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I am submitting herewith a thesis written by Sarah Leah Cantrell entitled "Ascorbyl Palmitate as a Shortening Replacer, Dough-Strengthener and Crumb Softener in Commercially Produced Hamburger Buns." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

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ASCORBYL PALMITATE AS A SHORTENING REPLACER, DOUGH-STRENGTHENER AND CRUMB SOFTENER IN COMMERCIALLY PRODUCED HAMBURGER BUNS

A Thesis

Presented for the

Master of Science

Degree

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Sarah Leah Cantrell

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ABSTRACT

L-ascorbic acid 6-palmitate (AP) was investigated as a dough strengthener, crumb softener and shortening replacer in commercially produced hamburger buns. Farinograms in which either AP, sodium stearoyl 2-lactylate (SSL) or a commercial surfactant (surfactant A, a mixture of 45% soft monoglycerides, 45% ethoxylated monoglycerides and 10% succinylated monoglycerides) were added to flour at 0.25, 0.50, 0.75 or 1.00% (flour basis) were obtained as a measure of dough strength. Peak time, stability, tolerance index, arrival time, time to breakdown and water absorbance were determined from each farinogram and two replications of each surfactant-concentration combination were completed. SSL measured across concentration had a significantly greater peak time, departure time, stability and time to breakdown than AP or surfactant A. Concentration of SSL and surfactant A significantly affected peak time. Departure time, stability and breakdown time increased linearly as the concentration of SSL increased from 0.25 to 1.00% but were not affected significantly by AP or surfactant A. All three surfactants caused a significant decrease in tolerance index as concentration increased.

Three replications of hamburger buns containing either 0.2500, 0.3125, 0.3750 or 0.4375% ascorbyl palmitate and no shortening and a control bun containing 3% shortening, 0.375% monoglycerides and 0.625% surfactant A were commercially produced at a local bakery. Specific bun volume, crust color, crumb color, crust toughness, compressibility during storage and proximate analysis were measured for each run of buns produced. No significant differences were found between the control bun

and the AP bun for specific volume; however, a significant increase in specific bun volume occurred as the concentration of AP increased. The control bun had a redder top crust and lighter, less red crumb color than the AP bun. As the concentration of AP increased, significant effects for top crust lightness and "b" value were found and crumb lightness generally decreased. The control bun had significantly higher percent protein and lipid and significantly lower percent moisture and ash than the AP bun. The AP bun had significantly lower compressibility on day 2 and day 7 than the control bun, but there were no significant differences between the control bun and the AP bun for compressibility on day 0, 1, 3, 4 or 5. No significant differences were found between the buns for staling rate. Consumer ratings for overall acceptability and texture were significantly higher for the control bun. Both buns were rated between "like very much" and "like moderately" for overall acceptability. The control bun was rated just above "moderately soft" for texture and the AP bun was rated just below "moderately soft."

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CHAPTER I

INTRODUCTION

Antistaling additives are of great importance to the baking industry because of their contribution to product stability. There is particular interest in additives such as sodium stearoyl 2-lactylate which act as crumb softeners and dough strengtheners and are shortening sparing. Ascorbyl palmitate (L-ascorbic acid 6-palmitate) has been reported by several investigators to be an effective crumb softener and dough strengthener and does not require the presence of shortening in the bread formula to exert its effects. Hoseney et al. (1977) and Offelt and co-workers (1958) showed that ascorbyl palmitate without shortening was as good an antistaling agent as monoglycerides with shortening. Melton et al. (1979) demonstrated that sodium stearoyl 2-lactylate in bread with or without shortening was not as effective in softening crumb as ascorbyl palmitate without shortening. Ascorbyl palmitate was also shown to produce better bread volume than sodium stearoyl 2-lactylate or monoglycerides.

Laboratory investigations have shown ascorbyl palmitate to be an effective antistalant, dough strengthener and shortening replacer in bread. No studies have been reported in the literature which explore the feasibility of its use as a crumb softener and dough strengthener in commercial bread production. Some investigators (Offelt et al., 1958; Hoseney et al., 1977) have also noted that ascorbyl palmitate is difficult to disperse in flour and may result in poor functionality and

discoloration of crust and crumb. Thus, this study was undertaken to develop processing procedures to disperse ascorbyl palmitate uniformly in commercially prepared hamburger burns and determine its effects as a crumb softener, dough strengthener and shortening replacer. The effects of ascorbyl palmitate on bun volume, crust and crumb color, crust toughness and consumer acceptance in comparison to a bun containing shortening and commercial softeners and strengtheners will also be reported.

CHAPTER II

LITERATURE REVIEW

I. STALING OF BREAD

Staling was defined by Betchel and co-workers (1953) as a term implying decreased product acceptance by the consumer for causes other than microbiological spoilage. Hertz (1965) described staling in general as all changes occurring in bread following baking. Geddes and Bice (1946) reported that some of the specific changes which occur in bread during staling are:

1. Change in taste and aroma.
2. Increased hardness of crumb.
3. Increased opacity of crumb.
4. Increased crumbliness of crumb.
5. Increased starch crystallinity of crumb.
6. Decreased susceptibility of crumb to attack by β-amylose.
7. Decreased soluble starch content.

Willhoft (1973) contended that the most critical changes which occur during staling are an increase in crumb firmness, loss of crust crispiness and flavor deterioration.

Katz (1915) using x-ray diffraction was first to demonstrate that starch crystals form during staling and contribute to crumb firmness. Meyer in 1942 proposed that crystallization of amylose, the linear fraction of starch, was the main cause of staling. The author's conclusions were drawn from the observation that amylose appeared to

retrograde after gelatinization during baking while amylopectin aggregated and precipitated from solution. Schoch and French (1947), however, found that amylose completely retrograded following baking since they extracted primarily amylopectin from aged bread. They believed staling was caused by spontaneous aggregation of the branched amylopectin starch fraction. Recent work by Kim and D'Appolonia (1977) indicated that both the branched and linear fraction of starch play a role in crumb firming during staling. They showed that initial crystallization of starch involved both amylose and amylopectin, but that subsequent retrogradation the first day following baking involved primarily amylopectin.

The role of moisture in bread staling has been investigated by several researchers. Early work by Boussingault (1852) showed that staling could occur in bread without loss of moisture. MacMasters (1961), however, showed that loss of bread moisture may accelerate reactions which affect staling rate. Work of Senti and Dimler (1960) illustrated that a reduction in moisture absorption capacity of starch occurs during staling. They suggested staling causes a transfer of moisture from starch to gluten. Willhoft's (1973) studies showed the opposite effect —a transfer of moisture from gluten to starch. Willhoft (1973) proposed this transfer results in a minor softening effect on starch with a pronounced rigidification of the gluten fraction. Bushuk and Mehrotra (1977) found a positive correlation between crumb firmness and bound water in bread as determined by differential thermal analysis.

Specific volume has been shown to be related to the rate of staling. Axford and co-workers (1968) found a reduced staling rate in

bread with higher specific volume. The work of Elton (1969) supported these findings also.

Temperature also affects the rate of staling. Cornford et al. (1964) demonstrated that staling rate increased as storage temperatures of bread approached freezing. Willhoft (1973) reported maximum staling occurred at -2°C.

Although the term staling is well-defined, the process by which it occurs is still not fully understood. Various studies support theories that retrogradation of amylose or amylopectin is the primary cause of staling. Some researchers, however, propose that both fractions of starch as well as gluten are involved in the process. Moisture content, loaf volume and storage temperature have also been shown to influence the rate of staling in bread.

II. ACTION OF SURFACTANTS AS ANTISTALANTS

Surfactants have been shown to be effective in retarding bread staling. Favor and Johnson (1947) were the first investigators to report reduced staling in bread when polyoxyethylene was incorporated at the .50% and 1.00% level of flour weight. Hopper (1949) used x-ray patterns to illustrate how monoglycerides might inhibit bread staling and reduce crystallization of starch. Coppock et al. (1954) reported that monoglycerides might inhibit bread staling by causing: (1) enhanced fat dispersion during mixing; (2) retention of soluble starch in starch granules; (3) inhibition of starch gelatinization; (4) greater moisture availability to gluten, and (5) improved retention of moisture in gluten. Bourne and co-workers (1960) found sucrose monostearate acted primarily

on the amylose component of starch by absorption onto the surface. It was theorized that this absorption sealed moisture inside the granule and prevented moisture migration to the outside of the crumb. Collison et al. (1960) reported that starch granules heated with a nonionic surfactant showed greater water absorption with less disintegration and reduced intergranular adhesion compared with starch granules heated without a surfactant. They concluded that the surfactant formed a hydrophobic monolayer on the surface of the granule and prevented starch granules from binding together. It was suggested that this phenomena reduced rigidity of the crumb structure and improved bread softness during storage. Jongh (1961) proposed that surfactants absorbed on the surface of the starch granules offset electrostatic and steric attraction between protein fibrils and starch molecules. The author believed this reduced attraction allowed starch granules to remain in a more separate, random state and permitted closer association with water molecules. Thus, with surfactants, moisture retention of the crumb is improved and bread softness enhanced.

Lagendijk and Pennings (1970) evaluated the starch-complexing abilities of monoglycerides with different fatty acid moieties on staling rate of bread. Increasing amounts of monoglycerides were found to complex with starch in a linear response with increasing carbon chain length up to sixteen carbons (glyceryl monopalmitate). A positive relationship was noted between amount of monoglycerides complexed with starch and softness of bread.

Birnbaum (1971) theorized that surfactants create a clathrate structure with linear segments of the starch granule. This structure

would inhibit swelling of the entire starch network, thus reducing water absorption by the starch and supplying more moisture to soften gluten.

Recent work by DeStefanis and co-workers (1977) showed that during dough development surfactants were bound to the protein fraction of the bread but as starch gelatinized during baking the surfactants translocated and were bound by starch. The authors concluded that the effectiveness of a surfactant as an antistalant is dependent on uniform dispersion of the additive prior to baking.

Many researchers have investigated the antistaling properties of surfactants; yet the mechanism by which antistalants work is not clear. It is generally agreed among investigators, however, that the primary antistaling action of surfactants occurs from binding with major components of flour during various stages of baking.

III. ACTION OF SURFACTANTS AS DOUGH STRENGTHENERS

Tenny (1978) distinguished antistalants or softeners as those ingredients which bind to starch and enhance crumb softness; strengtheners or conditioners were defined as those ingredients which bind primarily with flour protein and contribute to dough strength.

MacDonald (1968) reported that the functions of strengtheners in bakery products include:

1. Improved ingredient and processing tolerances.
2. Improved dough characteristics.
3. Improved grain, texture and overall quality of baked bread.
4. Reduced rate of crumb firming.

Dough strengtheners were described by Barrett (1970) as ingredients which strengthened the dough, compensated for production variations in equipment and improved crumb structure to enhance shelf life. Moncrieff (1970) defined dough strengtheners as additives which give a proofed, unbaked loaf of bread tolerance to production abuses and shock.

Several investigators have reported on the effectiveness of surfactants as dough strengtheners. Mixogram studies by Swanson and Andrews (1942) showed that the addition of anionic surfactants to flour extended dough mixing time. Sodium dioctyl sulfosuccinate and sodium lauryl sulfate were reported by Swanson and Johnson (1944) to increase mixing time at levels below 0.25% in flour. Sullivan (1952) investigated the effects of several surfactants on mixing characteristics of flour in the farinograph. Sodium alkyl acyl sulfonate at a 1.0% concentration was shown to improve mixing and tolerance properties of the dough. Thompson et al. (1954) found by farinograph studies that calcium stearoyl 2-lactylate improved dough tolerance and mixing time at a optimum level of .50%. The same level of calcium stearoyl 2-lactylate added to bread also improved bread volume and crumb characteristics.

Effectiveness of surfactants as dough strengtheners is related to their interactions with flour protein. Fullington (1969) suggests lipid-protein interactions may take the form of chelate structures. Pomeranz (1971) described a variety of types of surfactant-protein bonds which may occur including co-valent, ionic, hydrogen, Van der Waals and hydrophobic. Hoseney et al. (1970) proposed that the gliadin fraction of gluten binds to lipids by hydrophilic bonds and the glutenin binds by hydrophobic bonds.

Sodium stearoyl 2-lactylate and calcium stearoyl 2-lactylate were reported by Chung (1973) to form aggregates consisting of complexed protein and starch. Grosskreutz (1961) investigated the interaction of calcium stearoyl 2-lactylate with proteins and concluded that the surfactant formed bimolecular layers between sheets of protein platelets which acted as slip planes in the dough.

Two types of surfactant-protein complexing were suggested by Greene (1975). The author proposed that the nonpolar portion of anionic surfactants bind to protein through hydrophobic forces and nonionic surfactants bind to protein by hydrogen bonds. Greene (1975) further projected that hydrophilic chains on nonionic surfactants complex to adjacent protein macromolecules. The overall effect is the formation of an intermolecular gluten network which strengthens the dough.

Dough conditioners or strengtheners have been shown to exert their effects by complexing with proteins in the dough. Several types of binding may occur depending on the nature of the surfactant and the fraction of protein involved.

IV. COMMERCIAL SOFTENERS AND CONDITIONERS

Several surfactants used in commercial production perform the dual function of antistalants and dough conditioners. Birnbaum (1971) stated that monoglycerides, primarily bread softeners, have some ability to strengthen dough as well. This property of surfactants is derived from the capacity to interact with more than one flour component. Lactylates, ethoxylated compounds and combinations of these are most commonly used in commercial bakery production. Numerous researchers have reported on

the relative softening and conditioning effect of these additives. Zobel (1973) compared starch complexing ability and starch crystallization inhibition of several surfactants in bread. He found that a blend of sodium stearoyl 2-lactylate with mono-and diglycerides and polysorbate 60 controlled starch crystallization to the greatest extent and produced a softer crumb. Tenny (1978) compared dough conditioning and antistaling properties of eight surfactants. Sodium stearoyl 2-lactylate, calcium stearoyl 2-lactylate and two ethoxylated compounds were shown to have the greatest strengthening ability as measured by volume of bread. Compressibility data indicated succinylated monoglycerides, sodium stearoyl 2-lactylate and monoglycerides were the most effective antistalants.

V. SURFACTANTS AS SHORTENING SPARERS AND SOFTENING, CONDITIONING AND SHORTENING-SPARING PROPERTIES OF ASCORBYL PALMITATE

Shortening is desirable in bread formulations because of its contribution to bread volume, dough machinability, texture and softness (Tsen and Hoover, 1971). Shortening sparing surfactants maintain these characteristics and condition and/or soften bread with reduced levels of shortening or no shortening added. Pomeranz et al. (1969) reported bread made with levels of 0.25% to 0.50% glycolipids had volume and texture equal to or better than bread containing 3% shortening. Finney and Shogren (1971) found that 1.5 grams of calcium stearoyl 2-lactylate and 0.5 grams of sodium stearoyl 2-lactylate both produced bread with better volume and more desirable crumb than bread with 3% shortening

added. Tsen and Hoover (1971) tested the shortening-sparing action of sodium stearoyl 2-lactylate in bread with added soy flour. A level of 0.25% sodium stearoyl 2-lactylate or 0.5% calcium stearoyl 2-lactylate with 1% to 2% shortening added improved the characteristics of the bread. These additives at the 0.5% level without shortening produced equally desirable volume and crumb characteristics. In addition, 0.5% sodium stearoyl 2-lactylate without shortening added prevented staling to a greater extent than shortening alone.

Ascorbyl palmitate has been reported to be an effective antistalant in bread with shortening-sparing properties. Offelt (1958) first reported on the antistaling effectiveness of ascorbyl palmitate in bread. He noted, however, that the compound gave an undesirable browning to the crumb. Hoseney and co-workers (1977) later investigated ascorbyl palmitate as a conditioner and softener. Charred specks appearing in the crust indicated that the additive was not well-dispersed and full functionality not achieved. The authors discovered that thorough grinding of ascorbyl palmitate with flour or converting ascorbyl palmitate to a salt form improved dispersibility. The sodium salt of ascorbyl palmitate was reported to be as effective in retarding staleness in bread with shortening as monoglycerides. Levels of 0.5% ascorbyl palmitate without shortening, however, were found to be more effective than monoglycerides in preventing staleness. Melton et al. (1979) investigated the effect of ascorbyl palmitate, monoglycerides, succinylated monoglycerides and sodium stearoyl 2-lactylate with and without shortening on bread volume, color and compressibility. Ascorbyl palmitate without shortening and monoglycerides with shortening produced

bread with equal volume and better antistaling properties than other surfactants. Melton (1979) concluded that ascorbyl palmitate was as good or better than monoglycerides and was shortening-sparing. Furthermore, sifting of ascorbyl palmitate into the flour allowed for uniform dispersion and no discoloration in the crust or crumb was observed.

Ascorbyl palmitate has been shown by investigators to act as a dough conditioner and strengthener in bread. When uniformly dispersed, ascorbyl palmitate has been reported to produce good volume, desirable crumb and crust color and act as an effective antistaling agent without the presence of shortening. Additional work is needed to determine ascorbyl palmitate's functionality as a shortening replacer, antistaling agent and dough conditioner in commercially produced bread.

CHAPTER III

MATERIALS AND METHODS

I. FARINOGRAPH STUDIES

Materials

Two sixty-pound lots of flour were obtained from Kern's Bakery, Knoxville, Tennessee, for investigation of dough strengthening effects of three surfactants; sodium stearoyl 2-lactylate (SSL), surfactant A (a mixture of 45% soft monoglycerides, 45% ethoxylated monoglycerides and 10% succinylated monoglycerides) and ascorbyl palmitate (L-ascorbic acid 6-palmitate). Each lot of flour was obtained from a different shipment to Kern's Bakery on different days and was used for a single replication (Sanders, 1979).

Sodium stearoyl 2-lactylate was provided by Swan's Sunbeam Bakery, Knoxville, Tennessee and surfactant A by Kern's Bakery. Ascorbyl palmitate was provided by Hoffman LaRoche, Inc., Nutley, New Jersey.

Investigation of dough strength was done at 30°C on a Brabender farinograph (model SKC47AB10) at White Lily Food Company, Knoxville, Tennessee. The farinograph was equipped with a 300 gram bowl.

Method

Farinograms were obtained by the A.A.C.C. farinograph procedure (A.A.C.C., 1972). The dough strengthening effects of each of the three surfactants was investigated at concentrations of 0, 0.25%, 0.50%, 0.75% and 1.00% (flour basis) and two replications were run. A completely

randomized design was used and the order in which each surfactant-concentration combination was run was randomly selected across replication (Table 1). Peak time, stability, tolerance index, arrival time, time to breakdown, water absorption and departure time were determined from each farinogram (Appendix, Figure A-1).

II. COMMERCIAL PRODUCTION OF HAMBURGER BUNS CONTAINING ASCORBYL PALMITATE AND THEIR EVALUATION

Ascorbyl palmitate (AP) was evaluated as a dough strengthener, antistaling agent and shortening replacer in commercially produced hamburger buns at Kern's Bakery. Different concentration of AP (0.2500, 0.3125, 0.3750 or 0.4375% flour basis) were substituted for shortening, monoglycerides and surfactant A in a hamburger bun formulation (Table 2). A single replication consisted of buns produced four times, each time with a different concentration of AP and a control bun containing shortening, monoglycerides and surfactant A (five treatments). The control bun was the bun normally produced by Kern's Bakery for market. Three replications were run. The order in which the different concentration-replication combination as well as the control were run was determined by ramdomization across replication. A total of 15 runs were done at the bakery. The experimental design for the commercial production of the buns is shown in Table 3 (Sanders, 1979).

A sponge and dough formula (Table 2) was used for the commercial production of the bun. A liquid sponge containing flour, water, salt, yeast, syrup and yeast food was held at 29°C for one to one and a half hours in a Groen sponge tank. The liquid sponge was pumped into a water-jacketed Baker Perkins horizontal mixer containing other dough

Table 1. Experimental design for farinograph studies.

Concentration	Treatment 1	2	3
1 (0.00%)	11[a]	12	13
2 (0.25%)	21	22	23
3 (0.50%)	31	32	33
4 (0.75%)	41	42	43
5 (1.00%)	51	52	53

[a]The first number is the concentration level and the second number is the treatment number.

Table 2. Sponge and dough formula for commercial production of hamburger buns.

Sponge ingredients	% Flour basis
Bread flour	60
Water	50
Salt	2
Syrup	3
Yeast food	0.5
Dough ingredients	
Bread flour	40
Gluten	3
Dairy base	3
Syrup	14
Calcium propionate	0.125
Bromate	3
Water	14.4
Ascorbyl palmitate	*
Monoglycerides	.375 (control)
Surfactant A	.625 (control)
Shortening	3 (control)

*0.00, 0.2500, 0.3125, 0.3750, 0.4375% according to treatment.

Table 3. Experimental design for commercial production of hamburger buns.

	Treatment				
		AP Concentration			
Replication	1 control	2 0.2500%	3 0.3125%	4 0.3750%	5 0.4375%
1	11[a]	12	13	14	15
2	21	22	23	24	25
3	31	32	33	34	35

[a]The first number is the concentration level and the second number is the treatment number.

ingredients. Prior to mixing, the ascorbyl palmitate was dispersed in approximately 9.5 liters of warm water (29°C) and added to the dough ingredients. The dough ingredients were mixed an average of 7 minutes until dough pickup and then were mixed an additional 5 minutes. The average dough temperatures following mixing was 28°C.

The developed dough was removed from the mixer, hoisted to a scaler-divider and scaled at 26 ounces per 12 buns. The dough was molded and panned into pans to produce four inch diameter buns on an American Machine and Foundry Company Pan-O-Matic.

The buns were proofed 50 to 55 minutes at 44°C and at a humidity of 90 to 95%. After proofing the buns were baked in a Baker Perkins traveling oven at 237°C for approximately 8 to 10 minutes and were cooled on moving conveyor belts for 20 minutes. After cooling, random samples of buns were removed from the production line unsliced for compressibility measurements. The remaining samples of buns taken were selected randomly following slicing with a band slicer and bagging.

III. EVALUATION OF COMMERCIALLY PRODUCED BUNS CONTAINING ASCORBYL PALMITATE

Compressibility during storage, specific volume, crust color, crumb color and crust toughness were measured in duplicate on each batch of freshly-baked buns. Twelve buns from each batch were oven-dried overnight and then ground in a Wiley Laboratory Mill for proximate analysis.

Staling Rate

The effect of ascorbyl palmitate on staling rate of the bun was determined from compressibility data obtained with an Instron Universal Testing Instrument (model 1132) equipped with a 5000 gram load cell. Representative unsliced samples from each run were collected, the bottom sliced to 1.5 cm width and stored in sealed plastic bags at 25°C for up to five days. Two buns from each run were sealed in plastic bags and stored at refrigerator temperature (4°C) for seven days. On the day of baking (day 0) and day 1, 2, 3, 4, 5 and 7 following baking, each bottom slice of two buns was compressed from 15 to 10 mm at a speed of ten centimeters per minute with a plunger having a flat surface area of 25.75 cm^2. The force required to compress the center of the bottom slice of each bun was divided by the distance compressed (5 mm) and averaged.

For each treatment-replication combination the compressibility of bread at 0, 1, 2, 3, 4 and 5 days (E_0, E_1, E_2, E_3, E_4 and E_5 respectively), which is a measurement of the firmness of bread, was subjected to Avrami analysis (Kim and D'Appolonia, 1977) and the Avrami exponent and rate constant were determined.

The Avrami exponent, n, was determined as the slope of the straight line defined by the equation

$$\log_{10}(-\log_e \frac{E_L - E_t}{E_L - E_0}) = \log K = n \log t$$

where $\frac{E_L - E_t}{E_L - E_0} = \theta$, the fraction of uncrystallized material, E_L =

compressibility of bread stored for 7 days at 4°C, t = storage time in days and K = the rate constant. The rate constant, K, was determined as the slope of the line with the equation

$$\log_e (E_L - E_t) = Kt + \log_e C.$$

The time constant, 1/K, may also be calculated.

Crust and Crumb Color

Hunter color values, "L," "a" and "b" were determined for buns from each run by a Hunterlab Color Difference Meter (model D2502). A white ceramic tile (standard number C2-136; L=93.4, a=-1.10, b=1.90) was used to standardize the instrument and crumb color values were taken from three predetermined spots on the crumb surface. An orange tile (L=26.1, a=12.0, b=14.9) was used as a reference for crust color and values were taken from three predetermined spots on the top crust and bottom crust. All color values were averaged to obtain single values of "L," "a" and "b" for top crust color, bottom crust color and crumb color.

Specific Loaf Volume

Volume of buns from each run was obtained by measuring the volume of four buns at one time in a rapeseed displacement cake volume meter. Specific volume was calculated by dividing the volume by weight of the four buns.

Crust Toughness

Crust toughness of freshly-baked buns was determined by a modification of the method developed by Dahle and Montgomery (1978) for

measuring strength and extensibility of the crumb. The procedure is as follows:

1. The top slice of the hamburger bun was centered on top of a 142.55 cm^2 cylinder mounted on the Instron Tester equipped with a 500 kg load cell.
2. A 5.5 cm diameter disc suspended by a 5 cm long shaft descended vertically at a speed of 10 cm per minute into the cylinder.
3. The amount of force (g) required to rupture the crust with the disc is reported as crust toughness.

Proximate Analysis

Proximate analysis was conducted on an air-dried, ground sample from each pilot run of buns baked. Percent moisture, protein, ash and total lipid were determined. A chloroform-methanol lipid extraction procedure (Melton et al., 1979) was used to determine percent lipid. Moisture, protein and ash were determined according to A.O.A.C. procedures (A.O.A.C., 1970).

Consumer Panel Test of Commercially Produced Buns

Consumer acceptance of the ascorbyl palmitate hamburger buns was determined by randomly distributing 200 packages of buns containing 0.375% (flour basis) AP and 100 packages of control buns (Kern's regular bun formula containing shortening, monoglycerides, surfactant A and no AP) to families representing a normal urban population. Each package contained eight buns and was coded for identification. Consumer panelists were asked to indicate their general acceptance and rate the softness/firmness of the bun. Panelists were also encouraged to comment on the bun's flavor, color, texture and other characteristics (Appendix, Figure A-2).

IV. STATISTICAL ANALYSIS

Farinograph Studies

Analysis of variance was conducted to determine significant effects of treatment and interaction of treatment with other independent classes on dependent variables (Table 4). Significance of treatment, concentration and interaction of treatment and concentration on variables was tested by Replication/T,C. Significant differences among variables means due to treatment effects were separated by Duncan's Multiple Range Test. Orthogonal polynomials were used to separate significant differences between means due to concentration (Sanders, 1979).

Commercial Production of Buns

Analysis of variance (Table 5) was used to determine significant effect of treatment on specific bun volume, compressibility during storage, crust and crumb color, crust toughness, Avrami exponent and rate constant and proximate analysis of commercially produced buns. Orthogonal comparisons were used to further separate treatment means into significant effects between controls and levels of AP (comparison 1, Table 6). Orthogonal polynomials were used to separate differences within levels of 0.2500%, 0.3125%, 0.3750% and 0.4375% AP based on flour weight (comparison 2, 3 and 4, Table 6).

Consumer Acceptance

Analysis of variance (Table 7) was used to determine significant treatment effects on consumer rating of overall acceptability and texture rating of commercially produced control buns and AP buns.

Table 4. Statistical analysis of farinograph studies.

Source	Degrees freedom
Treatment (T)	2
Concentration (C)	4
Treatment x Concentration	8
Error (Replication/T,C)	15
Total	29

Table 5. Statistical analysis of commercially produced buns.

Source	Degrees freedom
Treatment (T)	4
Error (Replication, R) + (RxT)	10
Observations/T,R	15
Total	29

Table 6. Orthogonal comparisons to separate treatment means for commercially produced buns.

	Treatment				
Comparison	1 control	2 .2500% AP	3 .3125% AP	4 .3750% AP	5 .4375% AP
1 (AP vs. control)	-4	+1	+1	+1	+1
2 (linear AP)	0	-3	-1	+1	+3
3 (quadratic AP)	0	+1	-1	-1	+1
4 (cubic AP)	0	-1	+3	-3	+1

Table 7. Statistical analysis of consumer acceptance.

Source	Degrees freedom
Acceptability	
Treatment (T)	1
Age group (A)	2
T x A	2
Error	455
Total	460
Texture	
Treatment (T)	1
Age group (A)	2
T x A	2
Error	463
Total	468

CHAPTER IV

RESULTS AND DISCUSSION

I. FARINOGRAPH STUDIES

Statistical analysis of the farinograph study of flour samples containing sodium stearoyl 2-lactylate (SSL), surfactant A, or ascorbyl palmitate (AP) are shown in Table 8. Differences ($P<.001$) due to treatment were found for peak time, departure time, stability and breakdown time of the flour. Treatment effects on arrival time, tolerance index and water absorbance were not significant. Separation of treatment means by Duncan's Multiple Range Test showed that SSL added to flour resulted in longer peak time, departure time, stability and breakdown time than surfactant A or AP (Table 9). Differences between surfactant A and AP were not significant for these variables.

Significant concentration effects were found for peak time, departure time, stability, tolerance index and breakdown time and significant treatment x concentration interactions for the same variables except tolerance index and water absorbance (Table 8). As concentration of the surfactants increased, the mean tolerance index across surfactant decreased linearly from 28.3 B.U. at 0.0% surfactant to 15 B.U. at 1.00% surfactant (Figure 1). Peak time as a function of surfactant concentration is shown in Figure 2. As the concentration of SSL increased from 0.0 to 1.0%, peak time increased in a quadratic fashion from 11.4 to 25.3 minutes. Increasing surfactant A from 0.0 to 0.25% slightly increased peak time, but further increases of surfactant A to 0.75%

Table 8. Analysis of variance of treatment effects on dough strength as measured by farinograph.

Source	Degrees of freedom	Mean Squares: Peak Time	Arrival Time	Departure Time	Stability	Tolerance Index	Absorbance	Breakdown Time
Treatment (T)	2	268.41[a]	1.84	448.93[a]	476.52[a]	17.50	0.46	591.96[a]
Concentration (C)[d]	4	17.46[a]	1.25	95.35[a]	84.72[a]	170.00[c]	0.17	115.28[b]
T x C[d]	8	32.01[a]	0.99	54.14[b]	58.32[a]	20.62	0.65	69.67[c]
SSL								
linear	1	266.45[a]	0.03	744.20[a]	735.08[a]	281.25[c]	1.49	775.01[b]
quadratic	1	13.58[c]	0.00	12.89[a]	13.23	72.32	0.30	29.01
cubic	1	2.63	0.00	0.38	0.31	0.00	0.74	13.61
quartic	1	0.50	0.00	0.43	0.35	11.43	0.60	0.51
Surfactant A								
linear	1	1.65	1.30	28.20	17.39	12.87	0.12	0.26
quadratic	1	2.43[c]	2.52	6.27	16.74	20.61	0.16	0.50
cubic	1	2.62[c]	4.95	2.81	0.30	23.40	0.20	0.00
quartic	1	0.32	3.93	0.06	2.98	25.71	0.07	0.00
AP								
linear	1	14.45	0.08	0.53	0.20	245.00	1.51	0.15
quadratic	1	1.08	0.18	1.88	0.89	32.14	4.32	0.25
cubic	1	0.38	0.00	0.25	0.25	5.00	0.05	0.33
quartic	1	20.25	0.12	16.63	17.68	57.86	103.72	0.54
Error	15	4.72	0.53	10.58	8.13	42.50	0.47	19.24

[a]Significantly different at the P<.001 level.

[b]Significantly different at the P<.01 level.

[c]Significantly different at the P<.05 level

[d]Concentration and T x C sum of squares were partitioned by orthogonal polynomials for each treatment.

Table 9. Treatment means of dough strengthening effects as measured by farinograph.

Treatment	Peak time (minutes)	Departure time (minutes)	Stability (minutes)	Breakdown time (minutes)
SSL	19.22[a]	32.97[a]	32.05[a]	33.60[a]
Surfactant A	11.67[b]	21.57[b]	19.92[b]	21.78[b]
AP	10.05[b]	21.17[b]	20.27[b]	19.07[b]

[a,b]Means in the same column with the same superscript are not significantly different.

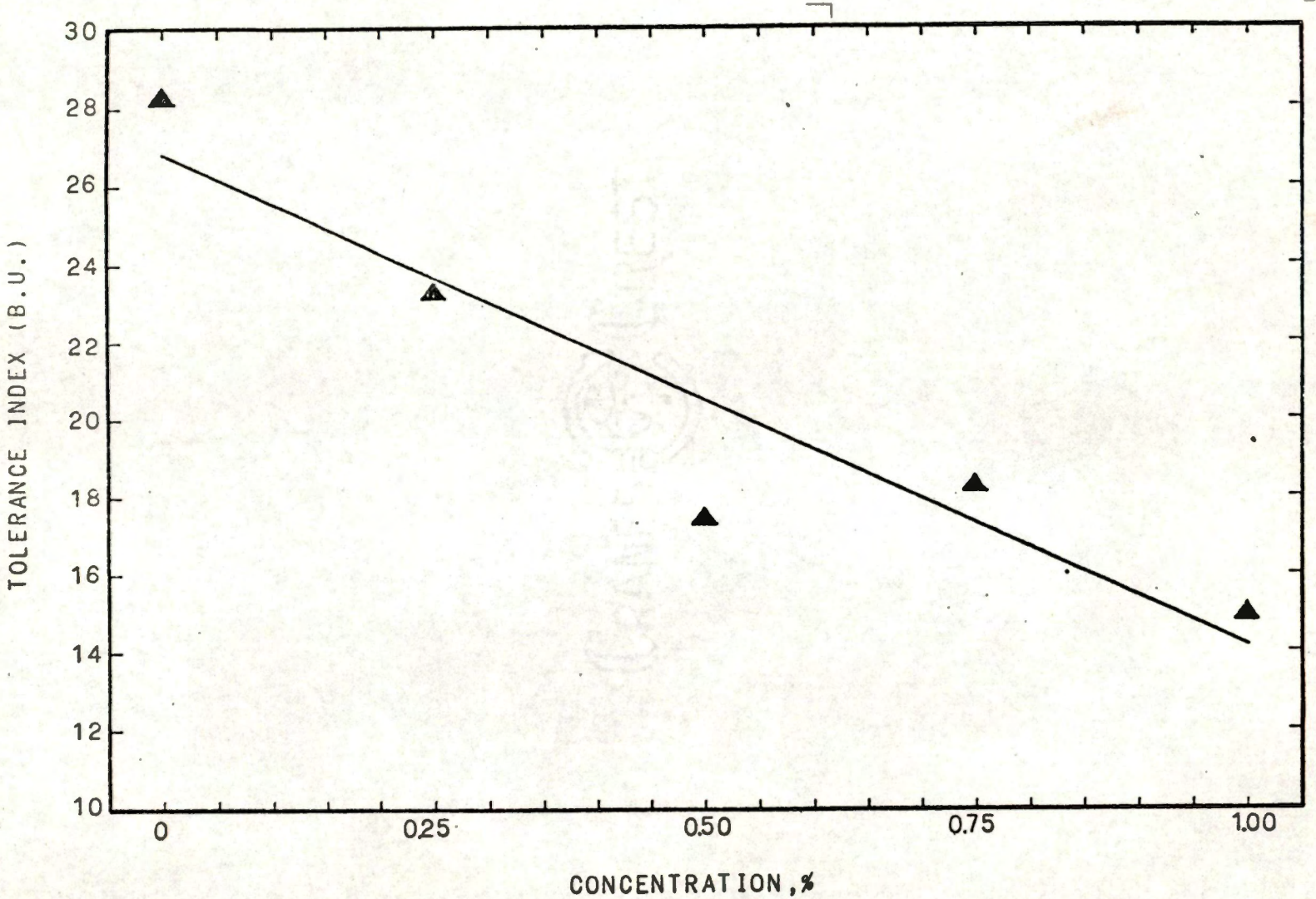


Figure 1. The average tolerance index across treatments of SSL, surfactant A and AP. (Each point represents the mean of three replications.)

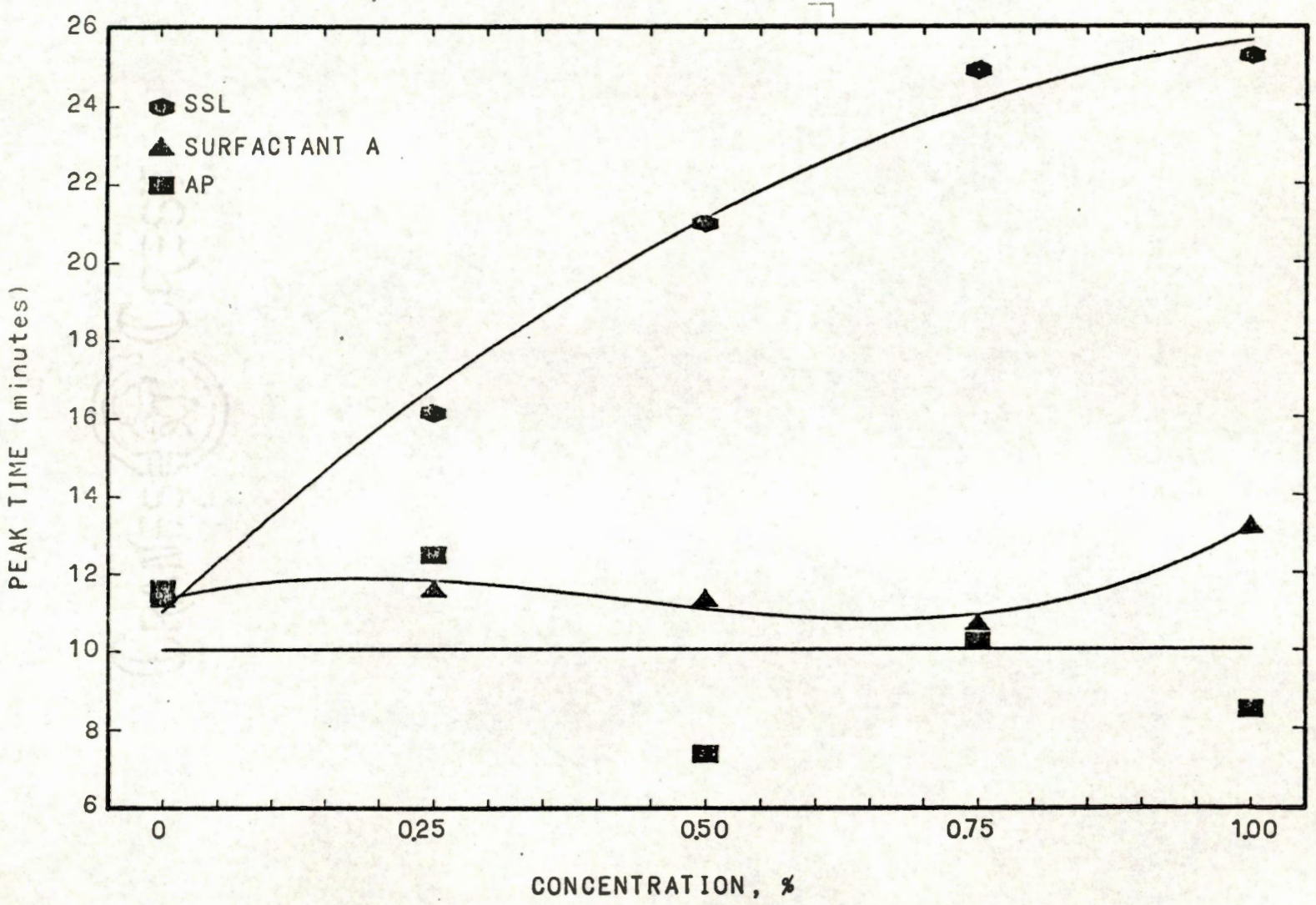


Figure 2. The average peak time of SSL, surfactant A and AP as a function of concentration. (Each point represents the mean of three replications.)

decreased peak time to 10.75 minutes. Addition of 1.00% surfactant A gave the longest peak time, 13.25 minutes. Peak time was not significantly affected by concentration of AP.

Figure 3 shows the departure time as a function of concentration of each surfactant. As the concentration of SSL increased from 0.0 to 1.0% departure time increased linearly from 18.6 to 42.6 minutes. Increasing concentration of AP or surfactant A did not cause a significant difference in departure time.

Stability is shown as a function of concentration of each surfactant in Figure 4. Stability increased linearly as the concentration of SSL increased. The concentration effects of surfactant A and AP on stability were not significant.

Figure 5 shows breakdown time as a function of concentration of each surfactant. Time to breakdown increased linearly as the concentration of SSL increased. No significant effects were found in breakdown time from increasing the concentration of surfactant A or AP.

Farinograph studies of Chung and Tsen (1975) showed similar results for the effect of SSL on dough strength. They found that peak time, departure time, dough tolerance and dough stability increased as levels of SSL increased from .25% to 2.00% of flour weight. Also, percent water absorption of the dough was found to decrease slightly as the level of SSL increased but SSL did not affect arrival time significantly.

Chung and Tsen (1975) reported that as levels of ethoxylated monoglycerides in bread increased from .25% to 2.00% (flour basis), a decrease in departure time, absorbance, dough tolerance, peak time and arrival time occurred. A maximum dough stability of 7.5 minutes was

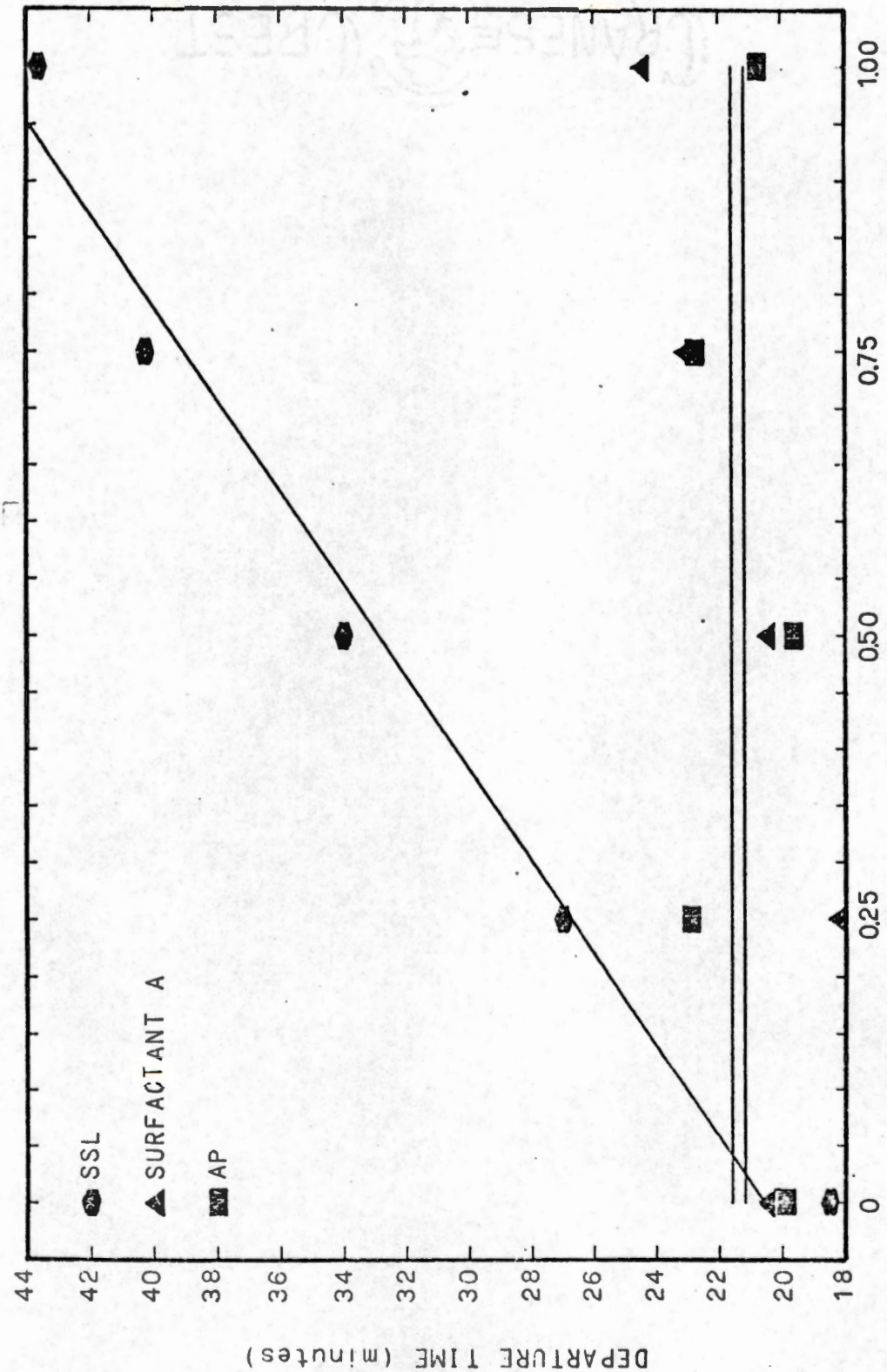


Figure 3. The average departure time of SSL, surfactant A and AP as a function of concentration. (Each point represents the mean of three replications.)

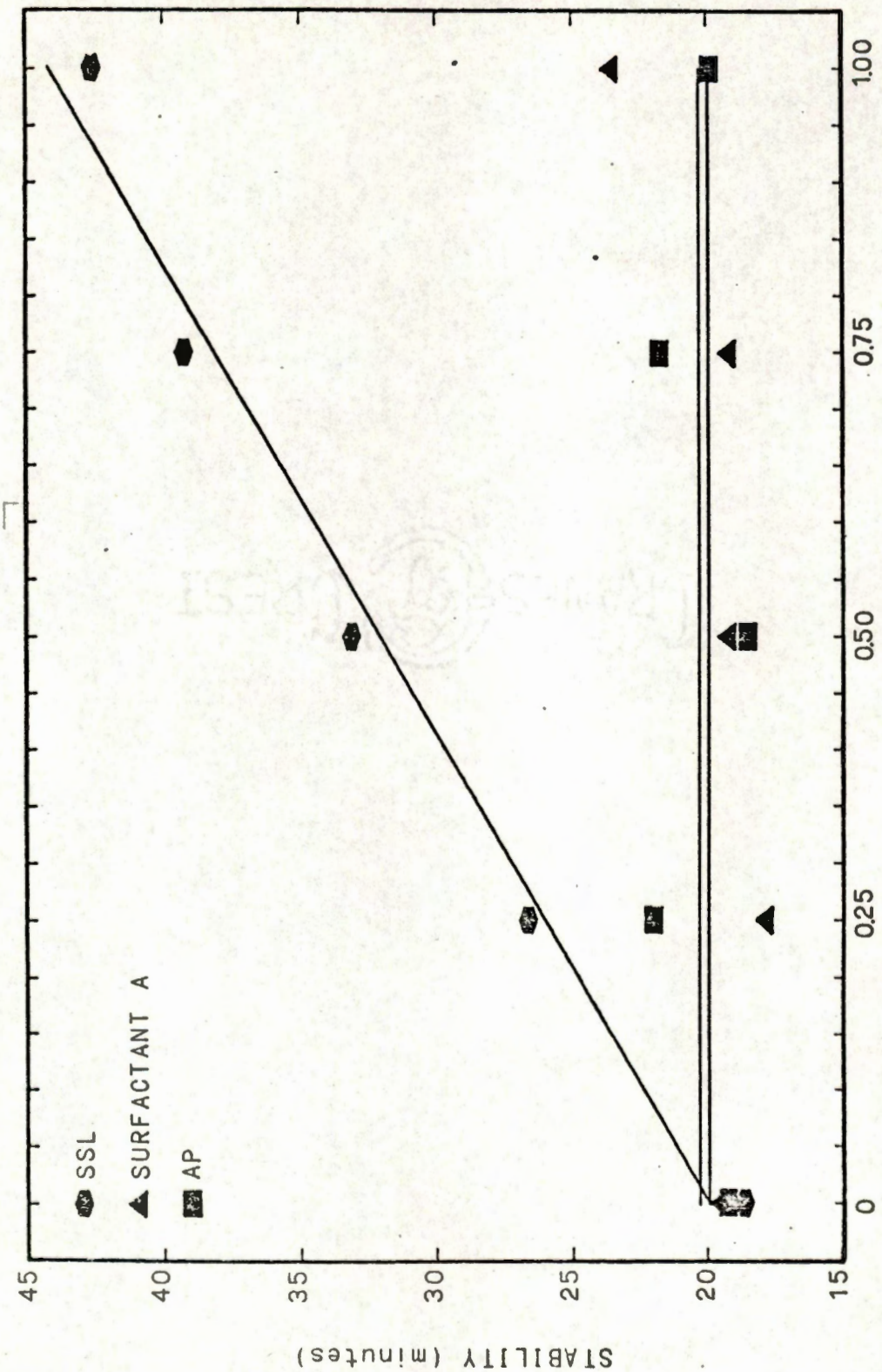


Figure 4. The average stability of SSL, surfactant A and AP as a function of concentration. (Each point represents the mean of three replications.)

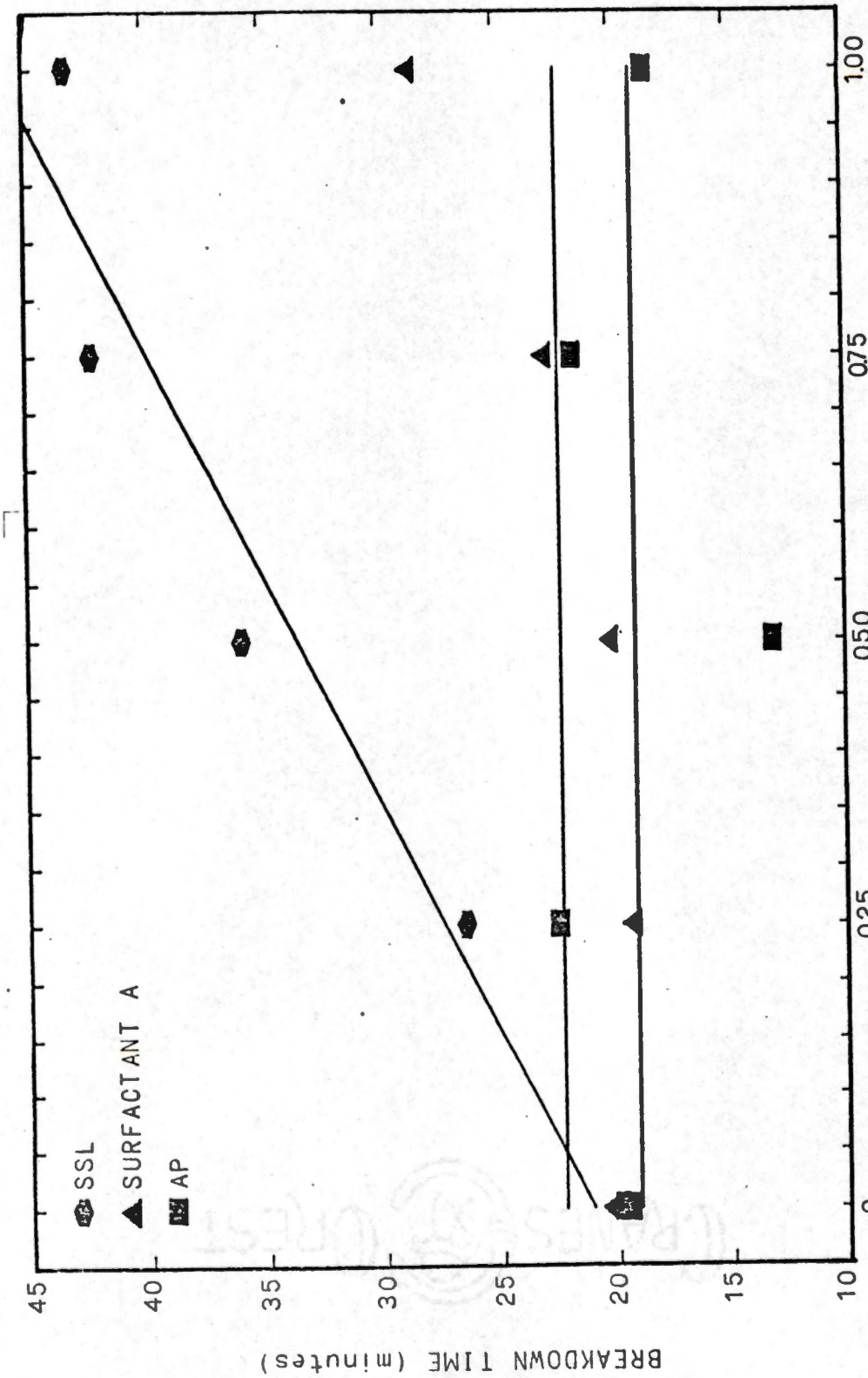


Figure 5. The average breakdown time of SSL, surfactant A and AP as a function of concentration. (Each point represents the mean of three replications.)

reported at a level of .5% ethoxylated monoglycerides followed by a decrease to 6.0 minutes at levels of .75% and 2.00%. The authors suggested that although both SSL and ethoxylated monoglycerides act as dough strengtheners in bread, ionic and nonionic surfactants operate through different mechanisms which are reflected differently through farinogram characteristics. Sullivan (1952) likewise reported anionic surfactants increased dough tolerance and mixing tolerance while cationic and nonionic surfactants did not. The author's baking experiments, however, did not reveal differences between types of surfactants.

In contrast to reported results, the present investigation showed that tolerance index decreased as concentrations of surfactant A, AP and SSL increased which indicate that all three surfactants contribute to dough strength. However, the present investigation also showed that surfactant A, currently used as a commercial dough strengthener, and AP, both of which are nonionic surfactants, showed no significant differences in other farinograph results. SSL, an anionic surfactant, resulted in significantly higher dough stability, peak time, departure time and breakdown time values. Thus, it is possible as Chung and Tsen (1975) propose, that the nonionic surfactant A and AP are effective dough strengtheners but do not operate by the same mechanism in dough as SSL.

A lack of correlation between farinograph study results and actual baking tests with dough ingredients has also been reported. Miller et al. (1956) found a correlation of 0.27 between farinograph peak time and baking mixing time with 186 samples of wheat flour. A correlation of 0.20 between farinograph mixing tolerances and weaking angle (from mixograph curve) was observed by the authors. Due to complexity of other

factors and ingredient interaction it has been suggested that parameters on dough strength can only, at best, estimate how a flour or ingredient will behave in a continuous mix system (Shuey, 1972).

II. EVALUATION OF CHARACTERISTICS OF COMMERCIALLY PRODUCED BUNS CONTAINING ASCORBYL PALMITATE

Volume, Crust Color, Crumb Color and Crust Toughness

Mean squares for the effect of treatment on characteristics of the commercially produced bun are presented in Table 10. Prior to separation of variation due to treatment by orthogonal comparison, the only significant treatment effect was for crumb lightness index. Partitioning of variation due to treatment by orthogonal comparisons, however, showed significant treatment effects on specific volume, top crust color and crumb color values of the buns. The commercially produced control bun and a bun containing 0.3750% AP illustrate these effects in Figures 6 and 7. Treatment means for each variable are shown in Table A-1, Appendix.

Comparisons within AP concentration (0.2500, 0.3125, 0.3750 and 0.4375%, flour basis) showed that as AP concentration increased, specific bun volume increased from 5.37 cc/g to 5.72 cc/g (Figure 8). The average specific volume for the control bun was 5.49 cc/g.

Several researchers have reported that increased specific volume of bread indicates increased dough strength (Greene, 1975; Tsen and Hoover, 1971; Tenny, 1978). Thus, based on specific volume data, AP at the lowest concentration, 0.2500%, without shortening is as effective a dough strengthener as a combination of shortening, surfactant A and

Table 10. Analysis of variance of treatment effects on characteristics of commercially produced buns.

Source	Degrees of freedom	Means Squares: Specific volume	Top Crust Color L	Top Crust Color a	Top Crust Color b	Bottom Crust Color L	Bottom Crust Color a	Bottom Crust Color b	Crumb Color L	Crumb Color a	Crumb Color b	Crust toughness
Treatment (T)	4	0.12	36.16	5.02	10.96	19.92	11.84	3.14	13.82[b]	0.55	23.30	8801177
Comparison 1, AP vs. control	1	0.05	2.42	17.53[b]	2.04	48.34	43.34	0.92	41.54[a]	2.04[c]	43.12	12707520
Comparison 2, linear, AP	1	0.38[a]	1.41	1.38	2.48	10.08	1.68	0.76	7.76[c]	0.01	27.50	990083
Comparison 3, quadratic, AP	1	0.06	126.64[a]	0.10	37.85[b]	14.98	2.44	0.08	0.68	0.05	16.88	21000104
Comparison 4, cubic, AP	1	0.00	14.17	1.09	1.49	6.28	0.07	10.79	5.31[c]	0.11	5.59	507000
Error (Replication,R/T)	10	0.08	26.56	2.07	5.31	28.04	15.92	1.03	1.03	0.32	65.58	7900020
Observations (T,R)	15	0.03	3.10	0.25	0.95	15.99	2.88	0.82	0.81	0.03	0.10	134770

[a]Significantly different at the P<.001 level.

[b]Significantly different at the P<.01 level.

[c]Significantly different at the P<.05 level.

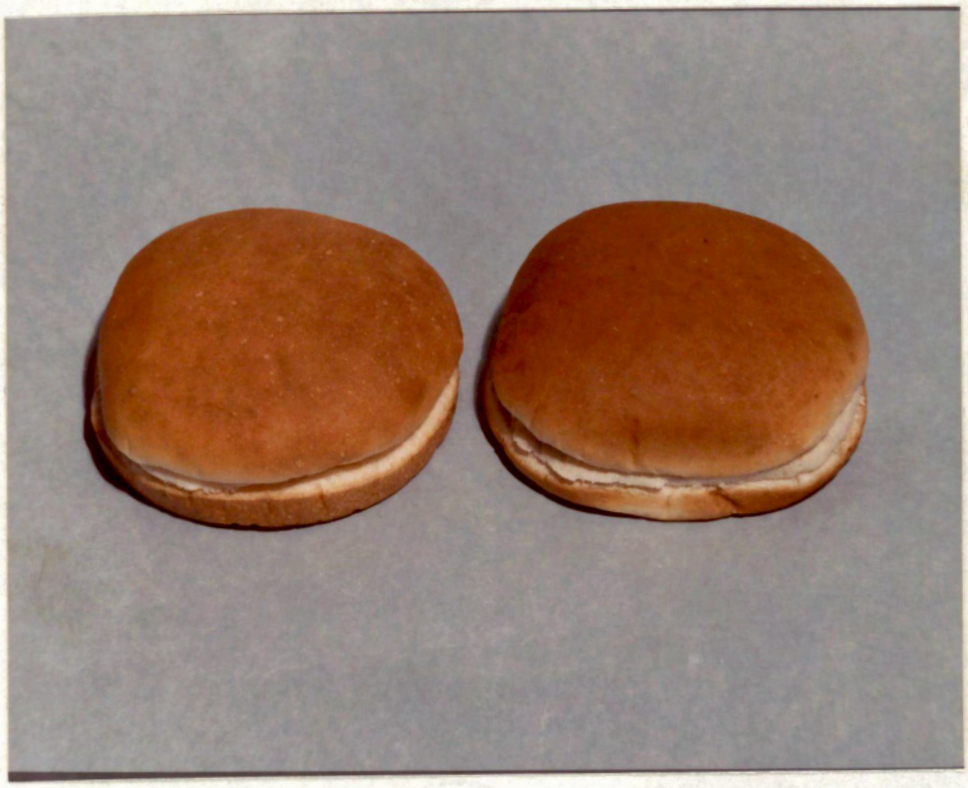


Figure 6. Commercially produced control bun and a bun containing 0.3750% AP (crust).

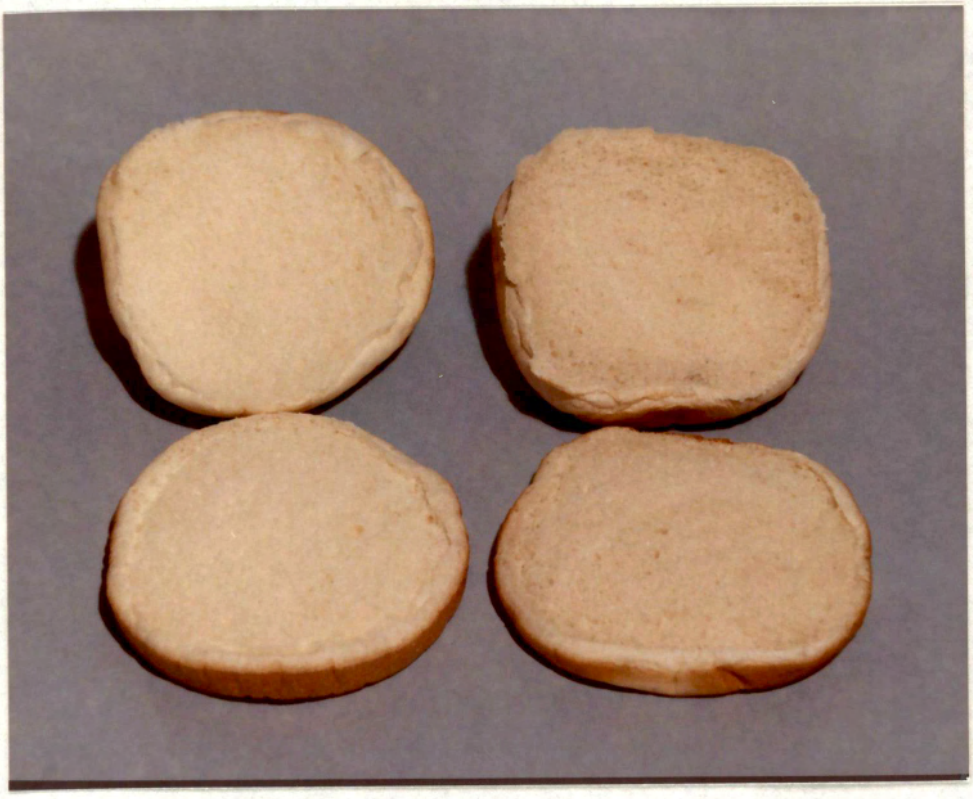


Figure 7. Commercially produced bun and a bun containing 0.3750% AP (crumb).

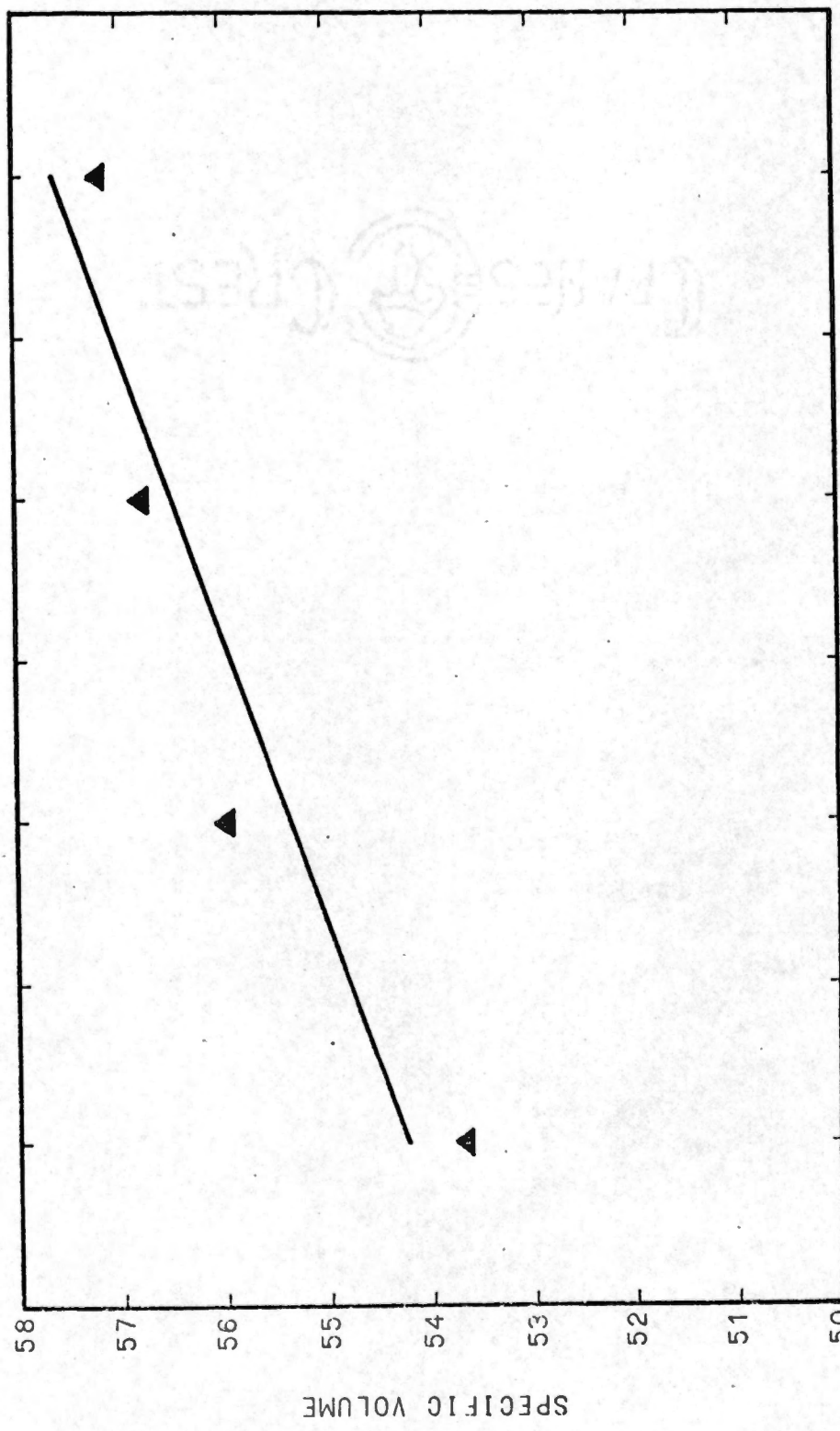


Figure 8. Specific bun volume as a function of AP concentration in commercially produced hamburger buns. (Each point represents the average of three replications.)

monoglycerides in commercial bun production. The ability of AP to improve bun volume and strengthen dough increased as the concentration of AP added to flour increased from 0.2500% to 0.4375% (flour basis). Hoseney et al. (1976) reported that levels of 0.50% and 0.75% (flour basis) sodium-6-O-palmitoyl L-ascorbate (SPA) added to bread without shortening produced bread volumes equal to or better than control bread containing 3% shortening and no surfactants. They found that levels of 1.0, 0.25 and 0.38% (flour basis) of SPA in bread without shortening, however, produced lower loaf volumes than the control bread. Melton et al. (1977) found no significant difference between specific volume of bread containing 0.5% AP and no shortening and 0.5% succinylated monoglycerides, SSL or monoglycerides. The average specific volume reported by Melton et al. (1979) for bread containing 0.5% AP without shortening was 5.72 cc/g and for the control loaf with shortening and no other surfactants was 5.12 cc/g. These values are comparable to specific volumes reported in this study.

Comparisons of AP concentration effect on top crust color showed a quadratic relationship of the Hunter Color "L" with AP concentration (Table 10 and Figure 9). As AP concentration increased from 0.2500 to 0.3125%, crust color "L" decreased from an average of 44.61 to 38.85. A further increase in AP concentration to 0.3750% resulted in an increase of crust "L" to 41.13. Buns containing 0.4375% AP had an average crust color "L" value of 44.57.

A quadratic relationship was also found between AP concentration and Hunter color value "b" for the top crust. Top crust color "b" decreased from 21.03 to 18.35 (became less yellow) as AP concentration

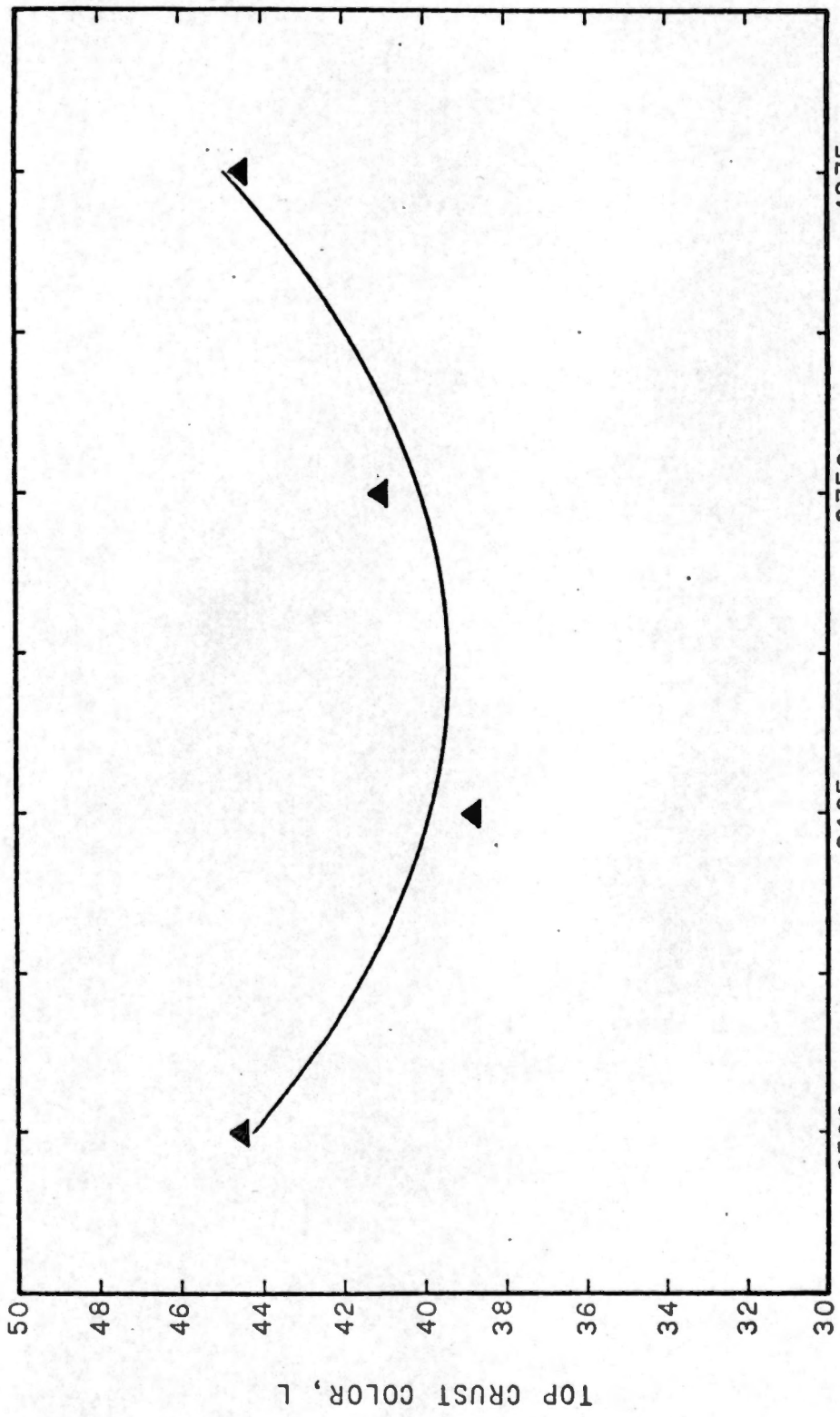


Figure 9. Top crust color "L" as a function of AP concentration in commercially produced hamburger buns. (Each point represents three replications.)

increased from 0.2500% to 0.3125%. An increase in crust color "b" from 19.31 to 21.67 (increase in yellowness) was found as AP concentration increased from 0.3750% to 0.4375% (Figure 10).

The top crust Hunter color "a" value was found to vary significantly between the control bun and the bun containing AP (Table 10). The control bun top crust with a Hunter color "a" value of 15.69 was redder in color than the AP bun top crust with a Hunter color "a" value of 13.78 (Table 11).

Hoseney et al. (1977) reported that numerous black specks appeared on the crust of bread when undispersed particles of AP charred during baking. However, in commercial production the AP appeared to be well-dispersed and few black specks were observed on the crust of any buns. Therefore, charring of AP did not contribute to the difference in crust color in this study. It is not known why the lightness and the yellowness of the crust was significantly affected by AP concentration or why it was less red than the control bun.

Orthogonal comparisons for crumb lightness, Hunter Color value "L," show that there was a significant difference between the control bun and all AP buns and that there was a significant cubic effect on crumb lightness as AP concentration increased (Table 10, page 37). The control bun "L" value was higher than the AP bun crumb "L" value as an average across all levels of AP (Table 11). In fact, the crumb color of the control bun (L=78.14) was lighter than the crumb of the bun with the lowest AP concentration, 0.2500%, (L=76.34, Figure 11). As AP concentration increased to 0.3125%, the crumb color became darker (L=74.65), and then became slightly lighter at 0.3750% AP (L=75.40).

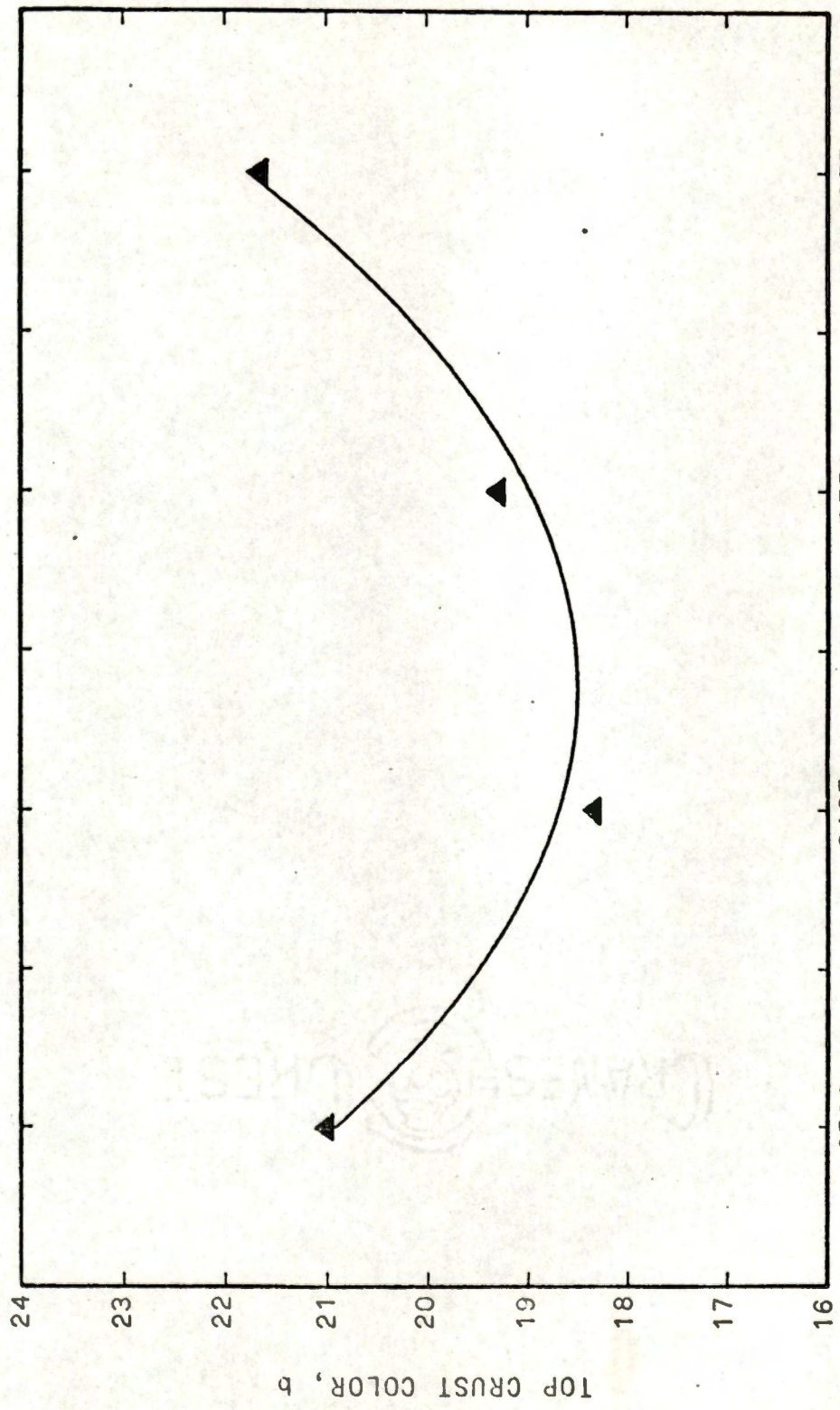


Figure 10. Top crust color "b" as a function of AP concentration in commercially produced hamburger buns. (Each point represents the average of three replications.)

Table 11. Means of selected characteristics of control bun and bun containing ascorbyl palmitate.

Item	Bun	
	Control[a]	AP[b]
Top crust color		
a	15.69[c]	13.78[d]
Crumb color		
L	78.14[c]	75.19[d]
a	-1.62[c]	-0.97[d]
Proximate analysis		
% protein	12.69[c]	11.96[d]
% moisture	32.34[c]	35.41[d]
% total lipid	4.51[c]	1.34[d]
% ash	2.45[c]	2.58[d]
Compressibility (g/cc)		
day 2	219.00[c]	138.38[d]
day 7	349.58[c]	259.65[d]

[a]Control bun, mean of 6 observations.

[b]Bun containing 0.2500 to 0.4375% (flour weight basis) ascorbyl palmitate, mean of 24 observations.

[c,d]Means in a row or column bearing unlike superscript letters are significantly different at the $p < 0.05$ level.

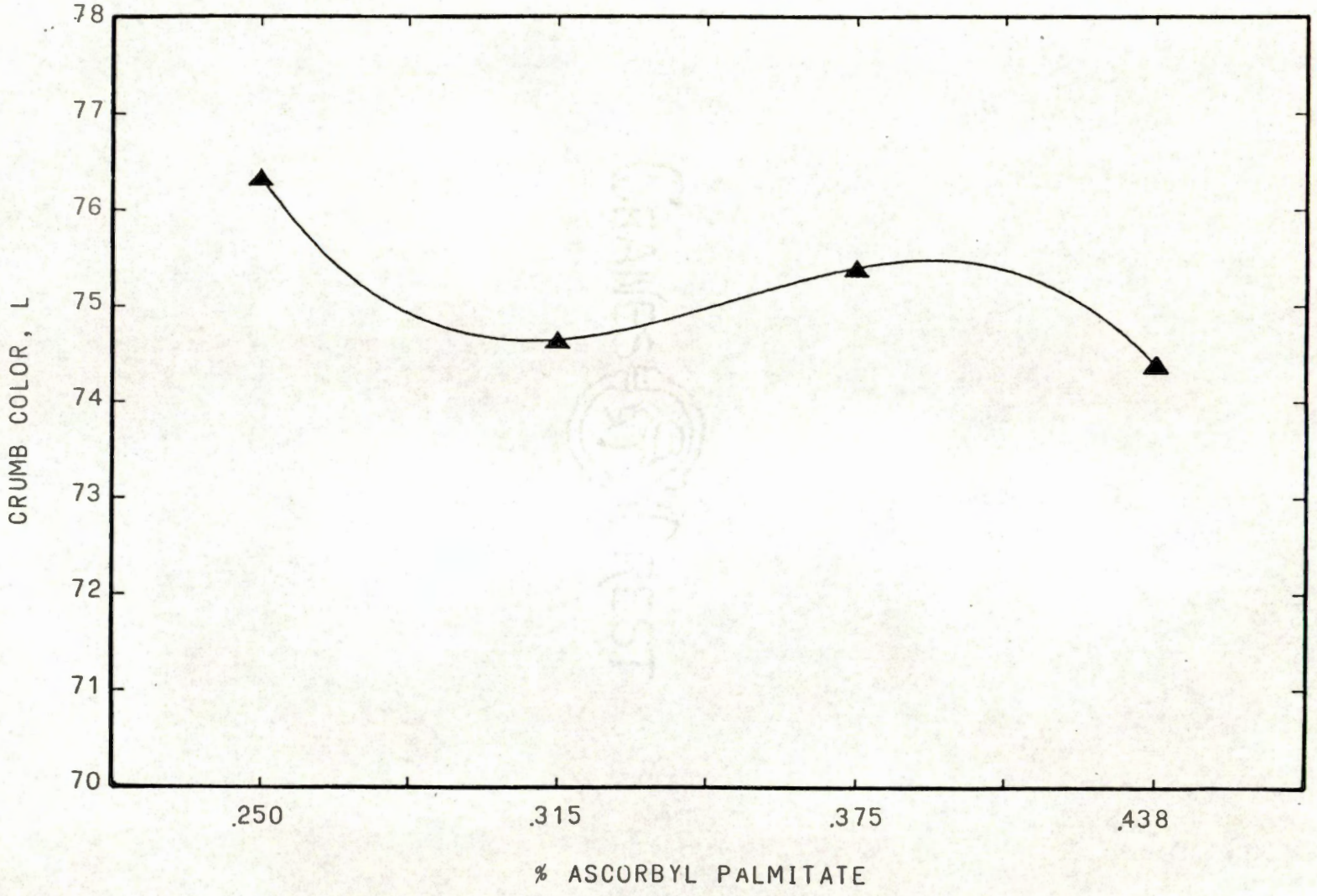


Figure 11. Crumb color "L" as a function of AP concentration in commercially produced hamburger buns. (Each point represents the average of three replications.)

However, the crumb color was the darkest at the highest AP concentration, 0.4375% (L=74.4, Figure 11).

Orthogonal comparisons for crumb color Hunter Color value "a" show that the crumb of the control bun had a lower "a" value or was less red than the crumb of the AP bun (Table 10, page 37, and Table 11). Increasing AP concentration has no significant effect on crumb "a" value (Table 10, page 37).

Ascorbyl palmitate has been reported to cause a dark, brownish crumb color when added at 0.4% to bread containing 3.6% shortening (Offelt et al., 1958). Melton et al. (1979) in contrast, found that 0.5% AP added to bread without shortening did not have a significantly darker crumb than bread made with other surfactants plus 3% shortening. Also, Hoseney et al. (1977) did not report any noticeable change in crumb color when AP was added to bread with or without shortening. The slight difference in crumb color between the control and a bun containing .03750% AP can be observed in Figure 6 (page 38). The color difference in the crumb appears to be a greyish color in the AP bun compared with the control bun. This greyish cast is attributed to the absence of shortening in the formula. Matz (1972) explains that the creamy yellowish crumb usually found in bread is caused by fat-soluble, yellow pigments in the wheat endosperm.

Compressibility and Staling Rate

Table 12 shows mean squares from the analysis of variance of compressibility data of hamburger buns stored from 0 to 5 days at 25°C and for 7 days at 4°C. Treatment compressibility means at all storage periods are shown in Appendix, Table A-2.

Table 12. Analysis of variance of compressibility data on hamburger buns containing ascorbyl palmitate and control buns during storage.

Source	Degrees of freedom	Mean Squares						
		Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 7
Treatment (T)	4	162.06	2139.70	7728.31	4059.17	5926.68	7214.99	10189.68
Comparison 1 Control vs. AP	1	6.30	6300.25	28766.11[c]	7760.21	12834.01	20241.02	38826.02[d]
Comparison 2 Linear, AP	1	214.67	299.25	1062.07	7792.41	585.21	335.00	494.10
Comparison 3 Quadratic, AP	1	65.01	1060.01	330.04	26.04	204.17	499.59	68.34
Comparison 4 Cubic, AP	1	362.27	899.28	755.01	658.01	10083.33	7784.35	1370.25
Error (Replication,R) + (R x T)	10	310.04	974.69	3889.47	4944.70	10621.21	12550.88	9400.60
Observation/ (T, R)	15	59.06	305.92	414.96	1006.43	924.76	1770.61	3241.68

[c]Significantly different at the level P<.05.

[d]Significantly different at the level P<.06.

No significant treatment effects were found for compressibility data at any storage period. Orthogonal comparison of the control bun with the AP bun, however showed significant differences in compressibility data for day 2 and day 7. Means presented in Table 11 indicate that on day 2 and day 7 the bun containing AP was softer than the control bun. Hoseney et al. (1977) and Melton et al. (1979) both also concluded that AP added to bread without shortening was as effective or more effective as a bread softener than shortening alone or shortening plus comparable levels of SSL or monoglycerides.

Mean squares from the analysis of variance of the Avrami exponent, n, and rate constant, K, are given in Table 13. No significant treatment effects were found for either. The plot of log $(-\log_e E_L-E_t/E_L-E_0)$ against the log t of the buns is diagrammed in Figure 12. The Avrami exponent, n, across treatments for commercially produced buns was 1.14 with a correlation coefficient of -0.9502. Cornford et al. (1964) proposed that an Avrami exponent close to unity (n=1) follows a pattern of nucleation. This indicates that staling of the buns occurred by retrogradation of starch through instantaneous nucleation and rod-like growth of starch crystals. Avrami exponents reported by Kim and D'Appolonia (1977) for bread containing 11 to 21% protein and stored at 21 and 30°C ranged from .92 to 1.04, slightly lower than the Avrami exponents determined across treatments for this study.

Figure 13 is the plot of $\ln(E_L-E_t)$ against storage time (days). The rate constant (K) across all treatments given by the slope of the equation was -0.2854 with a correlation coefficient of -0.9128. The time constant (1/K) across treatments was 3.50 days. This value is somewhat

Table 13. Analysis of variance of treatment effects on Avrami exponents and time rates.

Source	Degrees of freedom	time rate	Avrami constant
Treatment (T)	4	.0444	.6745
control vs. AP	1	.0000	.0321
linear (AP)	1	.0339	.0321
quadratic (AP)	1	.0262	.0491
cubic (AP)	1	.1175	.4477
Error (Replication, R + observations/R,T)	10	.0392	.4105

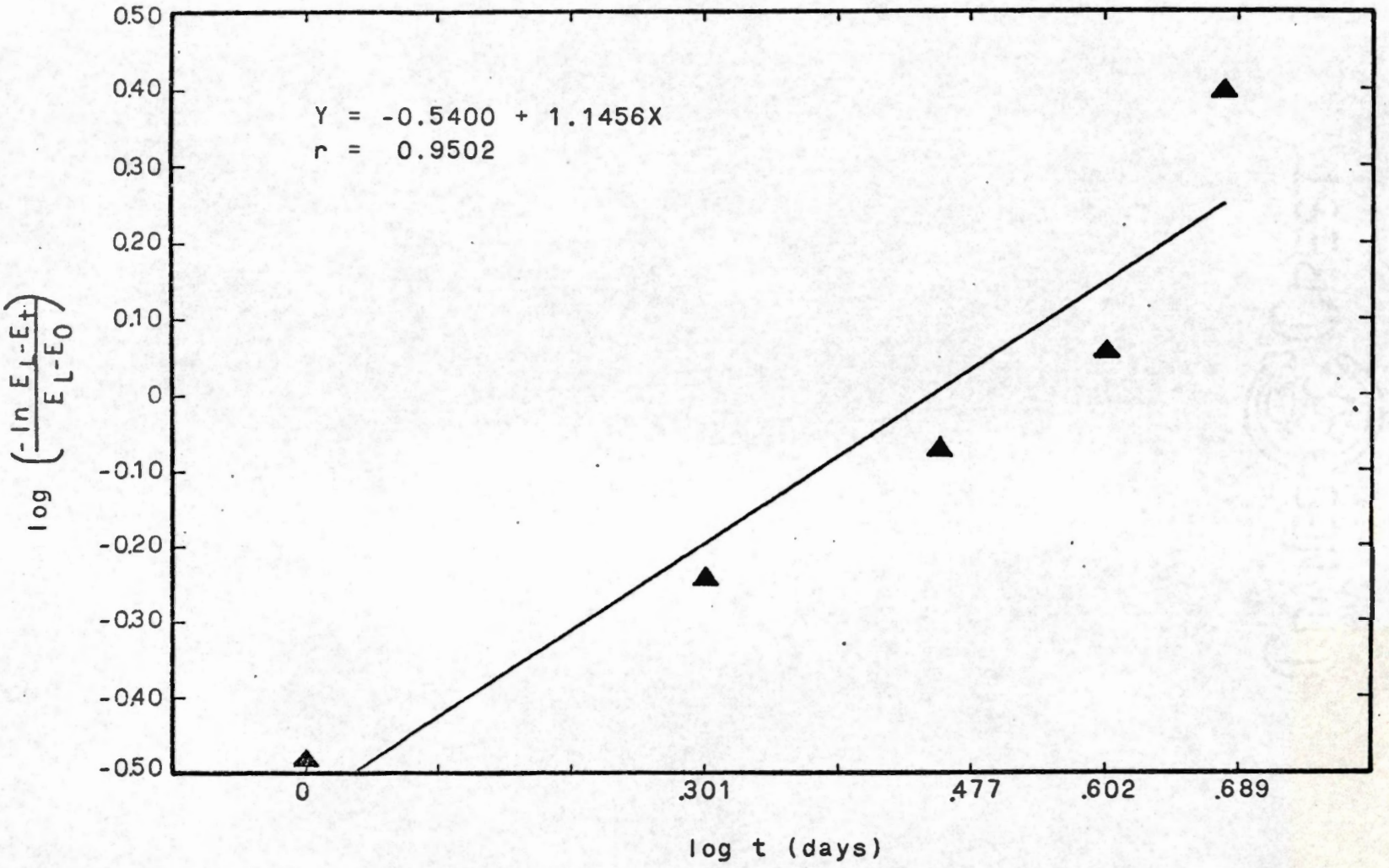


Figure 12. Plot of log $\left(-\log \frac{E_L-E_t}{E_L-E_0}\right)$ against log t of commercially produced hamburger buns.

(The slope of the equation represents the Avrami constant. Each point represents the mean of 30 observations.)

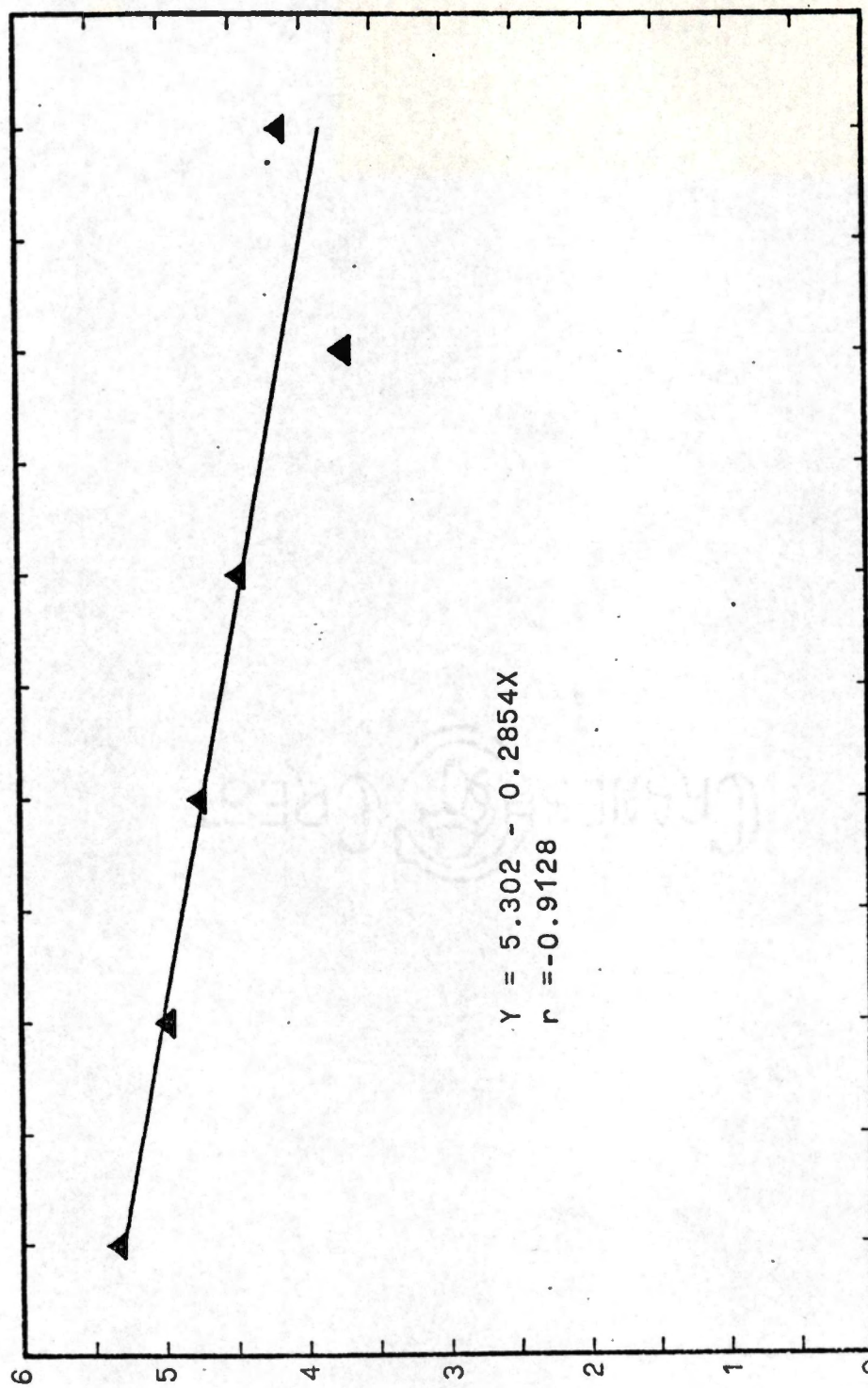


Figure 13. Plot of $\log_e (E_L - E_t)$ against storage time of commercially produced hamburger buns.

(The slope of the line represents the time rate constant, K. Each point represents the mean of 30 observations.)

less than the values reported by Kim and D'Appolonia (1977) which ranged from 3.74 days to 18.73 days for protein high bread. Elton (1969), however, found that bread made by the Chorleywood process and stored at 21°C had a time constant of 3.52 days and bread made by a conventional bulk fermentation process had a time constant of 3.76 days. These values are similar to the overall time constant reported in this study.

Proximate Analysis

Table 14 contains the mean squares from the analysis of variance for proximate analysis of control buns and buns containing AP. Significant treatment effects were found for percent lipid, percent moisture and percent ash. Orthogonal comparison within treatment levels also indicated significant difference in percent protein, percent lipid, percent moisture and percent ash. Means from proximate analysis show (Table 11, page 45) that the control bun had a higher percent protein and percent lipid than the AP bun. The 3% shortening (based on flour weight) present in the control bun, however, should cause that bun to be significantly higher in lipid than the AP buns. The buns made by adding .2500% to .4375% AP (flour basis) contained more moisture and had a slightly higher level of ash than the control bun.

Tsen et al. (1976) found similar results from proximate analysis of hot dog buns. They reported that hot dog buns prepared from commercial wheat flour contained 14.2% protein, 2.4% ash and 1.4% lipid.

Consumer Acceptance

Significant differences were found between treatments for consumer rating of overall acceptability and texture of commercially produced

Table 14. Analysis of variance of proximate analysis of control bun and buns containing ascorbyl palmitate.

Source	Degrees of freedom	Mean Squares			
		% Protein	% Lipid	% Moisture	% Ash
Treatment (t)	4	.4033	6.082[b]	6.478[b]	0.014[c]
Comparison 1, Control vs. AP	1	1.261[b]	24.046[a]	22.706[a]	0.040[a]
Comparison 2, Linear, AP	1	0.004	0.024	0.866	0.002
Comparison 3, Quadratic, AP	1	0.188	0.226	0.445	0.013
Comparison 4, Cubic, AP	1	0.160	0.031	1.897	0.00
Error (Replication, R) + Obs. (T, R)	10	1.568	1.632	6.944	.034

[a]Significant at the level P<.001.

[b]Significant at the level P<.01.

[c]Significant at the level P<.05.

buns (Tables 15 and 16). The average acceptability rating on a scale of 1 to 7 (1=dislike very much, 7=like very much) for the control bun was 6.55 and for the AP bun (.375%, flour basis) was 6.22. Both of the scores are between "like moderately" and "like very much." On a scale of 1 to 6 (1=very firm, 6=very soft) the control bun was rated an average of 5.17, or just above "moderately soft," and the AP bun was rated 4.75, just below "moderately soft." No significant differences were found among age groups for acceptability but in rating texture the children 12 and over rated the buns softer than the other age groups.

Tabulated results of the questionnaire are listed in the appendix in Table A-3. Equally favorable comments were made by panelists on color, texture and flavor characteristics of both the AP and control buns. Panelists were particularly complimentary on the consistency, flavor and aroma of the buns. Several panelists described both the control and AP bun as "fresh" and one panelist noted that the AP bun did not stale as quickly as some store brands.

Numerous unfavorable comments were also received on characteristics of the AP and control bun. Panelists described both buns as having crust "too dark" and texture which was "gummy" and "soggy." No comments were made about the crumb color of the control bun but many panelists described the crumb color of the AP bun as "greyish," "off-white" and "dark" and said they would prefer a more "yellowish" or "white" crumb. The flavor of the buns was criticized as being "sour" and "like sourdough" but several panelists also remarked that they liked the "yeasty" and "homemade" flavor.

Table 15. Mean squares from analysis of variance of consumer panel ratings.

Source	Degrees of freedom	Mean Squares
		Acceptability
Treatment (T)	1	11.754[a]
Age group (A)	2	0.820
T x A	2	1.612
Error	460	1.047
		Texture
Treatment (T)	1	19.109[a]
Age group (A)	2	7.285[a]
T x A	2	0.016
Error	468	1.677

[a]Significant at the $p<0.05$ level.

Table 16. Means of consumer rating of overall acceptability and texture of commercially produced buns.

Age Group	AP Bun	Control Bun	Mean
		Acceptability[c]	
Adults	6.19 (n=208)	6.64 (n=112)	6.35[a]
Children under 12	6.35 (n=45)	6.54 (n=33)	6.44[b]
Children over 12	6.25 (n=31)	6.25 (n=32)	6.25[a]
Mean	6.22[a]	6.55[b]	
		Texture[d]	
Adults	4.72 (n=211)	5.16 (n=115)	4.88[a]
Children under 12	4.44 (n=34)	4.91 (n=36)	4.68[a]
Children over 12	5.09 (n=46)	5.53 (n=28)	5.26[a]
Mean	4.75[a]	5.17[b]	

[a,b]Means in a row or column bearing unlike superscript letters are significantly different at the $p<.05$ level.

[c]Seven point scale with 1=dislike very much and 7=like very much.

[d]Six point scale with 1=very firm and 6=very soft.

The majority of panelists who evaluated the buns used them with hamburgers. Most panelists said they purchased hamburger buns "occasionally" (once or twice a month) and over 50% of the panelists evaluating either the AP or control bun said they "would certainly buy it sometimes."

It would seem, therefore, that both texture and crumb color of the buns made with AP contributed to its lower acceptability score.

CHAPTER V

CONCLUSIONS

Ascorbyl palmitate (AP), sodium stearyl 2-lactylate (SSL) and a commercial bread surfactant (a mixture of 45% soft monoglycerides, 45% ethoxylated monoglycerides and 10% succinylated monoglycerides) were investigated for dough strengthening effects at concentrations of 0.25, 0.50, 0.75 and 1.00% (flour weight). Farinograms were obtained and peak time, stability, tolerance index, arrival time, time to breakdown and water absorbance were determined. No significant treatment effects were found for arrival time, tolerance index or water absorbance, however, SSL added to flour resulted in significantly longer peak time, departure time, stability and time to breakdown than AP or surfactant A. As concentration of surfactant A increased, a significant cubic effect on peak time was found and as concentration of SSL increased, a significant increase was found for peak time, departure time, stability and time to breakdown. The effect of SSL on farinogram parameters indicate that it had the greatest influence on dough strength, however, it is also possible that both surfactant A and AP could act as dough strengtheners in a continuous mix bread system and not significantly affect farinogram parameters of dough strength.

The effectiveness of ascorbyl palmitate as a dough strengthener, crumb softener and shortening replacer in commercially produced hamburger buns was measured. Hamburger buns containing 0.2500, 0.3125, 0.3750, and 0.4375% AP without shortening and a control bun containing 3%

shortening, 0.375% monoglycerides and 0.625% surfactant A (five treatments) were produced in a local bakery. Three replications were run and the order in which the different concentration-replication combinations as well as the control were completed was randomized across replication. Compressibility during storage, crust and crumb color, crust toughness and proximate analysis on each batch of buns baked. Consumer testing of the control and a bun containing 0.3750% AP were also done.

There was no significant difference between the control bun and AP bun for specific volume but as AP concentration increased, a significant linear increase in volume was found. Increased specific volume has been related to increased dough strength, therefore, increasing AP concentration improved the dough strength during commercial production of buns without shortening.

The crust color of buns containing AP were significantly darker and less red than the top crust of the control bun. As the concentration of AP in the bun increased, there was also a significant increase in crust color darkness and yellowness. A significant difference was found between the AP bun and the control bun for crumb color "L" and "a" values. The AP bun had a less light, more red crumb than the control and crumb lightness decreased as AP concentration increased. The darker crumb color of the AP bun is believed to be caused by the absence of shortening in the formula to solubilize endosperm pigments responsible for the creamy crumb color usually found in bread.

The AP bun had significantly lower compressibility values for day 2 and day 7 of storage. No significant differences were found for

compressibility on the other days of storage or for the Avrami exponent and time rate constant. It would seem, therefore, that AP without shortening is at least as effective and possibly more effective than a combination of shortening, monoglycerides and surfactant A in softening crumb.

Consumer acceptance of the AP bun and the control bun was determined by distributing packages of buns to representative segments of the local population. Both buns were rated between "like moderately" and "like very much" but the control bun received a significantly higher acceptability rating (6.55) than the AP bun (acceptability rating = 6.22). The texture rating for the control bun was an average of 5.17 or just above "moderately soft" and the texture rating for the AP bun was 4.75, just below "moderately soft." Both buns received favorable and unfavorable comments on flavor, texture, color and other characteristics. However, many panelists described the AP crumb as greyish and off-white. No remarks were made about the crumb color of the control bun.

Crumb color and texture may have caused the AP bun to receive lower consumer acceptability ratings, however, over 70% of the respondents said they would be willing to purchase the AP bun in the future.

Difficulty in dispersing ascorbyl palmitate was overcome by stirring it into warm water prior to mixing. AP was found to produce good volume and replace shortening without loss of desirable crust and crumb characteristics. Problems encounted in consumer acceptability of crumb color and texture could probably be resolved through minor modification of formula and ingredients. Clearly, ascorbyl palmitate as a crumb softener, dough strengthener and shortening replacer in

commercially produced bread is feasible. However, at the present time AP is not as economical as the shortening and surfactants added to the control bun. On the basis of one hundred weight flour, the cost of shortening and surfactants in the control bun was $1.89 and the lowest concentration of AP added cost approximately $3.75.

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Table A-1. Treatment means for specific volume, crust color, crumb color and crust toughness.

Treatment % AP	(cc/g) Specific volume	Top Crust Color L	a	b	Bottom Crust Color L	a	b	Crumb Color L	a	b	Crust toughness
0.00	5.49	43.00	15.69	20.74	50.70	13.67	24.16	78.13	-1.62	19.06	3520.83
.250	5.37	44.60	14.13	21.02	54.18	11.32	23.60	76.34	-0.92	13.57	4550.00
.318	5.60	38.85	13.67	18.36	54.27	10.55	24.76	74.65	-1.12	17.07	5979.00
.375	5.68	41.13	14.02	19.31	55.06	10.17	22.79	75.40	-0.92	16.73	6187.50
.438	5.72	44.57	13.30	21.67	51.98	10.67	23.73	77.39	-0.93	16.88	3875.00

Table A-2. Treatment compressibility means for hamburger buns containing AP and for control buns during storage.

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 7
Control	54.00	148.67	219.00	226.00	246.92	284.83	349.58
.250% AP	48.75	121.08	148.50	208.67	195.58	221.42	225.25
.318% AP	55.08	115.58	145.17	199.83	222.00	241.17	249.17
.375% AP	47.33	96.00	124.17	169.67	162.58	189.50	273.50
.432% AP	60.25	117.08	135.67	165.00	200.67	227.67	260.67

Table A-3. Tabulated results of questionnaire on acceptability of commercially produced control bun and AP bun.

	AP	CONTROL
Total number of questionnaires received	127	66
Total number of responses	291	178

1. Texture rating	AP			CONTROL		
Response Alternative	Adults	Under 12	Over 12	Adults	Under 12	Over 12
(6) Very soft	76	26	14	55	17	11
(5) Moderately soft	75	12	5	41	9	18
(4) Slightly soft	14	2	1	7	2	1
(3) Slightly firm	24	-	10	7	-	2
(2) Moderately firm	17	4	4	4	-	3
(1) Very firm	5	2	-	1	-	-
Total number	211	46	34	115	28	35

2. Overall Acceptability	AP			CONTROL		
Response Alternative	Adults	Under 12	Over 12	Adults	Under 12	Over 12
(7) Like very much	106	29	21	82	24	18
(6) Like moderately	66	8	2	23	6	10
(5) Like slightly	20	4	3	4	-	-
(4) Neither like nor dislike	7	3	5	3	3	2
(3) Dislike slightly	6	1	-	-	-	2
(2) Dislike moderately	1	-	-	-	-	-
(1) Dislike very much	2	-	-	-	-	-
Total number	208	45	31	112	33	32

Table A-3 (continued)

3. Favorable Comments	AP	CONTROL
Crust Color	"golden brown" color "nice, brown" crust nicely browned excellent, very good, good very appealing	"nice, light brown" color "pleased with color" good, very good nice, brown crust
Crumb Color	"liked," "is excellent"	"like crumb color"
Texture	"liked texture, is coarse" "soft, like a light bread" "firm texture, not full of bubbles" "liked crust texture" "doughlike texture, chewy" "soft," "excellent," "superior," "unusually good" "didn't flake"	"didn't stick to roof of mouth" "good texture, doesn't crumble" "very good, wasn't soggy" "holds together well" "like wheaty texture" "chewy, smooth texture" "excellent"
Flavor	"liked flavor, slightly sweet" "excellent flavor, delicate" "good tasting," "delicious" "fresh," "superior," "tastes homemade," "flavorful" "tastes less starchy than other bread," "good—not too sweet," "liked flavor and aroma," "unusually good"	"liked flavor," "good" "tasted good," "excellent" "liked wheaty flavor" "loved the taste of yeast" "good taste and left no aftertaste"
Other	"like better than any I've had" "aroma is enticing" "substantial body," "liked size—thick," "liked aroma—smelled like hot rolls" "stayed fresh for a week—good for single person" "similar to homemade bread" "moist, very fresh," "liked plain better than with hamburger"	"bun is tasty, light" "very appealing and has delicious smell" "fresh—lasted for 6 days" "good appearance" "smell is very good" "good thickness and size"

Table A-3 (continued)

4. Unfavorable Comments	AP	CONTROL
Crust Color	"dislike crust color, should have been a little browner" "a little too dark" "color is off"	"crust has somewhat faint, mottled color," "too dark"
Crumb Color	"grayish color; would prefer yellowish color," "crumb seems a little dark" "dislike color" "looks off-white or grayish" "color was grayish compared to whiteness of most buns" "grayish, but not offensive" "turned dark after 2 days in refrigerator" "seemed very dark"	no comments
Texture	"gummy when chewed," "seemed too soft," "soggy," "dislike texture," "sticks to my dentures," "sticks to teeth," "chewy, hard to swallow," "gums up in mouth" "dislike toughness," "too coarse," "became leathery after microwaving"	"too soft," "sticky," "soft and soggy," "chewy" "too dry"
Flavor	"not as good as other buns" "dislike flavor," "slightly odd, sourdough taste" "not much flavor"	"dislike sweet flavor" "sour, stale taste" "not flavorful" "not very good"
Other	"strange smell but not offensive," "after 2 days in refrigerator turned gummy and dark"	"prefer whole wheat" "doesn't freeze well" "did not keep fresh very long"

5. Uses

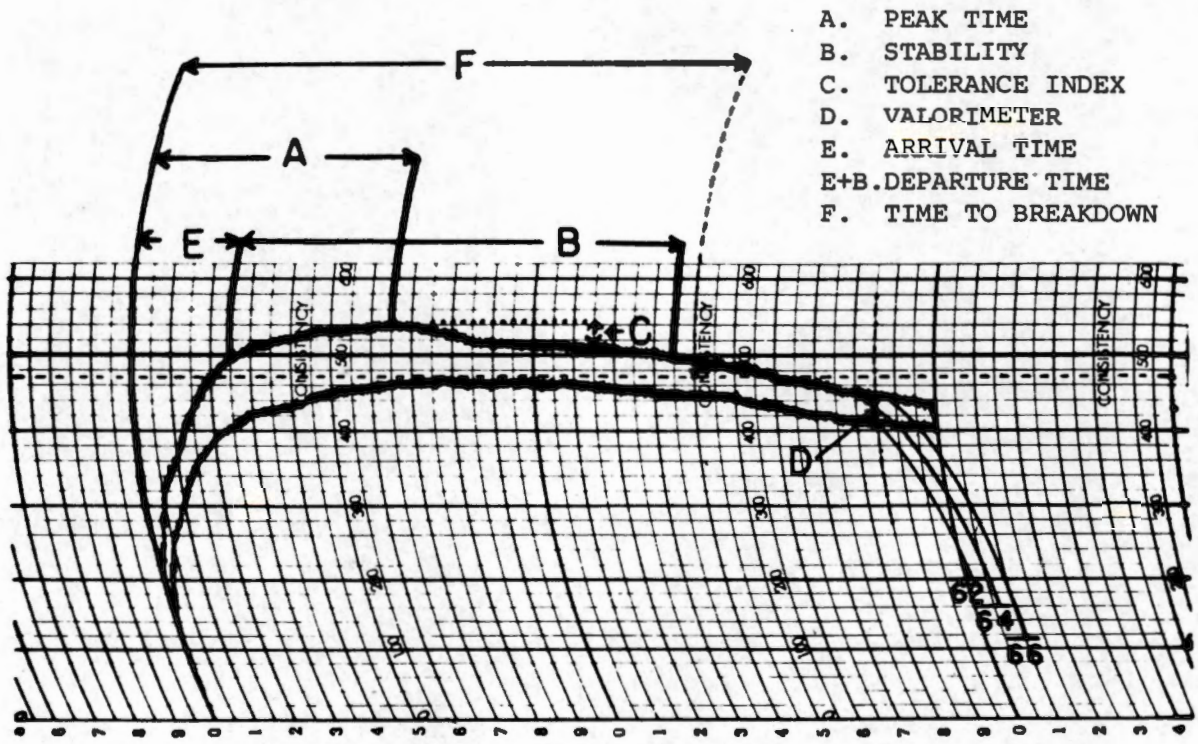
Response Alternatives	AP %	CONTROL %
hamburger	41.9	44.6
barbecue	7.3	7.0

Table A-3 (continued)

5. Uses (continued) Response Alternatives	AP %	CONTROL %
ham or luncheon meat	10.6	19.0
plain	25.1	17.8
chicken	1.7	0.0
other	13.4	11.9

6. Frequency of purchasing Response Alternatives	AP %	CONTROL %
Frequently (once or more per week)	26.0	21.9
Occasionally (once or twice per month)	43.1	60.9
Infrequently (once every few months)	29.3	15.6
Never	1.6	1.6

7. Willingness to buy Response Alternatives	AP %	CONTROL %
Would buy right away	28.2	30.6
Would certainly buy sometimes	45.3	56.5
May buy it sometimes	19.7	12.9
Don't think I'm interested in buying any	6.0	0.0
Positive, I would never buy any	0.8	0.0
8. Average household size	1.73	3.0



Peak Time: Time to the nearest half-minute from the first addition of water to the development of the dough's maximum consistency, minimum mobility and prior to the first beginning of weakening.

Stability: Is the difference in time, to the nearest half-minute, between the point where the top of the curve first intercepts the 500-B.U. line (arrival time) and the point where the curve leaves the 500-B.U. line (departure time). Is a general indication of tolerance to mixing a flour has.

Tolerance Index: Is the difference in Brabender units from the top of the curve at the peak to the top of the curve measured 5 minutes after the peak is reached. The lower the tolerance index, the stronger the flour.

Arrival time: The time required for the top of the curve to reach the 500 line after the mexer is started and the water is added. Is a measurement of the rate of water uptake.

Departure time: The time to the nearest half-minute from the first addition of water until the top of the curve leaves the 500 line and equals the sum of the arrival time plus stability. The longer the time, the stronger the flour.

Time to Breakdown: Is the time from the start of mixing to a decrease of 30 units from the peak point.

Figure A-1. Readings used in interpreting a farinogram (Shuey, 1972).

QUESTIONNAIRE

1. Please rate the bun for texture after biting into it. Place an "x" by the description that best fits the opinion of each person in your household.

	Self	Spouse	Children under 12			Children over 12		
Very soft								
Moderately soft								
Slightly soft								
Slightly firm								
Moderately firm								
Very firm								

2. Place an "x" on the appropriate line to indicate the overall acceptability of the bun for each person who tasted it.

	Self	Spouse	Children under 12			Children over 12		
Like very much								
Like moderately								
Like slightly								
Neither like nor dislike								
Dislike slightly								
Dislike moderately								
Dislike very much								

3. What, if anything, do you particularly like about the product; for example, crust color, crumb color, texture, etc.?_____

_____

_____

Figure A-2. Sample questionnaire for consumer testing of hamburger buns.

4. What, if anything, do you particularly dislike about the product; for example, crust color, crumb color, texture, flavor, etc.?_____

_____

_____

_____

5. How did you use the product?

_____sandwich for hamburger patty

_____sandwich for barbecued pork or beef

_____sandwich for luncheon meat or ham

_____sandwich for chicken

_____plain

_____other

6. How often do you buy hamburger buns for use at home?

_____frequently (once or more per week)

_____occasionally (once or twice a month)

_____infrequently (once every few months)

_____never

7. Willingness to buy; place an "x" on only one line.

_____would buy right away

_____would certainly buy it sometimes

_____may buy it sometimes

_____don't think I'm interested in buying any

_____positive I would never buy any

8. Number in household_____.

Thank you for your participation.

Figure A-2. (Continued)

VITA

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