EFFECT OF DOUGH CONDITIONERS ON THE BREAD-MAKING QUALITIES OF SOFT WHEAT FLOUR

by

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Chapter I

Introduction

For centuries man has been grinding cereal kernels into the food known as flour. One of the most common grains used today for flour is wheat, first grown in the Middle East. Over centuries, its cultivation grew to include many different climates (Fox and Cameron, 1982). Wheat flour, a component of many different food items, may be of different types dependent upon the wheat grown. Flours vary in protein content, and different milling techniques also produce different types of flours.

Three species of wheats have been grown in the United States: *Triticum aestivum* (common wheat), *Triticum compactum* (club wheat), and Durum wheat. Although all three species are milled into flour, Durum wheat is used exclusively for macaroni products (Charley, 1982). Wheat is classified also according to the color of the kernel (red or white) and the planting season (spring or winter) (Campbell, 1972; Charley, 1982; Sultan, 1982). Winter wheats require mild winters and are generally grown in more temperate climates. Spring wheats are grown in areas with severe winters, such as the northern United States and Canada (Finney and Yamazaki, 1967). Spring wheats must mature quickly for harvesting in the late summer, prior to the first killing frosts in the fall.

The terms 'hard' and 'soft' are used to classify wheats. Hard wheats have hard endosperms, and are difficult to crack during milling (Campbell, 1972; Charley, 1982). Campbell (1972) indicated that since the hardness of the endosperm resulted from increased protein content, hard wheats can be classified as having higher protein levels than soft wheats. Sultan (1982) wrote that the two types of flour can be utilized differently. Hard wheat flours have been used for breads and other products requiring a firm structure, while soft wheat flours have been more suited to delicate products such as cakes, pastries, and cookies.

The wheat kernel is composed of several layers. There are several outer bran layers which protect the interior. The endosperm comprises the largest fraction of the kernel and contains starch and gluten-forming proteins. Fat is found in the germ portion of the kernel.

Different types of flours have been produced during milling by including or excluding various components of the grain (Charley, 1982). Whole wheat flour is made from the entire kernel, while white flour includes only the endosperm. Since individual kernels differ in their protein-to-starch ratio, milled flours have been separated by air classification (Charley, 1982). Controlled air flow has been used to separate flour particles by size and weight (heavier pieces will have higher amounts of protein). The particles with similar size and weight can be combined and packaged as one type of flour (for example, heavier flours can be classified as all-

purpose, lighter ones as cake flour). Campbell (1972) listed these protein contents for commonly used flours: whole wheat, 13.3%; all-purpose, 10.5%; and cake, 7.5%. Flour used for bread has varied from 15.5 to 12.5%, depending on the type of bread to be made (Lee, 1983).

Sultan (1982) provided an overview of the milling process. First, wheat is washed and tempered. Tempering involves moistening the wheat under controlled conditions until it has a standard moisture content. This process facilitates removal of the bran and endosperm portions. Wheat is then sent through corrugated rollers to be cracked. This fraction is known as break flour. Bran and endosperm particles are removed. The remainder, called middlings flour, is sent through smooth rollers to remove additional bran and endosperm particles. This step is repeated several times and results in 'straight flour'. Removed bran and endosperm portions can be used for animal feed and certain foods for human consumption. The best portion of the straight flour is then removed and called patent flour. The remainder is called clear flour. Various grades of clear flour are separated by sifting. Finer portions contain higher quality gluten than coarser particles.

Flour used in this experiment was milled from the Coker 916 variety of *Triticum aestivum* soft red winter wheat. Different fertilization schedules and amounts were applied during the growing season.

There were two objectives to this study. The first was to test the effect of two dough conditioners, ascorbic acid and diacetyl tartaric esters of monoglycerides (DATEM), on the baking qualities of flour of two protein levels by bread baking tests. The second objective was to determine the effect of the dough conditioners and protein levels of flour on the rate of staling. One flour approximated the protein content of cake flour, the other approximated the protein content of all-purpose flour.

Chapter II

Review of Literature

There are four types of proteins found in wheat: albumins, globulins, gliadins, and glutenins. Of these four, gliadins and glutenins are the principal storage proteins, comprising about 80% of the protein found in flour. The two proteins come together when the flour is hydrated and mixed to form gluten, a three-dimensional viscoelastic network. Glutenins are responsible for the elasticity of dough; gliadins for extensibility. A proper balance is needed to obtain a high-quality dough for bread making (Cheftel et al., 1985).

The amino acid composition of the gluten proteins was found by Haard (1985) to be responsible for the characteristics of the three-dimensional gluten complex. A high content of amide groups is needed for hydrogen bonding; the presence of many proline molecules disrupts secondary structures; hydrophobic amino acids contribute to gliadin-glutenin interactions; and cystine groups are needed for intra- and intermolecular bonding (Haard, 1985).

Cheftel et al. (1985) reported that after gluten proteins are hydrated and kneaded, they align and partially unfold, enhancing hydrophobic interactions and disulfide interchanges. The three-dimensional network formed by gluten particles align into membranes

that trap other flour components such as starch granules and lipids (Cheftel et al., 1985).

Specific compounds added to bread dough are capable of strengthening the structure of gluten. Johnston and Mauseth (1972) reported that sulfhydryl groups present in the protein moiety of dough need to be oxidized rapidly to disulfide bonds to prevent the structure of dough from deteriorating after mixing. Oxidizing agents are added to catalyze the conversion of sulfhydryl groups into disulfide bonds. Chamberlain (1982) indicated that the development of the viscoelastic and gas-retaining properties characteristic of bread doughs is due largely to chemical and physical changes in the protein component. When gliadin and glutenin fractions of flour are hydrated, the proteins swell, weakening the cohesive forces (hydrogen and hydrophobic bonding; electrostatic forces) holding the proteins in a contracted conformation. Gluten is formed when hydration and manipulation causes aggregation of the proteins. Sulfide-disulfide interchanges play a major role in gluten formation. Removal of the catalytic sulfhydryls from the system stabilizes the gluten network. Chamberlain (1982) indicated that this mechanism is sensitive to the presence of oxidizing and reducing agents.

The addition of ascorbic acid or diacetyl tartaric esters of monoglycerides (DATEM) was reported to improve the physical properties of dough. The addition of each results in a stronger gluten network, improving gas retention and volume of the baked

loaves (Chamberlain, 1982; Church, 1973; Parrish, 1979). Researchers suggested that the oxidation-reduction potential of the dough conditioners increased sulfhydryl-disulfide interchanges and thus increased the intermolecular bonding of the gluten (Chamberlain, 1982; Dahle and Murthy, 1970; Johnston and Mauseth, 1972; Zentner, 1968).

Ascorbic acid

Ascorbic acid has a dual role in dough improvement. Johnston and Mauseth (1972) indicated that although ascorbic acid acts as a reducing agent, it also imparts effects characteristic of an oxidizing agent. In the presence of oxygen and the enzyme ascorbic acid oxidase (naturally present in flour), ascorbic acid is converted to dehydroascorbic acid (DHA) (Chamberlain, 1982; Church, 1973; Dahle and Murthy, 1970; Elkassabany et al., 1980; Johnston and Mauseth, 1972; Meredith, 1965; Tsen, 1965). The ascorbic acid converted to DHA then acts as an oxidizing agent.

Ascorbic acid not converted to DHA exerts a softening effect on dough (Johnston and Mauseth, 1972; Zentner, 1968). It does not reduce disulfide groups nor react with sulfhydryl groups. Johnston and Mauseth (1972) and Zentner (1968) found that ascorbic acid breaks hydrogen bonds between amino acids of gluten, but the mechanism is not clear. Ascorbic acid molecules do displace some of the water bound to gluten, which may account for the disruption. The overall effect of ascorbic acid is a softer dough, but Johnston

and Mauseth (1972) felt the DHA, over ascorbic acid, plays a larger role in dough improvement.

Once ascorbic acid is converted to DHA, most of the sulfhydryl groups in the dough are oxidized to disulfide groups within 60 minutes of hydrating the flour (Elkassabany et al., 1980; Tsen, 1965). Oxidation to disulfide groups results in a reconversion of DHA back to ascorbic acid. This reaction is catalyzed by DHA reductase (Tsen, 1965). Chamberlain (1982) reported that this mechanism depends on the presence of sufficient amounts of glutathione. Figure 1 gives a schematic view of these reactions.

DATEM

As the name implies, diacetyl tartaric esters of monoglycerides (DATEM) are glycerol molecules esterified with fatty acids and acetylated tartaric acid. Lorenz (1983) reported that DATEM has been sold in the United States for use as dough conditioners since 1948. It has appeared on the Food and Drug Administration's Generally Recognized as Safe (GRAS) list since 1973 (GRAS, 1973).

DATEM is categorized as a surfactant, related in structure to mono- and diglycerides. The addition of surfactants to dough systems is reported to: increase loaf volume by improving gas retention, shorten proofing time, increase oven spring, soften bread crumb, improve bread texture and grain, increase tolerance to overmixing, brighten crumb color, and improve symmetry (Anon, 1981;

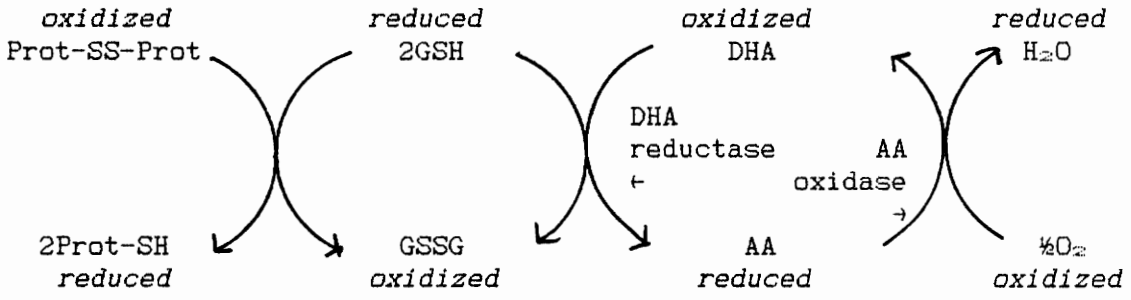

Figure 1. Reaction sequence for the improving effect of ascorbic acid (AA) by competition between dehydroascorbic acid (DHA) and protein disulfide (Prot-SS-Prot) for reduced glutathione (GSH). GSSG = oxidized glutathione and Prot-SH = protein thiol (Adapted from Chamberlain, 1982).

Birnbaum, 1981; Furia, 1968; Gregersen, 1979; LaBell, 1983; Lorenz, 1983; Rogers and Hoseney, 1983; Tsen and Weber, 1981). The most beneficial effects come from surfactants with sufficient plasticity to insure optimum incorporation into the dough (Furia, 1968).

The anionic nature of DATEM allows it to react with both the carbohydrate and protein moieties of flour. The interaction with the protein component of flour strengthens gluten formation, but the mechanism is not yet fully understood. Lorenz (1983) reported that strengthening of the gluten leads to improved loaf volume and oven spring. Birnbaum (1981) indicated that DATEM has a beneficial effect on gas retention by promoting the leavening effect of yeast and, in turn, shortening the proofing time. The association of DATEM with amylose chains prevents the formation of a rigid network. The result is a softer crumb. The addition of DATEM also counteracts deleterious effects on loaves (such as lower volume) supplemented with fiber (Shogren et al., 1981).

Staling

Staling is defined by many researchers as the changes that occur after baking with the exception of microbial spoilage. The changes include softening of the crust, firming of the crumb, increased crumbliness, and loss of fresh flavor or development of stale flavor (Fearn and Russell, 1982; Kim and D'Appolonia, 1977a; Knightly, 1977; Lagendijk and Pennings, 1970; Willhoft, 1973a,b). Kim and D'Appolonia (1977a) indicated that bread staling is

characterized by the retrogradation of the starch present in the crumb of bread.

During baking, heat causes gelatinization of the starch to occur by promoting the uptake of water into the starch granule. The water disrupts the system of the granule, breaking hydrogen bonds present between both the long straight-chained amylose molecules and branched amylopectin molecules. The amylose chains are then free to leach out of the granules, forming a sol. As the bread cools after baking, the loss of energy causes a new association through hydrogen bonding of both the amylose chains outside the granule and the amylopectin chains within the granule. The association of the starch molecules was reported to be actually the first stage of staling (Schoch, 1965). As the bread ages, the hydrogen bond formation brings the amylose and amylopectin chains closer together, displacing the water trapped between the chains. This process is known as retrogradation. The free water then migrates to the crust, causing it to soften but leaving the crumb less moist and more firm (Schoch, 1965; Schoch and French, 1947).

The question as to whether one starch component is more responsible for staling than the other, or if they both play equal roles, is controversial in the literature. The results of a study performed by Kim and D'Appolonia (1977c) showed that the role of amylose in staling is minimal. The amylopectin chains undergo the greatest amount of retrogradation and, therefore, are more responsible for staling than amylose. In addition, the contribution

of amylose to staling is greatest during the cooling of bread immediately after baking. The conclusions of the authors reflect the current theories concerning bread staling.

Staling, although a fact of life, is obviously undersirable from an economic standpoint. Staling decreases shelf-life and consumer acceptance. Researchers have looked for ways to decrease staling and the detrimental effects. The ability of DATEM and surfactants to associate with the carbohydrate moiety of flour resulted in a decreased rate of staling (Anon, 1981; Birnbaum, 1977; Furia, 1968; Gregersen, 1979; Knightly, 1977; LaBell, 1983; Lagendijk and Pennings, 1970; Lorenz, 1983; Russell, 1983b; Willhoft, 1973a). Monoglycerides are known to form complexes with amylose. Lagendijk and Pennings (1970) and Willhoft (1973a) indicated that the complexing of monoglycerides reduces the flexibility of amylose chains, restricting retrogradation. Hydrogen bonding is also inhibited, both between amylose chains and between amylose and amylopectin chains. Monoglycerides also form complexes with amylopectin chains, but to a much lesser extent (Knightly, 1977). Knightly concluded that if amylose plays only a small role in staling, the complexes it forms with monoglycerides can only be a partial explanation of their ability to slow staling.

The rate of staling is affected by components normally present in bread dough. The protein content of the flour used in baking was found to affect staling (Eliasson, 1983; Ghiasi et al., 1982; Kim and D'Appolonia, 1977a,b; Russell, 1983a; Willhoft,

1973b). In general, an inverse relationship exists between protein content of the flour and the rate of staling of bread upon storage (Kim and D'Appolonia, 1977a,b; Russell, 1983a). Eliasson (1983) and Willhoft (1973b) reported that the gelatinization of starch is altered by the presence of components that compete for the available water in the system. The degree of gelatinization decreases with more competition for water. Less gelatinization results in less retrogradation. Ghiasi et al. (1982) found that since gluten holds water, less is available to migrate to the starch granules during heating. Kim and D'Appolonia (1977a) indicated that a more complex process might be at work. They postulated that amide groups from the gluten proteins might form hydrogen bonds with the hydroxyl groups from starch, inhibiting the extent of retrogradation. The ratio of starch to protein in the dough then would be critical in determining the rate of staling.

Differential Scanning Calorimetry (DSC)

Differential scanning calorimetry has been used to study the extent and progression of the starch crystallization component of staling. The use of the DSC allows indirect measurement of changes occurring at the molecular level during staling (Fearn and Russell, 1982). A sample is heated at a constant rate and the resultant thermogram indicates the energy needed to break the hydrogen bonds formed between amylose and amylopectin chains, heat of transition (ΔH of enthalpy), as well as the temperature at which the process occurs (T_{max}).

In 1985, Eliasson used DSC to study staling, which he characterized as a crystallization process. Thermograms obtained from baked bread crumb were compared to those obtained from amylose and amylopectin alone. Superimposing the thermograms showed that the staling endotherm measured the melting of crystallized amylopectin. Eliasson (1985) also examined stored bread samples. The size of the staling peak increased with storage, although the temperature (T_{max}) did not vary. Samples with a surfactant added showed decreased ΔH values, but increased amylose-lipid peaks. Eliasson (1985) postulated that the surfactant may have decreased the extent of retrogradation by affecting the amount of water available to the starch granule during baking.

Russell (1983b) studied the effect of several different monoglycerides on the staling endotherms of bread. The results showed that monoglycerides decreased the development of the staling peak over three weeks, although T_{max} stayed roughly the same. The amylose-lipid peak did increase over untreated samples, but it stayed the same over aging, suggesting that amylose was not involved in staling.

All the experiments reviewed herein used flour milled from hard wheats. Breads are traditionally made from flours with protein contents higher than 12%, assuring the presence of adequate amounts of gluten proteins for structure. Utilizing soft-wheat flours for bread baking tests the quality of the proteins present. If the resultant bread has adequate volume and structure, the flour

proteins are of good quality despite their limited quantity (Hoseney and Seib, 1973). Dough conditioners compensate for lack of quality and quantity by supplementing protein interactions and reinforcing the gluten network.

Chapter III

Procedure

Experimental Plan

There were two objectives to this study. The first was to test the effect of two dough conditioners on the baking qualities of flour of two protein levels by bread baking tests. The second objective was to determine the effect of the dough conditioners and protein levels of flour on the rate of staling. Basic yeast breads were made from flours of two protein levels, with either no conditioner (control), a solution of ascorbic acid, or DATEM added to the dough during mixing. The statistical design of the experiment was an incomplete block design. Each variation was treated as a treatment. It was incomplete because not all treatments were baked on each day. Six repetitions were prepared of each flour treatment (Appendix A) according to a randomly chosen baking plan (Appendix B). All baking for the sensory and objective evaluation was done in six days over a three week period. Two additional loaves of each treatment were then baked separately over a two week period for DSC analysis.

Acquisition and Storage of Ingredients

All ingredients were obtained in bulk and stored in airtight containers at room temperature, except where noted, for the duration of the study.

The two flours used were milled from Coker 916 wheat grown and harvested in 1987 in Montgomery County, Virginia by the Agronomy Department, Virginia Polytechnic Institute and State University. Grain from two of the treatments in a nitrogen fertilization level experiment was chosen for this study. The low-protein flour was milled from wheat grown with 56 kilos/hectare of nitrogen, all of which was applied at Zadoks growth stage 25 (Zadoks et al., 1974). The high-protein flour was derived from wheat having had a total of 225 kilos/hectare of nitrogen applied, half at Zadoks growth stages 25 and 30, respectively (Zadoks et al., 1974). Grain from four replications of each treatment was used. Grain from each replication was milled separately, but the four flour samples were later pooled and thoroughly mixed to ensure an adequate uniform amount was available for these experiments.

The wheat was milled into flour on a Buhler Experimental Mill (Minneapolis, MN) set according to the experimental method of AACC (Mid-State Mills, Newton, NC). The mill provided data from farinograph and alveograph tests. The data included measurement of the tolerance index (MTI), calculated from farinographs. One flour was considered high protein-content soft wheat (protein = 11.59%; moisture = 12.62%; ash = 0.46%; and fat = 2.38%). The protein level

of this flour approximated the protein level of commercial all-purpose flours made from hard wheats. The other was a low-protein soft wheat flour (protein = 7.35%: moisture = 12.32%; ash = 0.42%; and fat = 1.23%). The protein level of this flour approximated the protein level of commercially available cake flours. The protein, moisture, ash, and fat content of the flours were determined by Association of Official Analytical Chemists methods (1975).

All ingredients were purchased at one time from a local supermarket. Kroger™ brand salt and nonfat dry milk (NFDM), Crisco™ shortening, and Fleischmann's™ active dry yeast were used. Thirty-two 7.0g packets of yeast were purchased and combined into one airlock bag which was then kept in the refrigerator. The sugar was obtained from the bulk supply of General Stores of Virginia Polytechnic Institute and State University. The ascorbic acid (reagent grade, MW=176.12) was obtained from the Fisher Scientific Company (Springfield, NJ). A one pound sample of DATEM was obtained from Eastman Chemical Products, Inc. (Kingsport, TN) marketed under the trade name Myvatem™.

Procedure for Yeast Bread

The bread formulas for the pup loaves baked are listed according to treatment in Appendix C. The method for preparing the breads is listed in Appendix D. The formula and method were adapted from AACC method 10-10A (American Association of Cereal Chemists, 1983).

A Mettler (Heightstown, NJ) top loading balance (model P1000) was used to weigh the ingredients to the nearest 0.1g. A KitchenAid (Troy, OH) Model K5-A mixer, connected to a power source through a Gralab (Dayton, OH) laboratory timer to control the mixing time, was used to mix and knead the bread dough. The loaves were proofed in a home-style electric oven kept between 30-40°C with bowls of hot water placed in the bottom. The loaves were then baked in a similar oven preheated to 220°C.

Sensory Evaluation

Eight volunteer panelists subjectively evaluated the yeast breads using the quantitative descriptive analysis method of sensory evaluation (QDA) (Stone et al., 1974). The panel consisted of four female graduate students, two male graduate students, one female laboratory technician, and one female faculty member. The panelists attended two training sessions to establish the sensory characteristics to be included on the scorecard and the appropriate anchor words (Appendix E). Samples were given to the panelists in individual booths with fluorescent lighting, located adjacent to the baking area. The panelists received two slices of bread per session, one of each treatment baked that day. All panelists received the same treatments at the same time. There were six tasting sessions corresponding to the six baking days. None of the panelists missed a session. The bread samples were presented with a code of randomly chosen three digit numbers and placed on white

plates. The panelists were instructed to cleanse their palates between samples with tap water at room temperature.

The samples were prepared by slicing two of the cooled loaves in a cutting guide. The guide was a wooden board, 15x9cm, with plexiglass sides. The sides had slits cut into them approximately one centimeter wide. The knife was run through the bread according to these guides. Approximately 10 slices were obtained from each loaf. Of these, the middle four from each loaf were used for sensory analysis.

The bread samples were scored using a graphic rating scale. A line, 13cm in length, was included for each attribute to be evaluated. The left side of the line included the anchor word 0.3cm from the end for one extreme of the characteristic, while the right side held the anchor word 0.3cm from the end for the opposite extreme. The panelists were instructed to put a slash through the point on the line for the attribute in relation to the two anchor points. The length of the corresponding line segment was measured and recorded as the score.

Objective Evaluation

Volume: Volume was determined twenty minutes after baking by rapeseed displacement (Cathcart and Cole, 1938). The volumeter was calibrated using a 500cm^3 block prior to measurement. The loaf was placed in the lower chamber. The low-density seeds were allowed to fall and fill the chamber. The amount of displacement was read off of the scale located on the neck of the instrument.

Color: Both crust and crumb color were measured 30 minutes after baking using a Hunter Color Difference Meter (Hunter Labs; Fairfax, VA) Model D25. The instrument measures color as seen in daylight using an 'L', 'a', and 'b' scale. The 'L' value measures lightness, zero indicating black, 100 indicating white. The 'a' value measures green (a negative number) to red (a positive number); the 'b' value measures blue (negative) to yellow (positive). Readings were taken in three places along the length of the sample and averaged into one value. A white tile #C20-1651 (L = 91.97, a = -0.8, and b = -1.0) was used to standardize the instrument prior to the readings. The total color difference was calculated using the formula:

$$\Delta E = \sqrt{L^2 + a^2 + b^2}$$

The samples were prepared by cutting open the loaf used for volume measurement lengthwise 0.5cm from the top. The crust layer was placed with the top facing the photo cell. The exposed crumb from the remainder of the loaf was then measured.

Moisture: Moisture analysis was performed 40 minutes after baking by the oven drying method with the Brabender moisture tester (Hackensack, NJ). Two 10.0g samples were taken from underneath the crust layer used for color determination. The samples were dried to a constant weight at 155°C.

Tenderness: Tenderness was evaluated 50 minutes after baking using a Hi-accuracy Penetrometer (Lab-Line Instruments; Melrose Park, IL). A 5x5cm slice was cut from the middle of the bottom part

of the loaf. Readings were taken in four places on the slice and averaged.

Differential Scanning Calorimetry (DSC)

A Perkin-Elmer (Norwalk, CT) DSC-4 instrument was used to analyze the retrogradation of the starch component of the breads by the modified methods of Fearn and Russell (1982), Russell (1983a), and Soulaka and Morrison (1985). Tests were conducted to determine the degree of staling as represented by exothermic reactions (Fearn and Russell, 1982) after 1, 2, 4, 7, 10, and 14 days of storage at 27°C. A 20 to 30mg sample of bread was taken from the center of the prepared loaves. The samples were put into a DSC pan with water added to make a 1:1 (by weight) solids to water mixture. The pans were hermatically sealed with a press and weighed. An empty pan was used as a reference. The samples were heated from 15-130°C at a rate of 10°C per minute. The base area was kept the same for all endotherms. The endotherms were rescaled to 1mcal/sec for interpretation of results. An indium standard was used for calibration.

Three peaks were observed. The peak at approximately 55°C represented staling as determined by the temperature at which crystalline bonding of starch molecules was disrupted. The peak was labeled 'S' on thermograms. The second peak at approximately 85°C was unidentified; the third at approximately 103°C was due to the melting of the amylose-lipid complex. On the thermograms, this peak was labeled 'M'. The area of the peaks was measured by multiplying

the width times half the height (mm). The area was then divided by the sample weight (mg). The T_{max} was recorded from the thermogram (Russell, 1983a).

Statistical Analysis

The results obtained from both objective and sensory evaluation were analyzed for significance by analysis of variance (ANOVA) (SAS, 1985). Objective or sensory characteristics found to be significant were further analyzed by Duncan's Multiple Range Test at two significance levels: $p<0.05$ and $p<0.01$.

Chapter IV

Results and Discussion

There were two objectives to the study. The first objective was to test the effect of two dough conditioners on the baking qualities of flour of two protein levels by bread baking tests. Quality measurements included a determination of the effect of the conditioners on volume, moisture content, loaf tenderness, and crust and crumb color. Sensory evaluation measured the crust color, aroma, crumb color, cell size, cell evenness, compressibility, mouth feel, moistness, flavor, and overall aftertaste attributes of the bread. The second objective was to determine the effect of the dough conditioners and protein levels of flour on the rate of staling.

For the purposes of discussion, loaves baked with the high-protein flour (11.59%) will be referred to as 'high', while loaves baked with the low-protein flour (7.35%) will be referred to as 'low'. To represent the addition of the dough conditioners, the 'low' or 'high' will be followed with control, ascorbic acid, or DATEM, indicating the breads prepared from the low- or high-protein flours with no conditioner, ascorbic acid added, or DATEM added, respectively.

The results are presented in three sections. Section one pertains to the objective testing of the bread. Section two covers the sensory evaluation. Evaluation of staling using DSC appears in section three.

Objective Evaluation

Color: The mean values for crust and crumb color are reported in Table 1. Significant differences ($p<0.05$) were observed in the color of the crust of breads made from flours of the two protein levels. All breads made from the high-protein flour had significantly lower ΔE and L values, indicating a darker crust color (Figure 2). With more protein present in the flour, a higher rate of Maillard browning probably occurred. Neither of the conditioners significantly affected crust color. No significant differences were observed in crumb color. Lorenz (1983) reported similar results of no significant differences in crumb or crust color when DATEM was added to bread doughs.

Volume: The mean values for volume are shown in Table 2. In this study, no significant differences were found among loaves made from the two flours nor with the conditioners. Figures 3, 4, and 5 show that the loaves appeared fairly uniform in size across protein contents and conditioners. Some of the loaves, especially those baked with the low-protein flour, were higher on one side of the loaf than the other. No explanation for this phenomenon could be found in the literature. Rogers and Hoseney (1983) found significantly higher volumes when DATEM was added at the 0.5% level

Table 1. Mean scores for the objective evaluation of crust and crumb color of pup loaves[1,2].

	Crust		Crumb	
Treatment[3]	ΔE[4]	L[5]	ΔE	L
low aa	63.14±0.53[a]	58.98±0.77[a]	81.31±0.25[a]	79.58±0.12[a]
low d	62.69±0.64[a]	58.44±0.09[a]	78.26±0.88[a]	76.42±0.80[a]
low c	63.12±1.27[a]	58.66±1.74[a]	81.21±4.38[a]	79.33±4.35[a]
high aa	53.56±1.73[b]	48.16±1.48[b]	79.54±0.41[a]	77.94±0.33[a]
high d	53.86±1.94[b]	48.24±1.77[b]	79.44±1.04[a]	77.83±0.95[a]
high c	55.05±1.86[b]	49.46±0.64[b]	79.64±0.65[a]	77.86±0.55[a]

[1]mean of 6 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

[4]$\Delta E = \sqrt{L^2 + a^2 + b^2}$

[5]L represents lightness (100) or darkness (0)

Figure 2. Photograph showing darker crust color obtained from loaves baked with high-protein flour.

Table 2. Mean scores for the objective evaluation of volume, moisture, and tenderness of pup loaves[1,2].

Treatment[3]	Volume (cc[3])	Moisture (%)	Tenderness (mm)
low aa	675±71[a]	40.8±1.2[a]	36.1±1.5[a]
low d	550±00[a]	40.1±0.4[a]	21.1±0.0[b]
low c	650±71[a]	40.6±0.4[a]	28.2±6.2[ab]
high aa	637±53[a]	40.2±0.5[a]	30.5±2.8[ab]
high d	662±53[a]	40.3±0.6[a]	18.8±9.8[b]
high c	612±18[a]	39.7±0.6[a]	17.0±7.1[b]

[1]mean of 6 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

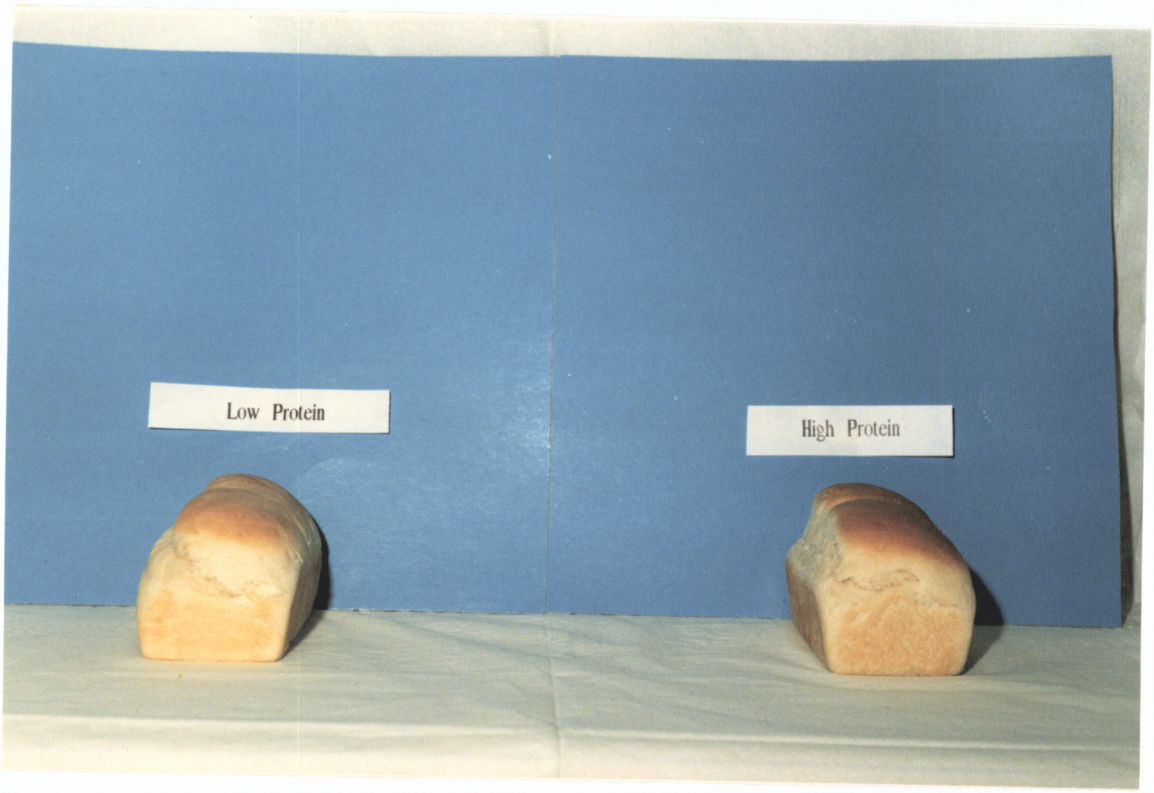

Figure 3. Photograph showing similar loaf volumes when using high- and low-protein flours with no dough conditioners.

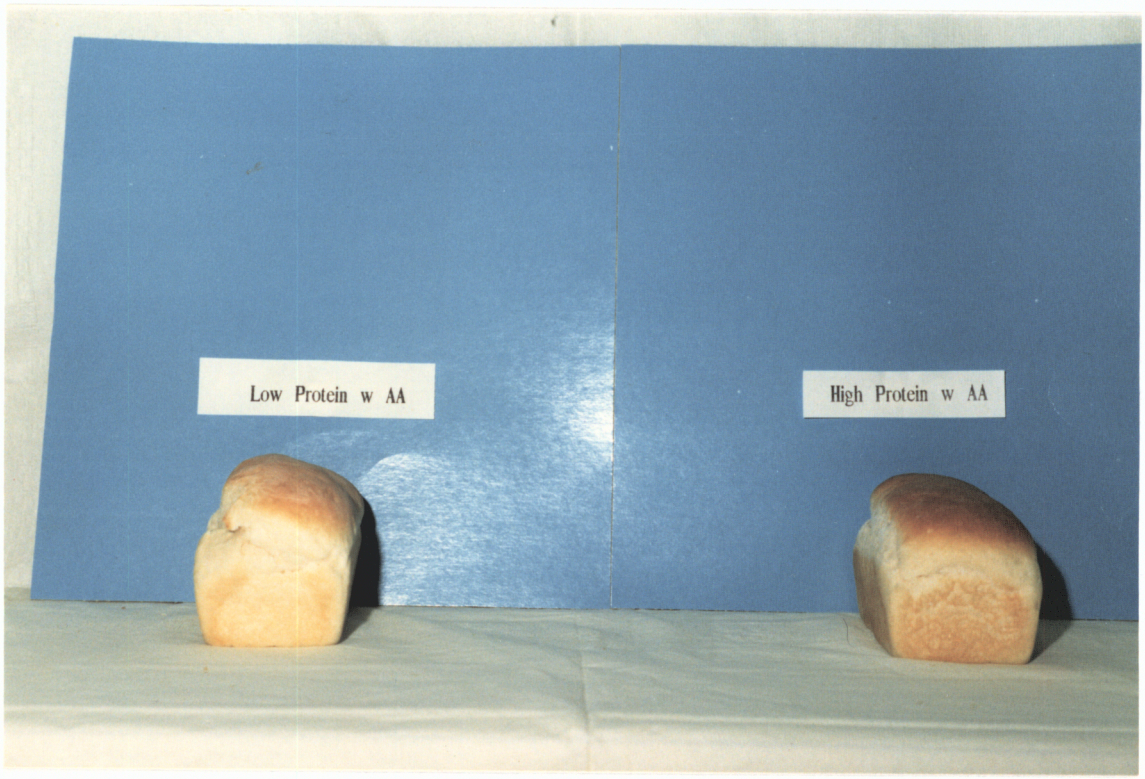

Figure 4. Photograph showing similar loaf volumes when using high- and low-protein flours with ascorbic acid as the dough conditioner.

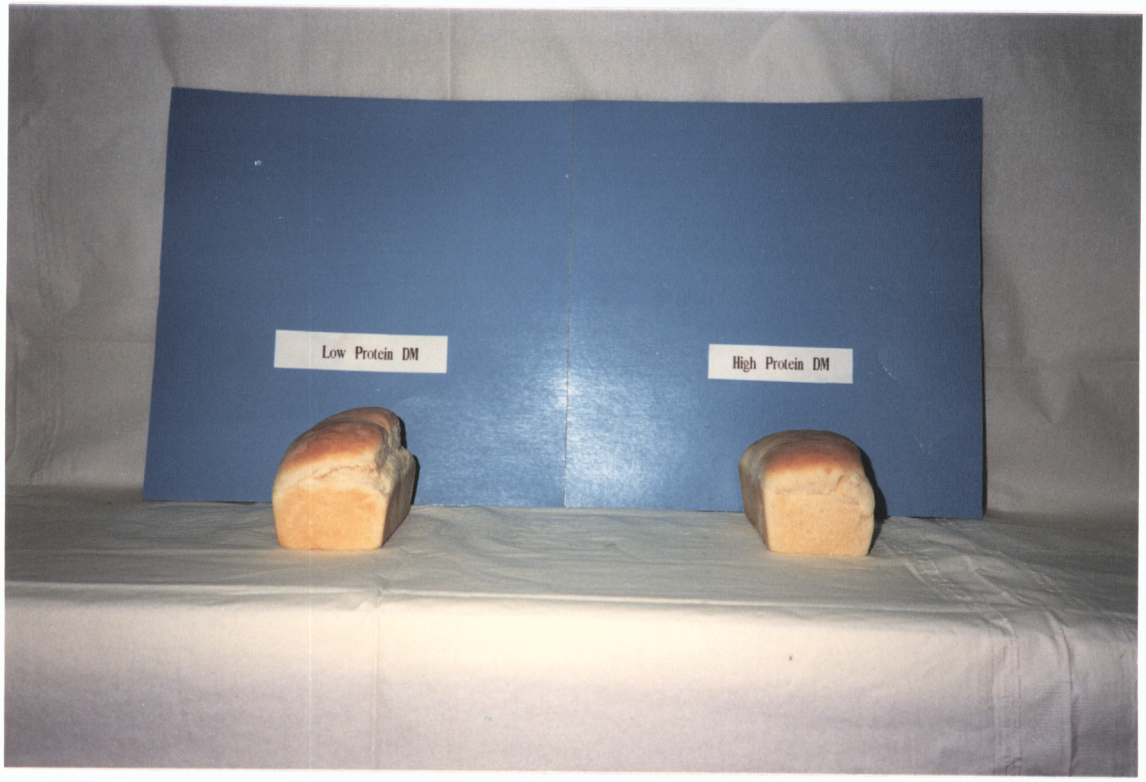

Figure 5. Photograph showing similar loaf volumes when using high- and low-protein flours with DATEM as the dough conditioner.

(the same as used in this study) to doughs of high protein-content flour. Chamberlain (1982) indicated that 75ppm ascorbic acid significantly improved volume, but that amount was greater than the 40ppm used in this study.

Moisture: No significant differences in moisture content were found among the six variations (Table 2). Although the gluten component of dough has been shown to hold water (Ghiasi et al., 1982), the higher protein content did not significantly alter the amount available in the bread. Neither ascorbic acid nor DATEM (both polar compounds) had a significant effect on the amount of available water.

Tenderness: The mean values for tenderness as measured by the penetrometer are shown in Table 2. Tenderness differed significantly among the six treatments. The low-ascorbic acid loaves were significantly more tender than the other five treatments ($p<0.05$). The high-control, low-DATEM, and high-DATEM loaves were significantly less tender than other treatments. Since no significant differences were found in moisture content, tenderness did not depend on the amount of available water. Birnbaum (1981), Lagendijk and Pennings (1970), and Willhoft (1973a) reported the addition of DATEM softened dough because it forms complexes with amylose chains, preventing them from associating into a rigid network. However, they did not indicate whether or not increased softness was present after the dough was baked.

The quality of the baked breads depended upon the quality of the proteins present in the flours. The tolerance index (MTI) is one measurement that can indicate the quality of proteins found in flour by measuring their rate of breakdown in Brabender units (BU). MTI is a measurement of the difference between the top of the curve at the peak (as obtained from a farinograph) and the top of the curve measured five minutes after the peak. The higher the difference, the higher the MTI value, and the weaker the dough. Larger differences mean the dough loses viscosity more quickly, hence the term 'weaker'.

Tolerance index values showed distinct differences between the two flours used in this study. The low-protein flour had an MTI value of 95 BU, which indicated a weak dough and may have accounted for the lopsided appearance of loaves baked with this flour. The high-protein flour had a value of 60 BU, representative of a stronger dough. Stronger doughs hold up better to handling and would be expected to result in increased gas retention and volume.

Sensory Evaluation

Crust color: The mean scores of the sensory evaluation for crust color are shown in Table 3. Significant differences ($p<0.05$) among the treatments were detected by the panel. The high-ascorbic acid loaves were evaluated as being significantly darker than all other treatments, which agreed with the results of the Hunter Color Meter. Loaves of the high-control and high-DATEM variations were significantly lighter than high-ascorbic acid loaves. The high-

Table 3. Mean scores for the sensory evaluation of crust and crumb color of pup loaves[1,2].

Treatment[3]	Crust color[4]	Crumb color[5]
low aa	3.6 ± 1.5^{cd}	4.5 ± 2.2^{a}
low d	3.8 ± 1.5^{cd}	6.0 ± 2.1^{a}
low c	4.4 ± 2.0^{bcd}	5.4 ± 2.3^{a}
high aa	7.3 ± 1.5^{a}	5.4 ± 2.1^{a}
high d	5.1 ± 2.3^{bc}	5.4 ± 2.5^{a}
high c	5.6 ± 1.8^{b}	6.0 ± 2.4^{a}

[1]mean of 16 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

[4]0 = light, 13.0 = dark

[5]0 = white, 13.0 = yellow

control treatment produced significantly darker colored loaves than all other treatments except for high-ascorbic acid. Low-ascorbic acid was significantly lighter than some of the other treatments, again agreeing with results from the Hunter Color Meter.

There was disagreement between sensory and objective evaluation of crust color. The panel did not find the loaves made from the high-protein flour to be consistently darker than their low-protein counterparts. The inconsistencies may have been due to dark or light shadows masking the differences measured by the Hunter Color Meter.

Crumb color: As with the objective measurement, no significant differences in crumb color were observed among the treatments or protein contents (Table 3). The crumb color was found to be more white than yellow.

Aroma, Flavor, Overall aftertaste: No significant differences were found in aroma, flavor, or overall aftertaste (Table 4). The addition of either conditioner did not impart a noticeable flavor change to the bread. All treatments were found to have a medium yeast smell, little aftertaste, and fairly weak flavor, which may or may not be good depending on personal preferences.

Cell size and evenness: Cell size was significantly larger ($p<0.05$) in the high-ascorbic acid loaves (Table 5) as compared to all other variations. Cell evenness also differed significantly

Table 4. Mean scores for the sensory evaluation of aroma, flavor, and overall aftertaste of pup loaves[1,2].

Treatment[3]	Aroma[4]	Flavor[5]	Overall aftertaste[5]
low aa	6.7±2.3[a]	5.5±2.2[a]	3.6±2.3[a]
low d	8.1±2.3[a]	5.3±2.6[a]	3.9±2.6[a]
low c	7.1±2.2[a]	5.4±2.7[a]	3.7±2.5[a]
high aa	7.1±2.4[a]	4.8±2.1[a]	3.6±1.9[a]
high d	7.5±2.2[a]	5.6±2.5[a]	4.7±3.1[a]
high c	6.4±2.5[a]	4.4±1.7[a]	3.6±2.3[a]

[1]mean of 16 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

[4]0 = no yeast, 13.0 = strong yeast

[5]0 = none, 13.0 = strong

Table 5. Mean scores for the sensory evaluation of cell size and cell evenness of pup loaves[1,2].

Treatment[3]	Cell size[4]	Cell evenness[5]
low aa	3.6±1.4[b]	7.1±3.1[a]
low d	3.3±2.0[b]	6.2±3.3[a]
low c	3.5±2.2[b]	7.9±2.7[a]
high aa	6.0±2.0[a]	4.1±2.3[b]
high d	3.6±2.1[b]	6.5±3.1[a]
high c	4.3±2.0[b]	6.6±2.8[a]

[1]mean of 16 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

[4]0 = small, 13.0 = large

[5]0 = not uniform, 13.0 = uniform

($p<0.05$) among the loaves (Table 5). The high-ascorbic acid loaves had significantly less uniform cell structure than all other treatments, which were not significantly different from each other. Both LaBell (1983) and Rogers and Hoseney (1983) reported the addition of DATEM resulted in a more uniform texture, devoid of large holes or gaps. The results of this study showed that both DATEM variations were evaluated midway between uniform and not uniform by the panel.

Compressibility, Mouth feel, Moistness: Compressibility, mouth feel, and moistness did not differ significantly ($p<0.05$) among treatments (Table 6). Tenderness as measured by penetrometer was not significantly different among the variations. The sensory panel rated the compressibility of all samples as being not springy. Compressibility was understood by the panel to relate to tenderness. All variations were evaluated as having a tender mouth feel and being between dry and gummy in moistness.

Differential Scanning Calorimetry (DSC)

The use of DSC allowed indirect measurement of changes occurring at the molecular level during staling (Fearn and Russell, 1982). Heating a sample at a constant rate resulted in a thermogram indicating the energy needed to break the hydrogen bonds formed between amylose and amylopectin chains, as well as the temperature at which the process occurred (T_{max}). Peaks having larger areas required more energy to break the bonds, therefore indicating an increased extent of staling.

Table 6. Mean scores for the sensory evaluation of compressibility, mouth feel, and moistness of pup loaves[1,2].

Treatment[3]	Compressibility[4]	Mouth feel[5]	Moistness[6]
low aa	6.7±3.5[a]	4.3±2.8[a]	8.4±1.5[a]
low d	5.4±3.5[a]	4.7±2.9[a]	7.7±1.9[a]
low c	5.5±2.9[a]	4.4±2.2[a]	7.8±1.7[a]
high aa	5.2±3.4[a]	5.1±3.2[a]	8.3±1.5[a]
high d	4.2±2.8[a]	4.1±2.3[a]	8.7±2.3[a]
high c	4.1±2.6[a]	4.4±2.5[a]	7.9±2.3[a]

[1]mean of 16 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

[4]0 = not springy, 13.0 = springy

[5]0 = tender, 13.0 = tough

[6]0 = dry, 13.0 = gummy

Effect of dough conditioner: The mean peak areas of the thermograms (area/mg) over the two week period the samples were tested are shown in Table 7. Mean ΔH values appear in Appendix F. Higher ΔH values indicated increased amounts of energy were needed to disrupt the crystalline structure formed during staling. In each of the six variations the energy required to break the hydrogen bonds increased over time. Three peaks were significantly different on Day 1. More energy was required to break the hydrogen bonds associated with staling of the low-control peak. The high-DATEM samples required significantly less energy to break hydrogen bonds. High-ascorbic acid loaves indicated significantly less staling than low-control loaves, but significantly more staling than three other treatments. Day 2 again showed high-DATEM loaves to require significantly less energy to break the hydrogen bonds than the other variations. Both low-control and high-ascorbic acid loaves required significantly larger amounts of energy than the rest of the variations, but did not differ from each other.

On Day 4, both DATEM treatments showed significantly lower amounts of energy needed to break hydrogen bonds than the other treatments. This trend continued through the rest of the two week period. The low-control and high-ascorbic acid loaves continued to require significantly larger amounts of energy than the remaining loaves produced with other treatments.

Figure 6 is a pictorial version of the data and indicates the rate of staling was increased with the low-control and high-ascorbic

Table 7. Mean peak area (mm^2/mg sample) of thermograms as an indication of staling of breads over a two-week period, grouped in descending size[1,2].

Treatment[3]	Time after baking in days 1	2	4	7	10	14
Low c	46.82^{a}	58.74^{a}	78.77^{a}	87.35^{a}	95.10^{a}	109.37^{a}
High aa	43.35^{b}	62.64^{a}	74.44^{a}	84.63^{a}	93.68^{a}	106.11^{a}
Low aa	43.23^{ab}	48.55^{b}	55.55^{b}	60.48^{b}	62.56^{b}	65.97^{bc}
High c	37.87^{bc}	46.97^{bc}	57.65^{b}	59.72^{b}	63.05^{b}	72.15^{b}
Low d	35.06^{bc}	40.67^{cd}	43.81^{c}	48.08^{c}	51.13^{c}	59.86^{c}
High d	30.71^{c}	38.64^{d}	39.86^{c}	45.41^{c}	53.41^{c}	59.07^{c}

[1]mean of 2 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

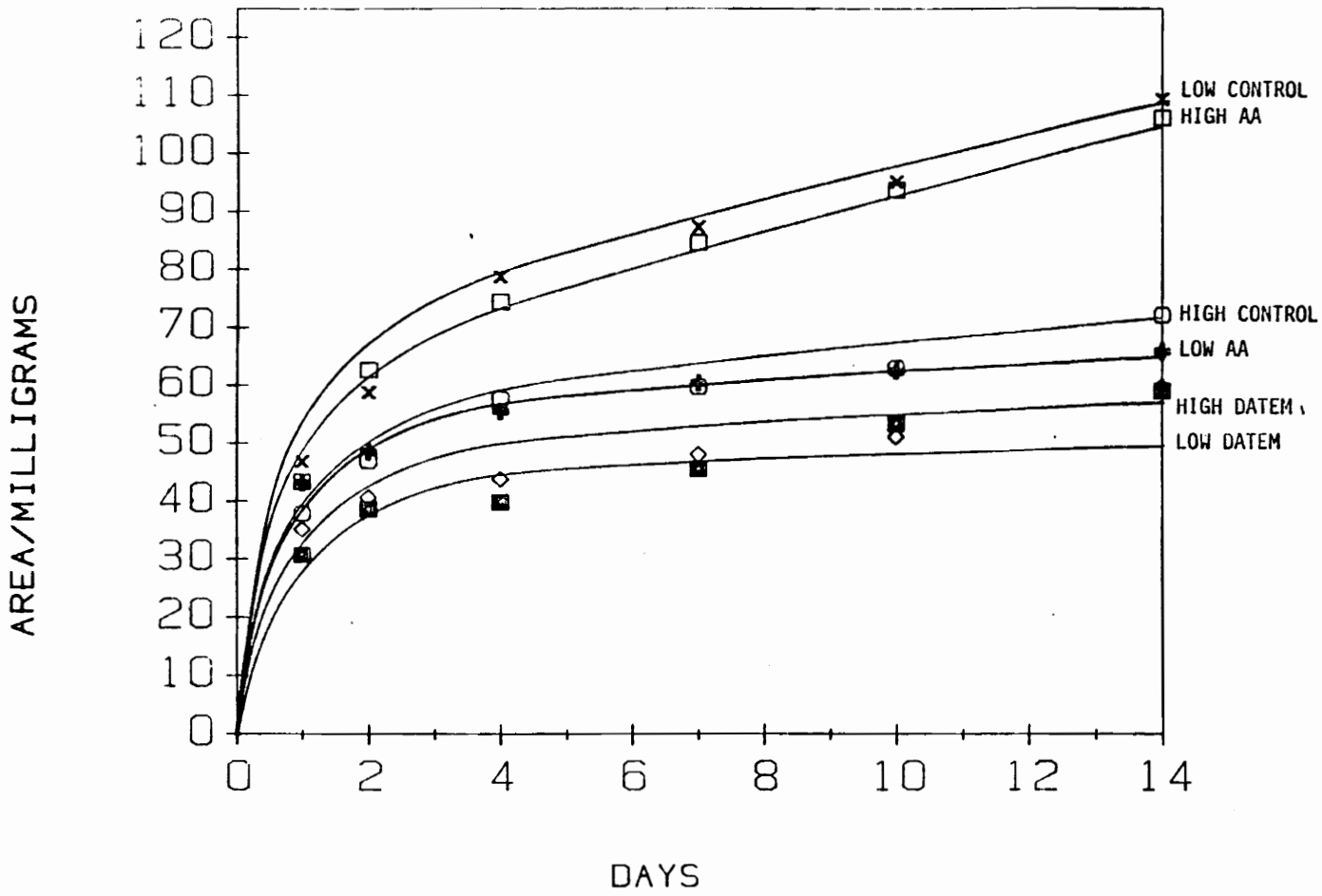

Figure 6. Plot of mean peak areas versus days of storage at 27°C, for high and low control, high and low ascorbic acid and high and low DATEM breads.

acid treatments. The curves for the two DATEM treatments seemed to plateau after the fourth day, indicating a slower rate of staling.

DATEM was the more successful of the conditioners in retarding staling (Figure 7). The staling peak of curve I was higher and more pronounced than on curve II. The results agreed with previous findings. Russell (1983b), using the monoglyceride glyceryl monostearate (GMS), reported nearly identical findings to the data from this study. He postulated that GMS affected the rate of staling (shown by decreased staling endotherms), but not the extent of staling. Staling would continue indefinitely. As with this study, he was unable to follow staling over a greater time period due to microbial spoilage of the bread. Future research should include the addition of microbial growth retardants to breads to extend the measurement of the staling process over time. An Italian bakery (Panital) reported a 30 day increase in shelf-life when DATEM was added (Anon, 1981), but the paper did not indicate how they measured the extent of staling.

No explanation was found for the inhibitory action of DATEM on staling. DATEM has been shown to complex with the amylose portion of starch, but only to a limited extent with amylopectin (Birnbaum, 1981; Lagendijk and Pennings, 1970; Willhoft, 1973a). Since the role of amylose in staling was minimal, DATEM must have inhibited the rate of staling through another mechanism.

The addition of DATEM did not significantly affect the size of the amylose-lipid complex as indicated by the peak at 103°C, even

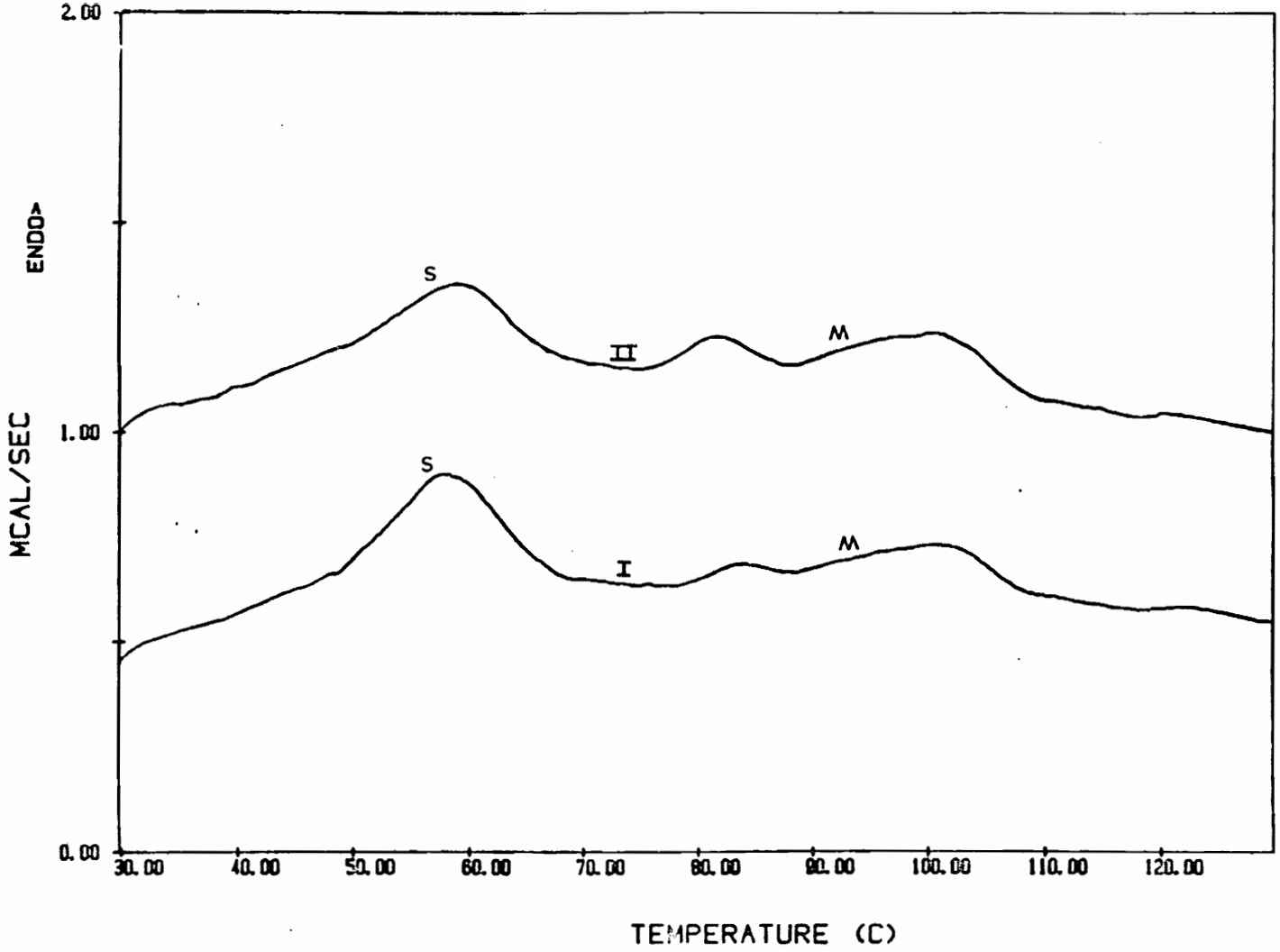

Figure 7. DSC thermograms of control (curve I) and DATEM-treated (curve II) bread, 240 hours after baking. For clarity the curves are plotted using different ordinates. Endotherm 'S' was the staling endotherm; 'M' was due to the melting of the amylose-lipid complex.

though monoglycerides complex with the amylose portion of starch (Table 8). The level of addition might not have been large enough to cause significant variation. Russell (1983b), using 1% GMS, found a larger peak for his treated sample.

None of the six variations showed a significant increase in the magnitude of the amylose-lipid complex over time (peak 'M' in Figure 7), which agreed with Russell (1983b). His results suggested that amylose was not involved in the recrystallization of starch during aging. Therefore, the peak of the thermogram which represented hydrogen bonds associating was best thought of as being due to the amylopectin component.

Protein content: An inverse relationship has been shown between protein content of flour and staling (Eliasson, 1983; Ghiasi et al., 1982; Kim and D'Appolonia, 1977a,b,; Russell, 1983a; Willhoft, 1973b). Protein is generally believed to compete with the starch for the available water, minimizing the amount of gelatinization; consequently, less retrogradation occurs with higher levels of protein.

The results of this study did and did not support those of other studies as reported in the literature, depending on which variation was examined. The staling pattern of the control loaves (without dough conditioners) supported findings from the literature. The low-protein loaves staled significantly faster over the two week period than high-protein loaves (Table 9). The higher protein level of the flour interferred with the amount of water available for the

Table 8. Mean areas of amylose-lipid complex as indicated by thermograms measured days 1-14 after baking and grouped in descending size[1,2].

Treatment[3]	Peak area(mm^2/mg sample)
High c	27.04[a]
High d	25.92[a]
Low c	25.54[a]
High aa	24.63[ab]
Low aa	24.55[ab]
Low d	20.11[b]

[1]mean of 2 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

Table 9. Mean peak area (mm^2/mg sample) of thermograms over two-week period grouped according to protein levels[1,2].

Treatment[3]	Time after baking in days 1	2	4	7	10	14
Low c	46.82^{a}	58.74^{a}	78.77^{a}	87.35^{a}	95.10^{a}	109.37^{a}
High c	37.87^{bc}	46.97^{bc}	57.65^{b}	59.72^{b}	63.05^{b}	72.15^{b}
Low aa	43.23^{ab}	48.55^{b}	55.55^{b}	60.48^{b}	62.56^{b}	65.97^{bc}
High aa	43.35^{b}	62.64^{a}	74.44^{a}	84.63^{a}	93.68^{a}	106.11^{a}
Low d	35.06^{bc}	40.67^{cd}	43.81^{c}	48.08^{c}	51.13^{c}	59.86^{c}
High d	30.71^{c}	38.64^{d}	39.86^{c}	45.41^{c}	53.41^{c}	59.07^{c}

[1]mean of 2 trials

[2]values with letters in common in the same column do not differ significantly ($p<0.05$)

[3]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

starch component, resulting in a decreased level of gelatinization and, therefore, retrogradation.

The loaves with ascorbic acid had staling patterns contradictory to theories reported in literature (Eliasson, 1983; Ghiasi et al., 1982; Kim and D'Appolonia, 1977a,b,; Russell, 1983a; Willhoft, 1973b). High-protein loaves were significantly more stale after Day 1. Ascorbic acid may have altered the amount of water available to the system. Ascorbic acid has been found to break hydrogen bonds of gluten, displacing bound water (Johnston and Mauseth, 1972; Zentner, 1968). The bound water could then be utilized for gelatinization. With flours containing higher protein levels, more protein would be available for interaction with ascorbic acid, causing more water to be released. Thus the starch component of the flour would be more completely gelatinized and initiate the retrogradation responsible for staling.

Breads made from low protein-flour and DATEM were not significantly more stale than their high protein counterparts. DATEM interacts with gluten to form a spiral complex (Lorenz, 1983). The interaction may have altered the amount of available water by releasing that bound to gluten. Since the actual mechanism of the interaction of DATEM and gluten is not known, it remains unclear what role, if any, the protein level played in the two variations in this research.

Although the magnitude of the staling thermogram changed with treatment and protein content, the T_{max} remained constant. Figure 8

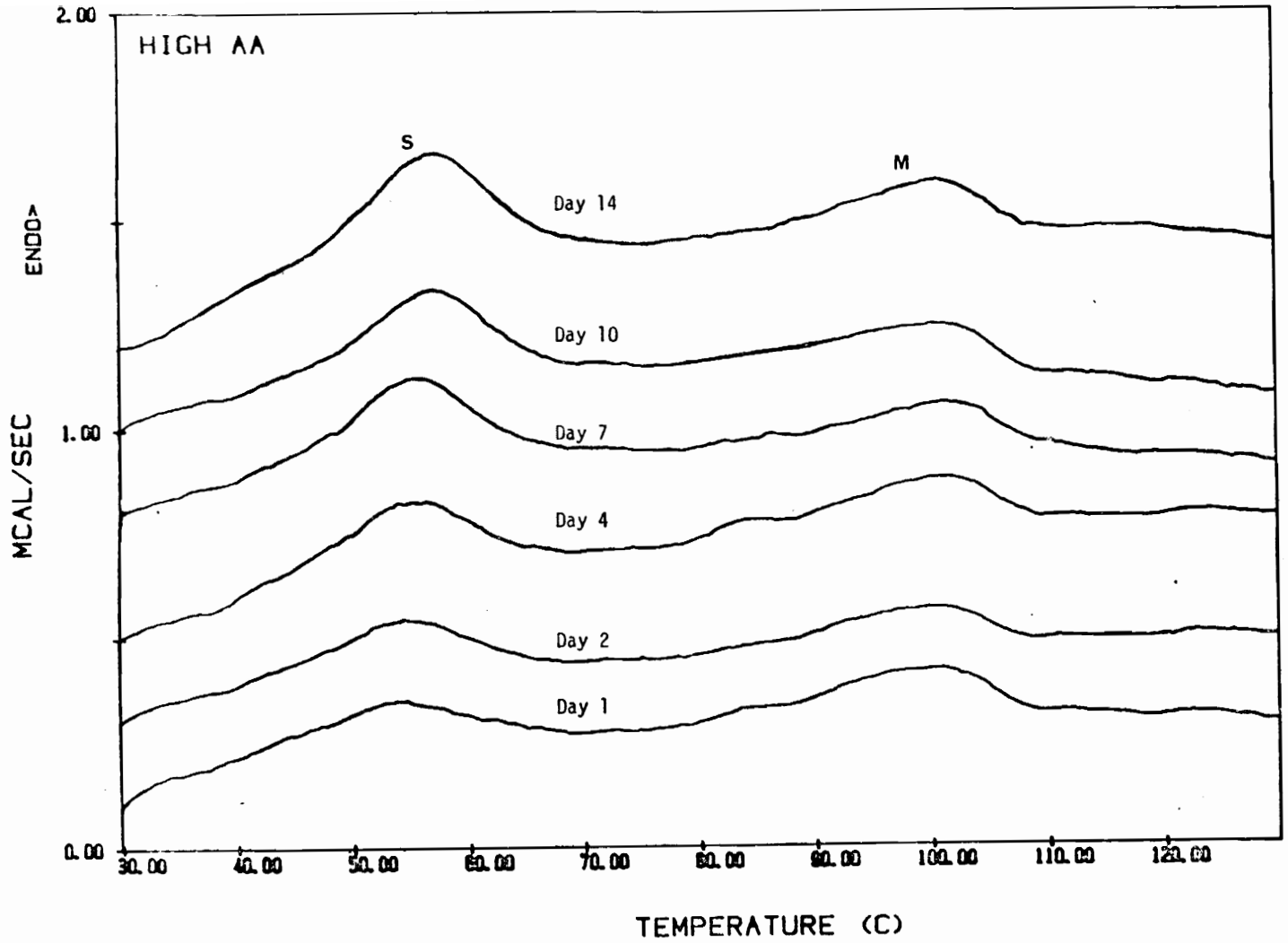

Figure 8. DSC thermograms of high protein-ascorbic acid treated bread from day 1 to day 14 after storage at 27°C. Endotherm 'S' was the staling endotherm; 'M' was due to the melting of the amylose-lipid complex.

shows superimposed thermograms obtained from the high protein-ascorbic acid variation over a two week period. The maximum temperature for the staling peaks (labeled 'S') remained constant around 55°C. From this figure, the increase in size of the peak over time was easily seen. The amylose lipid peak (labeled 'M') remained constant both in size and T_{max}.

Chapter V

Summary and Conclusion

Yeast breads were prepared from two flours differing in protein content. In addition, each flour type was used in breads with either no conditioner (control), ascorbic acid, or DATEM added. The breads were evaluated with both objective and sensory testing. The rate of staling of all bread variations was studied by differential scanning calorimetry (DSC) to determine if the dough conditioners would significantly reduce the rate. All results were analyzed using analysis of variance (ANOVA) and significant scores were further analyzed with Duncan's Multiple Range Test.

An eight member taste panel rated the breads for ten attributes: crust color, aroma, crumb color, cell size, cell evenness, compressibility, mouth feel, moistness, flavor, and overall aftertaste. Crust color was found by the panel to differ significantly among the treatments. In general, breads made with high-protein flours were evaluated as having darker crusts. The combination of high-protein flour and ascorbic acid resulted in a significantly larger cell size and a significantly less uniform cell structure, according to the panel.

The characteristics of the baked breads were measured by five objective tests: the Hunter Color Meter was used to measure crust

and crumb color; the penetrometer measured tenderness; volume was measured by rapeseed displacement; and oven drying measured the moisture content. All the high-protein flour treatments were found to have significantly darker crust colors. The combination of low-protein flour and ascorbic acid resulted in significantly more tender loaves. In general, breads made from the high-protein flours were significantly less tender.

Results showed that loaves made with DATEM, regardless of protein level of the flours used, had significantly slower rates of staling over a two-week period. An inverse relationship was shown between protein content and the rate of staling. In general, all breads made with the high-protein flour had significantly lower rates of staling.

In conclusion, both the low-protein and high-protein flours resulted in breads of similar characteristics, even when no conditioner was used. Few significant differences were found in objective or sensory testing of the loaves. Because no significant differences were found in volume among variations, the conclusion can be made that the quality of the proteins in the flours was appropriate for bread. The lack in quantity was compensated for by the high quality of the proteins. If the quality of the proteins present in the flours had been low, the conditioners would have been expected to significantly increase the bread-making characteristics of the flours.

Based on the results from the study, both flours obtained from Coker 916 wheat could be adequately utilized for bread baking. Neither of the dough conditioners needs to be added. To minimize the staling of bread held over time, it would be advisable to add DATEM to the dough. As the protein level of the flour used decreased, it would be necessary to supplement the dough with larger amounts of DATEM since lower protein levels were found to increase the rate of staling. It is not known whether flours obtained from other varieties of soft wheats would perform similarly if subjected to the same conditions of this study.

The study indicated the proteins present in both flours were appropriate for bread baking. However, before the overall quality of the flours can be completely judged, other baking tests must be performed. Future research should repeat the conditions of this experiment (flours, conditioners, quality measurements) substituting other baked goods for bread. The versatility of the flour could then be evaluated.

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Appendix A

Schematic View of Loaves Baked

Protein Content	Additive Treatment		
	None	Ascorbic Acid	DATEM
7.35%	6 repetitions	6 repetitions	6 repetitions
11.59%	6 repetitions	6 repetitions	6 repetitions

Appendix B

Randomly Chosen Baking Plan

Day	Flour protein content*	Additive	Number of loaves
1	11.59%	no additive	3
	11.59%	DATEM	3
2	7.35%	no additive	3
	7.35%	ascorbic acid	3
3	11.59%	ascorbic acid	3
	11.59%	no additive	3
4	7.35%	DATEM	3
	7.35%	no additive	3
5	11.59%	DATEM	3
	11.59%	ascorbic acid	3
6	7.35%	DATEM	3
	7.35%	ascorbic acid	3

*A coin was flipped to determine which flour would be used first. The flours then were alternated to help minimize day-to-day variations. Each treatment was written on a piece of paper and picked randomly out of a box.

Appendix C

Formula for Pup Loaves According to Treatment

Control

Ingredient	Flour basis (%)	Amount used
flour	100.0	350.0g
salt (NaCl)	1.5	5.5g
yeast (dry active)	2.0	7.0g
water	57.0	199.5ml
sugar	6.0	20.5g
shortening	3.0	10.5g
NFDM	4.0	14.0g

Ascorbic acid

Ingredient	Flour basis (%)	Amount used
flour	100.0	350.0g
salt (NaCl)	1.5	5.5g
yeast (dry active)	2.0	7.0g
water	57.0	182.0ml
sugar	6.0	20.5g
shortening	3.0	10.5g
NFDM	4.0	14.0g
40ppm ascorbic acid solution*	5.0	17.5ml

*0.47g ascorbic acid in 500ml water

DATEM

Ingredient	Flour basis (%)	Amount used
flour	100.0	350.0g
salt (NaCl)	1.5	5.5g
yeast (dry active)	2.0	7.0g
water	57.0	199.5ml
sugar	6.0	20.5g
shortening	3.0	10.5g
NFDM	4.0	14.0g
DATEM	0.5	0.9g

Appendix D

Method of Preparing Pup Loaves

1. The flour, salt, NFDM, shortenting, and 20.0g of the sugar were weighed out the day before and stored in airlock bags at room temperature overnight.

2. The day of baking, the yeast was combined with 0.5g sugar and 50.0ml warm water in a beaker and allowed to sit for 10 minutes. The dry ingredients were placed into a stainless steel mixing bowl and the mixer fitted with a dough hook.

3. The yeast was added to the dry ingredients and the beaker rinsed with the additional warm water. Any dough conditioners used were added at this time. The dough was kneaded on speed two for five minutes.

4. After mixing, the dough was placed in a greased bowl and turned once to grease the top. The bowl was covered with a clean towel and placed in the proofing oven.

5. After 50 minutes of proofing, the dough was rolled out on waxed paper using two 0.8cm dowels as guides. Both sides of the dough were rolled to smoothness. The dough was then folded in thirds, placed back in the bowl, and returned, covered, to the proofing oven.

6. After 25 minutes, step 5 was repeated.

7. After 10 minutes, the dough was weighed and divided into three equal portions. Step 5 was repeated for each portion. The dough was then rerolled on both sides using 0.5cm dowels. The dough was then tighly rolled into loaves and placed into greased 14½x8x5cm aluminum pup loaf pans. The pans were covered and placed in the proofing oven.

8. After 35 minutes, the loaves were baked for 10 minutes, three loaves at a time. Immediately upon removal from the oven, they were depanned and placed on wire racks to cool.

Appendix E

Scorecard for Sensory Evaluation of Baked Bread

Date _____

Sample number _____

crust color	light	dark
aroma	no yeast	strong yeast
crumb color	white	yellow
cell size	small	large
cell evenness	not uniform	uniform
compressibility*	not springy	springy
mouth feel	tender	tough
moistness	dry	gummy
flavor	none	strong
overall aftertaste†	none	strong

*as measured by the finger

†as measured after swallowing

Appendix F

Mean Enthalpy (ΔH) Values (calories/g) for all Treatments Over Two-week Storage Period[1]

Treatment[2]	Time after baking in days 1	2	4	7	10	14
Low aa	0.28	0.36	0.43	0.50	0.46	0.53
Low d	0.28	0.32	0.35	0.39	0.41	0.47
Low c	0.39	0.48	0.66	0.66	0.72	0.69
High aa	0.33	0.47	0.55	0.55	0.59	0.68
High d	0.23	0.30	0.29	0.34	0.39	0.42
High c	0.24	0.31	0.44	0.44	0.50	0.62

[1]mean of 2 trials

[2]'low' and 'high' refer to protein content of flour; 'd' = DATEM, 'aa' = ascorbic acid, 'c' = control

VITA

Yolantha Sophie Chlapowski was born in London, England on January 31, 1964. She attended public, parochial, and private schools in Gaithersburg, Maryland; Ann Arbor, Michigan; and Bethesda, Maryland. In addition, she spent two years at an international high school in Caracas, Venezuela. In May, 1986 she received a Bachelor of Arts degree in Biology and a Minor in Spanish from the University of Rochester. She entered graduate school at Virginia Polytechnic Institute and State University in September, 1986 to persue a Master of Science degree in Human Nutrition and Foods. While completing the requirements for her degree, Miss Chlapowski served as a graduate assistant to Dr. Marilynn Schnepf. After completing her degree, Miss Chlapowski will begin working for The Pillsbury Company.

Yolantha S Chlapowski

EFFECT OF DOUGH CONDITIONERS ON THE BREAD-MAKING QUALITIES OF SOFT WHEAT FLOUR

by

Yolantha Sophie Chlapowski

(ABSTRACT)

Low-protein (7.35%) and high-protein (11.59%) flours were tested for bread baking with and without the addition of two substances commonly used as dough conditioners: ascorbic acid and diacetyl tartaric esters of monoglycerides (DATEM). The bread-making properties of the flours were evaluated by measuring the loaf characteristics by objective and sensory evaluation. In addition, the effect of the dough conditioners on the rate of staling of baked bread was examined. No significant differences were found among the treatments with respect to volume, moisture content, or crumb color. Loaves baked with the high-protein flour had significantly darker crust colors. High-protein loaves were significantly less tender. The sensory panel found no significant differences in crumb color, aroma, compressibility, mouth feel, moistness, flavor, or overall aftertaste. The panel did find that high-protein loaves were significantly darker in crust color, and loaves baked with high-protein flour and ascorbic acid had significantly larger cell sizes and less uniform cell structures. The addition of DATEM to breads made with either flour resulted in significantly decreased rates of staling. Breads made with the high-protein flour staled slower than

their low-protein counterparts with or without dough conditioners. In conclusion, the bread-making characteristics of both flours were good and resulted in bread of good quality, even without conditioners present. DATEM can be added to retard the rate of staling, but more is needed with lower protein flours.