EFFECTS OF PROCESSING METHODS AND WHEAT FLOURS ON THE QUALITY OF STEAMED BREADS

by

TZE-CHING LIN

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Approved by:

Cho C. Tsen

Major Professor

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INTRODUCTION

Steamed bread has been a staple food in Oriental countries for centuries. Its processing method is similar to that of the sponge-dough method for making conventionally baked bread, but its formula is leaner and its flavor milder than those of conventionally baked bread (white pan bread). It is said that about 1700 years ago in ancient China, a well-known statesman and general named Chu Ko-liang conquered a barbarian tribe in South China; subsequently, he remodeled the tribe's dedication ceremony by shaping steamed bread in the form of a human head and stuffing it with meat (this was in lieu of using a real human head). Chu Ko-liang, in fact, was the inventor of steamed bread. From then on, steamed bread has not only saved many lives, but has also become a popular staple in China; at least one billion people now periodically eat steamed bread in China, Japan, Korea and other Asian countries. In Northern China, an estimated 50% of the wheat flour is used for steamed bread production; in Taiwan, the figure is around 17%.

Because of the high level of consumption, steamed bread is an important food worthy of research and development. The major objectives of this study have been:

1. To study the effects of processing conditions and ingredients on the quality of steamed bread.

2. To study the effect of wheat flours on the quality of steamed bread.

SECTION I

EFFECTS OF PROCESSING CONDITIONS AND INGREDIENTS ON THE QUALITY OF STEAMED BREAD

REVIEW OF LITERATURE

Limited scientific studies have been done toward improving the quality of steamed bread. In 1964, Gotthold et al. (13), found the protein quality of steamed bread was slightly less (0 to 9%) than that of the unbaked ingredients, but the protein quality of baked bread was significantly less (9 to 53%) than that of the unbaked bread. In 1977, Tsen et al. (47), found the nutritive losses in steamed bread are less than conventionally baked bread, and the nutritive value in terms of the protein efficiency ratio is higher than that of conventionally baked bread because less browning takes in steamed bread than conventionally baked bread. Other than that, there is no information available on the effect of processing conditions and ingredients. The major processing steps in production of steamed bread include mixing, fermentation, sheeting, proofing and steaming. Most of the steps are performed in a manner similar to those of conventionally baked bread.

Processing Steps

Mixing The first major step in the production of bread involves the uniform blending of the individual ingredients that make up the dough. The dough mixing process aims at two major objectives, namely, (a) the thorough and uniform dispersion of the ingredients to form a homogeneous mixture, i.e., a dough that is completely alike in all respects throughout every portion of its mass; and (b) to bring about the physical development of the gluten in the dough into a uniform structure with desired characteristics of plasticity, elasticity and viscous flow (36). Dough development may be assumed to have been achieved when the gluten of the dough has been transformed by the mixing action into a continuous three-dimensional network of thin, hydrated protein films (16). In dough mixing, the basic (and by far the most useful) work is accomplished by the kneading action of the mixing elements. The design of modern dough mixers ensures that these machines blend, combine, compress, fold, stretch and push the dough ingredients into their final state of desired dough development (36).

Mixing to the correct degree is of critical importance for the eventual behavior of the dough during subsequent processing and for the ultimate quality of the final bread. This involves attaining a proper balance of the various rheological properties of dough. These include (a) viscous flow, a property which enables the dough to assume the shape of the pan or other container which it occupies; (b) plasticity, by which the dough will retain the shape into which it was formed in the founding and moulding processes; (c) elasticity, which imparts the living spring to a properly developed dough and which permits it to return partially to its original shape following forming and moulding; and (d) visco-elasticity, which balances the characteristics of elasticity and of viscous flow (36).

In conventional mixing, dough development is achieved in four rather readily differentiated stages (20). During the initial stage, the main action is the incorporation of the dough ingredients. At this point, the dough is "slack" and rather wet and sticky to the touch. With continued mixing, the dough enters the second or "pickup" stage during which the gluten structure begins to form. The third phase of dough development, generally referred to as the "clean-up" stage, is the most definite check point in the mixing process. From this point on, the dough enters the final "development" stage. It involves the readily observable transformation of the dough from a dull, somewhat rough appearance to a smooth, satiny sheen. As mixing is continued through the development stage, the dough loses its elastic character and becomes increasingly soft, smooth and highly extensible and assumes a silky appearance. This is the so-called "let-down" stage. This change from microplug flow to laminar flow may be compared to the concept of "disaggregation" of flour proposed by Tsen (45) to explain dough development by mixing. Flour has been shown to contain distinct protein aggregates or bodies. To achieve dough development, these large protein aggregates must first be hydrated and disaggregated into smaller protein units which will more readily undergo the molecular orientation that is necessary for the formation of continuous protein films. This disaggregation can be obtained by various actions, including the shearing action of mixing, as well as the splitting of disulfide bonds by reducing agents such as glutathione and cysteine.

Fermentation Before a mixed dough can yield a light and areated loaf of bread, it must be fermented for a proper length of time during which the yeast cells, uniformly dispersed throughout the dough mass by mixing, act upon the available sugars, transforming them into carbon dioxide and alcohol as the major end products. During yeast fermentation, the gluten is rendered more elastic and springy, being acted upon by a variety of factors, such as proteolytic enzymes, the alcohol produced during fermentation, the various organic and inorganic acids that are formed, the increasing hydrogen ion concentration which develops in the dough, etc. All these factors alter the colloidal character of the gluten in such manner that it is able to form thin, gas-retaining walls and retain its extensibility and elasticity so that it can react without rupturing to the stresses developing within the dough. A dough in which the gluten has attained a state of maximum elasticity and springiness is said to be mature; the dough which is improperly matured either through insufficient fermentation or overfermentation will not yield quality bread (34, 36, 41).

A sponge should be set to ferment at a temperature of 74° to 78°F (23° to 26°C). A sponge time held within a range of 3.5 to 4.5 hours yields bread that possesses (a) better keeping qualities, (b) better grain, and (c) better textrue, than when fermentation is either greatly reduced or extended (36). According to Kamman (20), over-fermented sponges tend to produce an open, uneven grain, and coarse texture in the final bread. Young or unfermented sponges, on the other hand, produce "bucky" doughs that are difficult to machine properly and that yield large, round, thick-walled cells in the finished bread. The fermentation time adopted as optimum in a given baking laboratory or bakery represents the sum total of interrelated effects produced by such factors as character of flour, amount of yeast, temperature, formula ingredients, level of oxidation, and others. Experience has shown that there exists an inverse relation between the amount of yeast and fermentation time. Thus, a reduction in the amount of yeast will result in a longer fermentation time, while an increase in the amount of yeast will shorten the fermentation time. However, with too high a yeast concentration (over 4%) it is no longer possible to produce quality bread since the gluten will fail to develop properly and a noticeable yeast flavor will remain in the finished product so far as white pan bread is concerned (36).

Sheeting Sheeting is one of the mechanical works that are applied to dough. Reversed or repeated sheeting is done to stretch and fold the gluten in thin lamellae between gas cells, to obtain the greatest degree of gas expulsion, to subdivide and redistribute gas cells, and to orientate the protein chains to more or less parallel lamellae which form the gluten network. But excessive sheeting results in dough-rupture; the sheets are then converted into filements which tear and expose the sticky interior. On the other hand, too losse sheeting fails to achieve adequate degassing and proper cell dispersion (32, 36). The sheeting operation is accomplished by passing the dough piece through two or three sets of closely spaced rolls that progressively flatten and degas the dough. The first pair of rolls, generally referred to as head rolls, normally are spaced about 0.25 inch apart and serve the primary purpose of degassing the dough in preparation for the final sheeting; the second or center rolls will generally be spaced 0.125 inch apart; and the final rolls should be set with a clearance of 0.06 inch for optimum grain and texture development in the finished loaf (20).

The ideal dough for sheeting is dry, soft and extensible. Improperly mixed doughs will generally react unsatisfactorily, with overmixing tending to yield doughs that spread excessively when being sheeting, while undermixing doughs exhibit undesirable bucky characteristics. Defective sheeting is also encountered with sticky doughs that result either from the excessive use of malt or form improper humidity conditions during the intermediate proof. Doughs which have been dusted too heavily tend to acquire a thick, tough skin that resists the action of the sheeting rolls so that it will tear as the piece passes through the head rolls. Furthermore, such a skin lacks adequate sealing properties and may cause the moulded piece to uncurl during subsequent proofing and baking, resulting in deformed loaves (36).

Proofing The purpose of proofing is to create ideal fermentation conditions and to have the carbon dioxide gas areate the dough uniformly, causing it to acquire mellowness and extensibility. Proofing exerts a very definite effect upon the grain and texture of bread; in fact, proofing can greatly alter the characteristics of the final product. A correct combination of time, temperature and humidity must be held constant if a uniform product is to be obtained (20, 36).

The most universally used conditions include a temperature of 95°F (35°C) and a relative humidity of 85 percent, with a proofing time of 60 to 65 minutes (36). However, high-speed production plants have adopted higher temperatures in order to reduce the proof time. Temperatures as high as 120°F are in use although those exceeding 115°F present the dangers of inhibiting yeast action and, also, of producing a "shortening failure." The latter condition results when a plastic shortening reaches the temperature at which it turns to oil, causing a loss in volume and very poor grain and texture (20). Some differentiation is normally observed between the proofing condition for continuously-mixed and for conventionally-mixed doughs. The reason for this is that continuously-mixed doughs arrive at the final proofer with a temperature of 103° to $110^{\circ}F$ (39° to $43^{\circ}C$), in contrast to 80° to $85^{\circ}F$ (27° to $29^{\circ}C$) for regular sponge-doughs, so the continuously-mixed doughs are generally proofed with a temperature range of 105° to $115^{\circ}F$ (41° to $46^{\circ}C$). Bread made from over-proofed dough will exhibit a grain with coarse, round cells similar in appearance to those found in over-mixed bread. Under-proofing results in a more compact loaf, with an open and uneven grain. It is generally recommended, in the interest of bread uniformity, to proof to a predetermined standard height rather than for a given time (20, 36).

Processing Methods

Sponge-Dough Method By the sponge-dough method, the major fermentative action takes place in a pre-ferment, referred to as a sponge, in which normally more than one half of the total dough flour is subjected to the physical, chemical and biological action of an active yeast fermentation. As the sponge is subsequently combined with additional dough ingredients and receives its final physical development during the dough mixing stage, little useful purpose is served by mixing the sponge any more than is necessary to obtain a thorough blending of all the ingredients into a smooth, homogeneous mass. Gluten development should be carried only to the point at which the sponge will retain a sufficient amount of the envolving carbon dioxide gas to produce the characteristic increase in sponge volume as fermentation progresses.

The advantages of the sponge-dough method over the straight dough method may be summarized as follows: (a) There is a saving of approximately 20 percent in the amount of yeast used as compared to the amount required for a straight dough; (b) bread produced by the sponge-dough method tends to have greater volume and a more desirable texture and grain; and (c) the method possesses greater flexibility. Sponges can be held longer without serious deterioration in the final product quality, in contrast to straight doughs which must be taken up when ready. Perhaps the major disadvantage of the method is the greater labor cost that results from having to subject the dough to two mixing operations. There are also the additional costs arising from increased power consumption, greater wear of the mixing equipment and higher fermentation losses (36).

Liquid Ferment System The use of liquid ferments in breadmaking has a long history. Thus Jago and Jago give detailed instructions for the preparation of various types of barms, liquid or simi-liquid ferments, that were commonly used in France and England during the last century. The adoption of liquid ferments on a systematic basis by American bakers is, however, of relatively recent origin. It is attributable in large measure to the introduction of the Stable Ferment Process by the American Dry Milk Institute in 1954 (35, 36), and the widespread adoption of the continuous mixing process throughout the country (5, 10, 35, 36).

The original Stable Ferment Process was designed to simplify the sponge-dough method by replacing the sponge stage with a liquid, pumpable ferment. In practice, the process involves metering a given volume of water at a temperature of 95° to 100°F into a tank equipped with a stirring device. The solid ingredients are then dispersed mechanically in the water and the resultant suspension is permitted to ferment at a constant temperature for 6 hours.

Fermentation is conducted under constant, gentle agitation to maintain a uniform suspension. On completion of fermentation and conditioning, the mature ferment may either be used immediately for dough mixing, or maintained in a stable condition by cooling to 50°F, at which temperature it will retain its original fermentative vitality for a period of 48 hours or more (35, 36). Important aspects of ferment preparation are the levels of flour in liquid ferment and the control of pH. The major advantages of using high levels of flour are: increased bread volume, a firmer crumb body, retention of crumb resiliency, and accomodation. In addition, a more open grain and texture may be obtained, slicing characteristics are improved, lesser amounts of sugars are required without reducing in the sweetness level of the finished baked loaf, and the mechanical energy required to develop the dough is reduced substantially. In later years, nearly all the continuous mixing systems have been designed to handle liquid ferments containing 50 to 70 percent of the flour (39, 48). The pH of baked bread made by the liquid ferment process is generally slightly lower than that of bread by the conventional sponge-dough process, but well within the range of good production practices. The respective values are pH 5.4 for conventional bread, and a range of 5.14 to 5.36 for the liquid fermented bread, the different values in the latter case reflecting the influence of varying levels of sugar and non-fat dry milk used in the ferment (1, 21, 35, 36, 37).

The use of the liquid ferment system offers to the bakers some definite advantages, among which the following deserve special consideration: (a) Improved product control - this process facilitates the control of product quality and uniformity by eliminating many of the variables that are inherent in the sponge-dough method. (b) Customer acceptance - a survey of many present operators of the liquid ferment system indicates that practically all of them have experienced positive sales increases. (c) Product range - the liquid ferment process permits the production of virtually all types of yeast-raised products, including all variety breads, rolls, buns, sweet products, doughnuts, health-type breads, etc. This greatly simplifies plant operation and facilitates quality control. (d) Flexibility - since the liquid ferment is prepared, stabilized and held in a chilled state overnight, production additions and cuts can be handled with great efficiency. (e) Operational savings - the most important of which is in the cost of labor. (f) Others - including the elimination of the fermentation room, sponge troughs and the trough hoist, contributing to considerable savings in the plant area (5).

An understanding of conventional breadmaking steps such as mixing, fermentation, sheeting and proofing, and methods, such as sponge-dough method and liquid ferment system will be helpful to the study on effects of processing conditions and ingredients on the quality of steamed bread.

MATERIALS AND METHODS

Materials

Flour Wheat flour used in this study was milled from hard red winter wheat by a pilot mill in the Department of Grain Science and Industry, Kansas State University. Its chemical characteristics were: moisture, 11.8%; protein (N X 5.7), 11.1%; ash, 0.42%; and fat, 0.81%. Its farinographic measurements were: absorption, 57%; arrival time, 2 minutes; peak time, 7 minutes; departure time, 12 minutes; and dough stability, 10 minutes. It was malted, enriched, bleached by chlorine dioxide, and unbromated.

Shortening "Primex", Procter and Gamble, Cincinnati, Ohio.

Yeast "Fermipan", instant yeast, Gist-Brocades N. V., Holland.

Preparation of Steamed Bread

A primary study to test various methods for making steamed bread was conducted and revealed that steamed bread could be prepared by a modified sponge-dough method, as sketched in Figure 1.

The sponge was prepared by mixing flour, 85% (85% of 500 g flour); instant yeast, 0.72%; water, 47% (minus 10% from absorption); and sugar, 2% at a slow speed (No. 1 of Hobart mixer) for 3 minutes; the mixture was placed in a fermentation cabinet at 85^{o}F and 90% R. H. for 3 hours. The sponge was then mixed with the remaining flour for 5 minutes at a slow speed, divided into 120 g pieces, sheeted 2 times (the first time was at the gauge of 0.27 inch, and the second time was at 0.1 inch), moulded, rounded (by the rounder on the extensograph, C. W. Brabender), and proofed at

$85^{o}F$ and 90% R. H. for 30 minutes. The proofed loaf was steamed for 12 minutes by an aluminous steamer. Loaf weight and volume, measured by a rape seed displacement meter, were determined after cooling the bread for 1 hour.

The additional sheeting method (Figure 2) was developed from the abovementioned sponge-dough method process with the following differences: (1) the dough mixing time was 3.5 to 5 minutes, (2) the sheeting times were 12 to 16, and the mixed dough was sheeted before dividing, and (3) the ingredients contained shortening.

There were two procedures for making liquid ferment: (1) the brew was prepared without flour, and fermented in a water bath shaker (American Optical Co.) at $32^{o}C$ and 300 spm (stroke per minute) (Figure 3), and (2) the liquid sponge was prepared with 35% flour, and fermented at $85^{o}F$ and 90% R. H. (Figure 4).

Scoring

The scoring was done by utilizing scoring system established for this study. The following point values were: (1) appearance score - bread samples scored from 10 to 1 point for samples No. 1 to No. 10, respectively (Figure 5); and (2) internal score - bread samples scored from 5 to 1 point for samples No. 1 to No. 5, respectively (Figure 6). The higher the point is, the better the quality becomes. The internal score is half of the appearance score because the appearance is more important than internal grain for steamed bread. The appearance and internal scores of the steamed bread above 6 and 2, respectively, are regarded as acceptable.

Statistical Procedure

The experimental design was first proposed by Box and Behnken

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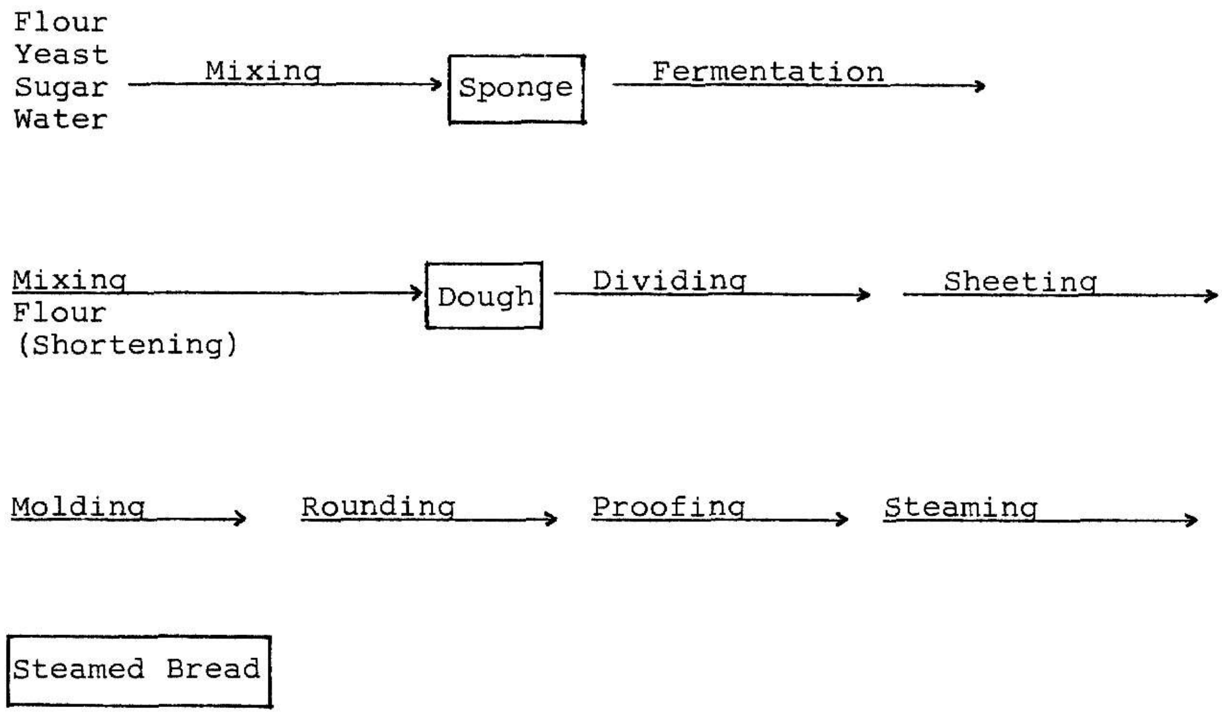

Figure 1. Processing of Steamed Bread - Modified Sponge-Dough Method

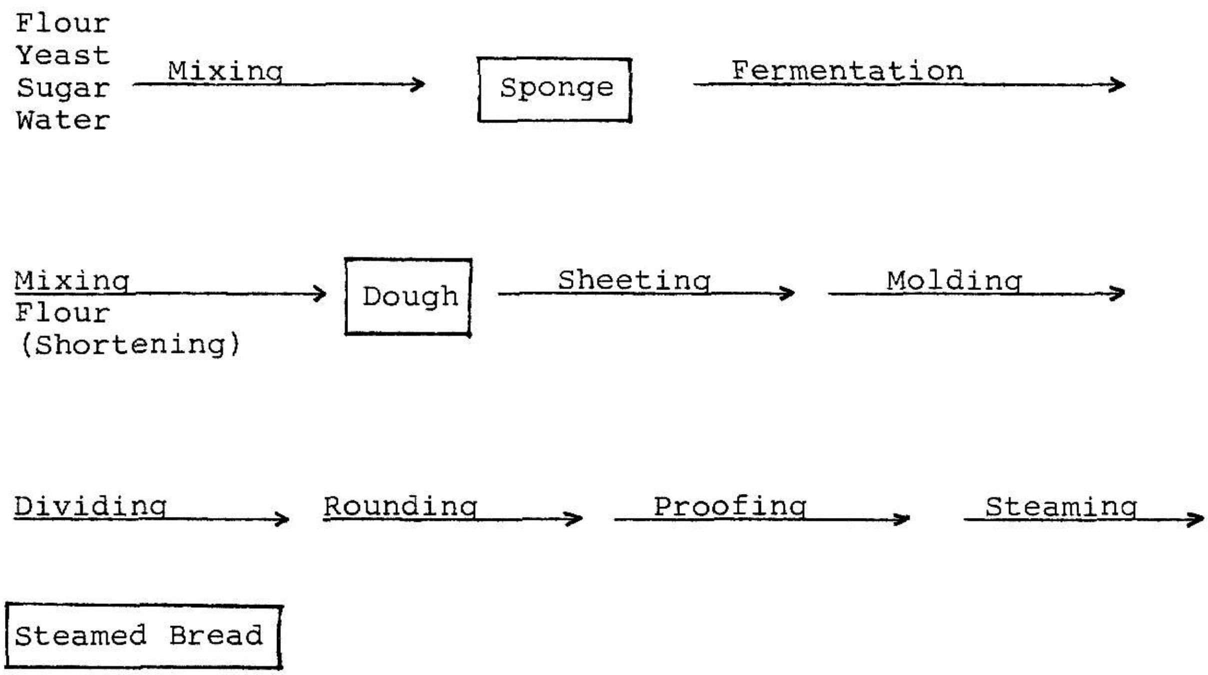

Figure 2. Processing of Steamed Bread - Additional Sheeting Method

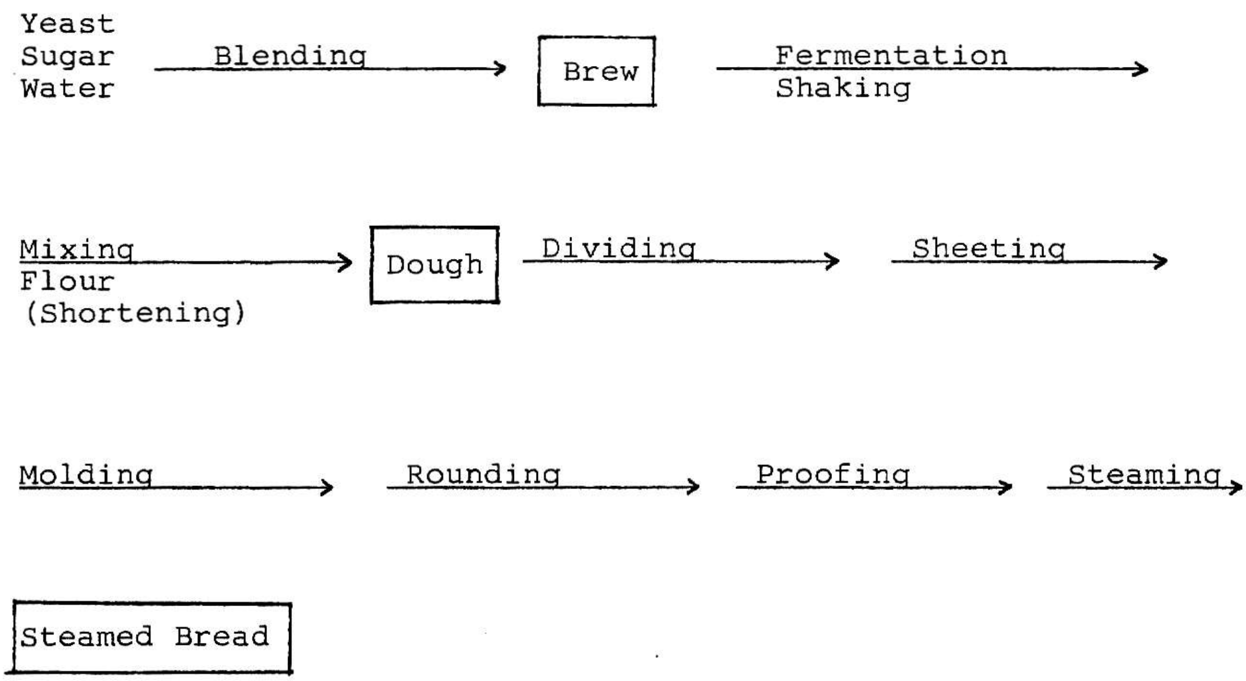

Figure 3. Processing of Steamed Bread - Liquid Ferment System (without flour)

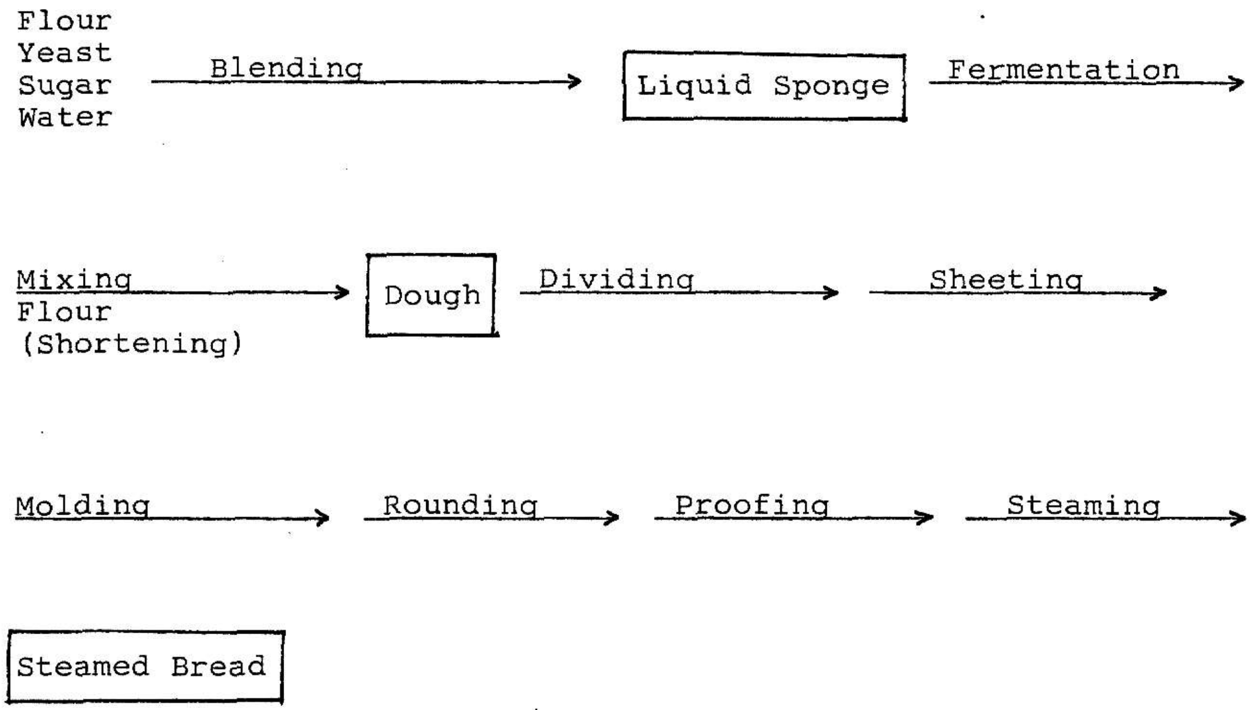

Figure 4. Processing of Steamed Bread - Liquid Ferment System (with flour)

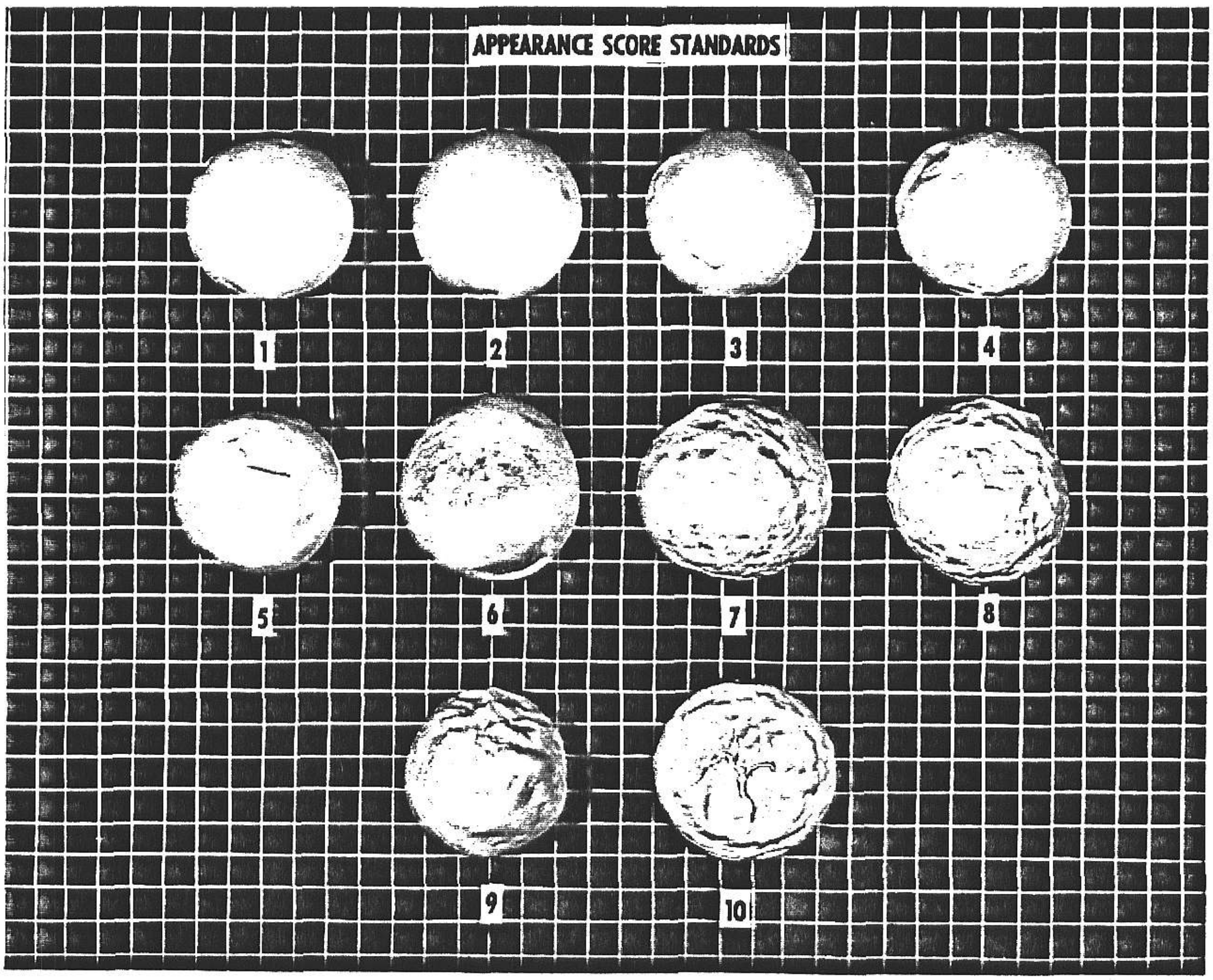

Figure 5. Appearance Score Standards - bread samples scored from 10 to 1 point for samples No. 1 to No. 10, respectively

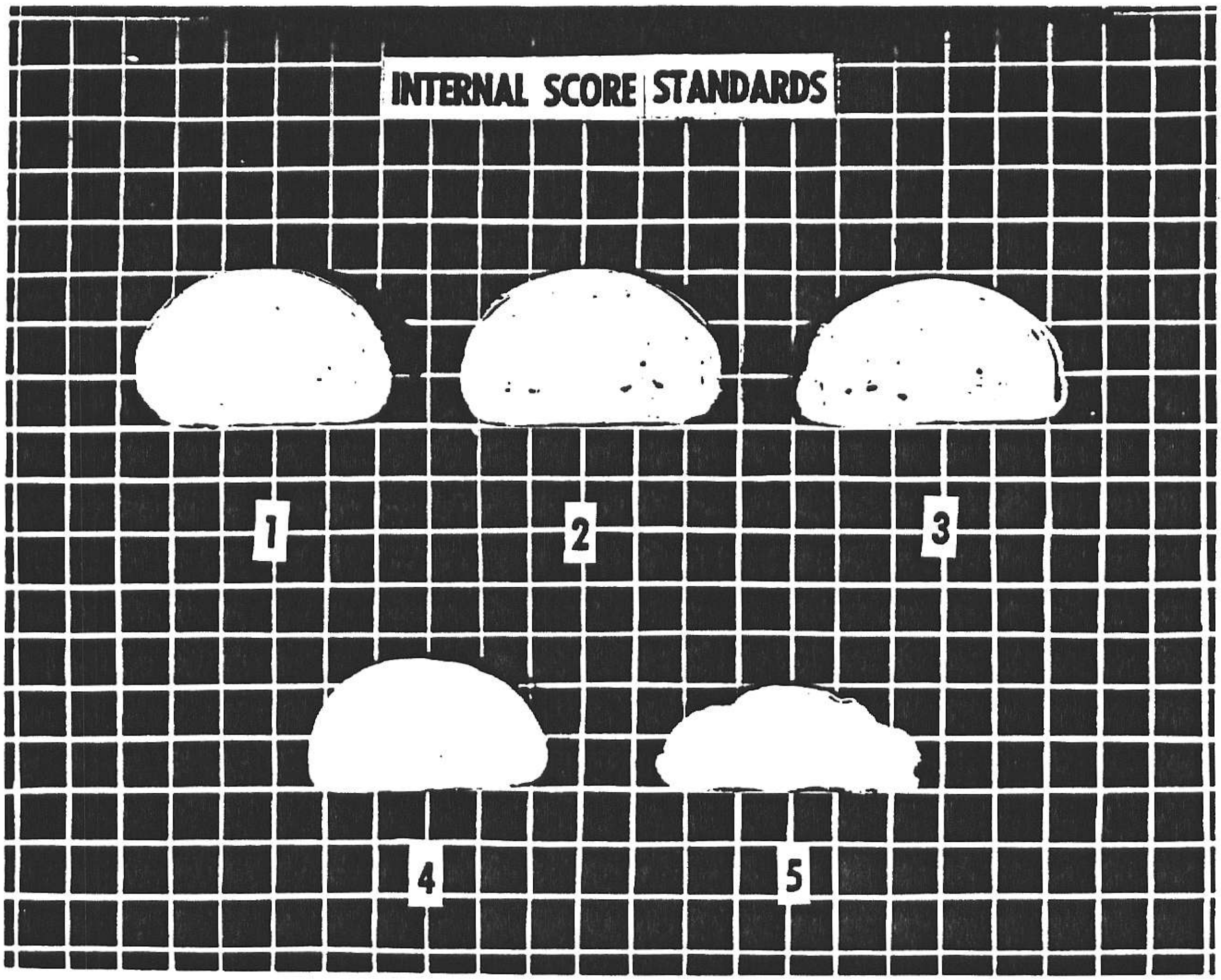

Figure 6. Internal Score Standards - bread samples scored from 5 to 1 point for samples No. 1 to No. 5, respectively

(4). The full model of the response surface for this experiment is expressed as:

$$Y = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \ldots\ldots b_{44}X_4^2 \quad (1)$$

The aim is to select the best regression equation from the full model in (1). The best model, as discussion by Draper and Smith (9) illustrates, is a compromise between two opposed criteria: (1) to include in the regression equation all independent variables (the full model), and (2) to include as few independent procedures as possible.

Several statistical procedures have been proposed for selecting the best regression equation for a particular response Y in terms of the independent variables X_1, X_2, X_3, X_4 and their squares and cross products. Among all the procedures in current use, the stepwise regression procedure is believed to be one of the best of the variable selection procedures. It is economical to use and avoids selecting more independent variables in the regression equation than are necessary. Regression equations with fewer independent variables have a smaller error variance of predicted values.

The stepwise selection procedure starts by selecting the independent variable X_i that is most correlated with the response of dependent variable Y to enter into the regression equation. If X_i is significant, the procedure searches for the second independent variable (X_j) to enter the model or regression equation. This is done by examining the partial correlation of all the independent variables not in the equation (all X variables other than X_i). The one with the highest partial correlation with Y (say X_j)

is entered and a second regression equation $X = f\ (X_i X_j)$ is fitted. The significance of each variable (X_i, X_j) in the equation is now checked and a variable is deleted if found not significant at a certain α level. The search goes on again for the next independent variable to enter the regression model. The same or different α levels may be used for a variable entry of 0.5 and exit of 0.1 and an entry and exit of 0.1 each. The two significance levels gave the same regression equations. The statistical analysis system (SAS) stepwise routine was used in analyzing the data. Before running the analysis, the data were examined using the Box and Cox transformation method (48) to determine if a transformation was needed. Results of the Box and Cox method clearly indicated that no transformation of the data was warranted.

For each dependent variable (Y), regions of optimality were determined by a simple grid search of the response surface. For each regression equation, points for Y were determined at all possible combinations of the X variables. Optimum values for Y_2, Y_5, and Y_6 corresponded to their maximum values. Values for Y_4 between 1.6 and 2.10 were considered optimum. From the optimum values for each of the dependent Y variables, a set of X variables was found that gave the best response for Y_2, Y_4, Y_5, and Y_6 considered simultaneously.

RESULTS AND DISCUSSION

Modified Sponge-Dough Method

Through preliminary studies on various traditional methods and formulae for making steamed bread, a modified sponge-dough method was developed (Figure 1). There are three main differences between the modified sponge-dough method and the conventional sponge-dough breadmaking method. The following are used for making steamed bread: (1) a leaner formula for its characteristic milder flavor, (2) lower absorption for easy handling and keeping shape during making, and (3) lower mixing action for avoiding too much development of the gluten in the dough. In general, steamed bread is easier to prepare and also lower in production cost than conventionally baked bread.

Effects of ingredients on the quality of steamed bread have been studied by Tsen et al. (46). The optimum formulation was suggested: sugar, 2.0-4.0%; shortening, 0-3.0%; SSL, 0-0.5%; and water, 47-51%. They also found that (1) the specific volume was related to sugar, SSL and water; spread ratio depended on SSL and water; appearance was related to sugar, shortening, SSL and water; and internal score was related to shortening and SSL. (2) 0.3% SSL in formula can improve the specific volume, appearance and internal score. (3) SSL, SSL + CSL (Patco 3), EMG, and Polysorbate 60 all can improve the quality of steamed bread significantly.

The effect of processing conditions on the quality of steamed bread was studied, in this study, according to the experimental design of the Box and Behnken statistical method. Table 1 shows the data of 27 treatments with 4 variables. The treatment of No. 4

Table 1. Effects of Fermentation Time (X_1), Remixing Time (X_2), Sheeting Times (X_3), Proofing Time (X_4) on the Specific Volume (Y_2), Spread Ratio (Y_4), Appearance (Y_5), and Internal Score (Y_6) of Steamed Bread - Modified Sponge-Dough Method

TRT	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
1	2	2.0	4	30	345	2.80	122.5	1.91	8.5	4.0
2	4	2.0	4	30	403	3.34	120.5	1.85	7.5	4.0
3	2	5.0	4	30	360	2.94	122.5	1.85	8.5	4.5
4	4	5.0	4	30	428	3.54	120.5	1.87	10.0	5.0
5	3	3.5	2	20	386	3.18	121.5	1.86	9.0	2.5
6	3	3.5	6	20	360	2.98	121.0	1.80	7.5	2.0
7	3	3.5	2	40	420	3.47	121.0	1.99	9.5	4.5
8	3	3.5	6	40	420	3.37	124.5	2.18	5.5	4.5
9	3	3.5	4	30	383	3.11	123.0	1.93	6.5	3.5
10	2	3.5	2	30	395	3.29	120.0	1.90	9.5	4.5
11	4	3.5	2	30	425	3.35	127.0	2.14	6.5	2.5
12	2	3.5	6	30	338	2.73	123.5	2.07	4.0	3.5
13	4	3.5	6	30	383	3.07	124.5	2.25	4.0	3.0
14	3	2.0	2	30	390	3.12	125.0	1.93	6.0	4.0
15	3	5.0	2	30	428	3.43	124.5	2.02	9.0	4.5
16	3	2.0	6	30	410	3.29	124.5	1.97	4.0	3.0
17	3	5.0	6	30	380	2.99	127.0	2.17	3.0	3.0
18	3	3.5	4	30	400	3.21	124.5	1.87	8.0	3.0
19	2	3.5	4	20	325	2.71	120.0	1.89	8.5	3.0
20	4	3.5	4	20	398	3.26	122.0	1.92	8.5	4.5
21	2	3.5	4	40	428	3.62	118.0	2.01	4.0	4.0
22	4	3.5	4	40	495	4.01	123.5	2.11	5.0	4.5
23	3	2.0	4	20	373	3.10	120.0	1.91	8.0	3.5
24	3	5.0	4	20	423	3.42	123.5	1.95	9.0	3.5
25	3	2.0	4	40	498	4.00	124.5	2.18	2.0	3.0
26	3	5.0	4	40	525	4.27	123.0	2.06	6.0	2.5
27	3	3.5	4	40	465	3.66	127.0	2.03	3.0	3.0

Formula: water 47%, yeast 0.72%, sugar 2%

yielded the best quality of steamed bread in this study. Its fermentation time, remixing time, sheeting times and proofing time were 4 hours, 5 minutes, 4 times, and 30 minutes, respectively. No. 7, 10, 15, and 24 produced good loaves also. A low-quality steamed bread was obtained from treatment No. 12, 13, 16, 17, 21, 25, or 27, with sheeting times more than 4 or remixing time less than 3.5 minutes, but proofing time longer than 40 minutes. The results show that excessive sheeting damages the gluten and breaks the continuous network of protein film; the steamed loaf collapses upon moving out of the steamer to yield a poor appearance (below 6 points). If the remixing time is not enough to develop the gluten well, the dough can not stay flat after rolling out during the sheeting operation, and steamed loaf will contract and yield a poor and wrinkled appearance. The results of the regression analysis are shown in Table 2. The regression equations show that specific volume (Y_2) is related to fermentation time (X_1), sheeting time (X_3), proofing time (X_4) and is a function of X_4, X_3X_3, X_1X_4 and X_4X_4. Spread ratio (Y_4) is related to fermentation time (X_1), sheeting times (X_3), and proofing time (X_4) and is a function of X_1X_4 and X_3X_4. Appearance (Y_5) is related to remixing time (X_2), sheeting times (X_3), and proofing time (X_4) and is a function of X_2X_2 and X_3X_4. Internal score (Y_6) is a function of X_3X_3. From these results, the following optimum conditions are obtained:

fermentation time	3 hours
remixing time	5 minutes
sheeting	2-4 times
proofing time	30 minutes

Table 2. Regression Equations Showing the Relation Between Independent Variables (X) and Dependent Variables (Y) - Modified Sponge-Dough Method

Processing conditions

A stepwise regression technique was employed to determine the functional relationship between 4 Independent Variables - fermentation time (X_1), remixing time (X_2), sheeting times (X_3), proofing time (X_4) and 4 Dependent Variables - specific volume (Y_2), spread ratio (Y_4), appearance (Y_5), and internal score (Y_6).

$$Y_2 = 4.7752 - 0.1506X_4 - 0.0081X_3X_3 + 0.0065X_1X_4 + 0.0027X_4X_4$$

$$X_4 = 1.7145 + 0.0017X_1X_4 + 0.0010X_3X_4$$

$$X_5 = 9.8192 + 0.0746X_2X_2 - 0.0339X_3X_4$$

$$X_6 = 3.9418 - 0.0196X_3X_3$$

Additional Sheeting Method

The dough structure that is already formed during mixing can be further developed by fermentation, punching, and moulding. The development by sheeting is based on the formation of a rigid network of protein molecules with occasional cross-links. Thiol-disulfide interchange reactions provide a logical explanation for the cross-linking of the protein network along with its development. Sheeting action also lines up protein molecules which will yield a finished loaf with a smooth, shiny and white skin, and uniform grain.

As shown in the previous section (Table 1), excessive sheeting could produce a poor quality of steamed bread. But if 2% shortening was added, its quality was greatly improved. According to the model of gluten sheet structure proposed by Grosskreutz (14), gluten, in a form usually recovered from doughs, is thought to consist of a collection of protein platelets formed from polypeptide chains with their hydrophilic side chains oriented outward and their hydrophobic chains oriented inward. Also, the gluten mass is thought to have a number of bimolecular leaflets of phospholipid material to which are attached two or more protein chains by means of saltlike linkages between hydrophilic groups. These lipoprotein leaflets, interspersed at random intervals among the protein platelets, are proposed to provide the slip-planes by which the flow properties of gluten are created (28). Addition of fat to the formulation used for the additional sheeting method will take on the function of lipoprotein leaflets and will prevent the gluten from being damaged by strong stress during sheeting.

The effect of the processing conditions of the additional sheeting method on the quality of steamed bread is shown in Table 3. Most of the treatments produced high quality steamed bread, especially No. 8, 9, 15, 17, and 27. The specific volumes of all 27 treatments were above 3.0, spread ratios were between 1.6 to 2.1, and appearance scores were mostly at the 10 point level (best). Appearance and internal score were found to be affected by proofing time; prolonged proofing time produced a little blister on the skin and larger air cells in the grain. Table 4 shows the results of the regression analysis. The specific volume (Y_2) is related to fermentation time (X_3) and proof time (X_4) and is a function of X_3 and X_4X_4. Spread ratio (Y_4) is related to proof time (X_4) and remixing time (X_1) and is a function of X_4 and X_1X_1. Appearance (Y_5) and internal (Y_6) scores are related to proof time (X_4) and are a function of X_4X_4 . From these results, the following optimum conditions are obtained:

fermentation time	60-90 minutes
remixing time	3.5-5.0 minutes
sheeting	12-16 times
proofing time	30 minutes

The effect of ingredients on the quality of steamed bread prepared by the additional sheeting method was studied by following the optimum conditions as described above. The results are shown in Table 5. Most of the treatments in this experimental design show good specific volume, spread ratio, appearance and internal scores, especially for No. 6, 9, 13, 27 treatments. The low water percentage (40%) affected specific volume because of the insufficient hydration of starch and gluten; thus the finished

Table 3. Effects of Remixing Time (X_1), Sheeting Times (X_2), Fermentation Time (X_3), and Proofing Time (X_4) on the Specific Volume (Y_2), Spread Ratio (Y_3), Appearance (Y_5), and Internal Score (Y_6) of Steamed Bread - Additional Sheeting Method

TRT	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
1	3	8	60	30	440	3.6	122.6	1.8	8	4
2	7	8	60	30	413	3.4	121.6	1.8	10	4
3	3	16	60	30	400	3.2	123.7	1.8	10	5
4	7	16	60	30	393	3.2	124.1	1.8	10	4
5	5	12	30	20	370	3.0	122.8	1.6	10	4
6	5	12	90	20	408	3.3	124.5	1.6	10	5
7	5	12	30	40	455	3.7	122.5	2.0	6	3
8	5	12	90	40	495	4.0	122.6	1.8	10	4
9	5	12	60	30	445	3.7	121.5	1.9	10	4
10	3	12	30	30	420	3.4	124.5	1.8	10	4
11	7	12	30	30	410	3.3	122.7	1.9	10	3
12	3	12	90	30	490	4.0	122.9	1.8	9	3
13	7	12	90	30	440	3.6	123.9	1.8	10	3
14	5	8	30	30	435	3.5	125.4	1.7	10	3
15	5	16	30	30	470	3.8	124.6	1.7	10	3
16	5	8	90	30	435	3.5	123.9	1.8	9	3
17	5	16	90	30	465	3.8	122.8	1.8	10	4
18	5	12	60	30	450	3.6	124.9	1.8	10	3
19	3	12	60	20	410	3.3	124.6	1.6	10	4
20	7	12	60	20	428	3.5	123.9	1.7	10	3
21	3	12	60	40	503	4.1	123.8	1.9	9	2
22	7	12	60	40	490	3.9	125.2	2.1	9	2
23	5	8	60	20	425	3.4	125.5	1.6	10	4
24	5	16	60	20	425	3.4	124.2	1.6	10	4
25	5	8	60	40	503	4.0	125.2	1.9	10	2
26	5	16	60	40	483	3.9	124.3	2.1	9	2
27	5	12	60	30	463	3.7	124.5	1.8	10	3

Formula: water 45%, yeast 1.5%, sugar 5%, shortening 2%

Table 4. Regression Equations Showing the Relation Between Independent Variables (X) and Dependent Variables (Y) - Additional Sheeting Method

Processing conditions

A stepwise regression technique was employed to determine the functional relationship between 4 Independent Variables - remixing time (X_1), sheeting times (X_2), fermentation time (X_3), proofing time (X_4) and 4 Dependent Variables - specific volume (Y_2), spread ratio (Y_4), appearance (Y_5), and internal score (Y_6).

$$Y_2 = 2.8469 + 0.0042X_3 + 0.0005X_4X_4$$

$$Y_4 = 1.2223 + 0.0175X_4 + 0.0018X_1X_1$$

$$Y_5 = 10.5423 - 0.001X_4X_4$$

$$Y_6 = 4.6107 - 0.0013X_4X_4$$

Table 5. Effects of Water (X_1), Yeast (X_2), Shortening (X_3), and Sugar (X_4) Percentages on the Specific Volume (Y_2), Spread Ratio (Y_3), Appearance (Y_5), and Internal Score (Y_6) of Steamed Bread - Additional Sheeting Method

TRT	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
1	40	1.0	2	5	283	3.1	123.5	1.6	10	4
2	50	1.0	2	5	440	3.6	122.7	1.8	9	4
3	40	2.0	2	5	408	3.3	125.4	2.1	6	2
4	50	2.0	2	5	488	3.9	126.5	2.2	8	2
5	45	1.5	1	2	423	3.3	126.3	2.0	10	2
6	45	1.5	3	2	463	3.8	123.0	1.9	10	3
7	45	1.5	1	8	430	3.4	124.9	1.8	10	4
8	45	1.5	3	8	465	3.7	124.9	1.8	9	4
9	45	1.5	2	5	453	3.7	122.6	1.9	10	3
10	40	1.5	1	5	303	2.4	125.6	2.0	10	1
11	50	1.5	1	5	478	3.9	123.6	2.0	10	2
12	40	1.5	3	5	410	3.3	125.7	1.8	10	3
13	50	1.5	3	5	465	3.8	123.0	2.0	10	4
14	45	1.0	1	5	450	3.6	125.3	1.8	10	3
15	45	2.0	1	5	415	3.3	123.8	2.2	8	2
16	45	1.0	3	5	450	3.6	125.7	1.9	10	4
17	45	2.0	3	5	463	3.7	124.8	2.1	10	2
18	45	1.5	2	5	453	3.6	126.0	1.9	10	3
19	40	1.5	2	2	400	3.2	125.6	1.8	10	3
20	50	1.5	2	2	428	3.5	122.8	2.0	10	3
21	40	1.5	2	8	450	3.6	124.7	1.7	10	3
22	50	1.5	2	8	500	4.1	121.6	2.0	9	3
23	45	1.0	2	2	400	3.2	124.4	1.8	8	5
24	45	2.0	2	2	450	3.6	125.1	2.1	8	4
25	45	1.0	2	8	425	3.4	124.4	1.7	10	2
26	45	2.0	2	8	498	4.0	124.3	2.0	10	2
27	45	1.5	2	5	443	3.6	122.7	1.8	10	4

Fermentation time 90 min., mixing time 5 min., sheeting times 16, proof time 30 min.

loaf is tough and small. High yeast percentage (2%) affected appearance and internal scores by producing blisters on the skin and forming large air cells in the grain because of strong gassing power. The results of regression analysis are shown in Table 6. The specific volume (Y_2) is related to water (X_1), yeast (X_2), shortening (X_3) and sugar (X_4) and is a function of X_1, X_2X_3 and X_4X_4. Spread ratio (Y_4) is related to water (X_1), yeast (X_2) and sugar (X_4) and is a function of X_1X_2, X_1X_4 and X_4X_4. Appearance (Y_5) depends on yeast (X_2). Internal score (Y_6) is related to yeast (X_2), water (X_1) and shortening (X_3) and is a function of X_2 and X_1X_3. From these results, the following optimum formulation is obtained:

yeast	1.5%
shortening	2.0-3.0%
sugar	5.0%
water	45.0%

Table 7 shows the comparative effects of fats and surfactant on the modified sponge-dough method and the additional sheeting method. The additional sheeting method without fat or surfactant produced bread with a much lower specific volume (2.3) than that of the modified sponge-dough method (3.3). This occurs because the gluten is damaged and broken by sheeting stress; the starch and gluten network can not form well enough to give spaces for gas expansion. Addition of fat or surfactant improves specific volume significantly, which is caused by interspersing fat among the protein platelets, providing slip-planes. The appearance produced by the additional sheeting with fat is better than that produced by the modified sponge-dough method due to the function of lined

Table 6. Regression Equations Showing the Relation Between Independent Variables (X) and Dependent Variables (Y) - Additional Sheeting Method

Ingredients-formulations

A stepwise regression technique was employed to determine the functional relationship between 4 Independent Variables - water (X_1), yeast (X_2), shortening (X_3), sugar (X_4) and 4 Dependent Variables - specific volume (Y_2), spread ratio (Y_4), appearance (Y_5), and internal score (Y_6).

$$Y_2 = 0.1294 + 0.0650X_1 + 0.1125X_2X_3 + 0.0046X_4X_4$$

$$Y_4 = 1.3437 + 0.0077X_1X_2 + 0.0011X_1X_4 - 0.0064X_4X_4$$

$$Y_5 = 3.067 + 10.2333X_2 - 3.8X_2X_2$$

$$Y_6 = 3.9805 - 1.3333X_2 + 0.0113X_1X_3$$

Table 7. Effects of Fats and Surfactant on the Quality of Steamed Bread Prepared by the Modified Sponge-Dough and the Additional Sheeting Method

Fat or surfactant %	Method[a]	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
0	M	3.3	1.7	8	3
	S	2.3	2.1	8	2
2% Lard	M	3.7	1.7	8	3
	S	3.7	1.9	10	3
2% Vegetable oil	M	3.6	1.7	8	3
	S	3.6	1.8	9	3
2% Shortening (premix)	M	3.7	1.7	8	3
	S	3.9	1.7	0	3
0.3% SSL	M	3.5	1.7	10	3
	S	3.5	1.8	10	3

[a]M - modified sponge-dough method

S - additional sheeting method

up protein molecules which form a good gluten network. 0.3% SSL improved both specific volume and appearance score, but the effect on specific volume was slightly less than that of 2% fats (Figure 7).

The effect of wheat gluten on the quality of steamed breads prepared by the modified sponge-dough method and the additional sheeting method is shown in Table 8. Without gluten added (control), the quality of steamed bread prepared by the additional sheeting method is better than that of the modified sponge-dough method in terms of larger specific volume and better appearance. With 4% gluten added, the additional sheeting method still produced bread with acceptable quality with 7 points appearance score, but the modified sponge-dough method produced unacceptable bread with 4 point appearance score. Therefore, the additional sheeting method is better than the modified sponge-dough method when high protein flour is used to make steamed bread, as shown by the results in Table 9. Olaf, commercial HRS, and Waldron flours are high protein flours; their protein contents are 12.2%, 13.0%, and 14.2%, respectively. The steamed loaves made from these flours by the additional sheeting method have a higher specific volume and a better appearance score than those made by the modified sponge-dough method.

Liquid Ferment System

The use of liquid ferments to replace the customary sponge offers several advantages, whether conventional or continuous breadmaking equipment is employed. The fermentation took place in a liquid ferment that contained no flour, with the sugar and

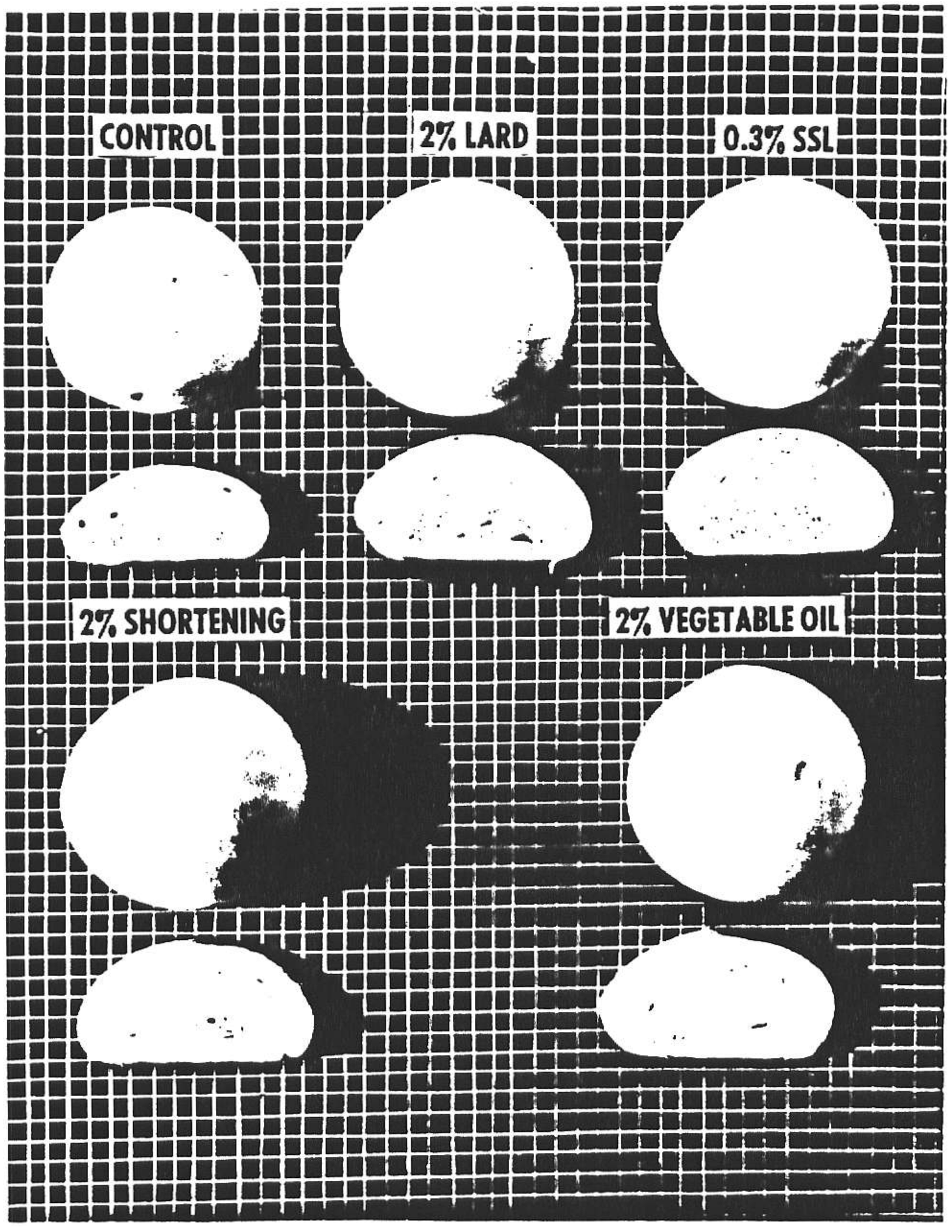

Figure 7. Effect of Fats and Surfactant on the Quality of Steamed Bread Prepared by the Additional Sheeting Method

Table 8. Effect of Wheat Gluten on the Quality of Steamed Breads Prepared by the Modified Sponge-Dough and by the Additional Sheeting Method

Gluten[a]	Method[b]	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
Control	M	3.7	1.8	9	3
	S	3.9	1.9	10	3
1	M	3.7	1.7	7	3
	S	3.9	2.0	10	3
2	M	3.8	1.7	6	3
	S	4.0	2.0	8	3
4	M	3.8	1.7	4	3
	S	4.1	1.9	7	3
6	M	3.7	1.8	3	2
	S	3.7	1.9	4	3
8	M	3.6	1.9	1	1
	S	3.8	1.8	3	3

[a]Commercial gluten: protein 74%, moisture 7.3%, ash 1.2%, fat 1.5%

[b]Formula: water 45%, yeast 1.5%, sugar 5%, shortening 2%

Condition: fermentation 90 min., mixing 5 min., sheeting 16 times for additional sheeting method other ingredients supplying the substrates for yeast activity. It was soon discovered, however, that fermentation of flour produced some desirabel results in finished bread, and increasing amounts of flour began to be added to the liquid ferment. In some later instances, the amount of flour in liquid ferment is added as high as 50 percent. In many cases, the fermentation for liquid ferment is similar to the fermentation as conducted in conventional baking, but considerably shorter and more vigorous than in batch processing.

The liquid ferment without flour was studied for making steamed bread. The results concerning the effect of processing conditions are shown in Table 10. The average specific volume is slightly lower than that made by the modified sponge-dough method because of no flour in the brew and short fermentation time. Prolonged mixing time (6 to 10 minutes) has no effect on the quality of steamed bread. Table 11 shows the results of regression analyses. The specific volume (Y_2) is related to floor time (X_3) and proofing time (X_4) and is a function of X_4 and X_3X_4. Spread ratio (Y_4) is related to proofing time (X_4). Appearance (Y_5) is related to floor time (X_3). From these results, the following optimum conditions are obtained:

fermentation time	60 minutes
mixing time	6 minutes
floor time	0-15 minutes
proofing time	30-40 minutes

In general, liquid ferment without flour produces steamed bread with a low specific volume and dense texture.

Since the addition of flour to a liquid ferment produces some

Table 9. Effect of High Protein Flours on the Quality of Steamed Breads Prepared by the Modified Sponge-Dough and the Additional Sheeting Methods[a]

Flour	Protein %	Method[b]	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
Olaf	12.2	M	3.1	1.6	6	3
		S	3.5	1.7	7	4
HRS (commercial)	13.0	M	3.4	1.7	5	3
		S	3.7	1.8	8	3
Waldron	14.2	M	4.0	1.7	4	3
		S	4.2	1.9	7	4

[a]Formula: yeast 1.5%, sugar 5%, shortening 2%

Condition: fermentation 90 min., sheeting 2 times for M - method, 16 times for S - method

[b]M - the modified sponge-dough method

S - the additional sheeting method

Table 10. Effects of Fermentation Time (X_1), Mixing Time (X_2), Floor Time (X_3), and Proofing Time (X_4) on the Specific Volume (Y_2), Spread Ratio (Y_4), Appearance (Y_5), and Internal Score (Y_6) of Steamed Bread - Liquid Ferment System (without flour)

TRT	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
1	30	6	15	40	378	3.1	123.6	1.9	8.0	3
2	90	6	15	40	385	3.1	123.8	1.8	8.0	3
3	30	10	15	40	368	2.9	126.1	1.9	8.0	3
4	90	10	15	40	385	3.1	125.2	1.9	8.0	3
5	60	8	0	30	338	2.7	124.3	1.7	10.0	2
6	60	8	30	30	350	2.8	124.2	1.7	8.0	3
7	60	8	0	50	393	3.1	125.3	1.9	10.0	3
8	60	8	30	50	440	3.6	123.8	2.1	8.0	2
9	60	8	15	40	373	3.0	126.3	1.8	8.0	3
10	30	8	0	40	330	2.6	127.2	1.7	10.0	2
11	90	8	0	40	350	2.8	124.9	1.8	9.5	3
12	30	8	30	40	358	2.9	123.2	1.8	8.0	3
13	90	8	30	40	373	3.0	124.8	1.8	8.0	3
14	60	6	0	40	375	3.0	124.9	1.8	10.0	5
15	60	10	0	40	345	2.8	124.7	1.8	9.5	4
16	60	6	30	40	385	3.1	123.8	1.8	8.0	3
17	60	10	30	40	385	3.1	124.7	1.8	8.0	3
18	60	8	15	40	370	3.0	123.7	1.9	8.0	3
19	30	8	15	30	345	2.8	125.2	1.7	8.5	3
20	90	8	15	30	363	2.9	124.3	1.7	8.5	3
21	30	8	15	50	360	2.9	124.5	1.8	9.5	4
22	90	8	15	50	380	3.0	124.8	1.9	9.5	3
23	60	6	15	30	323	2.6	125.0	1.6	10.0	3
24	60	10	15	30	315	3.5	124.0	1.7	9.5	3
25	60	6	15	50	385	3.1	124.4	1.9	8.0	3
26	60	10	15	50	393	3.1	126.3	1.9	8.0	2
27	60	8	15	40	393	3.1	126.6	1.7	9.0	3

Formula: water 47%, yeast 0.72%, sugar 2%

Table 11. Regression Equations Showing the Relation Between Independent Variables (X) and Dependent Variables (Y) - Liquid Ferment System (without flour)

Processing conditions

A stepwise regression technique was employed to determine the functional relationship between 4 Independent Variables - fermentation time (X_1), mixing time (X_2), floor time (X_3), proofing time (X_4) and 4 Dependent Variables - specific volume (Y_2), spread ratio (Y_4), appearance (Y_5), and internal score (Y_6).

$$Y_2 = 2.1185 + 0.0176X_4 + 0.0002X_3X_4$$

$$Y_4 = 1.3407 + 0.0117X_4$$

$$Y_5 = 9.6389 - 0.0611X_3$$

Y_6 = no variables met the 0.1 significance level desirable results in finished baked bread. The liquid ferment with flour was, therefore, studied for making steamed bread in this research. The results of the effects of flour percentage and conditions on the quality of steamed bread are shown in Table 12. The treatment of No. 15 gave the best quality of steamed bread with a flour percentage, fermentation time, proofing time and yeast concentration of 35%, 90 min, 30 min, and 1.0%, respectively. A higher percentage of yeast produced a larger specific volume but a lower appearance score because the strong gassing power produced blisters on the skin of the steamed loaf. Table 13 shows the results of regression analyses. The specific volume (Y_2) is related to flour percentage (X_1), fermentation time (X_2), proofing time (X_3) and yeast (X_4) and is a function of X_1X_3, X_2X_4 and X_3X_4. Spread ratio (Y_4), appearance (Y_5), and internal score (Y_6) are all related to proof time (X_3) and yeast (X_4). From these results, the optimum conditions are obtained:

flour	35-50%
fermentation time	60-90 minutes
proofing time	30-40 minutes
yeast	1%

A flour-water mixture is considered a non-Newtonian liquid system. Problems encountered are primarily those related to viscosity, foaming and changing density. Viscosity increases rapidly with increasing flour content and is influenced by the rate of flour hydration and the temperature of the mixture. This rapid increase in viscosity as the flour level is raised imposes practical limits on the amount of flour that can be accommodated with respect to the amount of water available. Flour must be introduced

Table 12. Effects of Flour Percentage (X_1), Fermentation Time (X_2), Proofing Time (X_3), and Yeast Percentage (X_4) on the Specific Volume (Y_2), Spread Ratio (Y_4), Appearance (Y_5), and Internal Score (Y_6) of Steamed Bread - Liquid Ferment System (with flour)

TRT	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
1	20	30	40	1.00	343	2.8	121.4	1.8	10	3
2	50	30	40	1.00	358	2.9	122.0	1.9	10	4
3	20	90	40	1.00	395	3.2	123.5	1.8	10	3
4	50	90	40	1.00	418	3.4	122.6	2.0	7	3
5	35	60	30	0.72	298	2.4	121.9	1.9	10	2
6	35	60	50	0.72	368	3.0	122.6	1.8	10	3
7	35	60	30	1.28	368	3.0	121.1	1.8	6	3
8	35	60	50	1.28	440	3.6	122.0	2.4	6	2
9	35	60	40	1.00	388	3.2	120.7	1.9	6	4
10	20	60	30	1.00	325	2.6	123.0	1.8	9	3
11	50	60	30	1.00	363	3.0	122.7	1.8	10	4
12	20	60	50	1.00	370	3.0	124.7	2.6	4	2
13	50	60	50	1.00	405	3.3	122.2	2.1	7	3
14	35	30	30	1.00	355	2.9	123.0	1.8	9	2
15	35	90	30	1.00	413	3.3	127.0	1.7	10	5
16	35	30	50	1.00	355	2.8	126.0	2.0	7	3
17	35	90	50	1.00	448	3.6	125.0	2.2	5	2
18	35	60	40	1.00	395	3.2	124.7	1.9	7	3
19	20	60	40	0.72	330	2.6	125.9	1.7	10	3
20	50	60	40	0.72	370	3.0	126.0	1.8	8	3
21	20	60	40	1.28	333	2.6	126.2	2.4	7	2
22	50	60	40	1.28	485	3.8	128.9	2.1	5	2
23	35	30	40	0.72	350	2.7	128.0	1.8	7	3
24	35	90	40	0.72	405	3.2	126.7	1.8	9	3
25	35	30	40	1.28	403	3.3	123.5	2.1	6	2
26	35	90	40	1.28	480	3.8	125.2	2.0	8	2
27	35	60	40	1.00	410	3.3	124.7	2.0	6	3

Formula: water 47%, sugar 2%

Table 13. Regression Equations Showing the Relation Between Independent Variables (X) and Dependent Variables (Y) - Liquid Ferment System (with flour)

Processing conditions

A stepwise regression technique was employed to determine the functional relationship between 4 Independent Variables - flour (X_1), fermentation time (X_2), proofing time (X_3), and yeast (X_4) and 4 Dependent Variables - specific volume (Y_2), spread ratio (Y_4), appearance (Y_5), and internal score (Y_6).

$$Y_2 = 1.7664 + 0.0003X_1X_3 + 0.0088X_2X_4 + 0.0085X_3X_4$$

$$Y_4 = 1.2670 + 0.0173X_3X_4$$

$$Y_5 = 12.5525 - 0.1203X_3X_4$$

$$Y_6 = 4.1732 - 0.0330X_3X_4$$

as rapidly as possible to insure quick hydration yet without gluten formation. Viscosity is not constant during the fermentation cycle. It increases rapidly as the flour hydrates, and after a short ime there is a significant drop. After 1 hour, the viscosity reaches a reasonably constant level.

Short time brews were studied by Bayfield and Young (2, 3). They found that a 30-minute brew time produced as high a total score as the 135-minute control, particularly at $104^{o}F$. The effect of fermentation temperature on the quality of steamed bread is shown in Table 14. The brew fermentation temperature of $104^{o}F$ yielded a slightly larger specific volume than that of $85^{o}F$.

Yeast foods contain yeast nutrients, minerals, buffers and oxidizing agents (bromate) which can stimulate yeast development, strengthen gluten and adjust pH in brew. So yeast foods are valuable adjuncts when used in liquid ferments for making conventional bread. The effect of yeast food (Arkady) in liquid ferment for making steamed bread is shown in Table 15. With an addition of 0.25% to 0.5% yeast food, the specific volume, appearance and internal scores are all decreased. This is largely because gluten was strengthened by oxidizing agents and the steamed loaf contracts upon cooling.

Sheeting can improve the quality of steamed bread prepared by the liquid ferment system as shown in Table 16. Most of the treatments yielded good quality steamed breads. The results of regression analyses are shown in Table 17. The specific volume (Y_2) is related to fermentation time (X_1) and proofing time (X_4) and is a function of X_4 and X_1X_1. Spread ratio (Y_4) is related to mixing time (X_2), sheeting times (X_3) and proofing time (X_4)

Table 14. Effect of Fermentation Temperatures on the Quality of Steamed Bread Prepared by Liquid Ferment System (with Flour)

Ferm. time min.	Fermentation time min.	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
30	85	3.1	1.6	9	4
	104	3.2	1.7	9	4
60	85	3.3	1.7	9	4
	104	3.4	1.7	9	3
90	85	3.6	1.7	9	4
	104	3.8	1.8	9	3

Formula: water 45%, sugar 5%, yeast 1.5%, shortening 2%, flour 35%

Table 15. Effect of Yeast Food (Arkady) on the Fermentation Time of a Liquid Ferment System and on the Quality of Steamed Bread

Level %	Fermentation time (min)	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
0	30	3.1	1.7	10	4
	60	3.3	1.8	10	4
	90	3.7	1.7	9	4
0.25	30	3.1	1.7	7	3
	60	3.2	1.6	8	3
	90	3.4	1.7	7	3
0.5	30	3.3	1.7	6	3
	60	3.2	1.7	4	2
	90	3.4	1.8	6	2

Formula: water 45%, yeast 1.5%, shortening 2%, sugar 5%, flour 35%

Table 16. Effects of Fermentation Time (X_1), Mixing Time (X_2), Sheeting Time (X_3), and Proofing Time (X_3) on the Specific Volume (Y_2), Spread Ratio (Y_4), Appearance (Y_5) and Internal Score (Y_6) of Steamed Bread - Liquid Ferment System with Additional Sheeting

TRT	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
1	30	3	12	30	383	3.1	122.0	1.6	8	4
2	90	3	12	30	445	3.6	123.9	1.8	10	4
3	30	7	12	30	468	3.8	123.9	1.8	10	3
4	90	7	12	30	468	3.8	123.9	1.8	10	3
5	60	5	8	20	410	3.3	122.6	1.7	10	4
6	60	5	16	20	395	3.2	122.5	1.6	10	4
7	60	5	8	40	468	3.9	120.6	1.9	9	2
8	60	5	16	40	450	3.7	123.1	2.0	10	2
9	60	5	12	30	415	3.4	120.8	1.8	10	4
10	30	5	8	30	408	3.4	120.7	1.7	10	4
11	90	5	8	30	478	4.0	120.6	1.7	10	3
12	30	5	16	30	400	3.3	120.6	1.8	10	3
13	90	5	16	30	460	3.8	121.9	1.9	10	3
14	60	3	8	30	410	3.4	121.7	1.7	8	4
15	60	7	8	30	463	3.8	120.6	1.8	10	3
16	60	3	16	30	413	3.4	122.2	1.7	8	3
17	60	7	16	30	420	3.4	123.0	1.8	10	3
18	60	5	12	30	398	3.3	121.2	1.9	10	5
19	30	5	12	20	373	3.1	121.0	1.7	10	4
20	90	5	12	20	363	3.0	120.9	1.7	10	4
21	30	5	12	40	470	3.8	122.8	2.0	10	2
22	90	5	12	40	465	3.8	121.6	2.1	10	2
23	60	3	12	20	395	3.3	121.0	1.7	10	4
24	60	7	12	20	390	3.1	123.9	1.7	10	4
25	60	3	12	40	475	3.9	122.9	2.0	10	2
26	60	7	12	40	418	3.4	124.0	2.1	10	2
27	60	5	12	30	415	3.3	124.5	1.8	10	5

Formula: water 45%, yeast 1.5%, sugar 5%, shortening 2%, flour 35%

Table 17. Regression Equations Showing the Relation Between Independent Variables (X) and Dependent Variables (Y) - Liquid Ferment System with Additional Sheeting

Processing conditions

A stepwise regression technique was employed to determine the functional relationship between 4 Independent Variables - fermentation time (X_1), mixing time (X_2), sheeting times (X_3), proofing time (X_4) and 4 Dependent Variables - specific volume (Y_2), spread ratio (Y_4), appearance (Y_5), and internal score (Y_6).

$$Y_2 = 2.4588 + 0.0292X_4 + 0.00004X_1X_1$$

$$Y_4 = 1.44 + 0.0017X_2X_3 + 0.003X_4X_4$$

$$Y_5 = 5.975 + 1.3333X_2 - 0.1083X_2X_2$$

$$Y_6 = 0.6667 + 0.3X_4 - 0.0067X_4X_4$$

and is a function of X_2X_3 and X_4X_4. Appearance (Y_5) is related to mixing time (X_2) and the internal score (Y_6) is related to proofing time (X_4).

SUMMARY

The processing conditions and formulation for making steamed bread are different from those for making conventional bread (white pan bread). The leaner formulation, lower water percentage and lower mixing action are the three main differences between these two methods. A modified sponge-dough method was developed for making steamed bread in this study. This method calls only for 0.72% yeast, 2% sugar in addition to flour; it provides an inexpensive way to produce steamed bread. The optimum conditions of this method are obtained by regression analyses of testing results: fermentation time, 3 hours; remixing time, 5 minutes; sheeting, 2-4 times; and proofing time, 30 minutes. With this method, excessive sheeting was, however, found to damage the gluten and break the continuous network of protein films easily, and yield a poor quality steamed bread.

In this study, additional sheeting was also found to produce high-quality steamed bread with a larger specific volume, good spread ratio, smooth and shiny appearance, and uniform internal grain. Fat was found essential to be included in the formula when the additional sheeting method was used. The optimum conditions and formulation of this method are obtained by regression analyses: fermentation time, 60-90 minutes; remixing time, 3.5-5.0 minutes; sheeting, 12-16 times; proofing time, 30 minutes; flour, 85% + 15%, water, 45%; yeast, 1.5%; sugar 5%; and shortening, 2-3%. With the additional sheeting method, the fermentation time could be reduced to 60-90 minutes - a short fermentation would be good for mass production. But yeast, sugar and shortening percentages

as well as in sheeting times should be increased if the additional sheeting method is used. The increase would raise the production cost for making steamed bread.

The liquid ferments system was studied and developed for making steamed bread in this study. The optimum conditions and formulation of this method are obtained by regression analyses: fermentation time, 60-90 minutes; mixing time, 5 minutes; sheeting, 12-16 times; proofing time, 30 minutes; flour, 35-50%, water, 45-47%; yeast, 1.0-1.5%; sugar, 5%; and shortening, 2-3%. The brew fermentation temperature of 104° was found to yield a better specific volume of steamed bread than that of 85°F. Yeast foods gave the steamed bread a low specific volume and poor appearance and internal scores. Additional sheeting was also found to improve the quality of steamed bread prepared by the liquid ferment system.

SECTION II

EFFECT OF WHEAT FLOURS ON THE QUALITY OF STEAMED BREAD

REVIEW OF LITERATURE

The chemical composition of wheat and its milling products vary over fairly wide limits. In general, wheats, in common with cereals as a whole, are characterized by a high carbohydrate content which averages about 70 percent of the total grain, a relatively low protein content in the order of 9 to 13 percent, and small amounts of fat, fiber, minerals and vitamins. The carbohydrates of wheat are chiefly starch and cellulose, with small amounts of sugar and pentosans. The proteins include glutenlins, gliadins, globulins, albumins and proteoses, of which the first two predominate and account for the characteristic gluten formation (36).

The baker's vital concern with flour is based on his well founded realization that while the quality of his products depends primarily upon his specialized skills, it is also to a very large degree determined by the flour's baking quality. The term "baking quality" is a rather broad concept that encompasses many factors. If we assume the final production objective to be a well-risen loaf of bread with a silky texture and a fine, uniform grain, then the flour's baking quality may be equated with its ability to produce such a loaf under appropriate production conditions. But most bakers would consider such a definition of flour quality too broad and general. They are equally concerned with such specific characteristics as the flour's tolerance to mixing, its absorption, the type of maturing treatment it requires, and the strength which the dough exhibits during fermentation and the final proof. All these factors enter into the overall concept of flour quality (34).

<u>Starch</u>

Since starch constitutes some 70 percent of wheat flour, the importance of its role in baking may be taken for granted. Opinions vary widely among investigators, however, as to whether its role is the passive one serving as a diluent of the protein, with the latter component being assigned the function of the major determinant of the flour's baking quality, or whether the starch itself through its properties, exerts a significant effect on the volume and crumb structure of the baked loaf. Early studies showed that starches from wheats of widely varying baking qualities differed in their paste viscosities (36).

In recent years investigative efforts have centered more on determining the qualitative factors in wheat starch that are responsible for its effect on bread quality. In 1961, Jongh and coworkers (18, 19) found doughs prepared by containing starch, water, salt, sugar and yeast, yielded bread with a stiff crumb and an irregular, very coarse structure. However, when glyceryl monostearate at a level of 0.1 percent was added to the starch dough, it acquired plastic properties and yielded a loose crumb with a fine and regular structure. The improved effect of the additive is assumed to result from its adsorption on the surface of the starch granules, thereby weakening the binding forces between the starch granules and bringing about an aggregate formation and a resultant coherent network. Instead of the starch granules becoming closely pressed together, as in the extremely firm crumb of the bread without the additive, the addition of glyceryl monostearate decreases the number of contact points between the starch granules, which are then linked together by "three-dimensionally distributed junction points."

The functions of starch are to provide a surface for the protein network, dilute gluten to a desired consistency, remove water from the gluten during starch gelatinization, and provide space for gas to expand. The chemical function of damaged starch is to provide sugar through the action of amylases (38). The role of starch in mixing has not been fully appreciated. However, several authors (6, 43) suggested that, during mixing, gluten film will surround each starch granule by a relatively strong electrostatic force. Although starch has a role in each stage of breadmaking, apparently it plays a greater role in the baking process. The starch swelling begins at a temperature of about 130°F (54°C). Because of the relatively small amount of water in the dough, restricted swelling or gelatinization of the starch granule and leaching of the more soluble amylose takes place at this stage (40). During cooling, the amylose leaches out and retrogrades, and at this stage it contributes to the final structure of the loaf. The flexibility of the starch granules contributes to the crumb softness (25). Although the degree of starch gelatinization depends in the main on the availability of moisture, the temperature to which the starch is exposed also plays a major role (51).

The superiority of wheat starch, as compared to rice, corn, wax corn, and potato starches, is attributed to several factors. These include the surface area and surface characteristics which contribute to the formation of a strong bond with the gluten proteins during mixing; the gelatinization properties that are governed, in turn, by such factors as the molecular size of amylose and amylopectin, their ratio to each other, and the nature of the micellar and amorphous areas within the granule; and the distribution in granule size, as it has been shown that dough systems containing a larger proportion of small granules produce stronger mixing curves (24).

The functions that have been established for starch in baking are listed by Sandstedt (38) to include the following: (1) dilutes the gluten to a desirable consistency; (2) furnishes sugar through amylase action on damaged starch; (3) provides a surface suitable for a strong union with the gluten adhesive; (4) becomes flexible, but does not disintegrate, during partial gelatinization (gelatinization in a deficiency of water), permitting further stretching of the gas cell film; (5) takes water from the gluten by gelatinization, causing the film to set and become rigid enough to lose its expanding potential and to break, and thus giving a bread structure that is readily permeable to gas so that the loaf of bread coming from the oven does not collapse on cooling.

Protein

Wheat is unique among cereals in that its milled product, flour, is alone capable of forming a dough that will retain the gas evolved during fermentation and, on baking, will yield a light, well aerated bread. This unique characteristic is imported to wheat by its proteins which, on combining with water, result in the gluten - the actual substance that confers on dough the property of gas retention.

When flour and water are mixed into a dough and kneaded throughly under water, either by hand or by machine, a cohesive, extensible and rubbery mass is obtained, consisting principally of protein and water. This so-called "crude gluten" contains about 65 to 70 percent water, while its solid matter, or dry substance, usually consists of 75 to 80 percent protein, 5 to 15 percent starch which fails to wash out, 5 to 10 percent lipids, and small quantities of mineral salts (36).

One of the first successful attempts to separate gluten into its major components was made by Osborne (26) when he separated the proteins of wheat into four main fractions on the basis of their solubility in different solvents. The fractions he obtained included the gulten-forming proteins, gliadin and glutenin, which constitute some 80 percent of the total wheat flour protein, and the nongluten-forming proteins, globulin and albumin. He also found a small quantity of proteose, which is a derived protein. These nongluten proteins, which are soluble in either water or dilute salt solutions, are assumed to be nonessential to the formation of gluten and are largely removed in the gluten washing process.

When crude gluten is treated with 70 percent alcohol, the gliadin fraction dissolves or disperses and can be obtained in fairly pure form. The remainder of the protein consists essentially of glutenin, which is soluble in dilute acid or alkali solutions. The use of alcohol in gliadin extraction has a pronounced denaturing effect upon the glutenin fraction which, as a consequence, becomes strongly resistant to practically all solvents except caustic alkali. Glutenin dispersed by dilute alkali is irreversibly changed in its physical properties and is no longer identical to the one originally present in gluten.

Pence and Elder (29) prepared purified samples of the nongluten-forming albumin and globulin fractions and subjected them to physical testing. They found that the albumin consists of at least six individual components and is characterized both by a tryptophan content considerably higher than that of other wheat proteins and by a low amide-nitrogen content. The average molecular weight of the albumins in dilute salt solutions is about 28,000; whereas in the presence of urea or sodium salicylate, it is decreased to about 17,000. The globulins consist of three individual components of low tryptophan and amide-nitrogen contents and a high arginine content.

Wheat flour proteins have been extensively analyzed for their amino acid composition in attempts to establish the correlation between their baking quality and composition. McDonald and Gilles (23) have compiled recent data on the amino acid composition of the protein fractions of wheat. It will be noted that the gluten proteins, gliadin and glutenin in particular, contain an excepally high level of glutamic acid and a relatively high content of proline. In contrast to many other proteins, gluten proteins do not contain a large proportion of helical polypeptide chains, probably because they interfere with the helix formation by causing the chain to bend.

Dimler (7) has offered a visual presentation of the main types of amino acids of wheat gluten as they are chemically linked together in the protein. Noteworthy is the fact that glutamic acid occurs mainly as the monoamide, glutamine. There is evidence that it is principally responsible for the cohesive, elastic properties of gluten. The unique structual configuration of proline supports the view that it represents one of the major sites at which folding of the polypeptide chains occurs. The last amino acid, cystine, depicts the manner in which a disulfide crosslinkage is established between two adjacent polypeptide chains.

The solubility and molecular association of protein in various solvents is determined by the different side-chains of the polypeptide chain (16), where the amino acid composition contains relatively small amounts of basic and acidic residues that are responsible for the solubilization of proteins. This deficiency accounts for the low solubility of the gluten proteins. On the other hand, their high content of glutamine leads to the formation of a correspondingly larger number of hydrogen bonds between the glutamine's terminal polar amide group and the electronegative oxygen on carbonyl and similar group. Gluten proteins also contain a large number of nonpolar side chains consisting of aliphatic and aromatic groups which, in aqueous solutions, tend to associate into so-called hydrophobic bondings.

By means of such physical-chemical methods as ultracentrifugation, electrophoresis, chromatograph, gel filtration, etc., it has been demonstrated that gluten proteins are of a wide range of sizes and shapes. Glutenin was shown to consist of a mixture of relatively large molecules in the range of 50,000 to well over 1,000,000 molecular weight, whereas gliadin molecules, with average molecular weights of 20,000 to 40,000, are both smaller and uniform in size (36). Glutenin forms a very tough, rubbery mass when fully hydrated, while gliadin produces a viscous, fluid mass on hydration. Normal gluten, in contrast, exhibits physical properties of cohesive, elasticity and viscous flow that combine the extremes of the two components (7, 8). The formation of elastic but extensible films of hydrated gluten, capable of retaining gas under some pressure, is the primary requirement in dough preparation. During the time of most rapid expansion of the dough in a baking oven, the gluten continues to be the main structural element of the loaf.

Water Solubles

When gluten was washed from flour, a portion of the flour became soluble in the washed water. The amount and composition of the solubles depended on the salt concentration in the washed water and, therefore, on the flour-to-water ratio. Pence et al. (30) obtained three fractions by dialysis of the buffer solubles: (1) the dialyzables, containing sugars, low molecular weight nitrogenous components, and buffer and flour-ash salts; (2) a crude albumin fraction, containing water soluble proteins and a considerable amount of pentosans (about 30-40% of the dry weight); and (3) a relatively small "globulin" fraction consisting of protein material insoluble in water. They found that soluble components were required for maximum performance of all glutens studied, except for durum wheat. A crude albumin fraction was responsible for the loaf-volume expansion. Pence (28) stated that albumins were implicated in the performance of flours and might account for a significant part of the difference in baking characteristics. However, how did the albumins influence rheological properties of dough was not established (29). Pence et al. (31) also found that both the albumin and globulin contents, as well as the ratio of albumins to globulins, varied significantly among 32 flours of widely varying types and baking qualities. The amount of soluble proteins increased with increasing flour protein, but decreased with increasing flour protein when expressed as percent of total flour protein.

Finney (12) found that the water-soluble material was not responsible for differences in baking quality. However, the water-solubles were necessary for normal baking characteristics in two of his three reconstituted flours. Hoseney et al. (17) found that when a flour-water ratio was selected to exclude gliadin proteins, the water-soluble fraction of flour was not responsible for loaf-volume differences; nevertheless, it was required to produce a normal loaf of bread. Increasing the amount of water-solubles above the amount normally present in flour did not increase loaf volume. The albumin or globulin proteins were not involved in bread making performance. The water-solubles were found to have a dual role of (a) contributing to gassing power and (b) modifying the physical properties of the gluten. The dialyzable fraction of the water-solubles contributed as much to gas production as the total water-solubles, but not so much to loaf volume. One of the nondialyzable fractions contained the water-soluble pentosans and glycoproteins, both of which were involved in the modification of gluten.

Shellenberger et al. (42) stated that water-soluble pentosans (which are about 20 to 25 percent of total pentosans) have been shown to affect hydration, dough development and mixing characteristics, and viscosity and oxidation requirements of a flour.

Tracey (44) has found that the poor volume and texture of bread made with isolated gluten and starch is greatly improved by the addition of flour solubles. By first treating the flour solubles with the enzyme pentosanase, which hydrolyzes pentosans, the improving effect of the flour solubles is destroyed. When the pentosanase preparation was added to bread dough, the result was a decrease in loaf volume on baking. Pentosans, therefore, exert an effect of some significance on the physical properties of dough and on the overall characteristics of bread. Studies (43) with reconstituted doughs have shown that when pentosans are omitted, the dough becomes slack, moist and soft. Adding the pentosans to the doughs restores their normal boldness, stickiness and dryness. Patil et al. (27) found that water-soluble pentosans were required to obtain normal loaf volume from reconstituted gluten and starch doughs. Diethylaminoethyl (DEAE) cellulose fraction II, a high-molecular-weight glycoprotein, greatly improved loaf volume of gluten-starch loaves in the absence of bromate. Reconstituting the water-soluble pentosans (no bromate) in place of the total water-solubles, produced a loaf-volume-improving effect equal to that of the water-solubles plus bromate.

Water-extracts of flour contain a third group of proteins, probably the proteose Osborne reported (26). That group has been identified as glycoproteins by Kundig et al. (17). The major glycoprotein fraction was shown to be responsible for the gelation of aqueous extracts of wheat flour in the presence of oxidizing agents. The principal glycoprotein fraction was found to contain, in addition to pentosans, about 15% protein, together with small amounts of phenolic compounds including ferulic acid (11). Tracey

(48) and Wrench (50) found that the carbohydrate part of the glycoprotein was necessary for normal baking characteristics.

MATERIALS AND METHODS

Flours

Wheat flours milled from 39 varieties collected from 5 suppliers were studied to determine the effect of flours on the quality of steamed bread. Among these flours, 28 were from the Wheat Quality Council, Manhattan, Kansas; 3 were from North Dakota University; 3 were from Western Wheat Quality Lab., USDA; and 5 were from Soft Wheat Quality Lab., USDA (Table 22). The protein levels ranged from 6.8% (Agree) to 14.2% (Waldron). Non-wheat flours such as long-grain rice flour, glutenious (waxy) rice flour, corn flour, sweet potato flour, and protein-rich additives such as full fat soy flour, defatted soy flour, and non-fat dry milk (NFDM) were used as wheat flour supplements for making steamed bread. The source and composition of these flours are shown in Table 18.

Farinograph

Farinograms were obtained by the constant weight method as described by AACC using the 50 g Farinograph mixing bowl. Water absorptions were adjusted to obtain a dough with a maximum consistency of 500 Brabender Units (B.U.).

Fractionation

Flour was fractionated into gluten and starch plus water-soluble fractions by the following procedure: 500 g of flour were mixed with an amount of water (the absorption minus 10%) in a Hobart mixer at a slow speed (No. 1) for 5 minutes. The mixed dough was placed into 4,000 ml of 0.1% sodium chloide tap water

Table 18. Composition of the Flours

Flours	Moisture %	Protein %	Ash %	Fat %	Source
KSU	12.6	11.6	0.41	0.91	Prepared in this Department
Sweet potato	5.8	3.2	3.40	1.10	From Taiwan, ROC
Corn	10.4	6.8	0.45	1.10	Lauhoff Grain Co. Danville, IL.
Long-grain rice	9.4	8.4	0.57	0.67	Prepared in this Lab.
Glutenious rice	11.4	6.0	0.45	1.00	Prepared in this Lab.
Full fat soy	4.6	40.0	6.00	21.80	Archer Daniels Midland Co., IL
Defatted soy	5.3	51.5	6.00	0.80	Archer Daniels Midland Co., IL
NFDM	4.2	33.5	7.90	0.12	Breadlac, Galloway West

(25°C) and the gluten washed out by hand. After the gluten had been washed until it became a smooth, coherent mass (20 to 30 min. of gentle manipulation), then the gluten was put into 1,000 ml of 0.1 sodium chloride tap water and washed for 5 minutes. Two portions of starch and starch plus water-soluble fractions were combined, frozen, and then lyophilized to give a combined starch and water-soluble fraction.

In addition, starch and water-soluble fractions were prepared by centrifuging the suspension of starch plus water-solubles at 2,000 rpm for 20 minutes to separate the starch from the water-solubles. The starch was slurried with approximately 1,000 ml distilled water and centrifuged again. The starch and the combined supernatants (water-soluble fraction) of the two centrifugations were frozen and lyophilized.

Lyophilized gluten, starch plus water-soluble, and starch fractions were ground in a cyclone sample mill to pass a 1 mm perforated metal sieve.

Panel Test

Sensory evaluation of the steamed breads prepared by composite flours was conducted by 29 KSU Chinese students as panelists at about 3:30 p.m. in a classroom under normal light. Panelists were given small, warm pieces on two consecutive days. Water was provided for rinsing. Panelists were not told what the steamed breads were made of and were asked to rank the steamed breads from excellent (6 points) to very poor (1 point), as described and statistically treated by Larmond's method (22).

Preparation of Steamed Bread and Scoring

Steamed breads were prepared by the modified sponge-dough method, and by the scoring system which was established for this study (Figure 5 and 6).

RESULTS AND DISCUSSION

Effects of Gluten and Starch

Effects of wheat protein and starch on the quality of steamed bread prepared by the modified sponge-dough method were studied by adding wheat gluten and wheat starch to hard red winter wheat flour. The results are shown in Tables 19 and 20. When the protein content in dough was increased by adding gluten from 1% to 8% (Table 19), the appearance score of steamed bread was decreased. This decrease is obvious even with the addition of gluten in increments of 1%. The steamed bread with a poor and wrinkled appearance, lower specific volume and internal score was produced by adding 4%, 6%, or 8% of gluten. It seemed the poor quality was caused by the contraction of the high levels of gluten as the steamed bread was moved out of the steamer. The steamed loaf contracted and collapsed upon cooling.

On the contrary, when the protein content in flour was diluted by adding wheat starch from 2% to 32% (Table 20), the appearance was improved, but yielded steamed bread with a specific volume and coarse texture particularly when more than 16% of wheat starch was added. The gluten was so diluted by wheat starch in dough that the dough could not form a desirable consistency for making steamed bread.

Table 21 shows effects of wheat gluten and starch on the quality of steamed bread prepared from soft wheat flour. When 1% to 8% of wheat gluten was added to a soft wheat flour with a protein content of 7.4%, the specific volume was increased from 2.7 to 3.3, but the appearance decreased as the protein content was

Table 19. Effect of Wheat Gluten on Steamed Bread Quality

Gluten[a] %	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
(Control)[b]	3.4	1.77	8.0	4
1	3.5	1.83	6.5	3
2	3.5	1.91	6.5	3
4	2.6	2.18	2.0	1
6	2.4	2.45	2.0	1
8	2.0	2.42	1.0	1

[a]Commercial gluten; protein 74%, moisture 7.3%, ash 1.2%, fat 1.5%.

[b]KSU flour; malted, enriched and bleached; protein 10.7%, moisture 11.9%.

Table 20. Effect of Wheat Starch on Steamed Bread Quality

Wheat starch[a] %	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
(Control)[b]	3.4	1.77	8.0	4.5
2	3.5	1.81	8.5	4.0
4	3.5	1.79	8.5	4.0
8	3.5	1.76	9.0	3.5
16	3.3	1.73	9.5	3.5
32	3.2	1.76	10.0	3.5

[a]Commercial wheat starch: protein 0.60, moisture 11.6, ash 0.19, fat 0.14%.

[b]KSU flour: malted, enriched and bleached; protein 10.7%, moisture 11.9%.

Table 21. Effect of Wheat Gluten and Starch on the Quality of Steamed Bread Prepared From Soft Wheat Flour

Gluten or starch	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
(Control)[a]	2.7	1.7	10	3
Gluten 1%	2.9	1.7	10	4
2%	3.0	1.6	9	4
4%	3.1	1.6	8	4
6%	3.3	1.6	6	3
8%	3.3	1.6	4	3
Starch 2%	2.7	1.6	10	2
4%	2.7	1.7	10	2
8%	2.7	1.7	10	2

[a]Daws flour: protein 7.4%, moisture 11.8%, ash 0.55%, fat 1.0%.

increased. When wheat starch was added to soft wheat flour from 2% to 8%, there was no difference in specific volume between the control bread and the wheat starch supplemented bread, but the internal score was decreased. From these results, flour with a very high or low protein content is inadvisable for making steamed bread because high protein flours could reduce the appearance score, whereas low protein flours could reduce the specific volume of steamed breads.

Effect of Flours

It is generally known that differences in composition of wheat are brought about by variety and environment. The flour obtained from hard wheat varieties is used principally in the production of yeast-leavened bread products. The soft wheats yield flour which is particularly adapted to the production of chemically-leavened products. Thus, each wheat is superior to the other in some respects and their ratings would depend upon the relative importance assigned to those quality factors in which they excel.

In the evaluation of the effect of different flours on the quality of steamed bread, flours milled from 39 varieties, which included hard and soft wheats, from several areas were studied. The performances of these flours are shown in Table 22. The protein of these flours ranged from 6.8% (Agree) to 14.2% (Waldron). The varieties of KS75210, 77682, SD7279, NE78698, CO779274, Newton and Houser produced better quality steamed bread; their protein level was from 8.8% (Houser) to 13.4% (KS75210). But some varieties such as TX71A916-3 (13.7%), Scout 66 (12.6%), Sprangue

Table 22. Effect of Different Varieties on the Quality of Steamed Bread

Source	Variety	Protein %	Specific volume cc/g	Spread ratio D/H	Appearance Score	Internal Score
Texas	TAM-W-101	13.7	2.7	1.8	8	4.0
	TX1A889	12.8	2.9	1.9	9	4.0
	TX71A916-3	13.7	2.5	2.1	6	2.0
Kansas	Scout 66	13.2	3.5	2.2	9	3.0
	KS75210	13.4	3.2	2.0	9	3.5
Neb.	Scout 66	12.3	2.8	2.4	8	2.5
	75414	11.6	3.0	2.0	10	3.0
	77465	11.7	3.2	1.8	8	4.0
	77682	12.0	3.3	1.9	9	4.5
NAPB	Centurk	12.1	3.1	2.0	8	3.5
	NAPB200	12.0	3.1	1.9	7	3.5
	NAPB 201	12.2	3.1	2.0	8	3.0
S. Dak.	Scout 66	12.1	3.1	2.5	7	2.0
	Dawn	12.7	3.2	2.1	7	3.0
	SD7279	12.2	4.0	2.1	9	3.5
	SD73177	13.2	2.7	2.2	7	2.0
Neb.	Scout 66	12.6	2.4	2.3	7	2.0
	NE75424	13.7	2.7	2.2	7	2.0
	NE78696	11.3	2.7	2.0	8	2.0
	NE78698	11.3	3.4	1.9	9	4.0
Colo.	BACA	10.5	3.2	1.9	10	4.0
	CO778785	9.9	3.2	1.8	10	4.5
	CO786741	11.6	2.9	2.0	9	3.5
	CO779274	11.4	3.5	2.1	9	3.0
Rohm & Haas	Newton	13.1	3.5	1.9	9	3.0
	Pierce	11.9	2.7	2.0	8	3.0
	TAM-101	11.7	3.0	2.0	9	3.0
	Jackson-Apache	10.3	3.0	2.0	9	3.0
WWQL USDA	Sprangue	8.8	2.5	1.8	9	2.0
	Moro	8.5	2.8	1.8	10	2.0
	Daws	7.4	2.7	1.6	10	3.0
N. Dak. State	State Mill	13.0	3.0	1.8	4	2.0
	Waldron	14.2	2.7	2.4	4	2.0
	Olaf	12.2	2.7	1.6	4	3.0
SWQL USDA	Houser	8.8	3.4	1.9	10	3.0
	Composite Titan	9.2	3.1	1.9	10	2.0
	Agree	6.8	2.3	1.8	10	2.0
	Augusta	9.8	2.8	1.8	10	3.0
	Frankenmuth	9.9	3.0	1.9	10	3.0

(8.8%), State Mill (13.0%), Waldron (14.2%), Olaf (12.2%), and Agree (6.8%) produced poor quality steamed bread with a low specific volume or low appearance score. In general, soft wheat produced lower specific volume but better appearance, whereas hard wheat produced a larger specific volume but a lower appearance score. Hard wheat flour is more suitable for making steamed bread than soft wheat flour, but it depends on the variety from which the flour is obtained.

Various flours show different results, even when their protein contents are the same. As shown in Table 23, there were four pairs of flour samples, the protein contents of each pair were the same, but they were different varieties. The performances of Houser, NE 78698, 77682, and SD7279 were better than those of Sprangue, NE78696, NAPB200, and NAPB201, respectively, in specific volume, appearance and internal scores. The qualitative difference indicates that other flour components, in addition to flour protein, are responsible for the quality of steamed bread.

<u>Effect of Water Solubles</u>

In order to find out the qualitative differences as shown in Table 23, the flours of Sprangue and Houser were fractionated into a gluten fraction and a starch plus solubles fraction, respectively. The gluten fractions of these two flours were exchanged to study their effect on the quality of steamed bread. The results are shown in Table 24. The mixture of the gluten fraction of Sprangue with the starch plus solubles fraction of Houser produced a better steamed bread with a greater specific volume (3.1) than the bread from the mixture of the gluten fraction of Houser with the starch plus solubles fraction of Sprangue. This indicates

Table 23. Comparison of Different Flours at the Same Protein Content for Making Steamed Bread

Variety	Protein %	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
Sprangue	8.8	2.5	1.8	9.0	2.0
Houser	8.8	3.4	1.9	10.0	3.0
NE78696	11.3	2.4	2.1	8.0	2.0
NE78698	11.3	3.3	1.9	9.5	4.5
NAPB200	12.0	3.1	2.0	7.5	3.5
77682	12.0	3.3	1.9	9.0	5.0
NAPB201	12.2	3.1	2.0	8.5	3.5
SD7279	12.2	4.0	2.1	9.0	3.5

Table 24. Effect of Gluten, Starch Plus Solubles Fractions on the Quality of Steamed Bread

Flour	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
Sprangue	2.5	1.8	10	2
Houser	3.4	1.9	10	3
GH+SSS[a]	2.6	1.5	10	3
GS+SSH[b]	3.1	1.8	10	4

[a]GH+SSS: Gluten from Houser + starch plus soluble fractions of Sprangue.

[b]GS+SSH: Gluten from Sprangue + starch plus soluble fractions of Houser.

that the starch plus solubles fraction plays an important role in deciding the volume of steamed bread.

Additional fractionation work was conducted to separate these two flours into the gluten, starch, and water-solubles fractions; the effect of these three fractions on the quality of steamed bread was then studied. The results are shown in Table 25. The reconstituted Houser flour still produced good quality steamed bread with a specific volume of 3.3, but the mixture in which water-solubles fraction was substituted by that of Sprangue showed lower specific volume of 2.9. This result indicates that water-solubles fraction is an important component of wheat flour in determining the volume of steamed bread.

Effect of Composite Flours

Since steamed bread is a staple food in Oriental countries among which most are deficient in wheat, they rely on imported wheat for making steamed bread, noodle and bakery products. If a portion of imported wheat could be replaced by native starchy crops, the saving of wheat flour could be achieved.

A feasibility study was undertaken. Its first objective was to replace part of the wheat flour with non-wheat flours like rice, corn, and sweet potato flours to lower the production cost of steamed bread. The second objective was to supplement the wheat flour with protein-rich additives such as soy flour and non-fat dry milk to raise the nutritive value of steamed bread.

The results concerning the effect of composite flours on the quality of steamed bread are shown in Table 26. The steamed breads prepared from the composite flours with supplements of 15% long grain rice flour, glutenious (waxy) rice flour, sweet potato flour

Table 25. Effect of Gluten, Starch, and Water-Solubles Fractions on the Quality of Steamed Bread

Flour	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
GH+SH+WSH	3.3	1.6	10	3
GH+SH+WSS	2.9	1.5	10	3

GH - Gluten of Houser

SH - Starch of Houser

WSH - Water Solubles of Houser

WSS - Water Solubles of Sprangue

Table 26. Quality of Steamed Breads Prepared From Composite Flours

Flours	Specific volume cc/g	Spread ratio D/H	Appearance score	Internal score
Control[a]	2.93	1.63	8.5	4.5
15% Long-grain rice	2.50	1.72	10.0	4.5
15% Glutenious rice	2.83	1.84	9.0	4.0
15% Sweet potato	2.45	1.57	10.0	4.5
15% Corn	2.56	1.69	10.0	4.5
7.5% Full fat soy	2.88	1.66	9.0	4.5
7.5% Defatted soy	2.55	1.75	6.5	2.0
7.5% NFDM	2.56	1.72	5.0	3.5

[a]KSU flour; malted, enriched and bleached

and corn flour, respectively, were low in specific volume, but good in appearance score. This is because the wheat protein content was diluted by these no-gluten flours. These composite flours also yielded weaker dough and decreased dough development time, especially the flour supplemented with sweet potato flour. The addition of 7.5% full fat soy flour, defatted soy flour or non-fat dry milk, respectively, increased dough absorption, but produced steamed bread with a lower specific volume and poor appearance because of the high protein content of these flours. In general, these composite flours produced acceptable steamed bread, except for those fortified with defatted soy flour and non-fat dry milk.

Sensory evaluation on the acceptability of these steamed breads was carried out by Chinese students at Kansas State University. Data from the 29 panelists who participated in all the panel tests were analyzed, and the results are shown in Table 27. The steamed breads prepared from the 15% rice flour replacement showed no significant difference in acceptability as compared to the control. But the steamed breads supplemented with corn flour, sweet potato flour, full fat soy flour, defatted soy flour, and non-fat dry milk all showed significant differences when compared to the control.

Table 27. Sensory Evaluation - Acceptability of Steamed Breads Prepared From Composite Flours

Sample	1st (mean)[a,b]	2nd (mean)[a,b]
Control	4.55[a]	4.79[a]
15% Long-grain rice	4.41[a]	4.62[a]
15% Glutenious rice	4.48[a]	4.69[a]
15% Corn	3.79[b]	4.00[b]
15% Sweet potato	3.10[c]	3.59[c]
7.5% Full fat soy	4.34[b]	4.41[ab]
7.5% Defatted soy	4.34[b]	4.41[ab]
7.5% NFDM	4.21[b]	4.45[ab]

[a]Means without a common letter in each column differ significantly ($P < 0.05$).

[b]More than 3 was acceptable.

SUMMARY

Effects of wheat protein or starch on the quality of steamed bread were studied by supplementing hard red winter or soft wheat flour with extra wheat gluten or starch. When the protein content in dough was increased by adding gluten, such supplemented dough was found to produce steamed bread with a low specific volume, wrinkled appearance and poor internal score. The poor quality was likely caused by the contraction of the high levels of gluten as the steamed bread was moved out of the steamer. On the other hand, if the protein content in flour was reduced by adding wheat starch, the appearance of steamed bread was improved, but with a lower specific volume and coarse texture. Wheat starch could dilute the gluten in dough so that the dough could not form a desirable consistency for making steamed bread.

In the evaluation of the effect of different flours on the quality of steamed bread, flours milled from 39 wheat varieties from different areas were studied. Hard wheat flours with protein contents ranging from 10 to 12% were found more suitable for making steamed bread than soft wheat flours. However, flours with the same protein content but of different varieties differed in their performances for making steamed bread.

The qualitative difference existing between two different varieties with the same protein content indicated that other flour components, in addition to flour protein, were also responsible for the quality of steamed bread. In order to find out their qualitative differences, the flours of Sprangue and Houser were fractionated into the gluten, starch, and water-solubles fractions.

The results showed that the water-solubles is an important component of wheat flour in determining the volume of steamed bread.

Composite flours, supplemented with non-wheat flours or protein-rich additives, were studied for making steamed bread. Supplements of 15% each of rice flour, corn flour, sweet potato flour or 7.5% each of soy flour, non-fat dry milk, were found to reduce the specific volume of steamed bread.

CONCLUSIONS

Based on the results of this study, the following conclusions are drawn:

1. A modified sponge-dough method and a liquid ferment system for making steamed bread have been developed in this study.
2. Additional sheeting was found to improve the specific volume, appearance and internal scores of the finished bread.
3. The specific volume and internal score of the steamed bread increased, while its appearance score reduced with the addition of wheat gluten to the dough formulation. Wheat starch exerted an action contrary to that of gluten on the steamed bread.
4. Flours with a protein content ranging from 10 to 12% were found suitable for making steamed bread.
5. High-protein flours (protein >13%) gave the finished bread a low specific volume, wrinkled appearance, and dense texture. Whereas low-protein flours (protein < 9%) gave the bread a good appearance, but a low score in both specific volume and texture.
6. Water-solubles fraction of wheat flour was found to play an important role in determining the volume of the steamed bread.
7. Composite flour, wheat flour supplemented with 15% each of rice flour, corn flour, or sweet potato flour, or 7.5% each of soy flour or non-fat dry milk, was found acceptable for making steamed bread.

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EFFECTS OF PROCESSING METHODS AND WHEAT FLOURS ON THE QUALITY OF STEAMED BREADS

by

TZE-CHING LIN

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ABSTRACT

A modified sponge-dough method with or without a liquid ferment system has been developed as a suitable method for making steamed bread in this study. Additional sheeting was found to produce high-quality steamed breads with a larger specific volume, good spread ratio, smooth and shiny appearance, and uniform internal grain by the modified sponge-dough method.

The protein content of flour affected the quality of steamed bread. The specific volume and internal score of the steamed bread increased, while its appearance score was reduced with the addition of wheat gluten to a dough formula. Wheat starch exerted actions contrary to those of gluten on the steamed bread through the dilution of gluten in dough.

High protein flours gave the finished bread with a low specific volume, wrinkled appearance, and dense texture, whereas low-protein flours produced the bread with a good appearance, but a low specific volume and internal score. Hard wheat flours with a protein content ranging from 10 to 12% were found more suitable for making steamed bread than soft wheat flours. In addition to flour protein, a water-solubles fraction of wheat flour was found to play an important role in determining the volume of steamed bread.

Composite flour, wheat flour supplemented with 15% each of rice flour, corn flour, or sweet potato flour, or 7.5% each of soy flour or non-fat dry milk, was found acceptable for making steamed bread.