EFFECT OF INGREDIENTS ON THE QUALITY OF FROZEN DOUGH

by

MAY MEI-JIUN HUNG

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INTRODUCTION

Frozen dough products provide important advantages to both consumers and food manufacturers. For fresh bread lovers, frozen dough provides a fresh bread aroma and some of the satisfaction of baking bread at home. For the retail bakers and food service operators, frozen dough supplies a diverse product line, improves production scheduling and efficiency, and gives flexibility for sudden changes in demand. Also, frozen dough can be produced in centrally located plants with higher output, volume purchasing, and distribution over a wider area. (Lorenz 1974). In recent years frozen doughs have been gaining market share by being used in new in-store bakeries in supermarkets. The total in-store bakery market today is about three billion dollars per year (Gregory 1984); over 42% of this comes from products that have been made by the "bake-off" process in the store from frozen dough (Anon. 1984). As of 1984, 49 percent of all in-store bakeries were bake-offs (Gaynor 1985). The bake-off operation is less costly than a complete bakery ($6,000 vs $30,000), requires half the space, lower labor costs, fewer skilled operators, and allows flexibility in production to meet demand or shopper traffic (Vetter 1979).

Because of these advantages, the production of frozen dough is increasing world wide, even in underdeveloped countries. In most underdeveloped countries, wheat flours with low protein content (9%) are generally used for bread making. When these flours are made into frozen doughs the qualities of subsequent breads are poor because several researchers have shown that frozen dough products require wheat flours with higher protein content (11 to 13 %) to produce high quality products (Javes 1971, Marston 1978 and Boyd 1980).

Theobjectives of this research were to investigate the relation among different ingredients on the quality of frozen dough products during sixteen weeks of storage by studying the following:

1. The effect of different oxidants on quality of frozen dough made with low protein flour.
2. The effect of dough strengtheners on quality of low-protein-flour frozen dough.
3. The effect of adding gluten on quality of frozen dough made with low protein flour.
4. The effect of different flour types on quality of frozen dough products.

LITERATURE REVIEW

Development of Frozen Dough

The first known commercial production of frozen dough was in 1945 (Anon. 1967). Since then, frozen dough products have been sold in an increasing number of markets around the country. In 1984, frozen bakery products held third place in poundage with 512 million, and seventh place in dollar volume at $739 million, compared to all other frozen food products (Beck 1984).

In the beginning of the frozen dough industry, sales were not expected to be high because of the limited shelf life and the inconvenience of preparation (Vetter 1979). Also, for home use, ideal proofing and thawing conditions were not usually available. However, a new marketing channel, supermarket in-store bakeries, changed the situation.

The number of in-store supermarket bakeries continued to increase. By the end of 1985 an estimated 17,300 in-stores will be in operation. In-store bakery sales were expected to register the largest sales percentage increase of the three bakery industry segments (wholesale, retail, and in-store), with projections calling for 1985 sales of $4.2 billion, a 13.5% increase from $3.7 billion in 1984. The growth was linked to an expected 14% increase in the number of in-store bakeries (Gaynor 1985).

Problems in Frozen Dough Production

Frozen, unbaked, yeast-leavened dough is a biologically active system. A major objective in the freezing of these doughs is the reversible inhibition of yeast activity at low temperatures. Improper freezing and/or storage of frozen doughs may have significant adverse effects on the subsequent performance of doughs when converted to baked bread (Vetter 1979).

The major problem with marketing frozen doughs is deterioration in quality during storage. Frozen doughs produced by current procedures today perform satisfactorily for only a few weeks (Hsu et al 1979a). As the age of the dough increases, the proof time becomes very long and the dough rises slowly, resulting in a dense, heavy product of unsatisfactory nature (Merritt 1960). Studies reported that frozen dough stability was related to yeast quality, dough formulation, processing, freezing and thawing conditions (Hsu et al 1979a, 1979b; Vetter 1979).

Effect of Yeast on Frozen Dough Stability

Many workers have suggested that increasing the yeast (*Saccharomyces cerevisiae*) level from 4% to 6% will extend storage of frozen dough. Sugihara and Kline (1968) studied residual gassing power of doughs frozen for up to fifteen weeks. Increasing the yeast level to 6% and decreasing the dough fermentation period were found to give adequate residual gassing power of frozen doughs after 13 weeks of storage. Several workers (Lorenz 1974; Javes 1971; Drake 1970; Merritt 1960) have suggested the use of 4-5% yeast in frozen dough formulations. Lorenz (1974) found that using 3% yeast resultedin

20% longer final proof time than with 4% yeast. Yeast levels higher than 5% were found to give a yeasty aroma and flavor to the bread.

It has been reported by several workers (Godkin and Cathcart 1949; Kline and Sugihara 1968; Hsu et al 1979a; Thiessen 1942) that yeasts from different sources and different lots vary greatly in their susceptibility to freezing damage. Hsu et al (1979a) attempted to correlate stability of yeast in frozen doughs with yeast protein content and gassing power ability. Neither of these two parameters could be used to predict yeast stability during frozen storage.

Godkin and Cathcart (1949) reported that aged yeast was more susceptible to freezing damage than fresh yeast. Other workers (Hsu et al 1979a, Kline and Sugihara 1968) have reported that refrigerated storage of yeast prior to incorporation into a frozen dough system protected yeast from freezing damage. The improved stability was attributed to an increased lag time in the fermentation rate of the yeast. Some researchers have suggested that dry yeast may be superior to compressed yeast in terms of stability to freezing (Merritt 1960, Zaehringer et al 1951). Theoretically the longer lag period of dry yeast should minimize fermentation prior to freezing and thus give a more stable dough. Kline and Sugihara (1968) found that doughs made with dried yeast had somewhat longer proofing times than doughs made with compressed yeast. It was suggested that the release of reducing agents from the dry yeast could be the reason for the longer proofing times.

Wolt and D'Appolonia (1984), researched the stability of frozen dough, and found a difference in the amount of thiol compounds leached from different yeasts. Thiol compounds released by yeast were thought to be primarily glutathione. They also reported that compressed yeast performed slightly better than active dry yeast and instant dry yeast in frozen doughs in terms of proof time stability. The difference was attributed to the performance of the yeast itself and not to the higher levels of thiol compounds released by the dry yeast.

Effect of Some Basic Ingredients on Frozen Dough Quality

Ingredients used in frozen dough formulation are similar to regular doughs, but some modifications are necessary to obtain a quality finished product with a longer shelf life (Javes 1971, Marston 1978). Each ingredient influences the quality of frozen dough product, and in some cases it differs from the role in fresh baked dough (Javes 1971). In general, formulations with higher percent of ingredients provide longer freezer life (Fuhrmann 1978). Comparisons of major ingredients (except yeast) in fresh dough and frozen dough are presented in the following sections.

A. Flour

Javes (1971) concluded that the flour used for frozen dough should have higher protein content than that normally used in regular bread production. He also found this kind of flour would produce larger volume and open grain characteristics of "home-baked" bread, which many consumers desired. Marston (1978) reported that the flour used should be of 11 to 13 percent protein. Tressler et al (1968) suggested that a high quality protein flour was important, but the amount of protein was not critical. However, Fuhrmann (1978) reported that the higher protein content gave better dough tolerance and better product stability during freezing and thawing.

Little work has been reported on the effect of flour type on frozen dough stability. Boyd (1980) used an unbleached spring wheat flour treated with bromate and malt, and obtained good quality frozen products. Lorenz and Bechtel (1965) compared the stability of doughs made from spring and winter wheat flours at various levels of oxidation. At optimum levels of oxidation for each flour, no difference in proofing time stability was noticed. If potassium bromate did have an inhibiting effect on yeast in a frozen dough, as concluded by Kline and Sugihara (1968), then a spring wheat flour, which in general required a lower level of oxidation, might be preferable to a winter wheat flour. In general, flours that produce slack doughs have poor gas retention and oven spring, resulting in undesirable products.

Wolt and D'Appolonia (1984) reported that flour type was an important variable in the proof time stability of doughs. They also concluded that, based on flours they used, protein content was not a reliable indicator of a flour's performance in frozen dough.

B. Water

To facilitate handling and machining, water content in dough designed for freezing should be about 58% as compared to 62% in conventional dough (Fuhrmann 1978; Javes 1971; Lorenz 1974). Fuhrmann (1978) explained that lower absorption also prevented crystallization of water during freezing, and helped retain the shape of the product during freezing. Too high an absorption might increase the loaf's tendency to soften and break-down in the grocer's freezer, especially if exposed to too many freeze-defrost cycles (Lorenz 1974).

C. Yeast Foods

A 0.5% level (based on flour weight) of yeast foods (calcium sulfate 30.0%, ammonium chloride 9.4% , potassium bromate 0.3%, sodium chloride 35.0%, starch and moisture 25.3%) was recommended for use in frozen dough (Lorenz and Bechtel 1964). As in regular doughs, yeast foods stimulate yeast activity, help to control acidity, condition the dough for good machine ability and provide oxidizers.

D. Sugar

Proper sugar levels were important with regard to freezer stability. Excessive use of sugar could slow down yeast activity causing excessive proof times (Fuhrmann 1978). A sugar level of 6% was found to be satisfactory (Lorenz 1974, Lorenz and Bechtel 1964).

E. Salt

Salt is a buffering agent and regulates the rate of fermentation. It strengthens the gluten and contributes to the flavor of the bread product (Fuhrmann 1978). It is usually used in the normal percent (1-2%) as in regular doughs (Merritt 1960).

F. Shortenings

Shortenings have an extending effect on freezer life and slow down the dehydration of the product held in frozen storage (Fuhrmann 1978). Shortening levels from the normal 3% to 5% result in bread with a finer and smoother texture (Lorenz 1974, Lorenz and Bechtel 1964).

G. Nonfat Dry Milk (NFDM)

It was shown that NFDM has a very important buffering effect during fermentation before freezing (Sugihara and Kline 1968). The NFDM prevented a large pH drop, which seemed to result in increased yeast stability, especially when combined with further yeast addition at the dough stage. Optimum level was found to be 4 percent which gave a pleasant crust color (Lorenz and Bechtel 1965). In recent years rising milk prices have generated more interest in another dairy product-whey, often in combination with soy flour.

Uses, Functions and Improving Mechanism of Oxidants in Baking

Oxidants are used to provide greater loaf volume,improve internal characteristics such as grain and texture, and enhance the symmetry of products. As used by bakers, oxidizing agents are functional additives that replace, speed up, and control the natural aging of flour. They strengthen the flour by stabilizing the gluten andincreasing the elasticity of the dough, and also reduce the extensibility to improve the gas retention (Kamman 1984).

The most commonly used oxidants are potassium bromate, iodate, ascorbic acid, and azodicarbonamide (ADA). All of these are believed to accomplish the same general effect, namely, oxidation of sulfhydryl groups. But they are used in different amounts and have different rates of reaction. The potassium and calcium bromates are slow acting oxidants, while the iodates are fast acting oxidants. The ascorbic acid is a unique oxidant, which has an intermediate reaction rate (Tsen and Hlynka 1967; Johnston and Mauseth 1972).

Food and Drug Administration (FDA) Regulations limit the level of all oxidants permitted for use in bakery foods, except for ascorbic acid. The levels are based on the amounts of flour used in the baked products rather than on the product weight. Bromates and iodates should not exceed 75 ppm (singly or in combination) based on flour used in the formula. ADA may be used in addition to bromates and iodates at a level of 45 ppm (Kulp 1981).

A. Ascorbic Acid

L-Ascorbic acid is unique among flour improvers because it is a vitamin and also it is a reducing agent while other improving agents are oxidizing agents.

In 1935, Jorgensen (1939) reported that ascorbic acid , a reducing agent, was found to exert an improving action similar to that of bromate. Since then ascorbic acid was widely used, especially in Europe and Australia, as a bread additive (Birch and Parker 1974). Kulp (1981) concluded that ascorbic acid was important in the United States of America, especially in short, no-time dough systems, and frozen dough. He also suggested ascorbic acid levels of 30 to 40 ppm for short time dough systems, 60 ppm for no-time dough systems, and up to 100 ppm for frozen dough.

Tsen (1964, 1965) concluded that the improving mechanism of ascorbic acid involved the oxidation of ascorbic acid to dehydroascorbic acid by ascorbic acid oxidase and the subsequent reaction of dehydroascorbic acid to ascorbic acid by dehydroascorbic acid reductase, coupling with the oxidation of sulfhydryl (-SH) groups in dough. Tsen (1965) reported the molar ratio of -SH group oxidized per dehydroascorbic acid as 2:1. Tsen also found that ascorbic acid needs oxygen to exert its improving action and that bromate can enhance the improving action of ascorbic acid. Meredith (1965, 1966) demonstrated that ascorbic acid required air or bromate to give an improving effect on dough. He suggested that the reductive step was probably entirely enzymatic and the oxidative step was only partly enzymatic. Meredith (1966) also stated that the oxidative step was not inhibited by chelating agents such as EDTA (Ethylene Diamine Tetraacetic Acid). Several other studies (Sullivan et al 1940; Mecham 1959; Frather et al 1960; Tsen and Bushuk 1963; Tsen 1963) have suggested that the improving action of an oxidizing agent was due to oxidation of thiol groups in dough.

Elkassabany et al (1980) studied ascorbic acid and dehydroascorbic acid stability during mixing and subsequent resting. They found that practically all of the ascorbic acid was converted to dehydroascorbic acid in optimally mixed yeasted dough. Yeast accelerated the conversion of ascorbic acid to dehydroascorbic acid during mixing.

Ascorbic acid exerts synergistic effects when used with other oxidants, such as bromate. Tsen (1965) and Meredith (1965) showed that the improving effect of ascorbic acid and bromate together was greater than that of bromate or ascorbic acid alone.

B. Azodicarbonamide

Azodicarbonamide (ADA) was first introduced by Wallace and Tiermnan, Inc. in 1962. The usefulness of ADA as a flour-maturing agent in improving dough properties and baking qualities have been reported by Joiner (1962). He reported that ADA matured flour through oxidation. It did not react in the dry flour, but did react in the process of making dough. ADA-treated flours produced drier and more cohesive doughs than chlorine dioxide-treated flours. These drier doughs could tolerate higher absorption and were superior in machining properties (Tsen 1963). Joiner (1962) also found that the bread made from ADA-treated flour was characterized by increased loaf volume and improved grain texture and outside appearance. In 1963, Tsen also showed that when mixed into doughs, ADA oxidized the sulfhydryl (-SH) groups, exerting an improving effect. The oxidation was rapid and almost complete during the mixing. Neither further mixing nor prolonged resting could give a significant additional decrease in the -SH content. ADA did not bleach flour pigments. Tsen (1964) did a comparative study of several oxidants and found doughs treated with these agents showed an improving effect, as indicated by the increase in resistance to extension and the decrease in extensibility in the extensigram. On an equivalent basis, ADA is more rapid than iodate or acetone peroxides in oxidizing -SH groups of dough and in exerting the improving effect on dough.

Combinations of bromates and azodicarbonamide were at least as satisfactory as combinations of bromates and iodates in continuous bread production. The ability of bromate-azodicarbomanide combinations to produce doughs of greater strength could produce an advantage in many instances (AIB 1967).

C. Potassium Bromate

Bromate is a slow-oxidizing agent for cysteine and glutathione, particularly for the sulfhydryl (-SH) group of flour. Tsen (1968) found that oxidation of -SH groups in flour-water suspension by bromate could be increased slightly by lowering the pH of the suspension, but markedly by raising the temperature of the suspension. This temperature effect was confirmed with the determination of -SH groups oxidized by bromate in nonfermented and fermented doughs heated at various temperatures. It was also supported by the results of baking tests with bromated and unbromated doughs, whether fermented or not. Bushuk and Hlynka (1960) showed that the major bromate effect on oxidation of -SH groups occurred when dough was heated during the early stage of baking.

The studies of chemical mechanism of the action of oxidants, although not fully understood,show that their effects of these agents are on the protein components of flour.

Effect of Oxidants on Frozen Dough Quality

Higher levels of oxidants are commonly used in frozen dough formulations. Hsu et al (1979a) showed that an oxidant system containing 10 ppm potassium bromate and 100 ppm ascorbic acid gave shorter proofing times than a system using 20ppm of potassium bromate only.

Kline and Sugihara (1968) reported that bromate had a definite deleterious effect on yeast activity. They showed that increasing the level of bromate in doughs gave increased proofing time and decreased gassing power. High levels of bromate gave larger loaf volumes. They suggested that intermediate levels of bromate (20-30 ppm) would give the best combination of residual gassing power and bread volume.

Lorenz and Bechtel (1965) found that bromate might improve the volume, grain and texture of bread from frozen dough; however, bromate level did not increase the storage stability. Longer proof times were necessary when the level of bromate was increased.

Effect of Dough Strengtheners on Frozen Dough Quality

Dough conditioners, dough strengtheners, crumb softeners, emulsifiers - all are terms describing ingredients used in yeast-raised bakery food production to aid in production and/or improve certain quality factors (Dubois 1979).

Those materials used in the baking industry for dough strengthening and/or crumb softening are limited to those permitted by the FDA as following: mono- and diglycerides, diacetyl tartaric acid esters of fat forming fatty acids (DATA), polysorbate 60, sodium stearoyl monoglycerides, sodium stearoyl-2-lactylate (SSL), and ethoxylated mono- and diglycerides, etc.. Some of these materials perform the dual function of dough strengthening and crumb softening to some degree. These materials are multifunctional, and it is common practice to use two or more of these in combination (Dubois 1979). The FDA regulations for sodium stearoyl-2-lactylate and ethoxylated monoglycerides are that the total amount of these surfactants used alone or in combination cannot exceed 0.5% based on flour.

Langhans (1970) reported that increases in the mono- and diglycerides levels (approaching 0.5%) in frozen bread dough would provide a softer final product. Diacetyl tartaric acid esters of monoglycerides and SSL have both been shown to be effective in maintaining both volume and crumb softness of bread produced from frozen dough which has been subjected to extended storage (Davis 1981; Marston 1978; Varriano-Marston et al 1980). Davis (1981) found that SSL provided longer shelf life stability in terms of loaf volume.

Wolt and D'Appolonia (1984) reported that SSL and diactyl tartaric acid (DATA) decreased the effects of frozen storage on rheological properties, but they were not effective in reducing the time to proof doughs to a specific height. They also found that frozen doughs with SSL had greater loaf volume after baking than those with no SSL, because of great oven spring. The use of DATA was less effective than SSL in counteracting rheological changes and in maintaining loaf volume.

Effect of Processing on Frozen Dough Quality

A. Fermentation

Merritt (1960) reported that yeast stability was higher with unfermented dough. He explained that the greater stability was due to the relatively dormant condition of the yeast immediately after mixing. However, Lorenz and Bechtel (1965) obtained the opposite result. They found that full fermentation gave higher quality bread, and 20 minutes fermentation gave bread of low volume and poor appearance. Kline and Sugihara (1968a, b) then supported Merritt by giving evidence that increased fermentation time would decrease the yeast stability and gassing power in both straight and sponge and dough methods. They (1968a) recommended a combination of increased yeast level and decreased fermentation time in straight doughs, and also developed a modified sponge and dough procedure which included decreasing sponge time, addition of NFDM to the sponge, chilling the sponge before mixing, and addition of 2-5 % more yeast at the dough stage for the purpose of increasing yeast stability.

No complete explanation of the effect of fermentation on yeast viability in frozen dough has been given. Merritt (1960) suggested that actively fermenting yeast was in a state of incipient growth and, in such a state yeast, was more susceptible to damage from freezing. Godkin and Cathcart (1949) speculated that an accumulation of fermentation products in doughs had a detrimental effect on yeast viability during frozen stage. Hsu et al (1979a) reported that fermentation products had a damaging effect on the gassing power of yeast after frozen storage. Manufacturers of frozen dough avoid the detrimental effect of fermentation on yeast viability by using low dough temperatures and a minimum time between mixing and make up to retard fermentation. The shortened fermentation period, however, does not allow for optimum flavor and aroma in the final product.

A short-time straight dough or "no-time" dough process has been found to be the most suitable for the production of frozen dough (Marston 1978). The "no-time" dough process relies on oxidants to bring about development and maturation in the mixer and thus shorten the normal fermentation step.

Wolt and D'Appolonia (1984) found that glutathione had a loaf volume retarding effect on both "no-time" and straight dough formulations. The effect of glutathione was more pronounced in the straight dough formulation where no oxidizing agent was used.

B. Mechanical Processing

Lorenz and Bechtel (1964) reported that continuous mixed frozen doughs maintained their overall quality overa longer storage period by using higher amounts of oxidizers.

Meyer et al (1956) reported that the stage at which the dough was shaped was the most important factor affecting the quality of frozen dough rolls. They added that high quality was associated with manipulation of the dough after freezing and that inferior rolls were obtained from doughs shaped before freezing. After freezing storage, differences between rolls from fermented and unfermented doughs of similar shaping treatment was not marked.

C. Freezing

The two basic freezing systems that are available commercially are the cryogenic process, which involves the use of liquid nitrogen, and the mechanical refrigeration in which heat transfer is by air blast (Watson 1971). Mechanical freezing is the most commonly used method in bakery product freezing because it is cheaper, even though the cryogenic system utilizes much lower temperatures (Hsu et al 1979a).

The effect of freezing rate on yeast viability in frozen dough is a somewhat controversial area. Several studies have been done on the effect of freezing condition on the stability of frozen doughs. Godkin and Cathcart (1949) reported that a slow freezing rate was more detrimental to yeast viability than rapid freezing. They suggested that slow freezing subjected yeast to prolonged exposure to the temperature at the freezing point of dough but slightly above its own freezing point. They found that the cells were not destroyed, however, cells became weakened and gradually died during frozen storage.

Lorenz (1974) reported on studies of factors affecting the stability of frozen yeast suspensions. He found that cells frozen rapidly usually have lower survival rates than cells frozen slowly. Slow freezing of yeast in a suspension allowed yeast to dehydrate and prevented the formation of intracellular ice. Lorenz believed that rapid freezing, as it was practiced in the production of frozen dough , resulted in the formation of intracellular ice.

Several studies used a mechanical blast freezer which utilized temperatures ranging from -30o to-35oC with a wind velocity of 35 mph and a residence time of approximately 50 to 90 minutes (Boyd 1980, Marston 1978). Mazur (1963) formulated a mathematical model which indicated that a freezing rate of one degree centigrade per minute would prevent internal ice formation in most cells.

Hsu et al (1979b) reported that the final freezing temperature had a greater effect on frozen dough stability than did freezing rate. The minimum temperature to which cells were cooled was known to be a factor in the survival of yeast (Lorenz 1974). It is generally accepted that frozen dough should be stored at -10o to -20oC (Marston 1978, Tressler, et al 1968).

Marston (1978) suggested a two-stage freezing operation. The dough pieces were frozen in a blast freezer until the internal temperature of the dough reached zero degree centigrade, at which time the dough was placed in a holding room at -20oC for further reduction in temperature.

Lehmann and Dreese (1981) showed that a core temperature of 20oF (-6.6oC) produced breads with the most consistant overall quality. Doughs frozen in a conventional freezer (0oF,17.8oC) produced breads with the best storage stability. This data agrees with the suggestion made by Lorenz (1974) that slower freezing might produce more stable doughs; however, the data was in disagreement with the findings of Godkin and Cathcart (1949).

D. Thawing

Bender and Lamb (1977) showed that thawing rate did not influence gassing activity. Merritt (1960) reported that thawing at 35oF (1.7oC) and holding the dough for 48 hours, then proofing and baking was not harmful. Several other researchers recommended slow thawing in a refrigeration on retarder box (Davis 1981, Marston 1978). However, Lorenz (1974) stated that very rapid rewarming was a major factor responsible for high survival.

E. Packaging

Packaging designed for food must perform a number of functions, such as containing, protecting, identifying, and merchandizing the food (Klein 1971). Primarily, however, the major function is to protect the product.

Film to be used for frozen dough should possess the following characteristics:

1. Good moisture protection.
2. Good oxygen barrier characteristic.
3. Physical strength against brittleness and breakage at low temperature.
4. Good heat sealability.

The packaging should be done quickly to prevent surface thawing (Mazur 1961).

F. Storing

Product quality may be reduced by excessive holding time and the unexpected exposure of the frozen product to temperatures above $0^{o}F$ either in storage or during long transport delivery (Thomas 1971). The results showed that low storage temperature gave a good gassing activity (Bender and Lamb 1977). However Hsu et al (1979b) reported that frozen doughs were less stable if their storage temperature was lower than their freezing temperature. Merritt (1960) reported that the adverse conditions of storage which the product might encounter during its passage from producer to consumer had no adverse effect on the performance of the dough. For commercial bake-off operation, storage times are likely to be of the order of only 4 to 6 weeks (Bender and Lamb 1977).

MATERIALS AND METHODS

Materials

Flour Wheat flour used in this study was milled from hard red winter wheat on the pilot mill in the Department of Grain Science and Industry, Kansas State University. Five other flours also were utilized in the study on flour protein effects. Those five flours were two hard red winter wheat flours (HRW-1 and HRW-2) from the Ross Milling Company (Wichita, KS.), a hard red winter wheat flour (HRW-3) from the General Mills, Inc. (Minneapolis, MN.) and two hard red spring wheat flours (HRS-1 and HRS-2) obtained from the North Dakota State Mill (Fargo, ND.).

Analytical data for the six flour samples are shown in Table 1. Flour protein contents ranged from 9.1 to 14.4% (14.0% moisture basis).

Farinograph data for the flour samples are shown in Table 2. The farinograms for the flour samples are shown in Figure 1. KSU flour (control flour) showed the weakest mixing properties of these experimental flours. Among eight different flours tested, HRW-1 (11.7% protein) and HRW-2 (12.3% protein) showed similar mixing properties. HRW-3 (14.4% protein) gave the longest dough development time. HRS-1 (12.0% protein) and HRS-2 (14.1% protein) displayed similar shape farinograms, although HRS-1 had a higher mixing tolerance index value.

Oxidant For the study on the oxidizing agents system, three different oxidants were used (Table 3).

TABLE 1. Proximate Analyses of Materials

Materials	Moisture (%)	Protein (%)	Ash (%)	Source
Control Flour	12.1	9.1	0.40	KSU HRW
HRW-1	13.2	11.7	0.48	Ross Mill
HRW-2	13.3	12.3	0.47	Exp. Flour
HRW-3	11.4	14.4	0.49	General Mills
HRS-1	14.2	12.0	0.37	North Dakota
HRS-2	13.9	14.1	0.35	North Dakota
Vital Gluten	9.5	74.0	0.94	Midwest Solvents

TABLE 2. Farinograph Data on Experimental Flours

Materials	ABS[1] (%)	PT[2] (min)	MS[3] (min)	M.T.I.[4] (BU)
KSU Flour	54.0	1.5	7.5	40
KSU+4% Gluten	58.4	2.0	11.0	20
KSU+8% Gluten	59.4	2.5	24.5	20
HRW-1	60.4	8.0	13.5	20
HRW-2	60.0	6.5	12.0	20
HRW-3	66.2	11.5	14.0	30
HRS-1	57.1	5.0	9.0	40
HRS-2	63.8	6.5	11.0	20

[1]ABS : Absorption at 500 BU

[2]PT : Peak Time

[3]MS : Mixing Stability

[4]M.T.I. : Mixing Tolerance Index

Fig. 1. Farinograph Curves of Flour Samples.

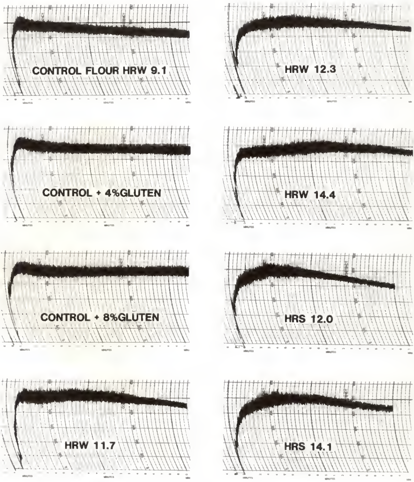

CONTROL FLOUR HRW 9.1
HRW 12.3
CONTROL + 4%GLUTEN
HRW 14.4
CONTROL + 8%GLUTEN
HRS 12.0
HRW 11.7
HRS 14.1

Table 3. Oxidants and Conditioners Used in the Experiment

Chemicals	Brand	Function	Manufacture
Ascorbic Acid	MCB	Oxidizing Agent	MCB Manufacting Chemists Inc. Cincinnati, Ohio.
Potassium Bromate	Fisher	Oxidizing Agent	Fisher Scientific Company Fair Lawn, NJ.
Azodicarbonamide	-	Oxidizing Agent	Pennwalt Corp. Buffalo, NY.
Ethoxylated Mono-diglycerides (EMG) and Mono-Diglycerides(MG) (50:50)	Xpando	Dough Strengthener	Breddo Food Prod. Corporation Kansas City, KS.
Sodium Stearoyl 2-Lactylate(SSL)	Emplex	Dough Strengthener Crumb Softener	Patco Products Kansas City, KS.

Surfactant Two different dough additives were used to study the effects of dough conditioners on frozen dough (Table 3).

Gluten A commercial vital wheat gluten from Midwest Solvents (Kansas City, Kansas) was used.

Yeast "Fermipan", an instant dry yeast, made by Gist-Brocades (MA Delft, Holland) was used in these experiments.

Whey Whey used was from the Best-O-Bake Company.

Malt Nondiastatic malt used was from the Rhodes Bake-N-Serv Inc. (Portland, OR.).

Methods

Moisture, ash and protein analyses were performed using approved AACC methods (AACC approved methods 44-19, 08-02, and 46-10, AACC, 1983). Protein and ash content were reported on the 14% moisture basis.

A. Farinograph. Dough mixing properties of the flours were investigated using the Brabender Farinograph according to the AACC method (AACC approved method 54-21, AACC, 1983). The 50 gram bowl and the constant flour weight method were utilized. Farinograph absorption, dough development time, mechanical tolerance index (MTI) and stability were reported.

The significant readings taken from a farinogram are : (1) the peak time or dough development time, which represents the time from the first addition of water to the point of maximum consistency; (2) the mixing stability, which is the amount of time that the curve stays on the 500 Brabender Units (B.U.) line;

(3) the mixing tolerance index (M.T.I.), which is the difference in B.U. from the top of the curve at the peak to the top of the curve five minutes after the peak. The peak time varies with different flours and indicates the gluten quality; peak time is about 8 min for strong flours, and about 4 min for weak flours. Mixing stability is about 17 min for strong flours and about 3 min for weak flours (Anon. 1976). Bakers want a long mixing stability so that mixing time does not need to be precisely controlled. Strong flour is usually used for bread and weak flour is used for cakes and cookies (Pyler 1973).

B. Preparation of frozen dough . A modified bread formula and baking procedure obtained from preliminary experiments, based on the characteristics of frozen dough development, was chosen for this experiment. The formula is presented in Table 4.

The baking procedure used in this experiment was as follows: The flour was added to the water-jacked Hobart Mixer A-200 with a constant water temperature of 50°F (10°C) and mixed dry. The surfactants were suspended in 100 ml water at 130°F (54.7°C) and added to the flour. The remaining ingredients except yeast and the rest of the water (60°F , 15.6°C) were added. These ingredients were mixed at low speed (No.1) for 30 sec; yeast was then added and the ingredients were mixed for an additional 30 sec. The mixing speed was then changed to medium (No.2) and the ingredients mixed until optimum dough development was attained. The dough temperature immediately after the dough was mixed was 68±2°F (20±1°C). The dough was then divided into 125 gram pieces. The scaled dough was then rounded and moulded.

Table 4. Basic Formula

Ingredient	Percent (Flour Basis)	Grams
Flour	100	1000
Water	Optimum	-
Yeast, Instant ADY	2.2	22
Salt	1.5	15
Dextrose	7.8	78
Whey	4.0	40
Yeast Food	0.2	2
Nondiastatic malt	0.5	5
Shortening (Primex)	4.0	40

For control samples from fresh dough, the moulded dough pieces were proofed to 1.5 cm above the pan at 100^{o}F (37.8^{o}C) and 95% relative humidity. The proofed dough pieces were then baked at 425^{o}F (218^{o}C) for 14 minutes.

The dough to be frozen was placed into the baking pan with the size of 6 X 3.5 X 2.2 inches (15.2 X 8.9 X 5.6 cm). After the freezing was completed at 0^{o}F (-18^{o}C), the doughs were transferred to a storage freezer, also at 0^{o}F (-18^{o}C). The doughs were wrapped in polyethylene bags and stored for 4, 8, and 16 week periods. At the end of each time period, frozen dough samples were taken out, proofed and baked as previously described.

C. Bread quality evaluation. Bread volumes were measured immediately after baking by rapeseed displacement and weights were measured for determination of specific volume.

The quality of the structure and texture of the inside of a loaf of bread is subjectively quantified and called "grain". Scores on grain were conducted by visual judgment. The bread samples were cut two hours after baking and the grain was scored from 1 (very poor) to 10 (excellent) points.

Crumb firmness of the sliced bread was measured 2 hours after baking. A one-inch thick middle slice of the bread was tested for firmness on the Voland-Stevens-LFRA Texture analyser (Voland Corp. Hawthorne, N.Y.).

D. Reproducibility. Every treatment studied was replicated twice. Six loaves were prepared per each dough period.

E. Experimental design. Four separate experiments were designed and conducted. The first experiment was to study the effects of oxidizing agents on frozen dough quality. Oxidants studied were ascorbic acid, potassium bromate and azodicarbonamide. The objective of this experiment was to find combination of these three oxidants which would produce the best quality frozen bread and to detect possible interactions among the oxidants.

The technique of Response Surface Methodology (RSM) was used. RSM was initially developed by Box and Wilson (1951). RSM is an experimental technique which helps to determine combinations of the design factors which will optimize a response varible. This technique involves modelling dependent variables, such as specific volume or grain texture, as quadratic functions of the design factors.

An optimum (centrally rotatabic response surface) design for three design factors is presented in Table 5 in coded values. Table 6 shows the variables and their levels in uncoded values.

Dependent variables were used as input data (Y) and modelled by

$$Y = B_0 + B1X1 + B2X2 + B3X3 + B11X1^2 + B22X2^2 + B33X3^2 + B_{12}X1X2 + B13X1X3 + B23X2X3 + \varepsilon$$

Table 5. Response Surface Methodology Design for Three Variables at Five Levels

Number	Variable		
	X_1*	X_2*	X_3*
1	-1	-1	-1
2	1	-1	-1
3	-1	1	-1
4	1	1	-1
5	-1	-1	1
6	1	-1	1
7	-1	1	1
8	1	1	1
9	-1.682	0	0
10	1.682	0	0
11	0	-1.682	0
12	0	1.682	0
13	0	0	-1.682
14	0	0	1.682
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0

* Refer to Table 6 .

Table 6. Oxidizing Agents and Their Levels in ppm for RSM Study

Oxidizing Agent	Symbol	Code				
		-1.682	-1	0	1	1.682
Ascorbic Acid (ASAD)	X_1	0	20.27	50.0	79.73	100
Potassium Bromate (BR)	X_2	0	15.21	37.5	59.79	75
Azodicarbonamide (ADA)	X_3	0	9.12	22.5	35.88	45

The computer program SAS-RSREG was used to estimate the coefficients of the quadratic regression model defined above.

In order to find the best combination the three oxidants, three dimensional graphic plots can be used. A series of contour lines for two variables could be drawn holding other variables constant.

A second experiment studied the effects of two commercial surfactants or dough strengtheners, SSL and Xpando (50:50 Ethoxylated mono-diglycerides and mono-diglycerides), on frozen dough bread qualities, especially on crumb firmness. Five different levels of each of these two dough strengtheners, namely 0.000, 0.125, 0.250, 0.375 and 0.500 percent, were combined with the restriction that the total amount could not exceed 0.500 percent. Fifteen combinations were tested. The quadratic RSM described previously was also used in this experiment.

The third experiment studied the effects of the added protein from vital wheat gluten on frozen dough bread quality. Bread was produced from frozen dough prepared with a low protein (9.1%) flour. Two levels of vital wheat gluten, 4 percent and 8 percent, were added to the flour to increase the protein level of the flour to 12 and 14 percents based on the laboratory analysis of the vital wheat gluten. The results were compared to those obtained without adding gluten.

Analysis of variance and multiple comparisons using the least significant difference (LSD) procedure described by Snedecor and Cochran (1980) were used to determine the significance of the differences between various treatments. This test was also performs on the computer by using SAS.

In a fourth experiment, six different protein levels of hard red winter and hard red spring wheat flours were used. The purpose of this experiment was to investigate the effect of flour quality on frozen dough bread characteristics. Correlation coefficients and their significance levels were computed using SAS-GLM.

RESULTS AND DISCUSSION

Preliminary experiments were conducted to determine an optimum basic formula for frozen bread dough (Table4) and procedures for this study.

Effects of Oxidant on Quality of Frozen Dough Bread

Three commonly used oxidizing agents, potassium bromate (BR), ascorbic acid (ASAD) and azodicarbonamide (ADA) were used in this study. Although potassium iodate is still utilized by industry, it was excluded from this study because many unfavorable iodate effects have been reported (AIB 1967, Ponte 1971).

Response surface methodology (RSM) was used to study these factors. This technique reduced the experimental work required to examine the effect of several processing conditions on a given response. The response surface equation and corresponding contour plots permitted the investigator to quickly locate the optimum solution to a problem and verify the predicted solution experimentally.

The response surface design (Cochran and Cox, 1957) used in this experiment required only 20 combinations. The highest level of oxidants used are according to FDA Regulations. The combinations, discussed above, were done in a random order. Two replications of the 20 combinations were mixed. From each batch, twelve pieces of dough were scaled. During each period of storage, three pieces of dough were removed, proofed and baked. The data from the three loaves were averaged. Statistical analysis was done with Statistical Analysis System (SAS) computer software.

Specific Volume Bakers prefer a high specific volume since it is an indicator of high quality bread. Response surface equations for specific volume are shown in Table 7. These equations were used to locate the best combinations and levels of these three oxidants to give a maximum specific volume when possible. Sometimes statistically predicted optimum levels included negative levels for some oxidants (an impossibility), and levels that were higher than those used in the experiments. Therefore, three dimensional graphs were drawn using response surface equations. From these plots, optimum levels of oxidants were selected. Generally, specific volume decreased with longer frozen storage.

The effect of bromate and ADA on specific volume for different periods of frozen storage can be seen for Figures 2, 3, 4, and 5. The specific volume was increased by raising the bromate level up to 75 ppm. The specific volume was increased by raising the ADA level up to 45 ppm. The improving effect of ADA was very small for the fresh dough (Fig. 2). However, after a period of frozen storage, ADA increased specific volume; after 4 weeks and 8 weeks, bromate was better than ADA, but after 16 weeks, bromate and ADA were about the same. Therefore, it seems that ADA,as a single oxidant, shows more tolerance during frozen

TABLE 7. Specific Volume Response Surface for Different Periods of Frozen Storage.

Storage Weeks	Response Surface
0	$SPVOL^{1} = 7.1426 + 0.0056\ X_1 + 0.0206\ X_2 + 0.0120\ X_3 - 0.0002\ X_1X_2 - 0.0001\ X_1X_3 - 0.0002\ X_2X_3 + 0.0002\ X_3^2$
4	$SPVOL = 6.4545 + 0.0217\ X_1 + 0.0258\ X_2 + 0.0326\ X_3 - 0.0001\ X_1X_2 - 0.0001\ X_2^2 - 0.0005\ X_1X_3 - 0.0002\ X_2X_3 - 0.0003\ X_3^2$
8	$SPVOL = 6.0857 + 0.0203\ X_1 + 0.0287X_2 + 0.0469X_3 - 0.0002\ X_1X_2 - 0.0003\ X_1X_3 - 0.0003\ X_2X_3 - 0.0005\ X_3^2$
16	$SPVOL = 5.8376 + 0.0224\ X_1 + 0.0253\ X_2 + 0.0506\ X_3 - 0.0001\ X_1X_2 - 0.0004\ X_1X_3 - 0.0004\ X_3^2 - 0.0004\ X_2X_3$

[1]SPVOL = Specific Volume

X_1 = Ascorbic Acid

X_2 = Bromate

X_3 = ADA

Fig. 2 Effect of Bromate and Azodicarbonamide (ADA) on Specific Volume with No Frozen Storage.

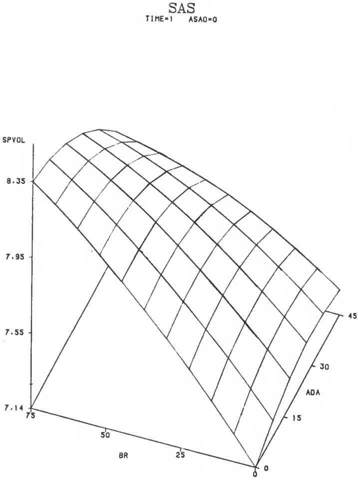

SAS
TIME=1 ASAO=0
SPVOL
8.35
7.95
7.55
7.14
75
50
25
0
BR
0
15
30
45
ADA

Fig. 3. Effect of Bromate and ADA on Specific Volume with 4 Weeks Frozen Storage.

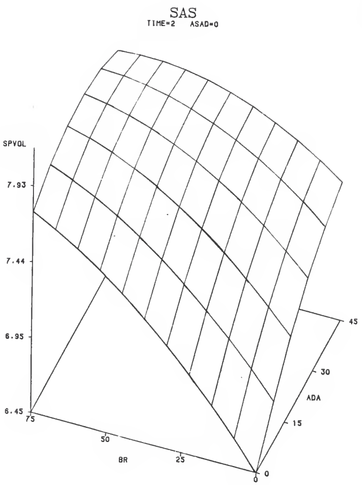

SAS
TIME=2 ASAD=0
SPVOL
7.93
7.44
6.95
6.45
75
50
BR
25
0
0
15
ADA
30
45

Fig. 4. Effect of Bromate and ADA on Specific Volume with 8 weeks Frozen Storage.

SAS
TIME=3 ASAO=0

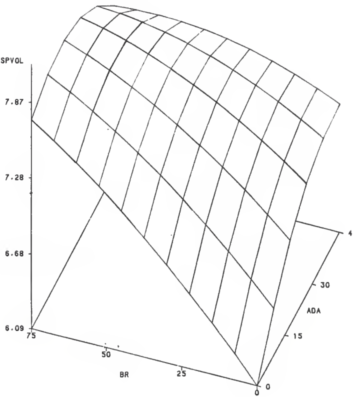
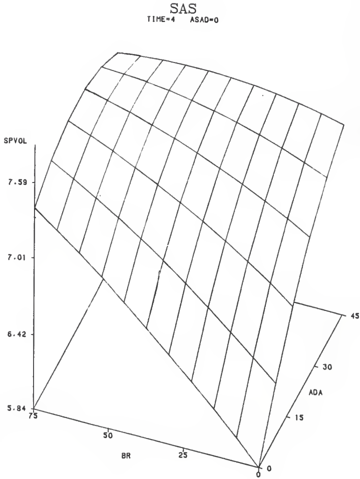


Fig. 5. Effect of Bromate and ADA on Specific Volume with 16 Weeks Frozen Storage.


SAS
TIME=4 ASAD=0
SPVOL
7.59
7.01
6.42
5.84
75
50
25
0
BR
0
15
30
45
ADA

storage, although the specific volume is not high enough.

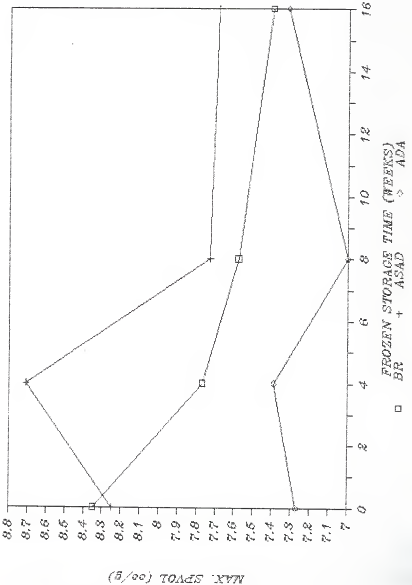
The effect of ADA on specific volume, with or without frozen storage, was generally less than that of ascorbic acid or that of bromate (Fig. 6).

When the levels of ascorbic acid and bromate were relatively high , that is, when the dough reached a certain amount of oxidation, ADA exerted a deleterious effect on specific volume. Fig. 7 shows a typical example of this kind of phenomenon.

Both bromate and ascorbic acid were quite effective in improving specific volume (Fig. 8, 9, 10, and 11). Compared to bromate, ascorbic acid was a little more effective except for the fresh dough, in which the largest volume was obtained with 75 ppm bromate (Fig. 8).

In fresh dough, with the bromate level set at 75 ppm, specific volume decreased at first, then tended to be stable with increments of ascorbic acid (Fig. 8). Same trend also shows in frozen storage for 4, 8, and 16 weeks (Fig. 9, 10, and 11). This is in agreement with Tsen (1965), who concluded that ascorbic acid is resistant to over-oxidation. Figure 8 also shows that at highlevels of ascorbic acid, the bread maintained a relatively high level of specific volume throughout the range of bromate addition (0 to 75 ppm). This is probably also due to the resistance of ascorbic acid to over-oxidation. However, when ADA level was over about 18 ppm, this phenomenon was not observed (Fig. 2). The combination of ascorbic acid and bromate showed addition effect on the specific volume.

Fig. 6. Specific Volumes with Single Oxidants at Their Maximum levels.



MAX. SPVOL (cc/g)
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
0
2
4
6
8
10
12
14
16
FROZEN STORAGE TIME (WEEKS)
□ BR + ASAD ◇ ADA

Fig. 7. Effect of ADA on Specific Volume.

SAS
TIME=2 ASAD=50

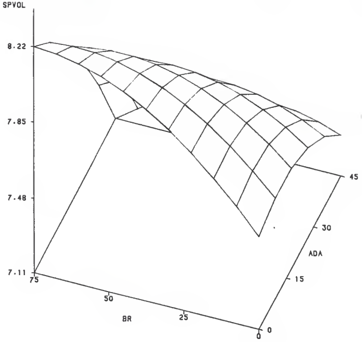
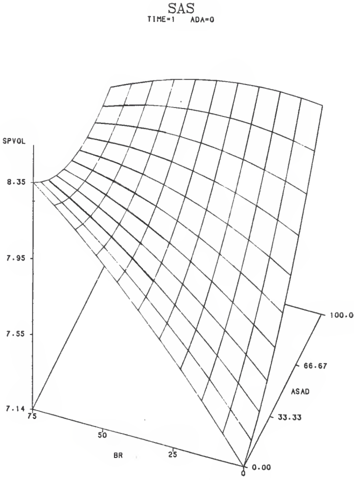


Fig. 8. Effect of Ascorbic Acid and Bromate on Specific Volume with No Frozen Storage.



SAS
TIME=1 ADA=0
SPVOL
8.35
7.95
7.55
7.14
75
50
BR
25
0
0.00
33.33
ASAD
66.67
100.00

Fig. 9. Effect of Ascorbic Acid and Bromate on Specific Volume with 4 Weeks Frozen Storage.

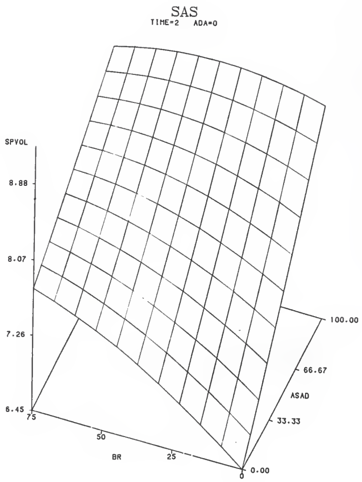

SAS
TIME=2 ADA=0
SPVOL
8.88
8.07
7.26
6.45
75
50
25
0
BR
0.00
33.33
66.67
100.00
ASAD

Fig.10. Effect of Ascorbic Acid and Bromate on Specific Volume with 8 Weeks Frozen Storage.

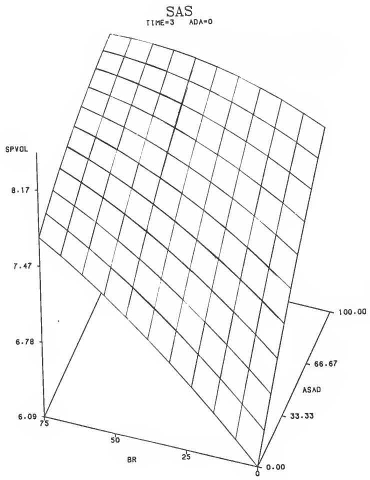
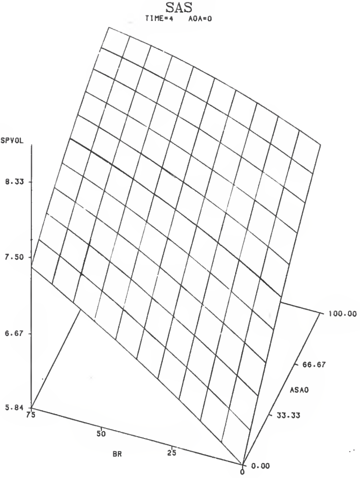

SAS
TIME=3 ADA=0
SPVOL
8.17
7.47
6.78
6.09
75
50
25
0
BR
100.00
66.67
ASAD
33.33
0.00

Fig.11. Effect of Ascorbic Acid and Bromate on Specific Volume with 16 Weeks Frozen Storage.


SAS
TIME=4 AOA=0
SPVOL
8.33
7.50
6.67
5.84
75
50
BR
25
0
100.00
66.67
ASAO
33.33
0.00

Grain The response surface for grain score is shown in Table 8. These equations did not satisfy the conditions for producing the true maximum. Therefore, a series of three dimensional graphic plots were used to locate the maximum points in the region covered by the experiment.

Grain score showed a trend very similar to specific volume (Fig. 12, 13, 14, and 15). High grain scores were generally accompanied by large specific volume, although the exact combination of oxidants that yielded maximum scores were not always the same as that for maximum specific volume. Fig. 16 shows grain scores with single oxidants at their maximum levels. All three oxidants showed the same behavior in grain as they showed in terms of specific volume, both singly and in combination. The highest grain scores were obtained with 100 ppm ascorbic acid, no ADA, and different levels of bromate for different periods of frozen storage.

Optimum Combination of Oxidants Table 9 shows the maximum specific volumes and maximum grain scores of bread and the combination of oxidants with which those maximum values were obtained. The of oxidants for maximum specific volume were not always the same as those for maximum grain score. Therefore, the optimum levels of oxidants, in which both satisfactory specific volume and satisfactory grain score can be obtained, were selected, as shown in Table 10 and Figure 17.

Frozen Storage Period Figure 17 shows that the best bread was obtained from the dough that had been frozen for four weeks.

TABLE 8. Grain Response Surface for Different Periods of Frozen Storage.

Storage Weeks	Response Surface[1]
0	Grain = 7.3469 + 0.0004 X_1 + 0.0180 X_2 − 0.0047 X_3 + 0.0001 X_1^2 − 0.0001 X_1X_2 − 0.0002 X_1X_3 − 0.0001 X_2X_3
4	Grain = 5.6506 + 0.0392 X_1 + 0.0389 X_2 + 0.0450 X_3 − 0.0003 X_1X_2 − 0.0002 X_2 − 0.0007X_1X_3 + 0.0001 X_2X_3 − 0.0006 X_3^2
8	Grain = 5.6983 + 0.0163X_1 +0.0258 X_2 + 0.044X_3 − 0.003 X_1X_3 − 0.0005 X_2X_3 − 0.0005 X_3^2
16	Grain = 5.4365 + 0.0093 X_1 + 0.0154 X_2 + 0.0353 X_3 − 0.0001 X_1X_2 − 0.0002 X_1X_3 − 0.0005 X_2X_3 − 0.0001 X_3^2

[1]X_1 = Ascorbic Acid

X_2 = Bromate

X_3 = ADA

Fig.12. Effect of Ascorbic Acid and Bromate on Grain with No Frozen Storage.

SAS
TIME=1 ADA=0

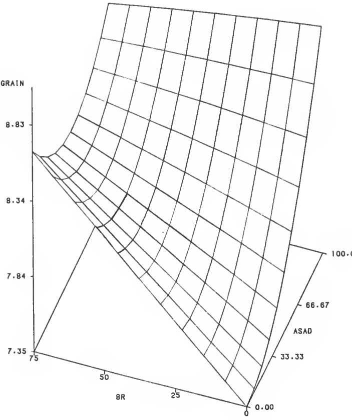


Fig.13. Effect of Ascorbic Acid and Bromate on Grain with 4 Weeks Frozen Storage.

SAS

TIME=2 ADA=0

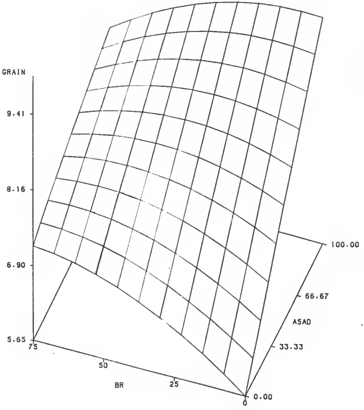


Fig.14. Effect of Ascorbic Acid and Bromate on Grain with 8 Weeks Frozen Storage.

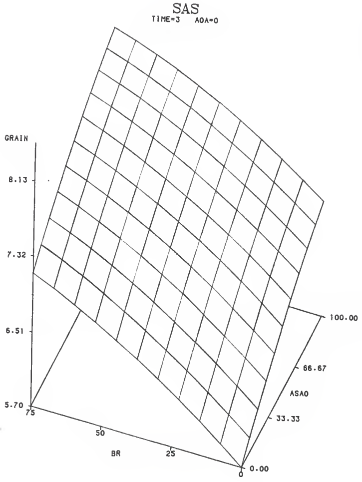

SAS
TIME=3 AOA=0
GRAIN
8.13
7.32
6.51
5.70
75
50
25
0
BR
100.00
66.67
ASAO
33.33
0.00

Fig.15. Effect of Ascorbic Acid and Bromate on Grain with 16 Weeks Frozen Storage.

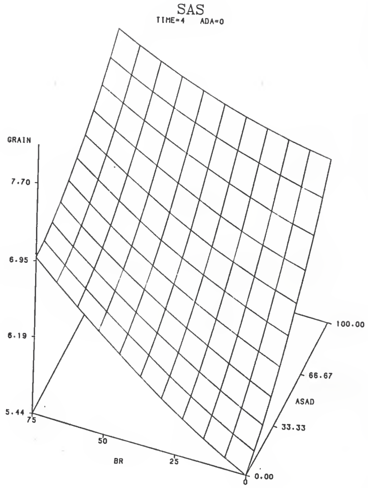

SAS
TIME=4 ADA=0
GRAIN
7.70
6.95
6.19
5.44
75
50
BR
25
0
0.00
33.33
ASAD
66.67
100.00

Fig. 16. Grain Scores with Single Oxidants at Their Maximum Levels.

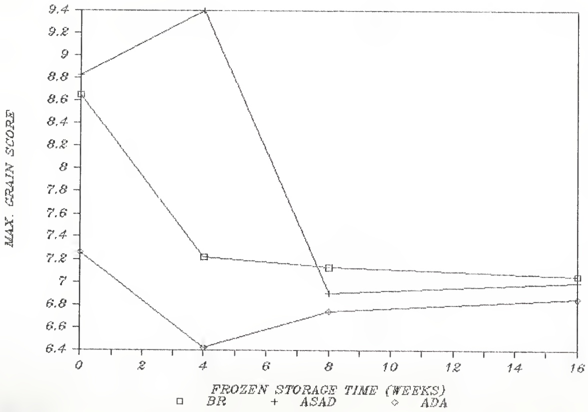

MAX. GRAIN SCORE
9.4
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
0
2
4
6
8
10
12
14
16
FROZEN STORAGE TIME (WEEKS)
BR
ASAD
ADA

TABLE 9. Maximum Specific Volume and Grain from the Oxidant Combinations.

Frozen Storage Time (Weeks)	Maximum SPVOL (cc/g)	Oxidant Combination ASAD (ppm)	Oxidant Combination BR (ppm)	Maximum GRAIN	Oxidant Combination ASAD (ppm)	Oxidant Combination BR (ppm)
0	8.35	0	75	8.83	100	0
4	8.88	100	37.5	9.41	100	25
8	8.17	100	67.5	8.13	100	75
16	8.33	100	75	7.70	100	75

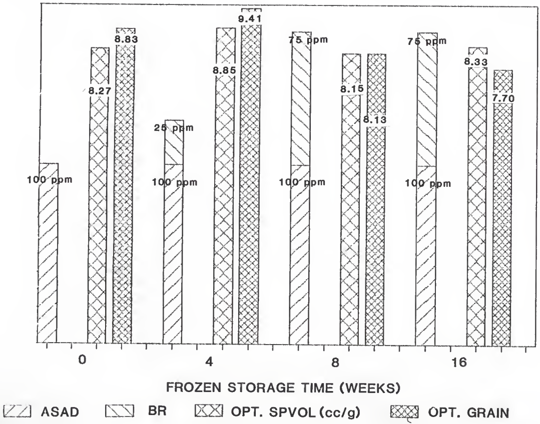
Similar research results were reported earlier (Lehmann and Dreese 1981). It is not known why 4 weeks of frozen storage improved the quality. The grain scores decreased with prolonged frozen storage after four weeks. The specific volume decreased between four weeks and eight weeks, but increased slightly between eight weeks and sixteen weeks. It was also shown that with a longer storage period, a higher level of oxidizing agent was required.

In summary, ascorbic acid and bromate, when used singly or in combination with each other, were effective in this experiment. Ascorbic acid was resistant to over-oxidation. ADA as a single oxidizing agent had some improving effects on frozen dough bread quality; however, when combined with relatively high levels of ASAD and BR the results were unfavorable. The effects of these oxidants on the specific volume generally coincided with the effects on grain score. The best combination of oxidants used in fresh bread was 100 ppm ascorbic acid and no bromate added. After frozen storage for 4 weeks, 100 ppm ascorbic acid and 25 ppm bromate showed the best result. Ascorbic acid at 100 ppm and bromate at 75 ppm were the best combination for frozen storage of 8 and 16 weeks. To obtain good results from frozen dough during these prolonged storage time, these higher levels of oxidizing agents were required.

TABLE 10. Optimum Levels of Oxidants for Specific Volume and Grain.

Frozen Storage Time (Weeks)	ASAD (ppm)	BR (ppm)	Specific Volume (cc/g)	Grain
0	100	0	8.27	8.83
4	100	25	8.85	9.41
8	100	75	8.15	8.13
16	100	75	8.33	7.70

Fig. 17. Optimum Combinations of Oxidants for Specific Volume and Grain.



100 ppm
8.27
8.83
25 ppm
100 ppm
8.85
9.41
75 ppm
100 ppm
8.15
8.13
75 ppm
100 ppm
8.33
7.70
0
4
8
16
FROZEN STORAGE TIME (WEEKS)
ASAD
BR
OPT. SPVOL (cc/g)
OPT. GRAIN

Effects of Dough Strengtheners

Dough strengtheners have been used widely in the baking industry in the United States. It has been reported by several workers that dough strengtheners increase the stability of frozen dough (Davis 1981, Marston 1978). Davis (1981) concluded that sodium stearoyl 2-lactylate (SSL) is the most effective additive for maintaining product volume and softness for those doughs that must undergo long term frozen storage.

SSL and Xpando (EMG/MG, ethoxylated mono-diglycerides together with mono-diglycerides) were investigated to determine their effects on the qualities of frozen dough. For this experiment, the original bread formula was modified by adding the combination of oxidants that had given the best results after four weeks of frozen storage. A response surface methodology experimental design was used to compare the two dough strengtheners at five levels. Fifteen combinations were tested in duplicate. The total weight of the strengtheners did not exceed the 0.5 percent (flour weight basis) limit set by FDA.

Specific Volume The response surface for specific volume are listed in Table 11. These equations specify plots defining oval contours, indicating interaction between SSL and EMG/MG. However, for maximum specific volume, these equations specified strengthener levels higher than 0.5 percent, the maximum shown on the plot. Therefore, several contour plots were drawn in the region covered by the experiment. Figures 18, 19, 20 and 21 show specific volume contour plots for different periods of

TABLE 11. Specific Volume Response Surface for Different Periods of Frozen Storage.

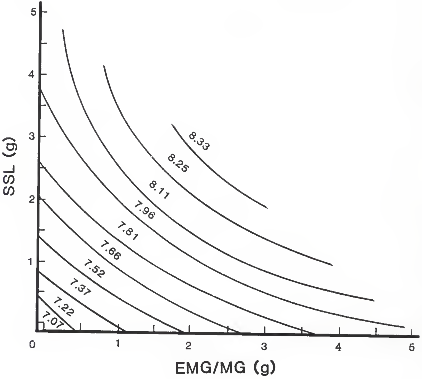
Storage Weeks	Response Surface[1]
0	$SPVOL = 7.0017 + 0.2634\ X_1 + 0.3392\ X_2 - 0.0197X_1^2 + 0.02262\ X_1X_2 - 0.0320\ X_2^2$
4	$SPVOL = 6.8861 + 0.2523X_1 - 0.9095\ X_2 - 0.0594X_1^2 + 0.0278\ X_1X_2 - 0.0239\ X_2^2$
8	$SPVOL = 6.6624 + 0.2900X_1 + 0.3487\ X_2 - 0.0227X_1^2 + 0.0143\ X_1X_2 - 0.0303\ X_2^2$
16	$SPVOL = 6.5170 + 0.2738\ X_1 + 0.2777\ X_2 - 0.0215X_1^2 + 0.0310\ X_1X_2 - 0.0159\ X_2^2$

[1]SPVOL = Specific Volume

X_1 = EMG/MG

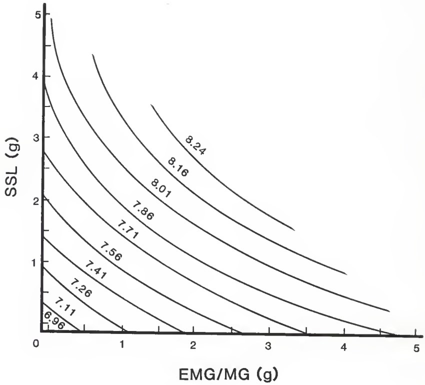
X_2 = SSL

Fig. 18. Contour Plot of Specific Volume (cc/g) of Fresh Dough Bread (Never Frozen) Affected by Sodium Stearoyl 2-lactylate (SSL) and Ethoxylated Mono-Diglycerides and Mono-diglycerides (EMG/MG) (g per 100 g flour).



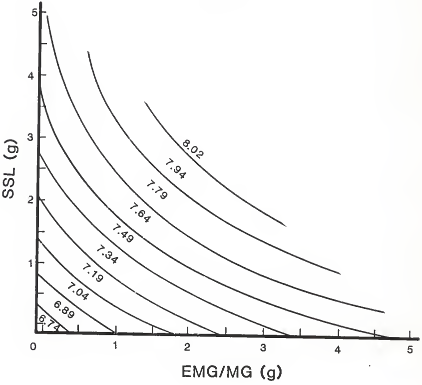
SSL (g)
EMG/MG (g)
0
1
2
3
4
5
8.33
8.25
8.11
7.96
7.81
7.66
7.52
7.37
7.22
7.07

Fig.19. Contour Plot of Specific Volume (cc/g) of Frozen Dough Bread After Frozen Storage for 4 Weeks Affected by SSL and EMG/MG (g per 100 g flour).



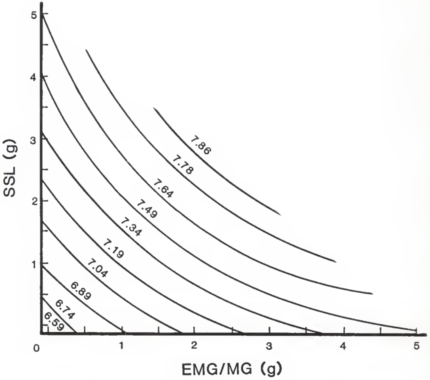
SSL (g)
EMG/MG (g)
0
1
2
3
4
5
6.96
7.11
7.26
7.41
7.56
7.71
7.86
8.01
8.16
8.24

Fig.20. Contour Plot of Specific Volume (cc/g) of Frozen Dough Bread After Frozen Storage for 8 Weeks Affected by SSL and EMG/Mg (g per 100 g flour).



SSL (g)
5
4
3
2
1
0
1
2
3
4
5
EMG/MG (g)
8.02
7.94
7.79
7.64
7.49
7.34
7.19
7.04
6.89
6.74

Fig.21. Contour Plot of Specific Volume (cc/g) of Frozen Dough Bread After Frozen Storage for 16 Weeks Affected by SSL and EMG/MG (g per 100 g flour).


SSL (g)
0
1
2
3
4
5
EMG/MG (g)
6.59
6.74
6.89
7.04
7.19
7.34
7.49
7.64
7.78
7.86

frozen storage. Figure 18 shows the effect of SSL and EMG/MG on specific volume of bread from fresh doughs (never frozen). The highest specific volume range was shown when using the combination of 0.18% to 0.3% EMG/MG and 0.2% to 0.3% of SSL. Figures 19, 20, and 21 show similar trends in specific volume for these three storage periods. The specific volume decreased with prolonged frozen storage time (Fig. 22).

Grain The response surface equations for grain texture is shown in Table 12. Figures 23,24, 25 and 26 show the effects of SSL and EMG/MG for different periods of frozen storage. These contour plots helped to locate the true maximum points. After four weeks of frozen storage, the best grain score was predicted to have come from adding 0.16%-0.29% EMG/MG together with 0.2%-0.33% SSL to the formula. The grain score gradually increased up to the maximum of 8.61. The relationship between these two dough strengtheners was shown very clearly in these contour plots. As frozen storage time increased, the grain quality decreased; linear regression between storage time and maximum grain score was near 1.00 (Fig. 22).

Firmness The response surface equations for crumb firmness are shown in Table 13. Contour plots from different frozen storage periods had similar patterns (Figures 27, 28, 29 and 30). After four weeks of frozen storage, 0.09% - 0.35% EMG/MG and 0.13% - 0.4% SSL provided the softest crumb. SSL appeared to be more effective than EMG/MG for maintaining crumb softness. The firmness readings increased with prolonged frozen storage period (Fig. 22).

Fig. 22. Specific Volume, Grain and Firmness of Frozen Dough Bread at Optimum SSL and EMG/MG Combinations.

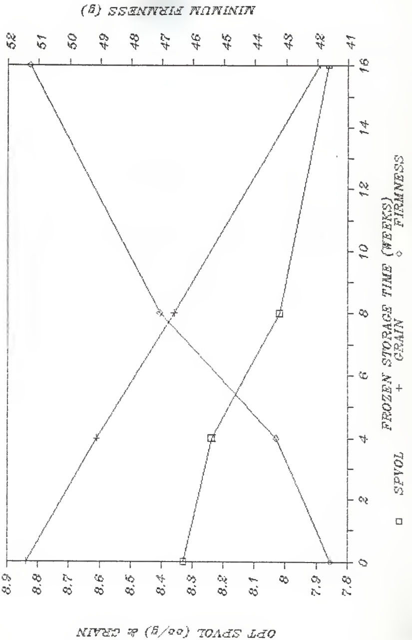

MINIMUM FIRMNESS (g)
52
51
50
49
48
47
46
45
44
43
42
41
OPT SPVOL (cc/g) & GRAIN
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
0
2
4
6
8
10
12
14
16
FROZEN STORAGE TIME (WEEKS)
□ SPVOL
+ GRAIN
◇ FIRMNESS

TABLE 12. Grain Score Response Surface for Different Periods of Frozen Storage.

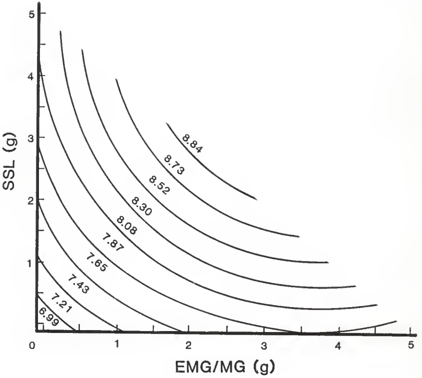
Storage Weeks	Response Surface[1]
0	$GRAIN = 6.8876 + 0.4304\ X_1 + 0.3876X_2 - 0.0594\ X_1^2 + 0.0777\ X_1X_2 - 0.0342\ X_2^2$
4	$GRAIN = 6.7610 + 0.3638\ X_1 + 0.3680\ X_2 - 0.0556\ X_1^2 + 0.0921\ X_1X_2 - 0.0361\ X_2^2$
8	$GRAIN = 6.4390 + 0.3433\ X_1 + 0.3652\ X_2 - 0.0537\ X_1^2 + 0.1097\ X_1X_2 - 0.0347\ X_2^2$
16	$GRAIN = 5.9908 + 0.4510\ X_1 + 0.5042\ X_2 - 0.0650\ X_1^2 + 0.0418\ X_1X_2 - 0.0566\ X_2^2$

[1]GRAIN = Grain Score

X_1 = EMG/MG

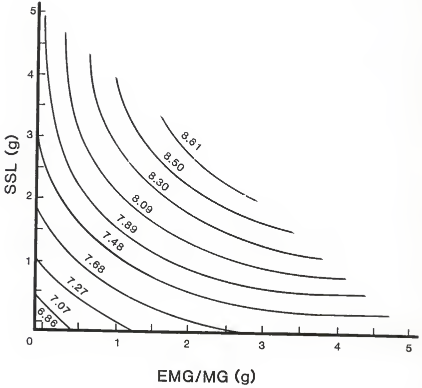
X_2 = SSL

Fig. 23. Contour Plot of Grain of Fresh Dough Bread (Never Frozen) Affected by SSL and EMG/MG (g per 100 g flour).



SSL (g)
EMG/MG (g)
0
1
2
3
4
5
8.84
8.73
8.52
8.30
8.08
7.87
7.65
7.43
7.21
6.99

Fig.24. Contour Plot of Grain of Frozen Dough Bread After Frozen Storage for 4 Weeks Affected by SSL and EMG/MG (g per 100 g flour).



SSL (g)
EMG/MG (g)
0
1
2
3
4
5
1
2
3
4
5
6.86
7.07
7.27
7.68
7.48
7.89
8.09
8.30
8.50
8.61

Fig. 25. Contour Plot of Grain of Frozen Dough Bread After Frozen Storage for 8 Weeks Affected by SSL and EMG/MG (g per 100 g flour).

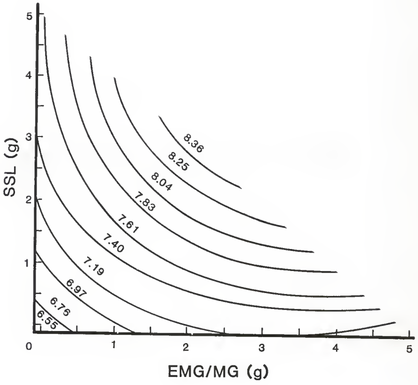
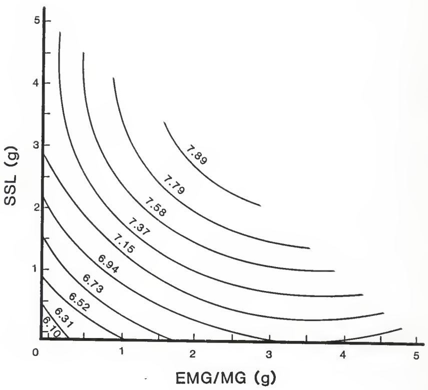

SSL (g)
EMG/MG (g)
0
1
2
3
4
5
1
2
3
4
5
8.36
8.25
8.04
7.83
7.61
7.40
7.19
6.97
6.76
6.55

Fig. 26. Contour Plot of Grain of Frozen Dough Bread After Frozen Storage for 16 Weeks Affected by SSL and EMG/MG (g per 100 g flour).



SSL (g)
EMG/MG (g)
0
1
2
3
4
5
7.89
7.79
7.58
7.37
7.15
6.94
6.73
6.52
6.31
6.10

TABLE13. Firmness Response Surface for Different Periods of Frozen Storage.

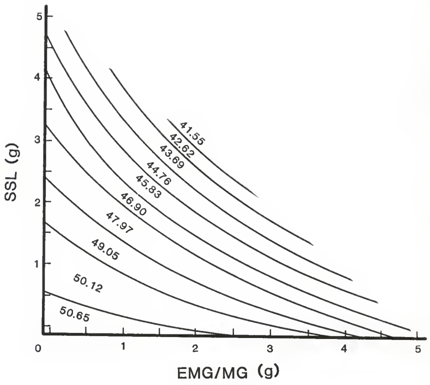
Storage Weeks	Response Surface[1]
0	$FN = 50.5333 + 0.3571\ X_1 - 0.9095\ X_2 - 0.2704\ X_1^2 - 0.9447\ X_1X_2 - 0.02396\ X_2^2$
4	$FN = 53.4524 + 0.2047\ X_1 - 1.0333\ X_2 - 0.2400\ X_1^2 - 1.0667\ X_1X_2 - 0.0723\ X_2^2$
8	$FN = 57.8238 - 0.1571\ X_1 - 2.2095\ X_2 - 0.1561\ X_1^2 - 0.7847\ X_1X_2 + 0.0990\ X_2^2$
16	$FN = 65.1348 - 1.1397\ X_1 - 3.4617\ X_2 + 0.0440\ X_1^2 - 0.7286\ X_1X_2 + 0.2466\ X_2^2$

[1]FN = Firmness

X_1 = EMG/MG

X_2 = SSL

Fig.27. Contour Plot of Firmness of Fresh DoughBread (Never Frozen) Affected by SSL and EMG/MG (g per 100 g flour).



SSL (g)
EMG/MG (g)
0
1
2
3
4
5
41.55
42.62
43.69
44.76
45.83
46.90
47.97
49.05
50.12
50.65

Fig. 28. Contour Plot of Firmness of Frozen Dough Bread After Frozen Storage for 4 Weeks Affected by SSL and EMG/MG (g per 100 g flour).

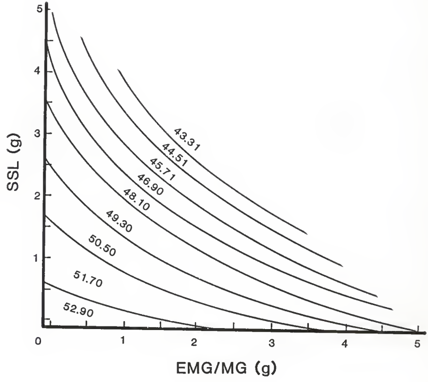

SSL (g)
EMG/MG (g)
0
1
2
3
4
5
43.31
44.51
45.71
46.90
48.10
49.30
50.50
51.70
52.90

Fig. 29. Contour Plot of Firmness of Frozen Dough Bread After Frozen Storage for 8 Weeks Affected by SSL and EMG/MG (g per 100 g flour).

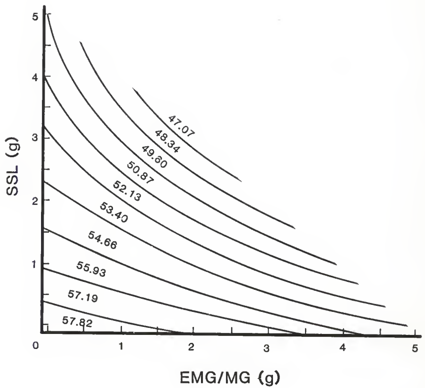
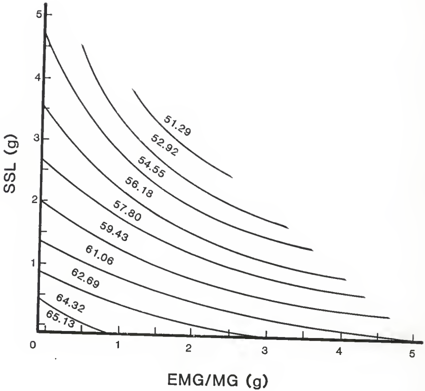

SSL (g)
EMG/MG (g)
0
1
2
3
4
5
47.07
48.34
49.60
50.87
52.13
53.40
54.66
55.93
57.19
57.82

Fig. 30. Contour Plot of Firmness of Frozen Dough Bread After Frozen Storage for 16 Weeks Affected by SSL and EMG/MG (g per 100 g flour).


SSL (g)
5
4
3
2
1
0
1
2
3
4
5
EMG/MG (g)
51.29
52.92
54.55
56.18
57.80
59.43
61.06
62.69
64.32
65.13

In summary, both of these two dough strengtheners (SSL and EMG/MG) had improving effects on specific volume , grain score and crumb firmness of frozen dough bread. For fresh dough and for frozen storage up to 16 weeks, the best combination of these two dough strengtheners was approximately 0.175% EMG/MG and 0.3% SSL. SSL was more effective than EMG/MG for maintaining specific volume, grain, and crumb firmness.

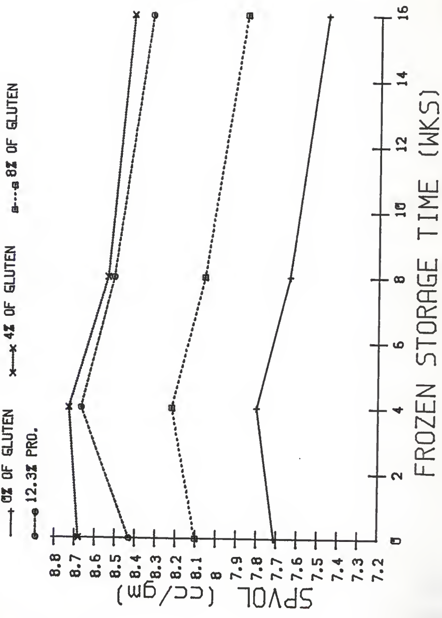
Effects of Gluten Addition

The effects of vital wheat gluten on the quality of frozen dough made from low protein (9.1%) flour were studied. Vital wheat gluten can be used to supplement and strengthen the natural flour protein.

In this study, mixing properties of the control flour were improved about equally by adding 4 or 8 % gluten (Fig. 1 and Table 6). However, baking properties were improved more by adding only 4 % gluten.

Specific Volume In Fig. 31 the 4% addition of gluten showed the largest specific volume after 16 weeks of frozen storage. Adding 8% gluten to the control KSU flour gave specific volume lower than expected. Apparently this relatively high gluten level provided more "strength", or adversely affected the ratio of dough elasticity to resistance to extension, than was optimum in this particular dough system. The curves with 0%, 4% and 8% gluten addition have very similar shapes, which indicates that the effect of frozen dough storage time on specific volume is virtually identical, with or without gluten addition. Fig. 32 also shows data obtained for a 12.3% protein HRW flour, to be further discussed in a subsequent section. These data show that the KSU flour with 4% gluten made bread with higher specific volumes than bread made with KSU flour and 4% gluten; the higher volumes were achieved thoughout the 16-week storage period, although the difference at 8 weeks was not statistically significant.

Fig. 31. Effect of Gluten Addition on Specific Volume of Frozen Dough Bread with Different Frozen Storage Period.


0% OF GLUTEN
4% OF GLUTEN
8% OF GLUTEN
12.3% PRO.
SPVOL (cc/gm)
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
0
2
4
6
8
10
12
14
16
FROZEN STORAGE TIME (WKS)

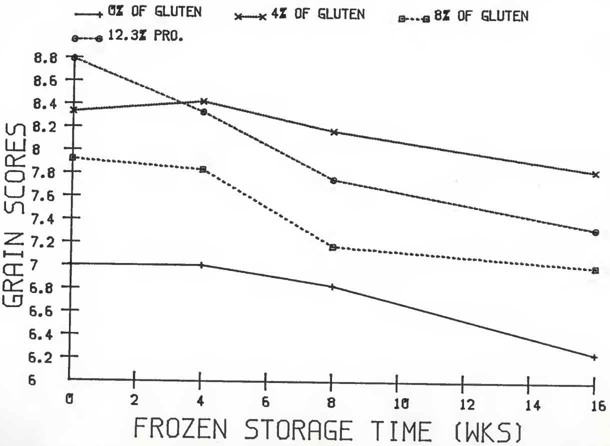
Grain Grain scores were influenced by the addition of gluten (Fig.32) in a manner similar to that shown by the specific volume data. However, the flour with 8% added gluten showed a shaper decline in grain between 4 weeks and 8 weeks of frozen storage. After the entire 16-week storage period, the 4% gluten treatment still showed acceptable internal grain characteristics (about 7.0).

Bread made with 12.3% protein HRW flour had a higher grain score at 0-week frozen storage (i.e. fresh bread), but at 4 weeks it was not statistically different than the bread made with ksu flour and 4% added gluten, and beyond this time quality of the 12.3% protein HRW flour bread was relatively lower. Thus, the weaker KSU flour bread with 4% gluten exhibited more tolerance in terms of grain score during storage compared to the stronger 12.3% protein HRW flour bread.

Firmness Figure 33 illustrates the firmness test results. Longer frozen storage periods resulted in higher firmness scores. The addition of 4% gluten to the control KSU flour produced the softest bread through out the entire frozen storage period. The addition of 8% gluten produced bread of intermediate softness. The effects of gluten on firmness may be at last partially explained on the basis of loaf volume; thus, the 8% gluten bread was firmer than the 4% gluten bread, in part because the former bread had less volume than the latter.

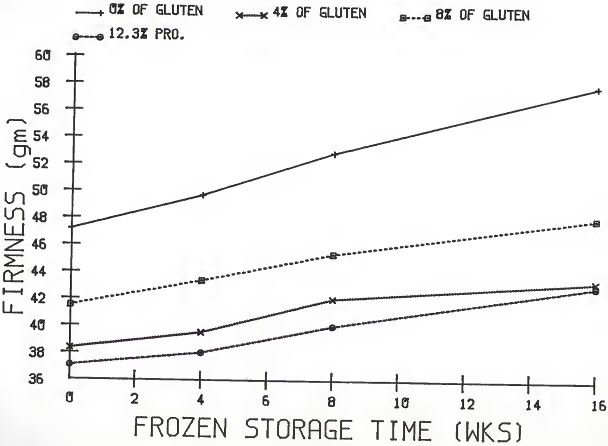
Bread made with the 12.3% protein HRW flour was the least firm bread during the period of frozen storage, except after 16 weeks, when the bread made with KSU flour and 4% gluten was

Fig. 32. Effect of Gluten Addition on Grain Score of Frozen Dough Bread with Different Frozen Storage Period.



0% OF GLUTEN
4% OF GLUTEN
8% OF GLUTEN
12.3% PRO.
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
GRAIN SCORES
0
2
4
6
8
10
12
14
16
FROZEN STORAGE TIME (WKS)

Fig. 33. Effect of Gluten Addition on Firmness of Frozen Dough Bread with Different Frozen Storage Period.



0% OF GLUTEN
4% OF GLUTEN
8% OF GLUTEN
12.3% PRO.
FIRMNESS (gm)
60
58
56
54
52
50
48
46
44
42
40
38
36
0
2
4
6
8
10
12
14
16
FROZEN STORAGE TIME (WKS)

slightly softer.

Table 14 shows that addition of gluten significantly (alpha=0.05) improved the specific volume, grain and softness of the frozen bread thoughout the frozen storage. However, there was no difference in grain between 0 and 8% gluten addition after 8 weeks of storage. Table 14 also indicates that the low protein (9.1%) flour with 4% added gluten yielded good quality bread, generally similar to that made with 12.3% protein HRW flour.

Vital wheat gluten was beneficial in bolstering the strength of a weak flour in making frozen dough. It improved the tolerance of the dough to processing and thereby improved the quality of the finished product. In this experiment, low protein flour when supplemented with sufficient vital wheat gluten (4%) gave frozen dough bread with acceptable quality.

TABLE 14. Gluten Addition as It Affected Specific Volume, Grain and Firmness[1].

Frozen Storage Weeks	Gluten Added (%)	Mean & Grouping[2] Specific Volume		Grain		Firmness	
	0	7.71	C	7.00	D	47.17	D
0	4	8.68	A	8.33	B	38.33	B
	8	8.10	D	7.92	C	41.50	C
	0[3]	8.43	B	8.79	A	37.08	A
	0	7.80	C	7.00	C	49.67	D
4	4	8.73	A	8.42	A	39.50	B
	8	8.22	B	7.83	B	43.33	C
	0[3]	8.67	A	8.33	A	38.00	A
	0	7.64	C	6.83	C	52.83	D
8	4	8.54	A	8.17	A	42.00	B
	8	8.06	B	7.17	C	45.33	C
	0[3]	8.51	A	7.75	B	40.00	A
	0	7.46	D	6.25	C	57.83	C
16	4	8.42	A	7.83	A	43.33	A
	8	7.86	C	7.00	B	48.00	B
	0[3]	8.33	B	7.33	B	43.00	A

[1]Alpha = 0.05.

[2]Grouping with the same letter compared vertically, by weeks are not significantly different.

[3]HRW flour, 12.3% protein.

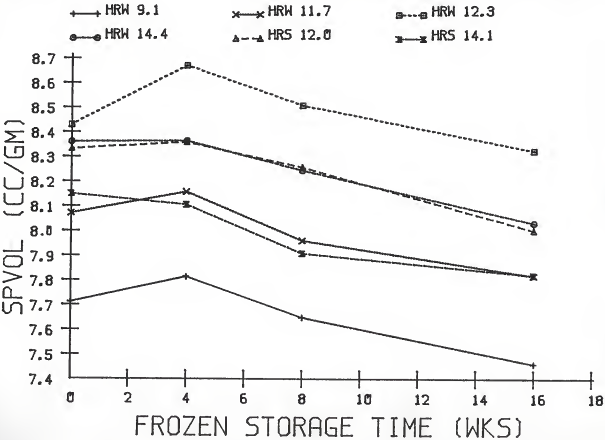
Effects of Flour Types

To study the effects of different flours on bread from frozen dough, six hard red wheats, with different protein contents wereused.

Specific Volume Figure 34 shows that four different levels of specific volume were seen ; from highest to lowest, the corresponding flours were : HRW 12.3; HRW 14.4 and HRS 12.0; HRW 11.7 and HRS 14.1; and HRW 9.1. Specific volume appeared to increase in some cases between 0 and 4 weeks of frozen storage. Table 15 summarizes the effect of flour types on specific volume (alpha = 0.05). For fresh baked bread, all six flours gave different specific volume. After 4 weeks of storage, no difference was observed between HRW 14.4 and HRS 12.0. However, there were differences between the other flours. After 8 weeks of storage, HRW 14.4 and HRS 12.0 again showed no difference , nor did HRW 11.7 and HRS 14.1; all other comparisons showed differences. After 16 weeks of storage, HRW 14.4 and HRS 12.0 again showed no difference in specific volume, nor did HRS 14.1 and HRW 11.7.

Grain Figure 35 shows that HRW 12.3 provided the best internal grain in every storage period. Both HRS 12.0 and HRW 14.4 produced fine grain, with HRS 12.0 having finer grain than HRW 14.4. The differences among the grain of HRS 14.1, HRW 11.7 and HRW 9.1 flours were small. Grain scores decreased with prolonged frozen storage because of the open grain and gummy feel of the crumb. Plate 1. shows the internal characteristics of the

Fig.34. Effect of Flour Types on Specific Volume of Bread from Frozen Dough.



HRW 9.1
HRW 11.7
HRW 12.3
HRW 14.4
HRS 12.0
HRS 14.1
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
SPVOL (CC/GM)
0
2
4
6
8
10
12
14
16
18
FROZEN STORAGE TIME (WKS)

TABLE15. Flour Types as It Affected Specific Volume1.

Frozen Storage Time (Weeks)	Flour Type	Specific Volume Mean (cc/g)	Grouping[2]
	HRW 12.3	8.43	A
	HRW 14.4	8.36	B
0	HRS 12.0	8.33	C
	HRS 14.1	8.15	D
	HRW 11.7	8.07	E
	HRW 9.1	7.71	F
	HRW 12.3	8.67	A
	HRW 14.4	8.37	B
4	HRS 12.0	8.36	B
	HRW 11.7	8.16	C
	HRS 14.1	8.11	D
	HRW 9.1	7.81	E
	HRW 12.3	8.51	A
	HRS 12.0	8.26	B
8	HRW 14.4	8.25	B
	HRW 11.7	7.96	C
	HRS 14.1	7.91	C
	HRW 9.1	7.65	D
	HRW 12.3	8.33	A
	HRW 14.4	8.03	B
16	HRS 12.0	8.00	B
	HRS 14.1	7.82	C
	HRW 11.7	7.81	C
	HRW 9.1	7.46	D

[1] Alpha = 0.05.

[2]Within each storage period,means with the same letter are not significantly different.

Fig.35. Effect of Flour Types on Grain scores of Bread from Frozen Dough.

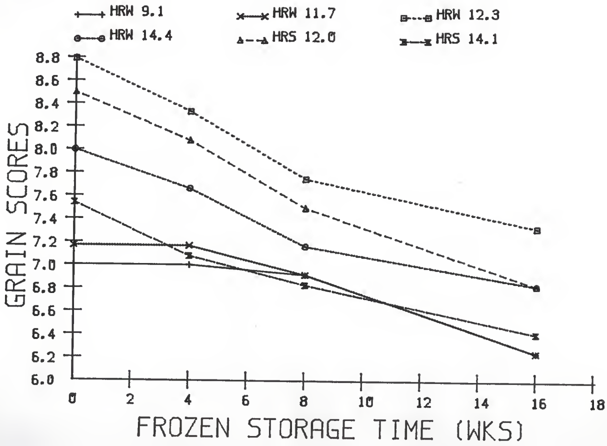
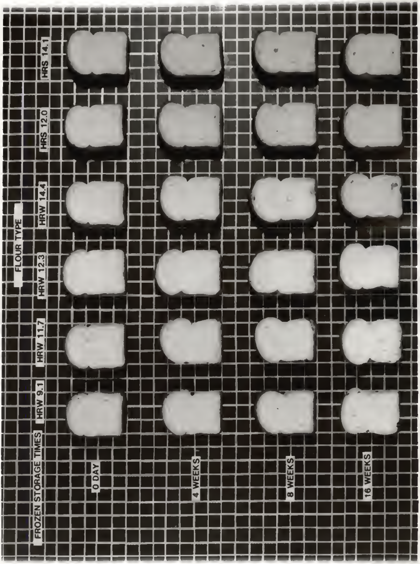

HRW 9.1
HRW 11.7
HRW 12.3
HRW 14.4
HRS 12.0
HRS 14.1
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0
GRAIN SCORES
0
2
4
6
8
10
12
14
16
18
FROZEN STORAGE TIME (WKS)

Plate 1. Internal Characteristics of Frozen Dough Bread Made with Different Flour Types.


FLOUR TYPE
HRW 9.1
HRW 11.7
HRW 12.3
HRW 14.4
HRS 12.0
HRS 14.1
FROZEN STORAGE TIMES
0 DAY
4 WEEKS
8 WEEKS
16 WEEKS

bread made from these flours after at different storage periods. Table 16 summarizes the effect of flour typeson grain. For fresh baked bread, there was no difference within these pairs: HRW 12.3 and HRS 12.0, HRW 14.4 and HRS 14.1, HRS 14.1 and HRW 11.7, and HRW 11.7 and HRW 9.1. However, there were differences between each pair. After storage for 4 weeks, HRW 11.7, HRS 14.1 and HRW 9.1 showed no difference in grain ; nor did HRW 12.3 and HRS 12.0. After 8 weeks of storage, HRW 14.4 , HRW 11.7, HRW 9.1 and HRS 14.1 had no significant difference in grain scores, nor did the other pairs (HRW 12.3 and HRS 12.0 ; HRS 12.0 and HRW 14.4). After storage for 16 weeks, there had difference in following groups : HRW 12.3; HRW 14.4 and HRS 12.0; and HRS 14.1, HRW 11.7 and HRW 9.1.

Firmness Different flours gave difference in crumb firmness as follows, in increasing order of firmness : HRW 12.3, HRS 12.0, HRW 14.4, HRS 14.1, HRW 11.7 and HRW 9.1 (Fig. 36). The flours with the two lowest protein contents provided firmer crumb compared to flours with higher protein content. Two pairs of winter and spring wheats with similar protein content had similar effects on firmness. Table 17 shows the effect of flour types on crumb firmness. Significant differences were observed among six flours after frozen storage for 4 and 16 weeks. For no storage and frozen storage for 8 weeks, there were no difference within the following groups: HRW 12.3 and HRS 12.0; HRW 14.4 and HRS 14.1; HRW 11.7; and HRW 9.1.

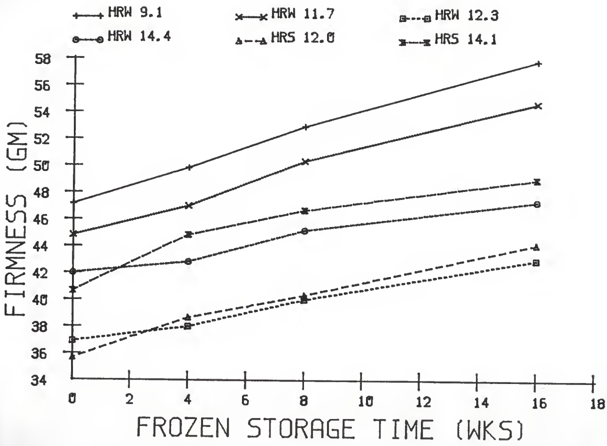
TABLE 16. Flour Types as It Affected Grain[1].

Frozen Storage Time (Weeks)	Flour Type	Grain Score Mean	Grouping[2]
0	HRW 12.3	8.79	A
	HRS 12.0	8.50	A
	HRW 14.4	8.00	B
	HRS 14.1	7.54	B C
	HRW 11.7	7.17	D C
	HRW 9.1	7.00	D
4	HRW 12.3	8.33	A
	HRS 12.0	8.08	A
	HRW 14.4	7.67	B
	HRW 11.7	7.17	C
	HRS 14.1	7.08	C
	HRW 9.1	7.00	C
8	HRW 12.3	7.75	A
	HRS 12.0	7.50	A B
	HRW 14.4	7.17	C B
	HRW 11.7	6.92	C
	HRW 9.1	6.92	C
	HRS 14.1	6.83	C
16	HRW 12.3	7.33	A
	HRW 14.4	6.83	B
	HRS 12.0	6.83	B
	HRS 14.1	6.42	C
	HRW 11.7	6.25	C
	HRW 9.1	6.25	C

[1]Alpha = 0.05.

[2]Within each storage period means with the same letter are not significantly different.

Fig.36. Effect of Flour Types on Firmness of Bread from Frozen Dough.



HRW 9.1
HRW 14.4
HRW 11.7
HRS 12.0
HRW 12.3
HRS 14.1
FIRMNESS (GM)
58
56
54
52
50
48
46
44
42
40
38
36
34
0
2
4
6
8
10
12
14
16
18
FROZEN STORAGE TIME (WKS)

TABLE 17. Flour Types as It Affected Firmness[1].

Frozen Storage Time (Weeks)	Flour Type	Firmness Mean	Grouping[2]
0	HRW 9.1	47.2	A
	HRW 11.7	44.8	B
	HRW 14.4	42.0	C
	HRS 14.1	40.7	C
	HRW 12.3	36.9	D
	HRS 12.0	35.7	D
4	HRW 9.1	49.8	A
	HRW 11.7	47.0	B
	HRS 14.1	44.8	C
	HRW 14.4	42.8	D
	HRS 12.0	38.7	E
	HRW 12.3	38.0	E
8	HRW 9.1	52.9	A
	HRW 11.7	50.3	B
	HRS 14.1	46.7	C
	HRW 14.4	45.2	C
	HRS 12.0	40.3	D
	HRW 12.3	40.0	D
16	HRW 9.1	57.8	A
	HRW 11.7	54.7	B
	HRS 14.1	49.0	C
	HRW 14.4	47.3	D
	HRS 12.0	44.2	E
	HRW 12.3	43.0	F

[1]Alpha = 0.05.

[2]Within each storage period, means with the same letter are not significantly different.

In summary, for good grain and firmness, 12 percent protein flours were better than 14 percent protein flours. The 9 percent protein flour produced inferior bread from frozen dough. There were no obvious differences between the spring and winter hard red wheats in making frozen dough bread..

CONCLUSIONS

The results are summarized as following :

1. Both ascorbic acid and bromate showed improving effects on specific volume and grain.
2. Azdicarbonamide (ADA) showed more tolerance for forzen storage compared with ascorbic acid and bromate.
3. The best oxidant system for various frozen dough storage times consisted of 100 ppm ascorbic acid with no ADA. The bromate levels in the best combinations, with 100 ppm ascorbic acid, for fresh bake , 4, 8, and 16 weeks frozen dough storage were 0, 25, 75, and 75 ppm, respectively. To produce satisfactory bread, with prolonged frozen dough storage, high levels of oxidizing agents were required.
4. Two dough strengtheners, sodium stearoyl-2-lactylate (SSL) and ethoxylated mono-diglycerides and diglycerides (EMG/MG), showed improving effects on specific volume, grain and crumb firmness of frozen dough bread.
5. The best combination of these dough strengtheners was approximately 0.175% EMG/MG and 0.3% SSL. SSLwas more effective than EMG/MG for maintaining specific volume, grain and crumb softness.
6. Vital wheat glutenexerted advantages in supporting the strength of a weak flour in making frozen dough.

7. The 4% vital wheat gluten provided enough strength for low protein flour (9.1%).
8. The 12% protein flours were better than the 14% protein flours in grain and firmness of frozen dough bread.
9. The 9.1% protein flour produced inferior bread.
10. There was no obvious difference between the spring and winter hard red wheats in making frozen dough bread.

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EFFECT OF INGREDIENTS ON THE QUALITY OF FROZEN DOUGH

by

MAY MEI-JIUN HUNG

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ABSTRACT

The relation of certain ingredients to the quality of bread baked from frozen dough during sixteen weeks storage was investigated by determining the optimum amount of these ingredients in frozen dough bread. These ingredients included oxidants, dough strengtheners, vital wheat gluten and flours of different protein contents. Response surface methodology and the multiple comparison least significant difference procedure were used; statistical analysis was obtained with a computer using the Statistical Analysis System (SAS) computer software.

Ascorbic acid and bromate, as a single oxidizing agent or combined with each other, were very effective in improving bread quality. Ascorbic acid showed resistance to over-oxidation. Azodicarbonamide (ADA) combined with relatively high levels of ascorbic acid and bromate was unfavorable, although ADA had some improving effects when utilized as a single oxidant. These oxidants were similarly effective on specific volume as they were on the grain score. The optimum combinations of oxidants were determined after different frozen dough storage periods. For fresh baked bread, 100 ppm ascorbic acid gave the best quality results. After frozen storage for 4 weeks, the best oxidant combination was 100 ppm ascorbic acid and 25 ppm bromate. For frozen storage for 8 weeks or up to 16 weeks, 100 ppm ascorbic acid and 75 ppm bromate were required. To obtain good results

from frozen dough during prolonged storage, higher levels of oxidizing agents were required.

In studing dough strengtheners, sodium stearoyl-2-lactylate (SSL) appeared to be more effective than ethoxylated mono-diglycerides and diglycerides (EMG/MG) for maintaining specific volume, grain and crumb softness. For fresh dough and doughs with frozen storage up to 16 weeks, the best combination of these two dough strengtheners was approximately 0.175% EMG/MG and 0.3% SSL.

Vital wheat gluten was shown beneficial in bolstering the strength of a weak flour in making frozen dough. In this experiment , low protein flour supplemented with 4% vital wheat gluten gave frozen dough bread of acceptable quality than compared favorably to bread made with higher protein (12.3%) flour.

Winter and spring wheat flours with different levels of protein content were used. The 12 % protein flours were better than the 14% protein flours in grain and firmness of bread. The 9% protein flour produced inferior bread. There was no obvious difference between the spring and winter hard red wheats in making frozen dough bread.