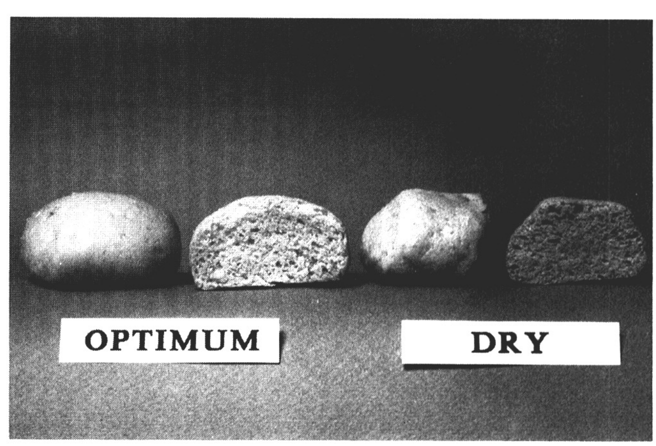

Fig. 4. Whole and cut steamed bread at optimum and at 3% less water (dry).

TABLE III
The Effect of Optimized Versus Fixed Water Absorption on Steamed Bread Volume

Sample[a]	% Protein (14% mb)	Optimum Water Absorption (%)	Volume (ml) with Water Absorption Fixed	Optimum	Difference (ml)
Weston (HRW)	12.3	60	696	1,048	352
Commercial (HRS)	13.3	62	677	1,056	379
Bread Standard	12.4	65	792	936	144
Cookie Standard	8.1	55	632	773	141
White Spear	8.7	54	688	860	172

[a] HRW = Hard red winter, HRS = hard red spring.

TABLE IV
Comparison of Steamed Bread Volume and Texture with Fresh Yeast and Instant Active Dry Yeast in a Straight Dough System

Replication Number	Volume (cm^3)	Specific Volume (cm^3/g)	Texture (g/cm^2)
1.5% Fresh yeast			
1	850	3.39	77
2	860	3.42	77
3	875	3.47	75
4	855	3.41	81
Av.	860	3.42	78
SD	10.8	0.03	2.5
1.08% Instant active dry yeast			
1	845	3.29	78
2	860	3.35	79
3	875	3.41	74
4	850	3.32	81
Av.	858	3.34	78
SD	13.2	0.05	2.9

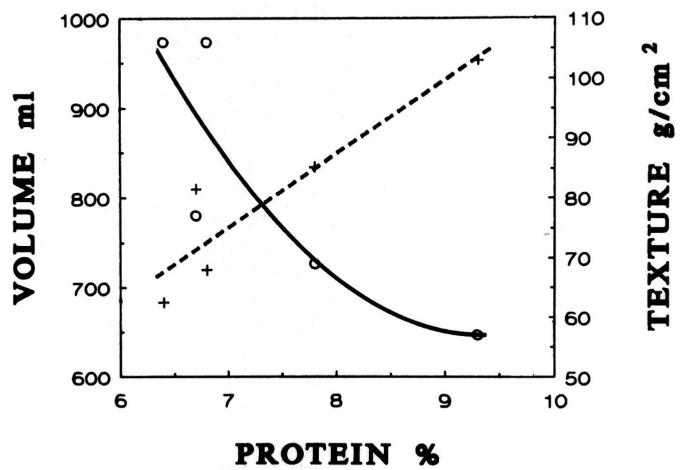

Fig. 6 Response of steamed bread volume (+) and texture (O) to flour protein within the cultivar Nugaines.

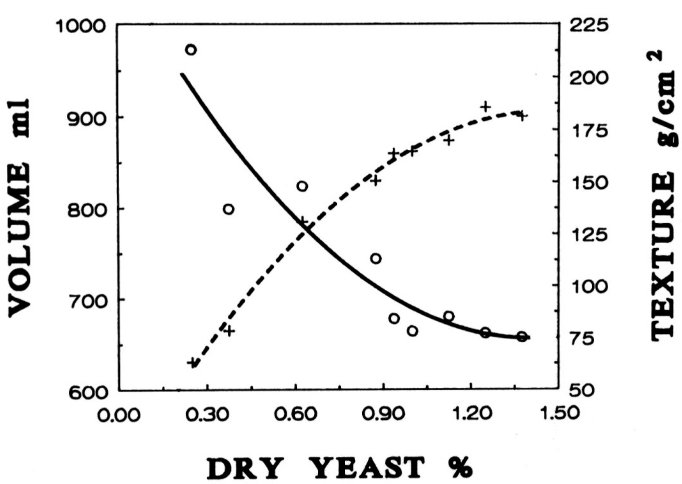

Fig. 5. A plot of the effects on steamed bread volume (+) and texture (O) of varying amounts of yeast.

All steamed bread properties were dramatically poorer at 82% flour extraction. The improvement at the intermediate extraction level of 76% was probably due to the higher protein level but offset with the higher flour ash (bran specks) associated with the 82% extraction. The eastern U.S. SRW wheat was outstanding in overall steamed bread quality. The French SRW was similiar to the higher protein SWW (no. 3). The Australian standard white was quite poor for steamed bread making.

Large differences in response to protein were found in two Pacific Northwest club and two SWW cultivars when grown at two locations and/or two crop years (Table VI). The club wheats Tres and Crew showed little or no effect on bread volume when the wide range of flour protein was tested. Stephens produced a large volume response to the high (15.6%) protein in the 1987 Lind, WA, nursery. The contrast is found for the Daws cultivar where the higher flour protein (14.0%) gave the smallest volume. The correlation between protein and steamed bread volume of the combined data in Tables V and VI is very poor, which points to a large variability within a cultivar and class that is probably due to environment, location, and/or crop year. These results suggest that steamed bread is sensitive to protein composition, maybe even more than pan bread.

CONCLUSIONS

Over the course of this study, the reproducibility of the steamed bread volume, texture, and crumb score was good. With 56 bakes over several months, the day-to-day variation of the control sample was small (Table VII). The basic formula of 160 g of flour (14% mb), 8% sugar, 2% shortening, and 1.0% instant active dry yeast with optimum water and dough mixing appeared to be a reliable straight dough system for a laboratory test in steamed bread production. Particular attention should be given to ensure an adequate water level in the dough to achieve the highest quality and to maximize differences when testing or screening flours for steamed bread making. When using instant dry yeast, an additional 3% of water and a slightly shorter mixing time were required for comparable dough consistency. A fermentation time of 3.5 hr followed by sheeting, dividing, molding, 58 min of proof, and 10 min in the steamer optimized the system. Shorter fermentation times and higher yeast levels did not produce steamed bread of equal quality. Identical steamed breads could be produced in a straight dough system and in the traditional sponge-dough procedure. Instant active dry yeast worked as well as fresh yeast in steamed bread dough and offers reproducibility often difficult to achieve over time with fresh yeast.

TABLE V
Steamed Bread Volume, Texture, and Score Among Various Classes (sub classes) and Sources of Soft Wheat Flours

Sample[a]	Flour Extraction (%)	Ash (%)	Protein (%)	Volume (cm^3)	Texture (g/cm^2)	Score (1-10)
SWW no. 1	72	0.36	6.8	733	86	5.0
	76	0.40	6.9	735	83	5.0
	82	0.55	7.2	620	155	5.5
SWW no. 2	72	0.40	7.8	793	84	5.0
	76	0.45	8.0	838	70	5.0
	82	0.66	8.6	640	168	6.5
SWW no. 3	72	0.40	8.2	833	72	5.5
	76	0.43	8.6	775	87	5.5
	82	0.66	9.0	633	144	6.5
Club	72	0.38	7.0	810	78	3.5
	76	0.42	7.2	768	93	4.0
	82	0.56	7.7	650	156	5.5
SRW	72	0.42	9.3	970	62	3.5
	76	0.48	9.6	998	46	3.5
	82	0.66	10.2	848	78	5.0
French SRW	72	0.48	8.7	828	75	3.5
	76	0.57	9.4	880	67	3.0
	82	0.76	9.7	623	170	6.5
ASW	72	0.49	9.4	678	51	9.0
	76	0.60	9.9	750	42	8.5
	82	0.73	10.3	763	54	6.5

[a] SWW = Soft white winter, SRW = soft red winter, ASW = Australian standard white.

TABLE VI
The Influence of Crop Year and Location on the Interaction of Flour Protein with Steamed Bread Volume

	1987						
	Lind		Pullman		Pullman 1988		
Cultivar/Class[a]	Volume (cm^3)	Protein[b] (%)	Volume (cm^3)	Protein (%)	Volume (cm^3)	Protein (%)	Response
Tres/Club	750	14.4	755	9.3	755	10.0	No effect
Crew/Club	965	14.4	860	9.3	905	9.1	Little effect
Stephens/SWW	1080	15.6	750	9.4	840	9.3	Beneficial
Daws/SWW	560	14.0	790	8.1	785	9.0	Adverse

[a] SWW = Soft white winter.
[b] Protein calculated as (N × 5.7, 14% mb).

TABLE VII
Statistical Analyses of 56 Individual Steamed Bread Replicates from a Single Flour Tested Over Three Months

Statistic	Volume (cm^3)	Texture (g/cm^2)	Score (1-10)
Range	865-885	60-69	3.0-4.4
Mean	875	63	3.3
SD	5.5	2.3	0.28
CV%	0.6	3.6	8.5
SEE	0.74	0.31	0.04

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[Received October 6, 1989. Accepted April 6, 1989.]