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Title: UNBLEACHED-FLOUR, HIGH-RATIO WHITE CAKES AS AFFECTED BY VARIATIONS IN CREAM OF TARTAR AND SUGAR/WATER LEVEL

Abstract approved: Dr. Zoe Ann Holmes

Unbleached-flour, high-ratio white cakes were prepared with -15, -10, -5, 0, +5 percent variations in sugar/water level from American Association of Cereal Chemists Method 10-90. Formulas with and without added cream of tartar were used.

Specific gravity, batter and crumb pH, volume, crumb and crust color and compressibility were objectively measured. Seven trained judges participated in sensory evaluation for cell uniformity, cell compactness, layering, grain, tenderness, moistness, softness, crumb color, flavor, half-cake shape and surface characteristics, evenness and degree of browning.

Analysis of variance showed a significant difference at the 0.05 level between bleached flour control and unbleached flour cakes for specific gravity, crumb pH, volume, crust hue characteristics, compressibility, cell compactness, layering, grain, softness,

tenderness, moisture, crumb color, flavor, half-cake shape and surface, degree and evenness of crust browning. Cream of tartar in unbleached flour cakes caused a significant difference in crumb pH. Sugar/water level variation caused significant difference in crumb color and evenness of browning.

Unbleached Flour High-Ratio White Cakes as Affected by Cream of Tartar and Variation in Sugar/Water Level

by

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INTRODUCTION

In 1958, the Food and Drug Administration compiled a list of substances used in foods that were generally regarded as safe (GRAS). Substances on that list are presently under study to substantiate their safety. As part of this review, a two year study on the safety of chlorinated flour is now in progress (Gumbmann, 1975). If harmful effects are noted, chlorine may be banned as a food additive for bleaching and maturing flour.

Chlorinating cake flour improves the baking characteristics of the flour (Montzheimer, 1931) although the exact mechanism of improvement is not completely understood (Frazier et al., 1974). Many researchers have studied the action of chlorine on various parts of the flour (Sollars, 1958b; Tsen et al., 1971). Without chlorine treatment, cakes have sunken contours, soggy interiors, thick cell walls and decreased volume (Wilson and Donelson, 1965).

If chlorination is banned, several alternatives to this chemical improver are possible. Natural flour oxidation may occur during storage causing bleaching and improvement similar to chemical treatment (Harrel, 1952). Aging flour through oxidation may present the problems of storage costs, insect invasion and uneven flour improvement due to air penetrating the periphery of bagged flour more than the interior. The cost of aging flour the required four or five months varies from 16-20% of the selling price of the flour, compared with 0.5% of the selling price if chlorine treatment is used.

Heat treatment of flour has also been used to improve cake baking properties (Russo and Doe, 1970). Turbo-milled, air-classified flour was separated into its protein and starch components. Before incorporation into cake batter, the starch was heated at 5° C increments between 100° and 140° C. At each temperature increment one sample of heated starch was used immediately while the other was kept hot for 30 minutes before batter preparation. Optimum heat treatment was 120° C; holding the starch at a higher temperature did not further affect improvement. A drawback to this method is that a conventional roller-milling process cannot be used since starch and gluten must be well separated to avoid agglomeration.

The purpose of this study was to look at ingredient variation as a possible alternative to chlorine treatment. A high-ratio cake formula with 140% (flour weight) sugar, 140% water and 50% shortening was the basis from which sugar/water levels were simultaneously varied with and without added cream of tartar. Altering sugar or water levels to avoid collapse of cakes made from unbleached flour was suggested by Bohn in 1934. Studies by Kissell (1962; 1964) have indicated that cake volume, internal characteristics and contour are very sensitive to changes in sugar/water levels. Cream of tartar was added to bring the pH of unbleached flour batter closer to the pH of bleached flour cake batter. Charley (1951) found that addition of cream of tartar to bleached flour cakes caused significant differences in internal characteristics of the cake. This cake rated higher than the control.

REVIEW OF LITERATURE

Flour Improvement and Bleaching

Natural Oxidation of Flour

Changes occurring during the natural aging of flour can be attributed to increased free fatty acids (Clayton and Morrison, 1972; Gracza, 1965), decreased protein sulfhydral content (Yoneyama et al., 1970) and decreased pH (Sharp, 1924; Bailey and Johnson, 1924; Gracza, 1965; Yoneyama et al., 1970). Changes in these properties are influenced by storage conditions (Clayton and Morrison, 1972; Gracza, 1965; Yoneyama et al., 1970). The presence of oxygen during storage (Yoneyama et al., 1970) increased temperature (Gracza, 1965; Clayton and Morrison, 1972), and increased moisture all hasten oxidative changes. The changes that occur during natural aging are reflected in rheological properties.

The ability of flour to pick up oxygen during mixing is increased with age (Cosgrove, 1956). Aged flour which has had the fatty acids removed by petroleum ether extraction showed a reduced ability to pick up oxygen, indicating that fatty acids were involved in the absorption.

Chlorine in Flour

Wheat flour contains inherent traces of the chloride ion (Utt, 1914; Sollars, 1961; Wilson et al., 1964). It is believed to be picked up from the soil during growth and deposited in the endosperm (Sollars, 1961). Utt (1914) determined the natural chloride content of flour to be between 44-58 milligrams percent, whereas Sollars (1961) found the chloride content to be 43-54 milligram percent. Samples analyzed by Wilson et al. (1964) were also within these ranges.

Sixty percent of the natural chloride content of flour is found in the water-solubles fraction (Sollars, 1961). The lower layer of starch remaining after three acid extractions, one water extraction, pH readjustment and centrifugation, referred to as prime starch, comprises 70% of cake flour yet contains only 20% of the chloride ion. Gluten, soluble protein fraction and starch tailings contain little natural chloride ion.

Use of chlorine to improve bread flour was first recorded in 1914 (Utt). It was not until 1931 that data were recorded for using chlorine for cake flour (Montzheimer, 1931). Beta-Chlora, which is 99% chlorine and 1% nitrosyl chloride, was used to treat flour for use in a hot-water sponge cake with improvement in volume, crumb color and texture (Montzheimer, 1931).

In commercial use, chlorine gas is mixed with flour during the on-stream milling process. The optimum amount of 0.5-2.6 ounces chlorine per 100 pounds flour (Kulp, 1972) as used by millers partially depends on the crop (Bohn, 1934). Low protein crops tend to produce better cakes and have a lower chlorine requirement. Optimum level of treatment also depends on the flour particle size (Bohn, 1934; Wilson et al., 1964; Yamazaki and Donelson, 1972). The finest granulation with mass median diameter of 5.9 microns absorbs three times more chlorine than the parent flour with mass median diameter of 21.3 microns (Wilson et al., 1964). At normal chlorine concentrations, flour only retains 1/2 to 2/3 of the chlorine that is available for uptake (Sollars, 1961). After chlorination the flour contains 131 189 milligrams of chlorine per 100 pounds flour, which is 2-1/2 to 4 times the amount that it contains naturally.

By comparing the ratio of titrable chlorine to chlorine uptake, Wilson et al. (1964) postulated that 1/3 to 1/2 of the added chlorine was covalently bound in flour, although noting the possibility that chlorine may be bound so tightly as not to be titrable. Wilson et al. (1964) summarized the conceivable reaction of chlorine with flour components as being the oxidation, substitution or addition of chlorine to unsaturated covalent bonds.

Of the added chlorine adsorbed by the flour, the largest concentration was found equally distributed in the water-solubles and gluten fractions of the flour (Sollars, 1961). Tailings and prime starch combined contained only 6-10% of the added chlorine. Five percent of the flour, the petroleum ether extractable lipids and water-solubles fraction, contained 90% of the added chlorine (Gilles et al., 1964). Of chlorine in the water-solubles, the largest proportion was in the low-molecular weight fraction (Sollars, 1961; Wilson et al., 1964).

Mechanism of Chlorine Improvements

Carbohydrates. Chlorine reacts with both the starch and hemicellulose of wheat flour. The hemicellulose, xylan, is particularly affected since its arabinose side-chains are split-off, leaving the xylan insoluble (Cole, 1970). This may affect the rheological water-absorbing properties of flour. With starch, there appear to be two types of reactions occurring on chlorination depending on moisture conditions (Uchino and Whistler, 1962). The reaction rate is higher under aqueous conditions where the action is mainly oxidative with attack on the glucose polymer between carbon 2 and carbon 3 converting these to carbonyl functions. Flour is normally 13% moisture. During these semidry conditions there appears to be non-hydrolytic depolymerization occurring between carbon 1 and the glycosidic oxygen (Uchino and Whistler, 1962; Ingle and Whistler, 1964) with the elimination of an aglycone conjugate as a hypochlorite ester (Whistler et al., 1966). Glycosyl chloride occurs which splits the linkage and forms new glycosidic bonds. The reaction is temperature dependent and is facilitated by high moisture content in the flour. Depolymerization increases the solubility of starch in water (Ingle and Whistler, 1964).

Proteins. Chlorinating flour causes a proportional decrease in pH (Bailey and Johnson, 1924; Bohn, 1934; Sollars, 1958b; Tsen, 1966; Tsen et al., 1971; Kissell, 1971). Tsen et al. (1971) observed increased protein solubility on chlorination as determined by nitrogen extractability tests which indicated that protein was broken down into smaller units. Another worker (Kissell, 1971) found that the amount of soluble protein in flour increased significantly with chlorination until the flour reached pH 4.7.

At higher levels of chlorination, 16 ounces per 100 pounds flour, the ultraviolet spectrum did not show the usual peak at 280 millimicrons indicating that aromatic amino acids were oxidized by chlorination (Tsen et al., 1971). This concurs with Ewart (1968) finding that at ten times normal chlorine levels one-third of the tyrosine and one-half of the histidine were destroyed. At this level chlorine oxidized about 40% of the cystine to cysteic acid and 67% of methionine to sulphone. Deamination occurred, possibly due to hydrolysis by hydrochloric acid, with approximately 20% of the amides being lost.

Lipids. Some essential fatty acid destruction as well as a new gas-liquid chromatography peak have been shown with high levels of chlorination (Coppock et al., 1960). The new peak has been tentatively identified as dichlorostearic acid formed from stearic acid. A significant decrease in linoleic acid content has been shown by analyzing petroleum ether and acetone extracts of chlorinated flour (Daniels, 1960). Iodine values of flour lipids treated with 0, 1, 2 and 4 ounces chlorine per 100 pounds of flour decreased from 105 to 50 (Gilles et al., 1964). This indicated an increase in saturation due to chlorination.

The improving effect of chlorination was attributed to a reaction of chlorine with the lipid coating of starch granules (Youngquist et al., 1969). In untreated flour, the lipid coating interacts with the starch granule thus reducing swelling and preventing release of soluble starch. Youngquist et al. (1969) postulated that chlorine derivatives of lipids were sterically unable to form starch-lipid complexes. This was supported by the fact that chlorination was shown to have no effect on gelation properties of defatted starch yet does alter properties of natural starch.

Mechanism of Chlorine Bleaching

Besides the maturing effect on flour components previously described, chlorine serves a functionally less important yet aesthetically desirable role of bleaching flour pigments (Sullivan, 1953). Flour pigments contain xanthophyll esters, carotenes other than alpha and beta carotene, flavones and an unidentified red pigment in red wheats, all of which are referred to in the literature as carotenes. Pigment content of flour containing 1.75 parts per million carotene was reduced to less than 1 part per million with 2 ounces chlorine per 100 pounds flour (Kulp, 1972). The impact of chlorination on lipids is pertinent because the pigments are generally fat soluble, unsaturated hydrocarbons, thus the decrease in saturation found by Gilles et al. (1964) may be applicable.

Effect of Chlorine on Simple Systems

Chlorination has been found to affect the functional properties of both starch and protein in simple systems. Dough stability as shown on a farinograph was increased with 2 and 4 ounce chlorine increments but was drastically reduced at 8 and 16 ounce levels per 100 pounds flour (Kulp, 1972) Since moderate levels of chlorination, 1 and 4 ounces chlorine, only caused minor increases in starch solubilities and swelling powers, it was concluded that water-binding capacity must be intergranular. In contrast, solubility of starch was shown to increase when the chlorine to starch ratio was 3:1 (Ingle and Whistler, 1964). This was attributed to depolymerization of starch at the alpha 1,4 linkage.

Initial increase in peaking and peak height on viscogram curves of starch pastes at 0, 2 and 4 ounce chlorine increments were identical (Kulp, 1972). Eight ounces of chlorine per 100 pounds flour caused a lower peak.

In contrast, viscogram peak heights for flour showed increases with each 0, 2 and 4 ounce chlorine increment (Kulp, 1972). Similar results were found when the chlorinated flour was in 50% sucrose solution (Bean et al., 1974). Inactivation of alpha-amylase may cause the peak height differences since silver nitrate which inactivates amylases caused peak height differences to disappear (Kulp, 1972). Staggered peaks for chlorinated flour versus identical peaks for chlorinated starch indicates that other flour components are affecting pasting characteristics.

Gel strength of flour to water slurries (1:2 by weight) were significantly increased by chlorination (Frazier et al., 1974). The differences measured on an Instron Tensile Tester began when the flour dispersion temperature exceeded 60° C and continued through 95° C maximum temperature. Similar results were reported by Bean et al. (1974) using a gelometer on gels heated to 97° C.

Effect of Chlorine on Complex Systems

Chlorination improved volume, crust, symmetry, silkiness, tenderness, grain and color of low-ratio white cakes (Kulp, 1972).

This improvement was noted on cakes chlorinated with 1 and 2 ounces of chlorine per 100 pounds of flour. Two ounces of chlorine were optimum although 4 ounces per 100 pounds of flour also produced an acceptable cake. Levels higher than 4 ounces chlorine per 100 pounds of flour caused a deterioration of grain, texture and symmetry. The difference in quality of cakes may be due to either gluten protein or prime starch (Sollars, 1958b). Sollars fractionated bleached and unbleached cake flour into water-solubles, gluten, tailings and prime starch to see which fractions contributed the most to white cake volume and scores. Gluten and prime starch contributed equally to lowering the score for quality of crust, symmetry, silkiness, tenderness, grain and color when either was from unbleached flour and substituted in with other bleached components. However, gluten was more effective than prime starch in raising the score.

Other workers have found that the omission of chlorine may cause collapse of cakes during baking (Russo and Doe, 1970). Using a miniature half-bake oven, they compiled cake growth curves indicating height of the baking cake over time. Collapse of unchlorinated cakes may be due to highly significant differences in gel strength for chlorinated and unchlorinated crumb (Frazier et al., 1974). Gel strength was shown by centrifuging cooled cake crumb to attain constant density, then compressing the crumb on an Instron Tensile Tester.

Role of Cake Ingredients

Flour used in cake making contributes proteins for structure, polyvalent cations for batter stability (Howard et al., 1968) and starch for thermal setting of the batter (Howard et al., 1968; Jacobsberg and Daniels, 1974). Proteins and polyvalent cations from milk and eggs also contribute to structure and stability of the batter (Howard et al., 1968).

Water in cake batter dissolves sugar, salt and baking powder and suspends flour and egg (Carlin, 1944). Water also provides the liquid for starch swelling and gelatinization which is necessary for batter setting (Jacobsberg and Daniels, 1974).

Sugar acts as a tenderizer by competing with proteins for water (Baxter and Hester, 1958) and delaying the gelatinization temperature of the starch (Hester et al., 1956; Bean and Yamazaki, 1973; Jacobsberg and Daniels, 1974; Miller and Trimbo, 1965).

Baking powder when dissolved in water produces carbon dioxide for leavening (Carlin, 1944). During heating, carbon dioxide expands the air cells which were trapped during mixing producing the leavening effect.

Shortening is necessary for retention of air incorporated during mixing (Valassi, 1956). Emulsifiers added to shortening help to stabilize the fat-in-water emulsion (Jooste and Mackey, 1952) by making the surface of the shortening more hydrophilic thereby reducing anti-foam characteristics of fat (Baldwin, 1972). Emulsifiers also allow a finer dispersion of air cells in batter (Jooste and Mackey, 1952).

During baking heat causes a convection current of batter (Trimbo et al., 1966). Air cells dispersed in the aqueous phase (Pohl et al., 1968) expand and flow with the batter (Trimbo et al., 1966). Proteins coagulate while starch swells and gelatinizes forming a starch-protein matrix. During gelatinization, free water is absorbed from the batter contributing to thermal setting (Howard et al., 1968; Jacobsberg and Daniels, 1974). Physical strength of cake crumb depends on this matrix.

Effect of Varying Sugar Level

Since the starch-protein matrix is important for the support and strength of the cake crumb, any variation in the formation of this matrix will affect the resultant quality of the cake. Sugar concentration in cakes has been shown to affect both the starch and the protein.

In studying the effect of various sugar concentrations on soft wheat, Baxter and Hester (1958) found that sucrose decreases gluten strength. This was shown by increased gluten development time in a mixogram. In control dough without sugar, gluten developed in 2.5

minutes. When 15 and 30 percent sucrose concentrations were added to flour before mixing, gluten development time increased to 6 and 12 minutes, respectively. With 60 and 120 percent concentrations no gluten developed. This is supported in work by Meiske et al. (1960) who reported that the critical concentration for the inhibition of gluten development by sugar is 55-65 percent. Baxter and Hester (1958) hypothesized that the effect of sucrose was due to competition between sugar and protein for water. This was tested by developing dough in the presence of 30 and 60 percent sucrose, washing the sugar out after dough development, then allowing the dough to hydrate for one hour before re-kneading. Gluten yield was similar in weight to the gluten extracted from the control flour.

Heat coagulation of gluten proteins was delayed by increasing sucrose concentration (Baxter and Hester, 1958). This was shown by the greater amount of soluble protein that could be extracted from heated gluten dispersions with increasing sucrose concentrations.

Sucrose also affects wheat starch, either alone or in flour, by increasing the gelatinization temperature (Hester et al., 1956; Bean and Yamazaki, 1973; Jacobsberg and Daniels, 1974; Miller and Trimbo, 1965). Gelatinization of wheat starch and flour in 50 and 60 percent sucrose solutions was delayed from 60° C to 85° C and 95° C, respectively for starch and to 80° C and 90° C for flour (Bean and Yamazaki, 1973). Diameter measurements of starch granules during heating indicate that starch swelling was delayed in concentrated sugar solutions. Once starch swelling began, it proceeded faster and swelled more than in water. The gels that were formed in the presence of 15.9 and 23.7% concentrations of sugar were less rigid than those without sugar (Hester et al., 1956). At 31.6% sucrose concentrations, no gels were formed.

The viscosity of starch pastes was also influenced by the presence of sucrose (Hester et al., 1956). At a given temperature, the decrease in viscosity of starch pastes when sucrose was added was attributed to delayed starch swelling. Decreased maximum viscosity of starch pastes in the presence of sucrose was attributed to less swelling. These changes in viscosity were influenced by diminished disintegration of starch granules resulting in less material diffusing from granules when sugar was present (Hester et al., 1956; Bean and Yamazaki, 1973).

In contrast to the starch and water systems, wheat flour and water slurries with added sugar show a higher maximum viscosity and form firmer gels than do the controls (Hester et al., 1956). Interactions of other flour components cause the effect of sucrose on starch to be a minor factor in determining the water-holding capacity, paste viscosity and gel rigidity in systems with flour (Hester et al., 1956).

The effect of adding varying sugar concentrations in low-ratio cakes was photographed and evaluated by Davies (1936). Increasing sugar by 25% caused less uniform cells, coarser grain, slightly larger volume and more tender texture than the control. Decreasing sugar by 25% caused a finer grain and smaller volume cake than the control, and a tough texture. Kissell and Marshall (1962) examined the effect of ratios of basic ingredients on white layer cakes formulated without milk and egg white for increased sensitivity. These lean formula cakes (Kissell, 1959) showed that alteration of sugar beyond a narrow optimum range caused marked quality reduction (Kissell and Marshall, 1962).

Effect of Varying Liquid Level

Optimum liquid level needed in a cake formula varies with the flour and specific formula used (Wilson and Donelson, 1963; Kissell, 1959). Variation in liquid tolerances may be due to inherent quality differences in flours with similar protein levels. Kissell and Marshall (1962) found in lean formula cakes that liquid level was in fine balance with other ingredients. Alteration of liquid level beyond a narrow optimum range caused decreased quality. The optimum liquid level in a formula is a result of the competition for water between the sugar and proteins from egg, milk and flour, and flour starch (Howard et al., 1968).

As reflected by the different effect of optimum liquid level on the two characteristics, crumb structure and volume, the problem is much more complex (Wilson and Donelson, 1963). These workers found that optimum crumb structure developed at a 6% higher liquid level than that level required for optimum volume. Possibly because of insufficient starch gelatinization, a low liquid level caused coarse grain and harsh dry texture in low-ratio cakes (Davies, 1936). Open crumb, low volume and sunken contour occurred with low liquid levels in lean formula cakes (Wilson and Donelson, 1963). In contrast, high liquid levels in low-ratio cakes produced fine grain cake with small volume and moist and tender texture (Davies, 1936), while high liquid levels produced a peaked contour in lean formula cakes (Wilson and Donelson, 1963).

Effect of Varying pH

Protein of flour is affected by changes in pH (Bennet and Ewart, 1962; Tsen, 1966). Addition of acids showed the most pronounced decrease in extensibility of dough until pH 4.6 was reached (Bennet and Ewart, 1962). The suggested mechanism is through the hydrogen ions from acid causing an unfolding of the protein. Additionally, at the more alkaline pH, wheat starch and protein interactions are decreased (Dahle, 1971).

The alteration of the pH of cake batter with cream of tartar or baking soda changed heat penetration during baking and quality of shortened cakes (Charley, 1951). Heat penetration with cream of tartar cake batters averaged 2-3° F higher than the control, with an almost linear increase for 20 minutes. Batters with added soda displayed a slower rate of heat penetration. Specific gravity of the batter was not significantly different with added cream of tartar, but was significantly less with added baking soda. Difference in heat transfer between acidic and basic batters is attributed to the difference in carbon dioxide evolved. Slight flattening of heat penetration curves for both variables was due to heat absorption during rapid gelatinization of starches.

Additionally, changes in pH with cream of tartar or baking soda affect other quality characteristics (Charley, 1951). Cakes with soda were significantly larger than cakes with cream of tartar; the latter cakes had significantly different scores in whiteness, fineness of cells, sweetness, flavor other than sweet, moistness, tenderness and overall desirability, rating higher than the control when tested by a panel. Coarseness and lack of uniformity of soda-based cakes may be due to the slow rate of heat penetration and starch gelatinization.

EXPERIMENTAL PROCEDURE

A modification of the American Association of Cereal Chemists (A. A. C. C.) Method 10-90 for studying the baking quality of flour was followed. Proportion of ingredients and all treatments are found in Tables 1 and 2, respectively. Henceforth, "cream of tartar" when referring to treatments refers to 0. 5 grams cream of tartar added to cake batter; "no cream of tartar" indicates no addition of cream of tartar to A. A. C. C. 10-90 formula. "Sugar/water levels" when referring to treatments indicates the five increments of 5% change in sugar/water level.

Counterpart bleached and unbleached flour analysis was 13. 5% moisture, 0. 325% ash, 8. 5% protein, pH 5. 75 for unbleached flour, pH 4. 55 for bleached flour. Other ingredients met specifications of A. A. C. C. 10-90.

Dry ingredients were pre-weighed on a torsion balance and stored at 3° C, until the day before usage. All ingredients were at room temperature before mixing with paddle attachment on a Kitchen-Aid mixer, model K 4-B at speeds 2 and 6. Four hundred and twenty-five grams of batter were scaled into 4xxxx tinned sheet steel, 20. 3 cm. by 5. 1 cm. cake pans. Pans were sprayed with Pam, a commercial lubricant, and lined with 7-15/16 inch parchment circles.

During one hour of pre-heating, a Rotary Despatch Oven was conditioned with water. Based on preliminary experiments to

Table 1. Weight and percentage of ingredients in high ratio white cakes.

Ingredient	Grams per batter	Percentage of batter flour
Cake flour[a]	200	100
Baker's Special, Extra-fine sugar	280	140
Pet Non-fat Dry Milk[b]	24	12
Kraft Spray-dried Egg White	18	6
Fleischmann's Baking Powder	10	5
Leslie, All-purpose Salt	6	3
Double-D Foods Hy-Ratio Cake and Icing Shortening	100	50
Distilled Water	280	140

[a]Bleached and counterpart unbleached cake flour donated by Mennel Milling, Fostoria, Ohio

[b]Donated by Pet Incorporated, Greenville, Illinois

Table 2. Experimental treatments on high-ratio white cakes as expressed by cream of tartar additions, percentage and direction of variation in sugar and water levels, and by type of flour used.

Treatment Number	Cream of Tartar	Percentage and Direction of Variation in Sugar and Water	Type of Flour
1	no[a]	+05	unbleached
2	no	0	unbleached
3	no	-05	unbleached
4	no	-10	unbleached
5	no	-15	unbleached
6	yes[b]	+05	unbleached
7	yes	0	unbleached
8	yes	-05	unbleached
9	yes	-10	unbleached
10	yes	-15	unbleached
11	no	0	bleached

[a]No cream of tartar added to A. A. C. C. 10-90 formula

[b]0. 5 gram cream of tartar added to A. A. C. C. 10-90 formula

determine crumb structure similarities, cakes were baked for 31 minutes and 23 minutes, respectively, for all experimental unbleached flour cakes and bleached flour controls.

Specific gravity was measured in an aluminum Evelyn pycnometer within five minutes of completion of mixing. The batter pH was also determined at this time following A. A. C. C. Method 02-52 for determining pH of flour.

A. A. C. C. Method 10-91 for measuring cake volume was used on half-cakes which were divided with an electric knife, as diagrammed in Figure 1. At this time crumb pH measurements were done, using an identical procedure to that done with the batter.

Color of crust and crumb was evaluated in a dark room on Photovolt Reflection Meter 670. The Y search unit was standardized in a downward position on a white enamel plaque with values on 51. 5 for the blue filter, 50. 0 for the green filter and 48. 5 for the amber filter. Data from Photovolt readings were converted to the Commission Internationale de L'Eclairage (C. I. E.) system of color identification, according to the procedures listed in the National Bureau of Standards monograph on colorimetry (U. S. Department of Commerce, 1968).

Compression, an indicator of tenderness, was measured on the Universal Testing Instrument, Instron 1132 (crosshead set at 2 inches per minute, range 2). Data are expressed as pounds of force per

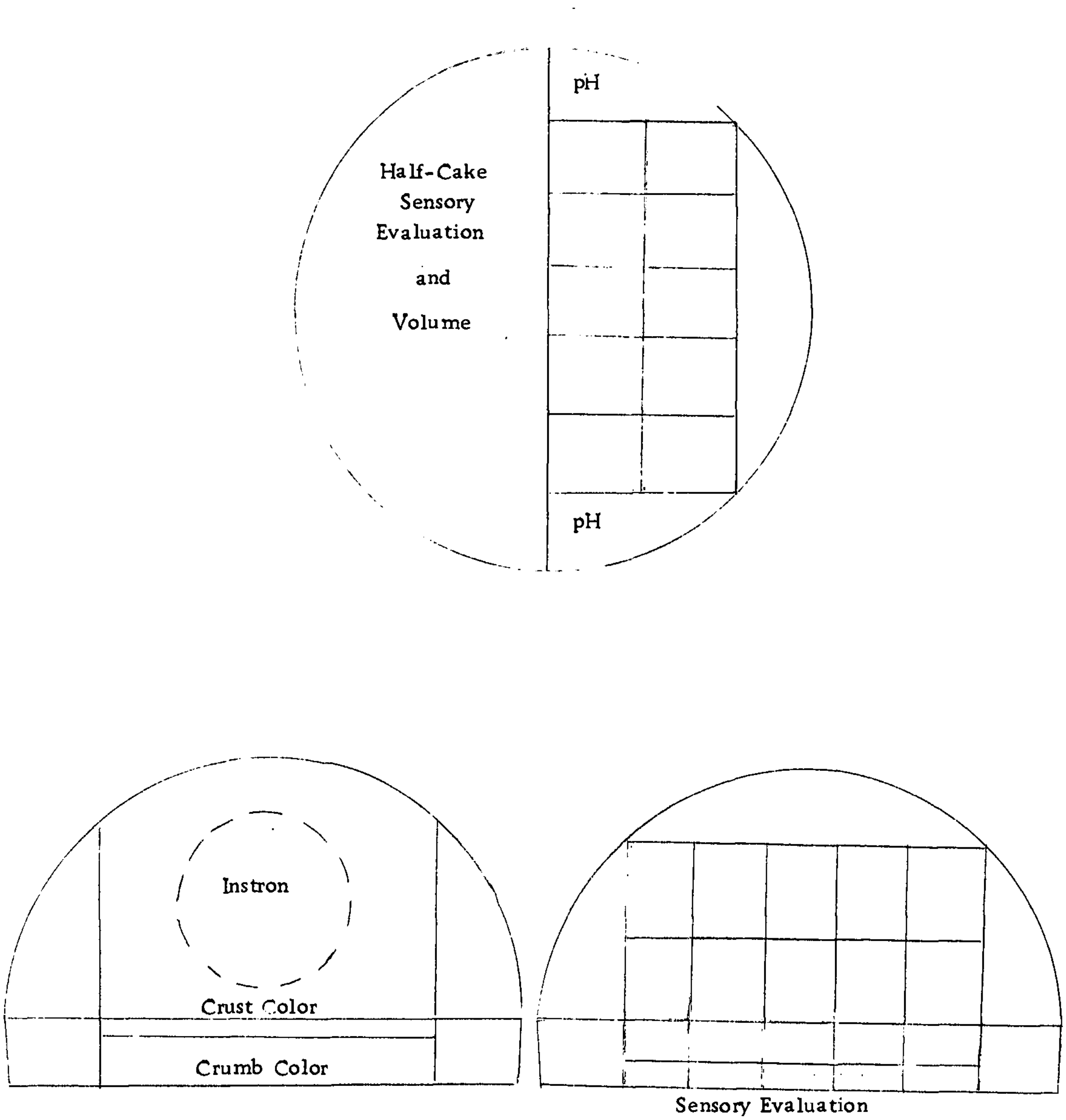

Figure 1. Sampling pattern for high-ratio white cakes.

1/2 inch of cake compressed. Maximum height of the curves was read directly from the graphs, while area under the curves was measured with a polar planimeter.

Seven trained judges who were faculty and students in Foods and Nutrition department of Oregon State University, Corvallis, Oregon, participated in sensory evaluation. Panelists received four randomly coded numbered samples of approximately 1" x 1" x 1/2". Using the score card shown in Figure 2, panelists evaluated the internal structure and texture of samples using 24 inch high fluorescent desk lamps in a darkened room. Crumb color was evaluated under a Daylight MacBeth lamp. Judging of half-cakes was done under 60 watt light bulb. Scores for the sensory data were compiled by assigning numerical values to characteristics under each heading in the order of their appearance on the card. The mean scores for the four replications within each treatment were then analyzed.

Four replications were performed on the control and all treatments. The four treatments prepared per baking day were randomly chosen and assigned code numbers from a random numbers table. Analysis of variance and correlation coefficient, r, were performed on the campus computer CDC-3300, OC3 Operating System, using *SIPS. F values were determined at the 0.05 significance level. Sources of variance in analysis of variance tables are: the bleached flour standard compared to all unbleached flour cakes; and, for

CHARACTERISTICS	SAMPLES			
INTERNAL APPEARANCE - individual samples CELLS Uniformity (a) indistinguishable (b) even (normal) (c) slightly uneven (d) uneven				
Compactness (a) indistinguishable (b) dense (c) close (normal) (d) open				
Layering (a) no layering (b) single, thin, gummy layer (c) single, thick, gummy layer (d) several gummy layers				
TEXTURE Grain (a) silky (normal) (b) rubbery (c) rough (d) harsh				
Softness (a) soft (normal) (b) slightly firm (c) firm				
Tenderness (a) very tender (normal) (b) tender (c) slightly tough (d) tough				
Moistness (a) all gummy (b) sticky (c) moist (normal) (d) slightly dry (d) dry				
CRUMB COLOR (a) bright white (normal) (b) slightly creamy (c) creamy (d) sl. dull & sl. creamy				
FLAVOR - (approx. 15 seconds after tasting) (a) normal (no off flavor) (b) slightly bitter after taste				
EXTERNAL APPEARANCE - half cakes SHAPE (a) rounded (b) flat (c) depressed (d) slightly sunken (e) sunken				
CRUST APPEARANCE Surface (a) bubbly (b) smooth (c) cracked				
Degree of browning (a) dark brown (b) brown (c) golden brown (normal) (d) pale brown				
Evenness of browning (a) even (b) slightly uneven (c) uneven				

Figure 2. Cake Quality Scoring Guide.

unbleached flour cakes alone, variation due to sugar/water level change or to addition of cream of tartar and interaction between sugar/water levels and cream of tartar.

RESULTS AND DISCUSSION

Objective Data

Specific Gravity

Specific gravity was not significantly different for batters with cream of tartar versus no cream of tartar nor for variations in sugar/water levels. As shown in Table 3, cream of tartar tended to lower specific gravity values from those of batters without cream of tartar at the 0, -10 and -15% levels. As sugar/water levels were reduced below the -5% level in cakes without cream of tartar, specific gravity declined. Standard cakes made with bleached flour had a significantly lower specific gravity than those with unchlorinated flour. The approximately 10% lower values were probably due to the lower amount of air incorporated with the unbleached flour cake.

Charley (1951) found that adding cream of tartar to bleached flour cakes did not significantly change specific gravity. In this experiment, specific gravity for all treatments and control were lower than those reported by Charley (1951) as well as those reported by Ellinger and Shappeck (1963) using high-ratio cake batters. The specific gravity in low-ratio cakes (Charley, 1951) was 12% higher while specific gravity for high-ratio white cakes (Ellinger and

Table 3. Specific gravity of unbleached flour cake batter at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	0.79	0.84	0.81	0.83	0.80	0.67
	2	0.80	0.84	0.86	0.86	0.76	0.80
	3	0.76	0.83	0.85	0.82	0.77	0.77
	4	0.86	0.80	0.78	0.78	0.77	0.76
	Mean	0.80	0.83	0.83	0.82	0.78	0.75[b]
With Cream of Tartar	1	0.83	0.76	0.79	0.83	0.81	
	2	0.75	0.84	0.87	0.67	0.82	
	3	0.82	0.77	0.87	0.80	0.72	
	4	0.80	0.81	0.78	0.82	0.73	
	Mean	0.80	0.80	0.83	0.78	0.77	

[a]Standard deviation = 0.14.

[b]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Shappeck, 1963) was 15% higher than the standard bleached cake in this experiment. In both instances bleached flour was used. The two investigations indicate that pH alone does not account for change in specific gravity. In the Ellinger and Shappeck (1963) study eggs were added during the second stage of mixing which may have contributed to the difference in specific gravity.

Contrary to this study, decreasing sugar ratios have been found to increase batter specific gravity in bleached flour cakes (Hunter et al., 1950). The range of specific gravity was 0.74 for high sugar formulas to 0.81 for low sugar formulas. In this experiment, decreasing sugar first increased specific gravity, but then caused it to decline.

Batter pH

Batter pH was not significantly different for cream of tartar versus no cream of tartar nor for variations in sugar/water levels. As shown in Table 4, addition of cream of tartar to unbleached flour cakes caused a lower batter pH than batters without cream of tartar except at the lowest sugar/water level, -15%. Variation in batter pH with sugar/water levels was noted, although no definitive trend was seen. Bleached flour batter pH was not significantly different from that of unbleached flour batter pH.

In this experiment batter pH changed 0.04-0.06 units with 0.5

Table 4. Batter pH of unbleached flour cake batter at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	6.87	6.92	6.93	6.86	6.92	6.86
	2	6.79	6.92	6.92	6.88	6.94	6.82
	3	6.88	6.86	6.91	6.88	6.92	6.84
	4	6.92	6.82	6.86	6.92	6.63	6.86
	Mean	6.87	6.88	6.91	6.89	6.85	6.85
With Cream of Tartar	1	6.86	6.86	6.86	6.83	6.91	
	2	6.76	6.84	6.91	6.83	6.89	
	3	6.82	6.79	6.84	6.82	6.91	
	4	6.84	6.87	6.77	6.85	6.88	
	Mean	6.82	6.84	6.85	6.83	6.90	

[a]Standard deviation = 0.06.

gram of cream of tartar. In a similar experiment with low ratio bleached flour cakes Charley (1951) also found no significant differences with a 0. 06 unit change due to 0. 5 grams cream of tartar addition. Ash and Colmey (1973) reported that stable layer cake batters were obtained between pH 5. 0 to 6. 0. As pH was raised above this level, batters began to curdle, reflecting a separation of the oil-in-water emulsion. Unbleached flour batters which ranged in pH from 6. 82 to 6. 91 in this experiment exhibited slight curdling at the sides of the bowl. The bleached flour control batter pH also in this range, did not appear curdled.

Crumb pH

Workers at Kansas Agricultural Experiment Station, found that at low levels of cream of tartar addition to cake batter, crumb pH was significantly decreased (Miller et al. , 1957). Their formula was 89% of the dry weight of the formula in this experiment, and incorporated 2. 5 gram baking soda, rather than baking powder. At their 3 gram addition of cream of tartar, cake volume increased and loss of carbon dioxide decreased. However, at higher levels of cream of tartar, there was a significant decrease in cake volume and loss of carbon dioxide. In this experiment with 0. 5 gram added cream of tartar, crumb pH was significantly lower than cakes made without cream of tartar. Although there was no significant difference in crumb pH with variation in sugar/water level, the mean did fluctuate within a range of 0.05 pH units on either side of pH 7.65 for cakes without cream of tartar. Cakes with cream of tartar also fluctuated within a 0.05 pH unit range (Table 5). Bleached flour standard cake crumb pH was significantly different than cakes with unbleached flour.

Volume

Volume was not significantly different for cream of tartar versus no cream of tartar nor for variations in sugar/water levels. As shown in Table 6, cream of tartar tended to increase the volume of unbleached flour cakes.

In addition to treatments, experimental error may have affected volume. In examining a plot of residuals versus time, it was noted that residuals appeared random for the first three baking days, but then showed a linear upward trend, indicating improved volume over time. The flour may have become oxidized and therefore improved on storage. Probable oxidation of this flour over the five month period from time of shipment to time of change in the flour characteristics may be supported by similar results in a number of investigations. Yoneyama et al. (1970) found a decreased sulfhydral content in unbleached flour after 90 days of storage at 30° C. Cosgrove (1956) found that the ability of unbleached flour to absorb oxygen during mixing was dependent on age and reached a maximum after two to three

Table 5. Crumb pH of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	7.65	7.71	7.67	7.80	7.64	7.55
	2	7.74	7.64	7.64	7.67	7.51	7.50
	3	7.69	7.68	7.62	7.57	7.66	7.52
	4	7.63	7.57	7.66	7.66	7.71	7.48
	Mean	7.68	7.65	7.65	7.68	7.63	7.51[b]
With Cream of Tartar[c]	1	7.52	7.36	7.50	7.48	7.50	
	2	7.52	7.59	7.52	7.48	7.49	
	3	7.59	7.52	7.48	7.50	7.54	
	4	7.53	7.49	7.52	7.54	7.55	
	Mean	7.54	7.49	7.51	7.50	7.52	

[a]Standard deviation = 0.06.

[b]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

[c]Unbleached flour cakes with cream of tartar are significantly different ($P \leq 0.05$) than cakes without cream of tartar.

Table 6. Volume (cc.) of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	655	739	823	754	743	1047
	2	725	706	580	669	741	1043
	3	771	627	791	817	900	984
	4	596	745	814	694	864	1016
	Mean	687	676	752	734	812	1023[b]
With Cream of Tartar	1	548	899	968	768	755	
	2	708	881	659	936	728	
	3	633	675	635	835	887	
	4	682	597	936	661	854	
	Mean	643	763	800	800	806	

[a] Standard deviation = 32.

[b] Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

months at room temperature. Although flour in this experiment was generally kept at 3° C there were fluctuations in temperature during storage and ingredient preparation.

The size of the pan may be a factor in results. Sollars (1958) found no significant difference in volume between six inch diameter chlorinated versus unchlorinated flour cakes. To test this anomaly he used different bakers and different paired flours, finding the same results. However, when he used eight inch pans, the unbleached flour cake was smaller in volume than unbleached flour control. Although the six inch pans corrected the volume differences in cakes, the sensory evaluation scores were lower, at 58 of 100 total points for unbleached flour cakes, to 84 of 100 total points for bleached flour cakes.

The quality of the flour used in this experiment may also have affected results. Tests done on the flour at the Soft Wheat Quality Laboratory, Wooster, Ohio, indicated less than optimum quality. Volume of bleached flour six inch diameter cakes were 552 cc. as compared to over 600 cc. for good performing flour.

Ellinger and Shappeck (1963) reported eight inch diameter bleached flour cake volume to be 1240 cc. , compared to 1023 cc. in this current experiment. Ellinger and Shappeck used a leaner formula cake. Volume differences have been attributed to procedural variation (Hunter et al. , 1950), types of ingredients (Kissell, 1975) and to inherent flour composition (Strobel and Howard, 1969; Miller et al., 1967). Unbleached flour control cakes in this experiment were 64% of the volume of unbleached flour cakes baked by Kulp (1972). His cakes were 88% the volume of counterpart bleached cakes, whereas in this experiment unbleached flour controls were 66% the volume of counterpart bleached cakes. When cream of tartar was added, unbleached flour cakes were 75% of the standard cake volume.

Volume in unbleached flour cakes was shown to have a negative correlation to specific gravity (with cream of tartar/without cream of tartar; $r = -0.57$/ $r = -0.58$). A similar negative correlation was found by Tinklin and Vail (1946) for bleached flour cakes. This may indicate that a well-aerated batter contributes to cake volume.

Sugar/water ratios in lean formula bleached flour cakes were shown to have a great effect on volume, since deviation from optimum level for either factor caused a decreased volume (Kissell, 1964). In contrast, a low-ratio formula was reported to produce larger cakes when sugar was increased or liquid was decreased by 25% (Davies, 1936). Volume was decreased with 25% less sugar or 25% more water, than the control.

Contrary to this experiment, Charley (1951) found that addition of 0.5 grams cream of tartar caused a lower volume. However, this was in a bleached flour cake and difference was not significant.

Instron Peak and Area Under the Curve

Instron peak and area under the curve provide an index of compressibility, an indicator of tenderness (Bourne et al., 1966). Peak height refers to the pounds force required to compress the 3/4 inch slice of cake to a 1/4 inch slice (Table 7). Area under the curve reflects the total amount of work required in the compression process (Table 8). A smaller number shows less force was required to compress a sample, therefore indicating a more tender piece of cake. There is a highly significant correlation between peak height and area under the curve, for both cakes with cream of tartar and without cream of tartar (with cream of tartar/without cream of tartar: $r = 0.63$ / $r = 0.65$). This indicates that both methods of measuring compressibility will give similar results.

Values for the Instron peak and area under the curve were not significantly different for cream of tartar versus no cream of tartar, nor for variations in sugar/water levels. Hunter et al. (1950) found similar results when using a Baker Compressimeter; decreasing sugar/water levels did not significantly affect compressibility. The trend of cream of tartar was to decrease area under the curve, although peak height response was variable. Decreasing sugar/water levels tended to increase peak height and area under the curve, except at the lowest sugar/water level, -15%. The bleached flour

Table 7. Instron peak height (pounds) of unbleached flour cake at +5, 0, -5, -10 and -15 percent variations in sugar and water levels, with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	4.19	4.00	4.50	4.36	4.47	2.31
	2	2.30	4.60	4.52	4.99	5.40	1.80
	3	2.44	4.13	5.01	4.51	2.99	1.48
	4	4.50	3.24	2.81	5.51	3.34	1.60
	Mean	3.36	3.99	4.21	4.84	4.05	1.80
With Cream of Tartar	1	3.90	4.01	2.12	5.17	4.50	
	2	2.86	3.50	5.01	3.92	4.16	
	3	4.00	5.35	4.41	5.50	4.68	
	4	4.00	3.26	3.04	4.33	4.80	
	Mean	3.69	4.03	3.65	4.73	4.54	

[a]Standard deviation = 0.84.

Table 8. Instron area under the curve (square cm.) of unbleached flour cake at +5, 0, -5, -10 and -15 percent variations in sugar and water levels, with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	366	428	370	400	390	132
	2	422	451	472	540	451	103
	3	149	445	402	371	151	92
	4	454	216	437	516	294	94
	Mean	348	385	420	457	321	105[b]
With Cream of Tartar	1	389	391	97	438	364	
	2	286	198	457	177	374	
	3	428	448	575	383	254	
	4	394	356	143	491	320	
	Mean	374	348	318	372	328	

[a]Standard deviation = 117.

[b]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

standard was significantly different than unbleached flour control, indicating a more tender sample.

Crumb and Crust Color

Crumb and crust color values are in terms of a right-angle chromaticity diagram where the 0 intercept is considered as blue, with increasing values on the x axis indicating red and increasing values on the y axis indicating a greener hue (Clydesdale, 1969; U. S. Department of Commerce, 1968). Near white surfaces have the additional yellowness value. A higher crumb yellow value represents a more yellow sample. In the discussion that follows, the Commision Internationale de L'Eclairage (C. I. E.) values indicate differences in color although they do not necessarily reflect colors usually associated with a standard cake.

Crumb color is located in a hueless zone due to the whiteness of the sample. Extrapolation of designated hue zones makes it possible to describe the location of cake crumb and crust color on the chart. By this method, crumb color was located in the yellow-green region (Nickerson, 1947; Clydesdale, 1969). Plotting the x and y co-ordinates (Table 9, 10) showed that adding cream of tartar caused a slight shift in color location closer to the green hue border. Decreasing sugar/water levels gave a variable color response. The higher y (green) value of the bleached flour standard indicated

Table 9. Crumb x of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	0.40	0.33	0.34	0.34	0.34	0.35
	2	0.33	0.33	0.31	0.34	0.34	0.39
	3	0.33	0.34	0.33	0.33	0.33	0.32
	4	0.34	0.33	0.33	0.40	0.33	0.32
	Mean	0.35	0.33	0.33	0.35	0.34	0.35
With Cream of Tartar	1	0.34	0.33	0.33	0.38	0.34	
	2	0.33	0.33	0.32	0.39	0.32	
	3	0.33	0.33	0.34	0.33	0.39	
	4	0.33	0.32	0.33	0.32	0.39	
	Mean	0.33	0.33	0.33	0.35	0.36	

[a]Standard deviation = 0.02.

Table 10. Crumb y of unbleached flour cake battter at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	0.44	0.35	0.35	0.35	0.35	0.46
	2	0.35	0.35	0.32	0.35	0.35	0.43
	3	0.35	0.35	0.35	0.36	0.35	0.34
	4	0.35	0.35	0.35	0.44	0.36	0.34
	Mean	0.38	0.35	0.34	0.38	0.35	0.39
With Cream of Tartar	1	0.36	0.36	0.35	0.45	0.35	
	2	0.35	0.35	0.36	0.45	0.32	
	3	0.35	0.36	0.35	0.35	0.45	
	4	0.35	0.32	0.35	0.32	0.45	
	Mean	0.35	0.35	0.35	0.39	0.39	

[a]Standard deviation = 0.04.

increased intensity or chroma.

Cream of tartar versus no cream of tartar and variations in sugar/water levels in unbleached flour cakes had fluctuating effects on the yellowness value for cake crumb (Table 11). In contrast, Charley (1951) found that addition of cream of tartar to bleached flour batters produced a whiter cake.

Crust color, in general, was located in the extrapolated hue section ranging from greenish-yellow to orange-pink. Bleached flour standard had a significantly higher crust y (Tables 12, 13), indicating the dominant wavelength as yellow. Cream of tartar versus no cream of tartar and changes in sugar/water level had a variable effect on crust color response. This is in agreement with Rubenthaler et al. (1964) who found that adding sucrose to a starch dough did not significantly change crust color. This is because sucrose is not a reducing sugar and therefore does not participate in carbonyl-amine browning reactions (Johnson et al., 1961).

Sensory Data

Cell Uniformity

Trained panelists tended to score cell uniformity for unbleached flour cakes at "slightly uneven" or "indistinguishable" (Table 14). During panelist training sessions, "indistinguishable" was defined

Table 11. Crumb yellowness of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	0. 69	0. 27	0. 28	0. 28	0. 28	0. 52
	2	0. 26	0. 26	0. 05	0. 28	0. 28	0. 70
	3	0. 26	0. 26	0. 22	0. 26	0. 26	0. 16
	4	0. 27	0. 24	0. 26	0. 75	0. 26	0. 17
	Mean	0. 38	0. 26	0. 20	0. 39	0. 27	0. 39
With Cream of Tartar	1	0. 30	0. 25	0. 22	0. 69	0. 29	
	2	0. 27	0. 27	0. 19	0. 69	0. 07	
	3	0. 25	0. 22	0. 27	0. 23	0. 70	
	4	0. 23	0. 07	0. 25	0. 07	0. 70	
	Mean	0. 26	0. 20	0. 23	0. 42	0. 44	

[a]Standard deviation = 0. 19.

Table 12. Crust x of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	0.39	0.44	0.44	0.43	0.42	0.43
	2	0.43	0.35	0.34	0.43	0.43	0.37
	3	0.43	0.43	0.42	0.44	0.43	0.45
	4	0.43	0.43	0.43	0.34	0.47	0.41
	Mean	0.42	0.41	0.41	0.41	0.44	0.42
With Cream of Tartar	1	0.38	0.41	0.43	0.37	0.43	
	2	0.43	0.45	0.43	0.43	0.35	
	3	0.44	0.33	0.44	0.43	0.43	
	4	0.43	0.33	0.42	0.34	0.42	
	Mean	0.42	0.38	0.43	0.39	0.41	

[a]Standard deviation = 0.04.

Table 13. Crust y of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	0.44	0.36	0.35	0.38	0.36	0.40
	2	0.38	0.41	0.35	0.37	0.37	0.48
	3	0.36	0.37	0.38	0.36	0.36	0.38
	4	0.35	0.37	0.35	0.47	0.32	0.42
	Mean	0.38	0.38	0.36	0.39	0.35	0.42[b]
With Cream of Tartar	1	0.34	0.38	0.39	0.45	0.37	
	2	0.33	0.31	0.37	0.37	0.36	
	3	0.36	0.25	0.35	0.36	0.36	
	4	0.37	0.36	0.39	0.36	0.38	
	Mean	0.35	0.36	0.38	0.38	0.37	

[a] Standard deviation = 0.03.

[b] Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Table 14. Cell uniformity[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	2.3	2.1	2.4	2.4	3.4	2.3
	2	1.6	2.3	1.3	2.1	2.1	2.3
	3	3.0	2.1	1.9	1.9	2.7	2.3
	4	1.1	2.7	1.7	2.4	2.6	2.1
	Mean	2.0	2.3	1.8	2.2	2.7	2.3
With Cream of Tartar	1	1.3	3.3	2.7	3.0	2.3	
	2	1.9	2.6	2.0	2.4	1.7	
	3	2.4	1.4	1.6	3.1	3.0	
	4	2.4	2.9	2.7	1.7	3.0	
	Mean	2.0	2.5	2.2	2.6	2.5	

[a] 1 = indistinguishable
2 = even (normal)
3 = slightly uneven
4 = uneven

[b] Standard deviation = 0.6.

as the cell uniformity characteristic associated with the gummy layer. For cakes with cream of tartar, there was a significant negative correlation between cell uniformity and layering ($r = -0.46$). The descriptions for evaluating cell uniformity and the scorecard format may have been factors in the consistent response (standard deviation 0.6) of the bleached flour standard and all treatments to be near "even."

Miller et al. (1967) observed the inside of an unbleached flour cake during baking with a special glass pan. Their observations of cell uniformity, compactness and layering during baking correspond to the baked cake characteristics in this experiment. First a gummy layer formed at the bottom of the pan, followed by a lighter colored mid-section, with a band of large air cells along the top of the batter. During baking the width of the large air cells increased. It follows that as gas in these cells condense during cooling, coupled with the force of gravity and possible atmospheric pressure (Russo and Doe, 1970) that the contour would sink, particularly since unchlorinated flour cake crumb does not have a strong support from the starch-protein gel matrix (Frazier et al., 1974).

Addition of cream of tartar tended to improve the score. This conforms with work by Charley (1951) where the addition of 0.5 grams cream of tartar significantly improved cell uniformity.

Cell Compactness

As increasing scores in Table 15 indicate, cream of tartar tended to bring scores towards the normal "close" from "dense." The exception to this at the -15% level is unexpected since the system would usually be less sensitive with decreased sugar. Evaluation of the sugar/water data indicate that lowering levels had a slight improving effect on scores, bringing them from "indistinguishable" towards "dense." This corresponds with the diminution of the gummy layer as can be seen by the highly significant negative correlation between gummy layer and compactness (with cream of tartar/without cream of tartar; r = -0.86/r = -0.75). As in the current experiment, Baxter and Hester (1958) observed that decreased sugar had less of a tenderizing effect on the structural proteins. This would give the sensitive system more stability to resist collapse. Cell compactness, however, was not significantly different for cream of tartar versus no cream of tartar, nor for variations in sugar/water level. In contrast, bleached flour scores did differ significantly from unbleached flour scores.

Layering

Layering was not significantly different for cream of tartar versus no cream of tartar nor for variations in sugar/water levels. As shown in Table 16, cakes made with cream of tartar were often

Table 15. Cell compactness[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	1.4	1.6	2.1	2.0	1.6	3.1
	2	1.7	1.9	1.4	2.1	1.9	3.0
	3	2.0	1.6	1.9	2.0	3.0	2.9
	4	1.1	2.0	1.8	1.6	2.1	3.0
	Mean	1.6	1.8	1.8	1.9	2.1	3.0[c]
With Cream of Tartar	1	1.1	2.0	2.7	2.0	1.6	
	2	2.0	2.9	1.7	2.6	1.3	
	3	2.0	1.4	1.3	2.6	2.0	
	4	1.7	1.6	3.0	1.3	1.7	
	Mean	1.7	2.0	2.2	2.1	1.6	

[a]1 = indistinguishable
2 = dense
3 = close (normal)
4 = open

[b]Standard deviation = 0.5.

[c]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Table 16. Layering[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	2.7	3.0	2.3	2.6	2.7	1.0
	2	3.0	2.9	3.0	2.7	2.6	1.0
	3	2.6	3.3	3.0	2.0	1.0	1.0
	4	2.8	2.4	2.8	3.1	2.3	1.0
	Mean	2.8	2.9	2.8	2.6	2.1	1.0[c]
With Cream of Tartar	1	2.9	1.9	1.0	2.4	3.0	
	2	2.4	1.0	2.9	1.4	2.6	
	3	3.0	2.7	3.0	2.1	1.3	
	4	3.0	3.0	1.1	2.9	2.3	
	Mean	2.8	2.1	2.0	2.2	2.3	

[a]1 = no layering
2 = single thin gummy layer
3 = single thick gummy layer
4 = several gummy layers

[b]Standard deviation = 0.6.

[c]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

scored closer to "single thin gummy layer" than cakes without cream of tartar which were scored closer to "single thick gummy layer." Occurrence of thick layering was more prevalent at higher sugar/water levels, for cakes with and without cream of tartar. This is similar to the slight layering found in high-ratio bleached flour cakes which disappeared in medium and low-ratio cakes (Hunter et al., 1950). The slight layering in bleached flour cakes was attributed to cake shrinkage.

Bleached flour standard cakes in this experiment had significantly less layering than unbleached flour control cakes. Panelists consistently indicated "no layering" for their samples. Miller et al. (1967) also observed layering in unbleached versus bleached flour cakes. As the lower layer developed, air cells began to rise and enlarge at the top portion of the batter.

Layering in this experiment is highly significantly correlated with compactness (with cream of tartar/without cream of tartar; r = -0.86/-0.75), grain (r = 0.86/r = 0.62), softness (r = 0.92/r = 0.85), moistness (r = -0.87/4 = -0.89), tenderness (4= 0.87/r = 0.89), and crumb color (r = 0.72/r = 0.80). For cakes with cream of tartar, shape (r = 0.79), uniformity (r = 0.46) and batter pH (r = -0.48) are also significantly correlated with layering. This indicates that as layering disappeared, panelists scores for other cake characteristics showed improved cake quality.

Grain

Bleached flour standards were significantly more "silky" than unbleached flour cakes (Table 17). These results are supported by a number of other investigations. Sollars (1958a) and Kulp (1972) found that bleached flour cakes had 60% and 67% respectively higher scores for silkiness than unbleached flour controls. These same investigators found that bleached flour cakes had 56% and 21% respectively higher scores for grain than unbleached flour cakes.

Davies (1936) reported that increasing sugar 25% or decreasing liquid 25% caused a coarser, less uniform grain than the low-ratio control. In contrast, Hunter et al. (1950) reported that low sugar ratio cakes had a slightly harsh crumb character, whereas medium or high-ratio cakes contributed to a more velvety grain.

Softness

As shown in Table 18, cream of tartar versus no cream of tartar improved the softness at the intermediary sugar/water levels of 0, -5 and -10%. With added cream of tartar no consistent softening could be distinguished through changing sugar and water levels. Without added cream of tartar, as treatment levels decreased, the lower softness scores for unbleached cakes indicated a softer crumb. This could be due to increased layering (with cream of tartar/without cream

Table 17. Grain[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream or Tartar	1	2.3	2.4	1.7	1.7	1.7	1.0
	2	2.1	2.3	2.3	1.9	2.4	1.0
	3	1.6	2.0	2.4	2.1	1.3	1.3
	4	2.3	1.9	2.4	2.3	2.3	1.0
	Mean	2.1	2.1	2.2	2.0	1.9	1.1[c]
With Cream of Tartar	1	2.1	1.6	1.3	2.1	2.1	
	2	2.1	1.4	2.3	1.6	2,3	
	3	2.4	2.3	2.0	2.3	2.0	
	4	2.3	2.1	1.3	2.3	2.0	
	Mean	2.3	1.9	1.7	2.1	2.1	

[a]1 = silky (normal)
2 = rubbery
3 = rough
4 = harsh

[b]Standard deviation = 0.3.

[c]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Table 18. Softness[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	2.7	3.0	2.3	2.3	2.7	1.0
	2	2.6	2.7	3.0	2.6	2.9	1.0
	3	2.1	3.0	2.9	2.6	1.3	1.4
	4	3.0	2.7	2.7	2.6	2.6	1.1
	Mean	2.6	2.9	2.7	2.5	2.4	1.1[c]
With Cream of Tartar	1	2.9	2.1	1.3	2.4	2.9	
	2	2.4	1.6	2.9	1.7	2.9	
	3	2.7	3.0	2.9	2.6	2.0	
	4	2.9	2.4	1.4	2.9	2.9	
	Mean	2.7	2.3	2.1	2.4	2.6	

[a]1 = soft (normal)
2 = slightly firm
3 = firm

[b]Standard deviation = 0.5.

[c]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

of tartar; r = 0. 92/r = 0. 85) at higher sugar/water levels. Bleached flour standards were softer ($P \leq 0.05$) than unbleached controls.

Tenderness

Panelists scores for softness were highly correlated with those for tenderness (with cream of tartar/without cream of tartar; r = 0. 95/ r = 0. 92). The addition of cream of tartar (Table 19) to cake formulas made with unbleached flour improved panelists scores for tenderness at the intermediate water levels: -10, -5 and 0%. Scores also indicated that unbleached flour cakes with cream of tartar were most tender at the -5% level. A reverse trend at 0% level was noted for cakes without cream of tartar. Occurrence of the most tender score at -15% for cakes without cream of tartar, and with the toughest at +5% for cakes with cream of tartar are unexpected because of the tenderizing effect of sugar. These scoring tendencies are also opposite the effect shown by the compression tests on the Instron. A reason for the discrepancy could be due to a panelist bias that gummy layers, due to their compactness, should be tough. Bleached flour controls were significantly different with scores near "very tender." Kulp (1972) and Sollars (1958a) also found unbleached flour cakes were less tender than bleached flour cakes. In their investigations, unbleached flour cakes attained 70% (Kulp, 1972) and 60% (Sollars, 1958a) of the ideal score for tenderness.

Table 19. Tenderness[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	3.1	3.6	2.9	3.0	3.3	1.0
	2	3.3	3.6	3.4	3.4	3.4	1.0
	3	2.6	3.3	3.7	3.1	1.9	1.3
	4	3.9	3.3	3.0	3.6	3.1	1.1
	Mean	3.2	3.4	3.3	3.3	2.9	1.1[c]
With Cream of Tartar	1	3.7	2.3	1.9	3.3	3.6	
	2	3.0	2.4	3.4	2.1	3.4	
	3	3.6	3.7	3.6	2.9	2.3	
	4	3.4	3.1	1.9	3.3	3.6	
	Mean	3.4	2.9	2.7	2.9	3.2	

[a]1 = very tender (normal)
2 = tender
3 = slightly tough
4 = tough

[b]Standard deviation = 0.5.

[c]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Tenderness in a low-ratio cake was reported to be improved by increasing sugar 25% (Davies, 1936). Tenderness decreased with 25% less sugar or water than in the control cake. Addition of cream of tartar to chlorinated cakes caused a higher rating in tenderness than control cakes (Charley, 1951).

Moistness

All treated cakes made with unbleached flour were "sticky" to "gummy" in moistness. Cakes with cream of tartar added at intermediate sugar/water levels were closer to "moist (normal)" The total average score for cakes made with cream of tartar at all sugar/water levels was 0.2 points higher than the total for cakes without cream of tartar. Other investigators have found that cream of tartar added to bleached flour cakes also improved ratings in moistness (Charley, 1951). Increasing liquid was found to increase moistness in low ratio cakes whereas decreasing liquid caused a dry crumb (Davies, 1936). Decreasing sugar/water levels in this experiment caused varying response (Table 20). Panelists were able to distinguish ($P \leq 0.05$) between the standard cake characteristic, "moist (normal)" and the unbleached cake characteristics "sticky" or "all gummy."

Table 20. Moistness[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	1.6	1.4	1.6	1.7	1.4	3.0
	2	1.3	1.7	1.1	1.7	1.4	3.3
	3	1.9	1.6	1.3	2.0	2.6	3.3
	4	1.0	1.7	1.6	1.4	1.7	3.1
	Mean	1.4	1.6	1.4	1.7	1.8	3.2[c]
With Cream of Tartar	1	1.0	2.4	3.0	1.9	1.4	
	2	1.7	2.6	1.3	2.6	1.7	
	3	1.4	1.4	1.3	2.1	2.1	
	4	1.0	1.6	2.1	1.7	1.6	
	Mean	1.3	2.0	1.9	2.1	1.7	

[a]1 = all gummy
2 = sticky
3 = moist (normal)
4 = slightly dry
5 = dry

[b]Standard deviation = 0.4.

[c]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Flavor

Flavor perception was not significantly different for cream of tartar versus no cream of tartar nor for variations in sugar/water level, nor for bleached flour control (Table 21). Regardless of treatment, flavor was perceived near, or at "normal, no off flavor."

Crumb Color

Kulp (1972) found that the level of carotene is reduced from 1.75 to less than 1.00 part per million with two ounces of chlorine per 100 pounds of flour. Unbleached flour cakes attained 67% of the ideal score in sensory evaluation for crumb color (Kulp, 1972; Sollars, 1958a). The bleached flour standard in this experiment was also whiter ($P \leq 0.05$) than the unbleached flour cakes.

In this experiment, cream of tartar tended to bring the score from "creamy" towards whiter description, "slightly creamy." Similarly Charley (1951) observed the addition of 0.5 grams cream of tartar also caused whiter crumb in bleached flour cakes. In this experiment decreasing sugar/water levels in cakes without cream of tartar also tended to raise the score from "creamy" towards "slightly creamy" except at -5% level (Table 22). Bleached flour standard was significantly different with a score near "bright white."

Table 21. Flavor[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	1. 1	1. 0	1. 0	1. 0	1. 0	1. 1
	2	1. 0	1. 1	1. 0	1. 1	1. 0	1. 1
	3	1. 1	1. 0	1. 0	1. 1	1. 1	1. 1
	4	1. 1	1. 0	1. 1	1. 3	1. 1	1. 1
	Mean	1. 1	1. 0	1. 0	1. 1	1. 1	1. 1
With Cream of Tartar	1	1. 1	1. 0	1. 0	1. 1	1. 0	
	2	1. 0	1. 0	1. 1	1. 1	1. 3	
	3	1. 1	1. 1	1. 0	1. 1	1. 0	
	4	1. 0	1. 1	1. 0	1. 1	1. 0	
	Mean	1. 1	1. 1	1. 0	1. 1	1. 1	

[a] 1 = normal (no off flavor)
2 = slightly bitter after taste

[b] Standard deviation = 0. 1.

Table 22. Crumb color[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar[c]	1	3.1	3.0	3.1	2.7	3.1	1.1
	2	3.3	3.3	3.6	3.3	3.0	1.0
	3	2.6	3.0	3.9	2.4	1.7	1.3
	4	3.6	2.7	2.9	2.9	2.7	1.1
	Mean	3.1	3.0	3.4	2.8	2.6	1.1[d]
With Cream of Tartar	1	3.7	2.0	2.1	2.7	3.0	
	2	2.7	2.4	3.1	2.3	2.6	
	3	3.3	2.9	3.1	2.7	2.3	
	4	3.1	2.9	2.7	3.0	2.4	
	Mean	3.2	2.5	2.8	2.7	2.6	

[a]1 = bright white (normal)
2 = slightly creamy
3 = creamy
4 = slightly dull and slightly creamy

[b]Standard deviation = 0.4.

[c]Sugar/water levels of cakes significantly different ($P \leq 0.05$).

[d]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Shape

Panelists scores for cake shape were not significantly different for cream of tartar versus no cream of tartar nor for variations in sugar/water levels (Table 23). The tendency of cream of tartar addition to improve and to bring the scores closer to "slightly sunken" from "sunken" was observed within the sugar/water levels. Of interest, the improving action of cream of tartar was most pronounced at the 0% level. Without cream of tartar the 0% sugar/water level was the most "sunken." Bleached flour standard was significantly different with scores at "rounded."

Wilson and Donelson (1965) found a highly significant difference in volume for cakes made from chlorinated versus unchlorinated flours. Volume differences may be related to their observation that cakes made from unbleached flour collapsed during baking. Russo and Doe (1970) also observed collapse of untreated flour cakes during baking.

In contrast, in this experiment, collapse of unbleached flour cakes was observed after baking, during the cooling phase. As mentioned previously, completion of baking was predetermined by crumb structure similarities between unbleached and bleached flour cakes. Sunken contours, indicating collapse, were highly correlated (r=0. 87) with layering in cakes with cream of tartar. Collapse on cooling was

Table 23. Shape of half-cake[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variations in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	4.3	4.7	4.4	4.1	4.3	1.0
	2	4.6	4.6	4.4	4.3	4.7	1.0
	3	3.6	4.7	4.7	4.7	2.0	1.0
	4	4.3	4.7	4.4	4.3	4.5	1.0
	Mean	4.2	4.7	4.5	4.4	3.9	1.0[c]
With Cream of Tartar	1	3.9	4.0	3.7	4.1	4.3	
	2	4.1	3.3	4.4	3.7	4.4	
	3	4.4	3.9	4.6	4.9	4.1	
	4	4.4	4.4	3.3	4.3	4.3	
	Mean	4.2	3.9	4.0	4.3	4.3	

[a] 1 = rounded
2 = flat
3 = depressed
4 = slightly sunken
5 = sunken

[b] Standard deviation = 0.5.

[c] Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

also noted by Miller et al. (1967). Additionally they observed that rate of batter rise, cake height and cake volumes of bleached and unbleached flour cakes were similar prior to collapse.

In studying ingredient interactions, Kissell (1962, 1964) found that sugar/water ratios had a great effect on top contour in both lean and full formula cakes. Other investigators found that in full formula cakes, decreasing sugar/water tended to produce a rounder cake contour, than a medium or high-ratio cake (Hunter et al., 1950).

Crust Surface

Crusts appeared bubbly on all cakes (Table 24), often with small cracks. Jooste and Mackey (1952) attributed blistered surfaces on cakes to either too low of an oven temperature or to lack of an emulsifier. Neither of these situations occurred in this experiment as the oven temperature was high and the shortening had mono- and diglycerides added to it. The bubbles in this experiment may have been due to air bubbles coalescing and rising to the surface. Miller et al. (1967) observed larger air cells rise to the surface of unbleached flour cakes. This may indicate that bubbles in this experiment were due to the structural matrix being unable to keep the air cells finely dispersed.

Table 24. Crust surface[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	1.0	1.0	1.0	1.3	1.0	1.0
	2	1.0	1.0	1.0	1.3	1.0	1.0
	3	1.0	1.0	1.3	1.0	1.0	1.1
	4	1.3	1.0	1.0	1.0	1.0	1.1
	Mean	1.1	1.0	1.1	1.1	1.0	1.1
With Cream of Tartar	1	1.0	1.0	1.0	1.0	1.0	
	2	1.0	1.0	1.3	1.0	1.0	
	3	1.3	1.3	1.0	1.0	1.0	
	4	1.3	1.0	1.0	1.0	1.0	
	Mean	1.1	1.1	1.1	1.0	1.0	

[a] 1 = bubbly
2 = smooth
3 = cracked

[b] Standard deviation = 0.1.

Degree of Browning

Degree of browning of the crust is not significantly different for cream of tartar versus no cream of tartar nor for variations in sugar/water levels. As shown in Table 25, panelists responses for degree of browning in cream of tartar versus no cream of tartar cakes were variable. Scores for sugar/water levels remained around "brown." Bleached flour control cake crust color was significantly different with a score at "golden brown." A standard deviation of 0 for bleached flour cakes indicates that the panelists were able to identify the standard consistently. The probable reason for the significant difference was the longer baking time for unbleached flour cakes necessary to insure sufficient starch gelatinization and heat coagulation.

Evenness of Browning

Evenness of browning was not significantly different for cream of tartar versus no cream of tartar (Table 26). Variation in sugar/water levels significantly affected evenness of crust browning. Decrease in these levels pulled scores towards "even" except for a diminished effect at -10% level when no cream of tartar was present. A similar increase in evenness with decrease in sugar was also observed with the treatments containing added cream of tartar.

Table 25. Degree of crust browning[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	2.0	1.7	2.0	2.1	2.1	3.0
	2	2.3	1.7	1.3	2.1	1.7	3.0
	3	2.1	1.9	2.3	1.7	2.1	3.0
	4	2.0	2.7	2.0	1.6	2.0	3.0
	Mean	2.1	2.0	1.9	1.9	2.0	3.0[c]
With Cream of Tartar	1	2.1	1.9	2.3	1.4	1.7	
	2	2.3	2.0	2.0	1.9	2.0	
	3	2.0	1.3	1.9	1.4	1.6	
	4	2.4	2.0	2.6	1.7	1.6	
	Mean	2.2	1.8	2.2	1.6	1.7	

[a]1 = dark brown
2 = brown
3 = golden brown
4 = pale brown

[b]Standard deviation = 0.3.

[c]Bleached flour standard cake significantly different ($P < 0.05$) from unbleached flour cakes.

Table 26. Evenness of crust browning[a] of unbleached flour cakes at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[b]	+5	0	-5	-10	-15	0
Without Cream of Tartar[c]	1	2.1	1.6	1.6	1.9	1.4	1.9
	2	2.1	2.4	1.7	1.7	1.9	1.6
	3	1.7	2.0	1.7	2.0	1.4	1.4
	4	2.0	1.9	1.7	1.7	1.6	1.3
	Mean	2.0	2.0	1.7	1.8	1.6	1.5
With Cream of Tartar	1	1.7	2.1	1.9	1.6	1.4	
	2	2.0	2.0	1.9	1.9	1.6	
	3	2.3	1.6	1.9	1.7	1.6	
	4	1.9	1.9	2.0	1.7	2.0	
	Mean	2.0	1.9	1.9	1.7	1.6	

[a]1 = even
2 = slightly uneven
3 = uneven

[b]Standard deviation = 0.2.

[c]Sugar/water level of cakes significantly different ($P \leq 0.05$).

Bleached flour standards were significantly different with scores closer to "even."

Conclusions

There are two probable causes of the low number of significant results. One is the possibility that the flour oxidized and therefore improved with age. A change in the flour would cause a higher statistical error and therefore lower the F values. The other probable reason contributing to the lack of significant differences is the less than optimum quality flour used. Since the ability to form a stable starch-protein matrix in an unbleached flour cake may be influenced by quality differences, less positive results may have occurred in this experiment than may otherwise have been found. A good performing flour may have had a better ability to withstand collapse.

The problem of finding an alternative to chlorinating cake flour, by altering ingredient ratios, has not yet been solved. The results of this experiment suggest that further research may be useful on the unbleached flour cakes at the -5% sugar/water level with cream of tartar. This combination of sugar/water level and cream of tartar produced a less drastic contour and larger volume than higher sugar/water levels, yet had better scores on the sensory characteristics of tenderness, softness, grain and crumb color than the lower sugar/water levels. This particular level may have been effective through lowering the gelatinization temperature from that in A. A. C. C. 10-90, yet not being so low as to unbalance the ratio of tenderizing to toughening ingredients. Future researchers may also find it useful to vary the cream of tartar ratio.

Another approach to the problem of finding an alternative to chlorine bleaching, may be through the use of an hydrocolloid. These gums may give support to the weaker starch-protein gel matrix found in unbleached flour cakes. Xanthan gum, used in a separate experiment with the unbleached flour showed possibilities, although the 0. 5% (batter weight) level incorporated was too high.

A third approach for further consideration could be the use of a different type of pan. A tube pan which may allow earlier setting of the batter through more rapid heat penetration could be helpful. A tube pan has the further advantage of allowing the cake to cool in an inverted position, thereby using the force of gravity in a positive manner to prevent collapse. Although the traditional solid circle cake could not be made with a tube pan, the trade-off would be a better contour cake. Although an alternative to chlorine bleaching was not elucidated in this thesis, a good groundwork was established for continued study.

SUMMARY

Cream of tartar and variations in sugar/water levels contributed to changes in unbleached flour high-ratio white cakes. Although a significant difference ($P \leq 0.05$) due to cream of tartar was only noted for crumb pH, the cream of tartar did tend to improve sensory evaluation scores for cell compactness, layering, softness, tenderness, moistness, crumb color and shape of half cake. Cream of tartar also tended to decrease specific gravity, batter pH and force required to compress samples. Volume tended to be higher in cakes with cream of tartar.

Decreasing sugar/water levels caused a significant difference ($P \leq 0.05$) in panelists response to evenness of crust browning and crumb color. Panelists scores also indicated that lowering sugar/water levels improved the cake characteristics: cell compactness, layering and shape. Decreasing sugar/water levels tended to increase the force required to compress the sample, except at the lowest level, -15%. Lowering sugar/water levels also caused increased cake volume.

Although decreasing sugar/water levels, adding cream of tartar and extending the baking period all contributed to improved characteristics in unbleached flour cakes, an alternative to chlorines bleaching and maturing action was not attained.

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APPENDIX

Appendix Table I. Crumb z of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

		Unbleached Flour					Bleached Flour
		Percent Change in Sugar and Water Levels					
pH Treatment	Replication[a]	+5	0	-5	-10	-15	0
Without Cream of Tartar	1	-0. 18	-0. 20	-0. 26	-0. 19	-0. 28	-0. 27
	2	-0. 16	-0. 23	-0. 05	-0. 28	-0. 25	-0. 38
	3	-0. 25	-0. 21	-0. 27	-0. 29	-0. 34	-0. 41
	4	-0. 21	-0. 25	-0. 26	-0. 19	-0. 28	-0. 42
	Mean	-0. 20	-0. 22	-0. 21	-0. 24	-0. 29	-0. 37[b]
With Cream of Tartar	1	-0. 20	-0. 27	-0. 33	-0. 18	-0. 25	
	2	-0. 19	-0. 30	-0. 23	-0. 24	-0. 06	
	3	-0. 22	-0. 18	-0. 25	-0. 28	-0. 26	
	4	-0. 22	-0. 02	-0. 29	-0. 04	-0. 26	
	Mean	-0. 21	-0. 19	-0. 28	-0. 18	-0. 21	

[a] Standard deviation = 0. 07.

[b] Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cake.

Appendix Table 2. Crust z of unbleached flour cake at +5, 0, -5, -10 and -15 percent variation in sugar and water levels, with and without cream of tartar, and a bleached flour control.

pH Treatment	Replication[a]	Unbleached Flour: Percent Change in Sugar and Water Levels +5	0	-5	-10	-15	Bleached Flour 0
Without Cream of Tartar	1	0. 60	0. 71	0 68	0. 71	0. 70	0. 38
	2	0. 59	0. 76	0. 40	0. 68	0. 68	0. 31
	3	0. 70	0. 71	0. 69	0. 68	0. 68	0. 40
	4	0. 69	0. 68	0. 65	0. 66	0. 64	0. 42
	Mean	0. 65	0. 71	0. 61	0. 68	0. 68	0. 37[b]
With Cream of Tartar	1	0. 73	0. 69	0. 58	0. 67	0. 72	
	2	0. 68	0. 71	0. 70	0. 64	0. 35	
	3	0. 70	0. 78	0. 72	0. 69	0. 68	
	4	0. 68	0. 38	0. 66	0. 40	0. 66	
	Mean	0. 70	0. 64	0. 66	0. 60	0. 60	

[a]Standard deviation = 0. 10.

[b]Bleached flour standard cake significantly different ($P \leq 0.05$) from unbleached flour cakes.

Appendix Table 3. Analysis of Variance for specific gravity.

Source of Variation	Degrees of Freedom	Mean Square	F Value[a]
Unbleached vs. bleached	1	1.03	5.15*
Cream of tartar (C)	1	0.24	1.20
Sugar/water level (L)	4	0.30	1.50
C x L	4	0.08	0.40
Error	33	0.20	

a = * = ($P \leq 0.05$)

Appendix Table 4. Analysis of Variance for batter pH.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value
Unbleached vs. bleached	1	1.08	0.33
Cream of tartar (C)	1	9.30	2.82
Sugar/water level (L)	4	1.47	0.45
C x L	4	3.68	1.12
Error	33	3.30	

a = values at 10^{-3}

Appendix Table 5. Analysis of Variance for crumb pH.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	18.33	5.58*
Cream of tartar C)	1	210.25	64.22*
Sugar/water level (L)	4	1.92	0.59
C x L	4	1.21	0.37
Error	33	3.28	

a = values at 10^{-3}

b = * = ($P \leq 0.05$)

Appendix Table 6. Analysis of Variance for volume.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	276.60	26.96*
Cream of tartar (C)	1	9.06	0.88
Sugar/water level (L)	4	25.18	2.45
C x L	4	5.87	0.57
Error	33	10.26	

a = values at 10^{3}

b = * = ($\leq$ 0.05)

Appendix Table 7. Analysis of Variance for crust x.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value
Unbleached vs. bleached	1	0.09	0.06
Cream of tartar (C)	1	1.00	0.70
Sugar/water level (L)	4	1.38	0.97
C x L	4	1.12	0.78
Error	33	1.43	

a = values at 10^{-3}

Appendix Table 8. Analysis of Variance for crust y.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	9.64[a]	9.54*
Cream of tartar (C)	1	0.32	0.32
Sugar/water level (L)	4	1.03	1.02
C x L	4	0.90	0.89
Error	33	1.01	

a = values at 10^{-3}

b = * = (P $\leq$ 0.05)

Appendix Table 9. Analysis of Variance for crust z.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	281.51	28.35*
Cream of tartar (C)	1	5.56	0.56
Sugar/water level (L)	4	2.98	0.30
C x L	4	9.95	1.00
Error	33	9.93	

a = values at 10^{-3}

b = * = ($P \leq 0.05$)

Appendix Table 10. Analysis of Variance for crumb x.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value
Unbleached vs. bleached	1	1.47	0.28
Cream of tartar (C)	1	0.06	0.01
Sugar/water level (L)	4	8.07	1.55
C x L	4	3.93	0.76
Error	33	5.19	

a = values at 10^{-4}

Appendix Table 11. Analysis of Variance for crumb y.

Source of Variation	Degrees of Freedom	Mean Square	F Value
Unbleached vs. unbleached	1	3.39	2.20
Cream of tartar (C)	1	0.81	0.53
Sugar/water levels (L)	4	2.00	1.30
C x L	4	1.13	0.85
Error	33	1.54	

Appendix Table 12. Analysis of Variance for crumb z.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	76.62	13.86*
Cream of tartar (C)	1	2.88	0.52
Sugar/water level (L)	4	3.61	0.65
C x L	4	6.11	1.10
Error	33	5.53	

a = values at 10^{-3}

b = * = ($P \leq 0.05$)

Appendix Table 13. Analysis of Variance for crumb yellow.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value
Unbleached vs. bleached	1	2.37	0.64
Cream of tartar (C)	1	0.13	0.04
Sugar/water level (L)	4	5.22	1.41
C x L	4	2.39	0.65
Error	33	3.69	

a = values at 10^{-2}

Appendix Table 14. Analysis of Variance for Instron peak.

Source of Variation	Degrees of Freedom	Mean Square	F Value[a]
Unbleached vs. bleached	1	19.42	27.74*
Cream of tartar (C)	1	0.01	0.01
Sugar/water level (L)	4	1.75	2.50
C x L	4	0.34	0.49
Error	33	0.70	

a = * = ($P \leq 0.05$)

Appendix Table 15. Analysis of Variance for Instron area.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	24.96	18.22*
Cream of tartar (C)	1	1.45	1.06
Sugar/water level (L)	4	0.81	0.59
C x L	4	0.62	0.45
Error	33	1.37	

a = values at 10^{3}

b = * = ($P \leq 0.05$)

Appendix Table 16. Analysis of Variance for cell uniformity.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value
Unbleached vs. bleached	1	0.05	0.02
Cream of tartar (C)	1	2.25	0.72
Sugar/water level (L)	4	5.33	1.71
C x L	4	1.52	0.49
Error	33	3.11	

a = values at 10^{-1}

Appendix Table 17. Analysis of Variance for cell compactness.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	45.47	20.67*
Cream of tartar (C)	1	0.62	0.28
Sugar/water level (L)	4	1.82	0.83
C x L	4	2.22	1.01
Error	33	2.20	

a = values at 10^{-1}

b = * = ($P \leq 0.05$)

Appendix Table 18. Analysis of Variance for layering.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	78.39	21.30*
Cream of tartar (C)	1	12.22	3.32
Sugar/water level (L)	4	3.76	1.02
C x L	4	3.75	1.02
Error	33	3.68	

a = values at 10^{-1}

b = * = ($P \leq 0.05$)

Appendix Table 19. Analysis of Variance for grain.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	39.09	34.59*
Cream of tartar (C)	1	0.51	0.45
Sugar/water level (L)	4	0.44	0.39
C x L	4	1.86	1.65
Error	33	1.13	

a = values at 10^{-1}

b = * = ($P \leq 0.05$)

Appendix Table 20. Analysis of Variance for softness.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	68.80	31.42*
Cream of tartar (C)	1	3.13	1.43
Sugar/water level (L)	4	0.79	0.36
C x L	4	3.20	1.46
Error	33	2.19	

a = values at 10^{-1}

b = * = ($P \leq 0.05$)

Appendix Table 21. Analysis of Variance for tenderness.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	147.06	51.06*
Cream of tartar (C)	1	3.72	1.29
Sugar/water level (L)	4	1.41	0.49
C x L	4	3.40	1.18
Error	33	2.88	

a = values at 10^{-1}

b = * = ($P \leq 0.05$)

Appendix Table 22. Analysis of Variance for moistness.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	80.49	45.73*
Cream of tartar (C)	1	4.60	2.61
Sugar/water level (L)	4	3.36	1.91
C x L	4	1.84	1.05
Error	33	1.76	

a = values at 10^{-1}

b= * = ($P \leq 0.05$)

Appendix Table 23. Analysis of Variance for crumb color.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	109.08	69.04*
Cream of tartar (C)	1	5.57	3.53
Sugar/water level (L)	4	4.57	2.89*
C x L	4	1.48	0.94
Error	33	1.58	

a = values at 10^{-1}

b = * = ($P \leq 0.05$)

Appendix Table 24. Analysis of Variance for flavor.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value
Unbleached vs. bleached	1	14.20	2.10
Cream of tartar (C)	1	0.00	0.00
Sugar/water level (L)	4	13.27	1.97
C x L	4	1.23	0.18
Error	33	6.75	

a = values at 10^{-3}

Appendix Table 25. Analysis of Variance for half-cake shape.

Source of Variation	Degrees of Freedom	Mean Square	F Value[a]
Unbleached vs. bleached	1	377.97	149.99*
Cream of tartar (C)	1	3.57	1.42
Sugar/water level (L)	4	0.62	0.25
C x L	4	4.29	1.70
Error	33	2.52	

a = * = ($P \leq 0.05$)

Appendix Table 26. Analysis of Variance for crust surface.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value
Unbleached vs. bleached	1	0.05	0.04
Cream of tartar (C)	1	0.00	0.00
Sugar/water level (L)	4	1.37	1.03
C x L	4	1.58	1.19
Error	33	1.33	

a = values at 10^{-2}

Appendix Table 27. Analysis of Variance for degree of browning.

Source of Variation	Degrees of Freedom	Mean Square	F Value[a]
Unbleached vs. bleached	1	40.94	50.54*
Cream of tartar (C)	1	0.59	0.73
Sugar/water level (L)	4	2.09	2.58
C x L	4	1.34	1.65
Error	33	0.81	

a = * = ($P \leq 0.05$)

Appendix Table 28. Analysis of Variance for evenness of browning.

Source of Variation	Degrees of Freedom	Mean Square[a]	F Value[b]
Unbleached vs. bleached	1	27.75	6.18*
Cream of tartar (C)	1	0.24	0.05
Sugar/water level (L)	4	17.38	3.87*
C x L	4	3.50	0.78
Error	33	4.49	

a = values at 10^{-2}

b = * = ($P \leq 0.05$)

Appendix Table 29. Correlation coefficient, r, between and within objective and subjective data for unbleached flour cakes with and without cream of tartar, at 0.05 and 0.01 significance level.

Variable 1	Variable 2	With Cream of Tartar	Without Cream of Tartar
Specific Gravity	Volume	-0.57**	-0.58**
Instron Area	Specific Gravity	0.54*	0.54*
Instron Peak	Batter pH		-0.45*
Crumb z	Volume	-0.63**	-0.74**
Crust x	Volume		0.51*
Instron Area	Volume	-0.76**	-0.59**
Crumb z	Crumb x		-0.83**
Instron Area	Crumb z	0.45*	
Instron Area	Instron Peak	0.63**	0.65**
Compactness	Uniformity	0.63**	
Layering	Uniformity	-0.46*	
Grain	Uniformity	-0.56*	-0.45*
Softness	Uniformity	-0.59**	
Tenderness	Uniformity	-0.70**	
Moistness	Uniformity	0.67**	
Crumb Color	Uniformity	-0.74**	
Layering	Compactness	-0.86**	-0.75**
Grain	Compactness	-0.77**	-0.57**
Softness	Compactness	-0.90**	-0.81**
Tenderness	Compactness	-0.85**	-0.77**
Moistness	Compactness	0.82**	0.77**
Crumb Color	Compactness	-0.68**	-0.52**
Shape	Compactness	-0.62**	
Grain	Layering	0.86**	0.62**
Softness	Layering	0.92**	0.85**
Tenderness	Layering	0.87**	0.89**
Moistness	Layering	-0.87**	-0.89**
Crumb Color	Layering	0.72**	-0.80**
Shape	Layering	0.79**	
Softness	Grain	0.89**	0.78**
Tenderness	Grain	0.91**	0.68**
Moistness	Grain	-0.83**	-0.57**
Crumb Color	Grain	0.75**	
Shape	Grain	0.72**	
Tenderness	Softness	0.95**	0.92**
Moistness	Softness	-0.88**	-0.84**
Crumb Color	Softness	0.72**	0.70
Shape	Softness	0.76**	0.80**
Moistness	Tenderness	-0.88**	-0.87**
Crumb Color	Tenderness	0.82**	0.70**
Shape	Tenderness	0.69**	

Appendix Table 29. (Continued)

Variable 1	Variable 2	With Cream of Tartar	Without Cream of Tartar
Crumb Color	Moistness	-0.88**	-0.82**
Shape	Moistness	-0.58**	
Shape	Crumb Color	0.47*	
Evenness	Specific Gravity	-0.44*	
Layering	Batter pH	-0.48*	
Evenness	Instron Area	-0.52*	
Uniformity	Crust y	0.50*	

* indicates significance at 0.05 level

** indicates significance at 0.01 level