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Development of a decreased calorie cake mix containing ascorbyl palmitate and fructose

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To the Graduate Council:

I am submitting herewith a thesis written by Judy Ann McKee Harrison entitled "Development of a decreased calorie cake mix containing ascorbyl palmitate and fructose." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

Sharon L. Melton, Major Professor

We have read this thesis and recommend its acceptance:

J. R. Mount, F. A. Draughon, C. A. Chance

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Judy Ann McKee Harrison entitled "Development of a Decreased Calorie Cake Mix Containing Ascorbyl Palmitate and Fructose." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

Sharon L. Melton

Sharon L. Melton, Major Professor

We have read this thesis
and recommend its acceptance:

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Graduate Studies and Research

DEVELOPMENT OF A DECREASED CALORIE CAKE MIX CONTAINING ASCORBYL PALMITATE AND FRUCTOSE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Judy Ann McKee Harrison
December 1981

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ABSTRACT

An experimental yellow cake mix was formulated which was used to determine the effects of ascorbyl palmitate (0.00, 0.33, 0.67, and 1.00% FWB) as a shortening-sparing agent and fructose as a replacement for sucrose at 0, 25, 50, and 75% of the total sugar on the quality of the baked cake. The FWB was the original flour weight in the cake mix prior to cellulose substitution. All possible combinations of ascorbyl palmitate (AP) levels and fructose levels were tested, and each combination was a treatment. The resulting 16 treatments and a control yellow cake were replicated twice. The cake mix contained 25% cellulose substituted for flour, 66.67% (FWB) total sugar, 7% (FWB) double action baking powder, 5% (FWB) shortening, 1% (FWB) distilled monoglycerides, 0.5% (FWB) lecithin, and 0.06% (FWB) beta-carotene. All cakes were analyzed for volume, weight, height, diameter, crumb color, hardness at 0, 1, 3, and 5 days storage, moisture, and lipid content and subjectively evaluated for softness, tenderness, moistness, flavor, cell size uniformity, cell size and wall thickness, grain, and color. In addition, cake batter specific volume and viscosity, AP recovery from the experimental cakes, and chemical composition of one rep of cakes were determined.

Substitution of fructose for sucrose resulted in decreased cake tenderness and volume and increased cake weight. Cakes containing 66.67% (FWB) sugar were judged between slightly sweet and moderately sweet except for cakes containing 50% fructose in the total sugar which were judged just above moderately sweet. Addition of AP generally produced a lighter cake with less moisture, a silkier grain, and more uniform cell size. AP also increased cake tenderness and decreased cake hardness. Addition of AP at or above 0.67% (FWB) in cake batters containing fructose also resulted in more panelists scoring cake texture as gummy. Fructose level at 75% of the total sugar resulted in more panelists detecting a gummy texture and an off-flavor in the cake. AP recovery ranged from approximately 15% in cakes made from batter containing 0.33% (FWB) AP to approximately 40% in cakes made from batters containing 1% AP (FWB).

The experimental cake was much heavier and softer (determined by shear), had larger, less uniform cells in the crumb, and a less silky grain than did the control. Compared with the control cake, the experimental cake had more moisture (41.1 versus 26.9%) and less fat (6.1 versus 14.1% on a dry matter basis).

The experimental cake with the sweetest flavor and best quality was made from batter which contained 50% fructose in the total sugar and 0.33% AP (FWB). The experimental cake had 229 calories/100 g compared to 344 calories/100 g for the control cakes which represented a 33.4% calorie reduction. Cost estimates showed that the cost of the experimental cake at the time the study was performed was 1.5 times as much as the cost of the control cake.

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CHAPTER I

INTRODUCTION

Concern for obesity in the United States has resulted in dietary guidelines which recommend increased intake of complex carbohydrates coupled with decreased intake of simple sugars and decreased caloric intake from fat. Investigators have reported that a high percentage of individuals in the United States feel they are overweight, and although they are motivated to lose weight, a large percentage fail to achieve their weight loss goals (Beck, 1978). Production of good tasting, low calorie counterparts of traditional foods is an important step toward the achievement of the recommended dietary guidelines and the weight loss goals of overweight individuals. These low calorie counterparts can be produced only through the use of special ingredients which allow for the replacement of usual carbohydrates or fat to reduce caloric value of the food without loss of desirable qualities (Beereboom, 1979). These special ingredients include such substances as cellulose (a bulking agent), fructose, and ascorbyl palmitate (AP).

This study was undertaken to develop a decreased calorie cake mix which produced a good tasting, acceptable quality cake by using cellulose as a bulking agent to replace part of the flour, fructose at decreased sugar levels for replacement of sucrose, and ascorbyl palmitate to replace most of the shortening. In addition, the ascorbyl palmitate was measured in the baked cake to determine if any AP survived the mixing and baking process.

CHAPTER II

LITERATURE REVIEW

I. DEFINITION OF AND NEED FOR DECREASED CALORIE FOODS

Because of the sedentary lifestyle brought about in many countries by industrialization, obesity has become a serious problem affecting as much as 40% of the world's population (Beereboom, 1979). The fact that obesity is associated with cardiovascular and respiratory diseases as well as diabetes has caused increasing concern over the problem of obesity. These concerns have contributed to the need for decreased calorie foods including bakery products to make weight control regimens more appealing and satisfying to weight conscious individuals.

Decreased calorie foods are foods which contain 33 1/3% fewer calories than their regular counterparts (Anon., 1980a). Beck (1978) has reported that a number of important considerations must be satisfied for low calorie products to succeed in helping people reduce weight. Two of these considerations are that the food item selected for production of a decreased calorie product should initially have a high caloric density and should contribute a significant proportion of calories in the diet of the population. Bakery products such as cakes fulfill these two considerations. White cake contains 365 calories/100 g while yellow cake contains 337 calories/100 g (Watt and Merrill, 1963).

The necessary decrease in calories can be achieved in two ways. Occasionally, as in dietetic soft drinks, it may be achieved by omitting an ingredient. In most cases, however, it is achieved by reduction of amounts of normal ingredients resulting in a significant decrease in calories (Beereboom, 1979). In both cases, substitution of other ingredients allows the omission or reduction of the normal ingredients.

II. INGREDIENTS USED IN CAKE MAKING

Flour

Flour can be described as a toughener which provides structure and toughens the cake and as a drier which absorbs and retains moisture thus providing body in the cake (Sultan, 1969). The flour used in cake making is soft wheat flour. The characteristics that make this flour more acceptable for cakes are its increased percentage of starch, decreased amounts of protein, and weaker, less extensible proteins than bread flour. This lack of strong proteins results in decreased expansion during preparation and increased density of the finished product (Kotschevar, 1966).

Sugar

The obvious function of sugar in a cake is to serve as a sweetener. Sugar can also be described as a tenderizer since it tenderizes the gluten thus producing a softer crumb (Kotschevar, 1966). The ability of the sugar to hold moisture in the crumb retards staling (Matz, 1972). Another function of sugar is to promote a brown crust color (Matz, 1972). Glucose and fructose are more effective in promoting this color on a weight for weight basis than sucrose, although sucrose is the sugar commonly used. Sugar is usually 110 to 160% on a flour weight basis in regular and high-ratio yellow layer and white layer cakes (Matz, 1972).

Shortening and Emulsifiers

A major component of most cakes is the shortening. Cake quality has improved greatly with the development of hydrogenated vegetable shortenings and the emulsified cake shortenings (Hartnett, 1977; Painter, 1981).

Investigators reported that shortening quality for cakes also was dependent upon its crystalline form. Moncrieff (1970) found that the best shortening for use in cakes was one that was stable in the beta-prime crystalline form.

Shortenings which are stable in the beta-prime crystal and contain various emulsifiers, usually mono- and di-glycerides or propylene glycol monoesters (PGME), can be formulated to have several functions in cake batters. One important function of the shortening is to incorporate air into the batter during mixing. The air bubbles contribute directly to the leavening and also serve as foci for gas expansion (Hartnett, 1977; Matz, 1972). The most common emulsifier in cake mixes is PGME which is present as 10-15% of the shortening (Rusch, 1981). Emulsifiers aid in forming a large number of small gas pockets in the batter by increasing the dispersibility of the shortening (Birnbaum, 1978). The shortening dispersion aids in obtaining proper grain (fine and regular), good texture (soft, tender, and moist), and good volume (large with a well-rounded top) in the cake (Painter, 1981; Yamazaki and Kissell, 1978).

Shortening tenderizes the cake by lubricating the ingredients, which prevents the formation of a strong gluten matrix, and by increasing water requirement in batter which results in increased water content in the cake (Kotschevar, 1966). Increased water content in the cake also causes increased resistance to staling (Hartnett, 1977). The amount of shortening used in layer cakes is normally between 30-70% FWB (Matz, 1972).

Color Additives

There are several ingredients available for adding color to baked goods. Beta-carotene, a carotenoid which is found in nature or manufactured synthetically in an oil soluble or water dispersible form (Metzner, 1978), is one such ingredient. Beta-carotene can be conveniently used to impart a rich, golden color to bakery products (Anon., 1981a).

Milk Solids

Milk solids act as tougheners in cakes and contribute to the cake structure. Milk solids which contain a high level of lactose also contribute to desirable cake flavor, aid in development of crust color, and help retard staling (Matz, 1972).

Eggs

Eggs are a very important ingredient of the cake and have many functions. Because of their contribution to batter aeration, eggs can be considered leaveners (Birnbaum, 1978). Egg white proteins aid in forming air cell walls thus enabling the batter to trap air (Matz, 1972). These proteins coagulate during baking and contribute to firmness of the finished product (Kotschevar, 1966). Egg yolks contain phospholipids which act as emulsifiers and contribute to crumb tenderness, and the yolks also contribute to the flavor of the product (Matz, 1972).

Leaveners

In addition to the leavening effect obtained from eggs and air incorporation into the cake batter, chemical leavening agents are added to most cakes. The proper quantity of leavening ingredient needed to provide optimum flavor, color, texture, and crumb characteristics may be determined by test baking. In white and yellow cake mixes, the most widely used leavening agents are blends of monocalcium phosphate and sodium aluminum phosphate with aluminum sulfate (Reiman, 1977).

III. MODIFICATION OF INGREDIENTS TO YIELD DECREASED CALORIE BAKERY PRODUCTS

Several substances are available for use in decreased calorie bakery products which permit reduction or replacement of usual ingredients without loss of acceptable characteristics. These ingredients which reduce the caloric density of the food may or may not contribute calories to that food. If the ingredient contributes calories, its usefulness may depend on its ability to replace a usual ingredient with lesser quantity which reduces caloric density in the product.

Increasing Fiber Content

Cellulose is a structural component of plant cell walls and is considered to be non-digestible in the human digestive tract (Furda, 1977; Trowell, 1974). Because of this characteristic, it serves to add fiber or bulk to the diet without addition of calories (Beereboom, 1979; Brys and Zabik, 1976) and can be used as a drier in bakery products thus replacing flour. Several types of cellulose are available including mechanically ground cellulose and hydrolyzed or microcrystalline cellulose. The finer particle size of mechanically ground cellulose contributes to its ability to absorb greater amounts of water (Zabik et al., 1977).

Zabik and associates (1977) found that addition of both types of cellulose to cakes resulted in increased batter viscosity, decreased uniformity of cell distribution, and increased tenderness compared to a control cake. A less chalky flavor was reported in cakes containing cellulose of larger particle size. Brys and Zabik (1976) substituted microcrystalline cellulose for flour in lean yellow cakes at levels of 20, 40, and 60% (FWB). Sensory results indicated replacement at the 20% level produced the most acceptable yellow cake (Brys and Zabik, 1976). Levels as high as 30% cellulose, however, produced high quality white cakes (Zabik et al., 1977). Higher amounts of cellulose in the white cake caused an undesirable increase in gumminess, decreased the volume, and increased tenderness of the finished product due to insufficient gluten to trap air and create a structure resistant to shear. Crust and crumb color was not significantly affected by the replacement (Zabik et al., 1977).

Decreasing Sugar Content

Fructose, a natural sugar found in honey, fruits, and berries (Olefsky and Crapo, 1980), is the sweetest of all natural sugars.

Fructose is reported to be up to 73% sweeter than sucrose (Anon., 1980b). Less fructose than sucrose, therefore, should be required to produce an equivalent sweetness level in foods which would result in decreased calories in the food product since sucrose could be reduced or possibly eliminated (Anon., 1980b).

Cardello and coworkers (1979), however, found no sweetening advantage of fructose over sucrose on an equal weight basis in vanilla cakes. These results indicated a masking of sweetness by concurrent flavors.

Researchers in the past reported problems associated with the use of fructose in baked products. The major problem reported by Volpe and Mears (1976) was crumb darkening due to the Maillard browning reaction. These researchers found that discoloration decreased when more leavening acid was used which lowered the pH. Hartnett (1979) reported that addition of 4-5% (FWB) of a 50% active emulsifier hydrate improved color in cakes using high fructose corn sweeteners. Redfern and Hickenbottom (1972) encountered few problems with use of high fructose corn syrups to replace sucrose in bakery products at levels as high as 25-50%.

Osberger (1978) indicated that successful replacement of sucrose with fructose in foods required addition of bodying agents such as carboxymethylcellulose. Bean and associates (1978) found that sugars had delaying effects to various degrees on starch gelatinization and thus a significant effect on cake volume and contour. These researchers discovered that the best cakes containing fructose were obtained when the water absorption level was decreased from the 100% required for sucrose-containing cakes to 65%.

Decreasing Shortening Content

Hanamoto and Bean (1977) reported that the addition of surfactants to layer cakes reduced required mixing time up to 25% and reduced the amount of shortening by up to 40%. Ascorbyl palmitate was one surfactant reported to produce good volume, desirable crumb and crust color, and to act effectively as an antistalant (Hanamoto and Bean, 1977).

Problems such as a dark crumb color resulting from AP in bakery products in the past were overcome through more uniform dispersal of the compound with other ingredients by Cantrell (1979). The author also reported the effectiveness of ascorbyl palmitate as a shortening-sparing agent. Melton and Horner (1979) reported the same shortening-sparing characteristics of AP in white layer cakes.

Ofelt and coworkers (1958) found ascorbyl palmitate had softening and antistalant effects comparable to that of monoglycerides. Hoseney et al., (1976) reported that ascorbyl palmitate was significantly more effective than monoglycerides in softening crumb in systems with reduced shortening.

IV. QUANTITATION OF ASCORBYL PALMITATE

In a time of increasing concern over additives in food products, the classification of ascorbyl palmitate as a GRAS substance (Anon., 1977) could mean even more widespread use of the compound in the future, especially in bakery products. Therefore, a rapid and accurate method is needed for analyzing ascorbyl palmitate in foods.

Few methods exist for analyzing this compound. Existing methods include a colorimetric determination (Budslawski and Poyorzelski, 1964) which is time consuming and difficult to reproduce and the method of Mauro and associates (1979) which analyzes for the sodium salt of ascorbyl palmitate by high performance liquid chromatography (HPLC).

Mauro et al., (1979) reported recoveries of only 12-25% of the compound believed to be due to binding of the AP with starch or protein. De Stefanis and Ponte (1972) reported effectiveness of alpha-amylase in breaking down starch complexes to free surfactants. Promising results were obtained when ascorbyl palmitate was extracted from wheat flour by the chloroform-methanol extraction procedure of Melton and coworkers (1979) and directly analyzed by high performance liquid chromatography (Harrison et al., 1981).

V. SUMMARY

A review of the literature has shown that successful replacement of flour by cellulose, shortening by ascorbyl palmitate, and sucrose by fructose is possible. The properties of these substances which make the replacements possible contribute to their usefulness in the development of decreased calorie bakery products.

CHAPTER III

MATERIALS AND METHODS

I. MATERIALS

Cake flour and sucrose used throughout the investigation were purchased locally. Centrolex lecithin (Central Soya, Fort Wayne, IN), distilled monoglycerides (Paniplus, Olathe, KS), and L-ascorbyl-6 palmitate or AP (Hoffmann-La Roche, Nutley, NJ) were the emulsifiers used in cake preparation. Other emulsifiers such as propylene glycol monoesters were contained in the cake shortening obtained from Humko, Inc., Memphis, TN. Cellulose (Key Cel 200) was obtained from Paniplus. Fructose and beta-carotene were products of Hoffmann-La Roche. Calcium propionate was provided by Kern's Bakery, Knoxville, TN. The double action baking powder used was the Clabber Girl brand.

II. FORMULATION OF A DECREASED CALORIE CAKE MIX

Formula Selection

The first step in the development of a decreased calorie cake mix was the development of a formula which could produce a cake having 33 1/3% fewer calories than a normal cake. Two formulations, a white cake and a yellow cake, were tested. In both formulations, cellulose was substituted for a percentage of the flour, fructose was substituted for a percentage of the sucrose, and ascorbyl palmitate was used as a shortening-sparing agent. The first approach involved use of these ingredients in the formula given in Method 10-90 (AACC, 1976) to produce a white cake. Cakes were prepared according to directions in the modification of the AACC method by Zabik and associates (1977), and the calories per 100 g were estimated.

The second approach to development of a decreased calorie cake mix involved the preparation of a yellow cake from the experimental formula given in Table 1 (Melton, 1981). Percentages of ingredients were based on the combined weight of flour and cellulose or the original flour weight before cellulose substitution (FWB). Dry ingredients, including ascorbyl palmitate, were weighed and sifted into a Kitchen Aid mixer (3.8 l bowl) and blended with a wire whip for 5 minutes on low speed. In a separate container, eggs were beaten to insure uniformity, and the proper amount weighed. Water and vanilla extract were blended with eggs and added to the dry mixture. (Water temperature was adjusted to obtain a batter temperature of 25.5 to 26.6°C.) Batter was mixed with a portable mixer for 2 minutes on medium speed. Five-hundred g of batter were baked in a greased, floured, and waxed paper lined pan (20.32 cm diameter) at 190.6°C until a toothpick inserted in the center came out clean (approximately 30 minutes). Caloric value per 100 g of cake was estimated. The formula which resulted in a decreased calorie cake was selected for further study and formula improvement.

Formula Improvement

In an attempt to improve cake quality, amounts of ingredients in the experimental formula (Table 1) were varied extensively. Cellulose levels varied from 25 to 40% (FWB). Total sugar levels varied from 50 to 100% (FWB) with sucrose levels ranging from 0 to 100% of the total

Table 1. Experimental cake formula

Ingredients	Actual Amount (g)[a]	% FWB[b]
Flour	210.0	70.0
Cellulose	90.0	30.0
Baking powder (double action)	13.5	4.5
Salt	3.8	1.2
Sucrose	50.0	16.7
Fructose	100.0	33.3
Ascorbyl palmitate	3.0	1.0
Distilled monoglycerides	3.0	1.0
Non-fat dry milk	40.7	13.6
Shortening (PGME)	15.0	5.0
Eggs	110.7	36.9
Water	461.4	153.8

[a] Amounts of ingredients were varied in batters in an attempt to find the best possible combination to produce a good quality, decreased calorie yellow cake.

[b] Percentages were based on the combined weight of flour and cellulose.

sugar. Variations in surfactant levels ranged from 0 to 1% (FWB) for ascorbyl palmitate and 0 to 1.5% (FWB) for distilled monoglycerides. Lecithin was added at a level of 0.5% (FWB) to improve volume and lightness in the cake. Baking powder was increased from 4.5 to 7% (FWB) to increase cake volume. Beta-carotene was added to produce a rich, golden color in the cake crumb. Water added ranged from 110 to 153.8% (FWB). Vanilla extract was added to improve flavor of the cake. Conditions of preparation remained the same. Cake quality was judged by physical analyses of volume, shape, and cake hardness and by subjective analyses of color, grain, moistness (texture), and flavor (AACC, 1976).

Conditions of Preparation

Optimum mixing time, amount of batter per 20.32 cm diameter pan, and baking temperature to be used were determined with the experimental formula. Batters were mixed 200 strokes by hand or 1, 2, or 3 minutes with a K-Mart portable mixer, Model 06-13-24, at mix speed. After determination of the optimum mixing time, batters were again prepared and 425, 450, and 475 g batter increments were baked. Having determined optimum mixing time and weights of batter to be used, batters were prepared and baked at 218.3, 232.2, or 246.1°C in a rotary despatch oven until done to determine the optimum baking temperature.

Optimum mixing time was selected on the basis of greatest cake volume and finest grain. The optimum batter increment was determined as the amount of batter that produced a cake with an approximate volume of 1100 cc. Good contour and minimal top crust cracking were cake characteristics used to determine the optimum baking temperature (Matz, 1972).

III. EXPERIMENTAL DESIGN AND CAKE PREPARATION

Experimental cakes were prepared from a basic mix formula (Table 2) according to 16 different treatments (Table 3). Each treatment was a different combination of AP level and a given sucrose: fructose ratio. Four AP levels, 0.00, 0.33, 0.67, and 1.00% (FWB), and four sucrose:fructose ratios, 100:0, 75:25, 50:50, and 25:75, were analyzed (Table 3).

To prepare the experimental decreased calorie cake mixes, dry ingredients including ascorbyl palmitate were weighed, sifted, and blended with a Kitchen Aid mixer using a wire whip attachment for 5 minutes on low speed. Shortening was cut into the dry ingredients in small portions during a 20 minute blending period at low speed (with most of the shortening added within the first 10 minutes and continued blending for 10 additional minutes).

Enough of each mix was prepared to yield three 20.32 cm layers. Mixes were stored in polyethylene bags at 25^{O}C until needed. In all cases, mixes were prepared and cakes were made from those mixes the same day. Conditions for cake preparations were those determined under conditions of preparation.

Control cakes were prepared using Method 10-90 (AACC, 1976) by mixing beaten eggs (40% FWB) with the first water addition. The 16 treatments and control represented one replication. Two replications were performed with the order of preparation of each treatment and the

Table 2. Experimental formula-basic mix

Ingredients	Amounts (g)	% FWB
Flour	365.6	75.00
Cellulose	121.9	25.00
Sucrose	X[a]	
Fructose	X[a]	
Ascorbyl palmitate	X[b]	
Salt	6.2	1.30
Distilled monoglycerides	4.9	1.00
Non-fat dry milk powder	66.3	13.60
Lecithin	2.6	0.50
Beta-carotene	0.3	0.06
Calcium propionate	0.6	0.12
Eggs	180.1	36.90
Shortening	24.4	5.00
Water	609.4	125.00
Vanilla extract	10.5	2.15
Baking powder (double action)	34.1	7.00

[a] Sucrose and fructose amounts varied in the recipe according to treatment as listed in Table 3. In all cases, total sugar equaled 66.67% of the weight of flour + cellulose.

[b] Ascorbyl palmitate level varied according to treatment as listed in Table 3.

Table 3. Experimental design

% AP[b]	Sucrose:Fructose Ratio			
	100:0	75:25	50:50	25:75
0.00	1[a]	2	3	4
0.33	5	6	7	8
0.67	9	10	11	12
1.00	13	14	15	16

[a] All numbers listed in table represent treatments having corresponding combinations of ingredients.

[b] Ascorbyl palmitate level in batter (% FWB).

control randomized across replication. All cakes were cooled 1-3 hours at approximately 25°C. Physical analyses were conducted on cooled cakes on day 0. In addition, cake hardness was determined on cakes stored in polyethylene bags on 1, 3, and 5 days of storage at 25°C. Cakes were stored in polyethylene bags 21-24 hours at 25°C prior to subjective analyses. Cakes were stored in polyethylene bags at -18°C until analyzed chemically.

IV. CAKE AND CAKE BATTER ANALYSES

Physical Analyses

The following physical analyses were made on all cake batters.

1. Batter Specific Volume

   Batter specific volume was measured on freshly mixed batter according to Method 72-10 (AACC, 1976).

2. Batter Viscosity

   Batter viscosity was determined at 25°C using a Brookfield Viscometer, Model LVF, with a No. 4 spindle at a rotation speed of 6 rpm.

The following physical analyses were made on all cakes.

1. Cake Weight

   Cake weight was determined to the nearest 0.1 g on a Mettler top-loading balance.

2. Cake Volume

   Cake volume was obtained by rapeseed displacement in a National Cake Volume Meter.

3. Cake Size or Contour

Cake height and diameter were determined with a template as described in Method 10-91 (AACC, 1976). Heights B, C, and D were measured as illustrated in Appendix A. Cake shrinkage (cm) was calculated as the difference between the pan diameter and the cake diameter.

4. Cake Hardness

The force required to shear a 42.25 cm^2 area piece of crustless cake of known weight in a Kramer Shear Compression Cell (Food Technology Corp.) was determined by an Instron, Model 1132, equipped with a 500 kg load cell which vertically descended at a speed of 10 cm/min. Maximum shear force divided by total weight of cake sheared was used as a measure of cake hardness.

5. Crumb Color

Crumb color (L, a, and b) measured by a Hunter Color Difference Meter standardized with a yellow plate (L_L=79.4, a_L=-2.4, and b_L=23.60), was determined on the square of crustless cake prior to determination of shear force on day of baking.

Subjective Analyses

Subjective analyses of cakes were made visually for uniformity of cell size, cell size, wall thickness, grain, and color according to Method 10-90 (AACC, 1976). Oral subjective analyses were made for softness, tenderness, moistness, and flavor of the experimental and control cakes according to a modified Method 10-90 (AACC, 1976). Scales for crumb color, softness, tenderness, moistness, and flavor were modified by the addition of descriptor words as illustrated in Appendices B and C. Six panelists with background knowledge of bakery products were chosen for the evaluation.

Cakes were prepared from three commercial cake mixes, one of which contained sorbitol as the sole sweetener, and were evaluated by the panelists using the scales in Appendices B and C. Each characteristic evaluated was thoroughly defined and discussed on three different occasions. After each panelist became familiar with the score sheets, evaluation of cakes made by each treatment-replication combination and the controls began.

Six different times, panelists evaluated samples from 5 or 6 cakes made from different treatment-replication combinations or the control. Each cake was cut into squares with the crust removed and was assigned a random 3-digit number. Each square was placed on a numbered plate and wrapped in polyethylene wrap just prior to testing. The cake samples were provided to the panelists one at a time under red fluorescent lighting for oral evaluation. Following oral evaluation of the samples, panelists visually evaluated a larger representative section of each sample under white fluorescent light.

For each cake, an average score across panelists was determined for each subjective analysis except for texture (moistness) and flavor. The texture scale which was used originally by the panelists (Appendix B) to score texture was rearranged into two scales: a 6-point scale for moistness (Appendix B) and a scale for gumminess where 6 was gummy and 7 was slightly gummy. Cakes which were rated 10, 9, 8, 5, and 4 on the texture scale were reassigned values of 6, 5, 4, 3, and 2, respectively, on the moistness scale. No cakes were rated below 4 on the texture scale. For each treatment in each replication, a moistness score was obtained by averaging moistness scores across panelists who thought the cakes were not gummy and who scored them by the appropriate descriptor word (moist, slightly moist, slightly dry, etc.). The number of panelists who scored cakes on the moistness scale or as slightly gummy or gummy were tabulated for each treatment across replication.

The flavor scale (Appendix B) was rearranged into 3 scales: a 4-point scale for sweetness with no off-flavor, a 3-point scale for sweetness with slight off-flavor and a 3-point scale for sweetness with definite off-flavor. Cakes originally scored as 10, 8, 6, and 1 on the flavor scale were reassigned values, respectively, of 4, 3, 2, and 1 on the sweetness, no off-flavor scale. Cakes originally scored as 9, 7, and 5 were reassigned values, respectively, of 4, 3, and 2 on the sweetness, slight off-flavor scale, and cakes originally judged as 4, 3, and 2 on the flavor scale kept those scores on the sweetness, definite off-flavor scale. On each sweetness scale, a score of 4 was sweet, a score of 3 was moderately sweet, and a score of 2 was slightly sweet. An average sweetness score across panelists and sweetness scales was obtained for each treatment-replication combination, and the average was statistically analyzed. The number of panelists scoring cakes as having no off-flavor, a slight off-flavor, and a definite off-flavor was tabulated across replication for each treatment.

V. CHEMICAL ANALYSES

Moisture and lipid content were determined for cakes of both replications of treatments (Table 3, page 17). Crude fiber, protein, and ash were determined only on Rep 1 cakes. Moisture, fat, protein, and ash were determined on both replications of the control cake. Crude fiber, moisture, protein, and ash were measured according to standard AOAC (1970) procedures, and a chloroform-methanol lipid extraction procedure (Melton et al., 1979) was used to determine the total lipid content in the samples.

VI. ANALYSIS OF ASCORBYL PALMITATE IN CAKES

Ascorbyl palmitate was extracted by two different methods from all experimental cakes except those containing 0% AP. The first method tested, the enzyme extraction procedure of De Stefanis et al., (1977) was performed on freeze-dried cake samples which had been ground in a water-cooled mill. The second method used was the chloroform-methanol extraction procedure of Melton and associates (1979) and was performed on cake samples which had been air-dried and ground using a Wiley mill. In each case, extracts were stored in a chloroform solution under nitrogen at $-18^{o}C$ until analysis.

Extracted samples were analyzed quantitatively for AP on a Waters High Pressure Liquid Chromatograph, Model 6000A, equipped with an ultraviolet absorbance detector by elution at a retention time of 3 minutes 10 seconds from a Whatman Partisil 10 column (250 mm length, 4.60 mm i.d.) with a 65:20:2 $CHCl_3:CH_3OH:H_2O$ solvent mixture. The isocratic mode of operation was used throughout the analysis, and the absorbance of AP was measured at 254 nm (Harrison et al., 1981). On each day of analysis, a standard curve of maximum absorbance versus AP concentration (1 to 10 μg) was obtained.

AP recovery from cakes was calculated. The μg of AP/g cake (dry matter basis) were calculated from the HPLC analysis, and the added μg of AP/g cake (dry matter basis) were calculated from the amount added to cake batter taking into account loss of moisture during baking. Percentage AP recovered was determined by dividing the amount calculated by HPLC analysis by the added amount and multiplying by 100.

VII. STATISTICAL ANALYSIS

Physical, Subjective, and Chemical Analyses

The effects of sucrose-fructose blends (expressed as percentage sucrose in total sugar) and ascorbyl palmitate level (0.00, 0.33, 0.67, and 1.00% FWB) were determined by analysis of variance for each dependent variable from physical and subjective analyses and for fat and moisture content of cakes. Analysis of variance (Table 4) was performed by the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) (Barr et al., 1979). Significant effects for sucrose levels, ascorbyl palmitate levels, and their interactions were separated by orthogonal polynomials (Sokal and Rohlf, 1969). The equation or model that illustrated how each variable was affected significantly was obtained by the GLM procedure. These equations included mainly those terms which were significant at $p<0.05$ and those terms which caused like terms raised to a higher power to be significant at $p<0.05$.

Table 4. Analysis of variance for physical, subjective, and selected chemical analyses of experimental cakes

Source	DF
Sucrose[a]	3
Ascorbyl palmitate[a] (AP)	3
Sucrose X AP	9
Error	16
Total	31

[a] See Table 3, page 17.

Comparison of experimental cakes with control cakes was not made by statistical analysis. Means of dependent variables for the experimental cakes (n=32) and control cakes (n=2) were listed in tabular form for relative comparison only.

AP Recovery

Recovery of ascorbyl palmitate was statistically analyzed as a function of the sucrose level in the total sugar and ascorbyl palmitate level (0.33, 0.67, and 1.00% FWB). Analysis of variance (Table 5) was performed by the GLM procedure in SAS. Significant sucrose and AP effects were separated and equations that described those effects were obtained as described for physical and subjective analyses. No statistical analysis was performed on AP recovery obtained from the extraction procedure of Melton et al. (1979).

VIII. CALORIE ESTIMATION

Caloric content was calculated for the experimental cake containing the levels of AP and fructose which produced the cake having the highest quality as judged by cake volume, height, flavor, tenderness, uniformity of cell size, and grain. Percentages of carbohydrate, fat, and protein in cakes as determined by chemical analyses were used to calculate calories/100 g of cake based on the calorie values of 4 calories/g of carbohydrate and protein and 9 calories/g of fat (Anon., 1981b). Calories in the control cake were determined by the same procedure. Percent calorie reduction was calculated by the following formula.

Table 5. Analysis of variance for ascorbyl palmitate recovery

Source	DF
Sucrose[a]	3
Ascorbyl palmitate[a] (AP)	2
Sucrose X AP	6
Error	12
Total	23

[a] See Table 3, page 17; the treatments containing 0% AP were deleted from this analysis.

$$\text{\% Calorie reduction} = \frac{\text{Calories in control cake} - \text{Calories in experimental cake}}{\text{Calories in control cake}} \times 100$$

IX. COST ESTIMATION

A cost estimate was determined for dry ingredients needed to make two 20.32 cm experimental cakes compared to regular yellow cakes (Melton, 1981).

CHAPTER IV

RESULTS AND DISCUSSION

I. FORMULA SELECTION

Cakes made from the experimental formula in Table 1, page 13, had approximately 35% fewer calories than their normal counterpart. This 35% reduction was greater than that achieved in cakes made from the modified AACC formula (Zabik et al., 1977). Therefore, the experimental formula was selected for further study in the development of a decreased calorie yellow cake mix.

II. FORMULA IMPROVEMENT

Results obtained when ingredients were altered in an attempt to improve the experimental formula (Table 1, page 13) led to the development of a basic mix formula (Table 2, page 16) which greatly improved cake quality.

III. CONDITIONS OF PREPARATION

Tests to determine the proper conditions for cake preparation resulted in an optimum mixing time of 3 minutes with a portable mixer, batter increment of 475 g per 20.32 cm diameter pan, and baking temperature of 218.3^{o}C.

IV. CAKE AND CAKE BATTER ANALYSES: PHYSICAL ANALYSES

Seven physical measurements were not affected significantly by sucrose, AP, or sucrose X AP interaction (Table 6). Those measurements included batter viscosity, cake height B, cake height C, diameter, and crumb color (Hunter values L and b).

Batter Specific Volume

Specific volume of the cake batter was affected significantly by sucrose X AP interaction (Table 6). When AP level was 0% (FWB), batter specific volume was 0.881 ml/g at all levels of sucrose (Figure 1). At AP levels less than 0.33% (FWB), batter specific volume linearly decreased as sucrose level increased from 25 to 100% of the total sugar. At an AP level of 0.67% (FWB), batter specific volume decreased to a minimum of 0.875 ml/g at a sucrose level of 46.2% of the total sugar before increasing as sucrose level increased. In batters containing 1% AP (FWB), specific volume increased linearly as sucrose level increased.

When sucrose was 25% of the total sugar, the batter specific volume decreased linearly as AP level increased from 0 to 1% (FWB). At sucrose levels between 50 and 100% of the total sugar, inflections in specific volume occurred. Maximum specific volume occurred when sucrose was 100% of the total sugar and AP level was 1% (FWB) (Figure 1).

Generally, when sucrose was between 50 and 100% of the total sugar, addition of greater than 0.33% AP increased aeration of batter (increased total specific volume). In batters containing more than

Table 6. Mean squares from statistical analysis of physical and selected chemical analyses

	Source								
	Sucrose		AP		Sucrose X AP		Error		Total
Variable	DF	Mean Squares	DF	Mean Squares	DF	Mean Squares	DF	Mean Squares	DF
	3		3		9		16		31
Batter Viscosity		0.6771		0.7313		0.7338		0.5013	
Batter Specific Volume		0.0001		0.0001		0.0008[b]		0.0002	
Height B		0.0095		0.0028		0.0067		0.0203	
Height C		0.0570		0.0078		0.0186		0.0441	
Height D		0.1133[b]		0.0158		0.0386[d]		0.0200	
Diameter		0.0136		0.0061		0.0081		0.0091	
Weight		28.7936[c]		26.6661[d]		5.3650		11.2341	
Volume		1053.0258[c]		806.0852		4464.4382		692.6884	
Crumb Color (Hunter Value)									
L_L		0.5411		0.2153		0.3128		0.4878	
b_L		0.6842		0.5258		1.0378		2.0669	
a_L		0.0511		0.8986[c]		0.1120		0.2034	

Table 6. (Continued)

	Source								
	Sucrose		AP		Sucrose X AP		Error		Total
Variable	DF	Mean Squares	DF	Mean Squares	DF	Mean Squares	DF	Mean Squares	DF
Hardness	3		3		9		16		31
Day 0		0.0009		0.0097[b]		0.0008		0.0013	
Day 1		0.0010		0.0094[b]		0.0016		0.0015	
Day 3		0.0012		0.0160[b]		0.0013		0.0023	
Day 5		0.0023		0.0202[b]		0.0039		0.0034	
Moisture		0.3826		0.8058[c]		0.3021		0.2414	
Fat		0.0002[a]		0.00002[c]		0.000007		0.000006	

[a] Significant at $p<0.001$ level.

[b] Significant at $p<0.01$ level.

[c] Significant at $p<0.05$ level.

[d] When partitioned, significance was found at $p<0.05$ level.

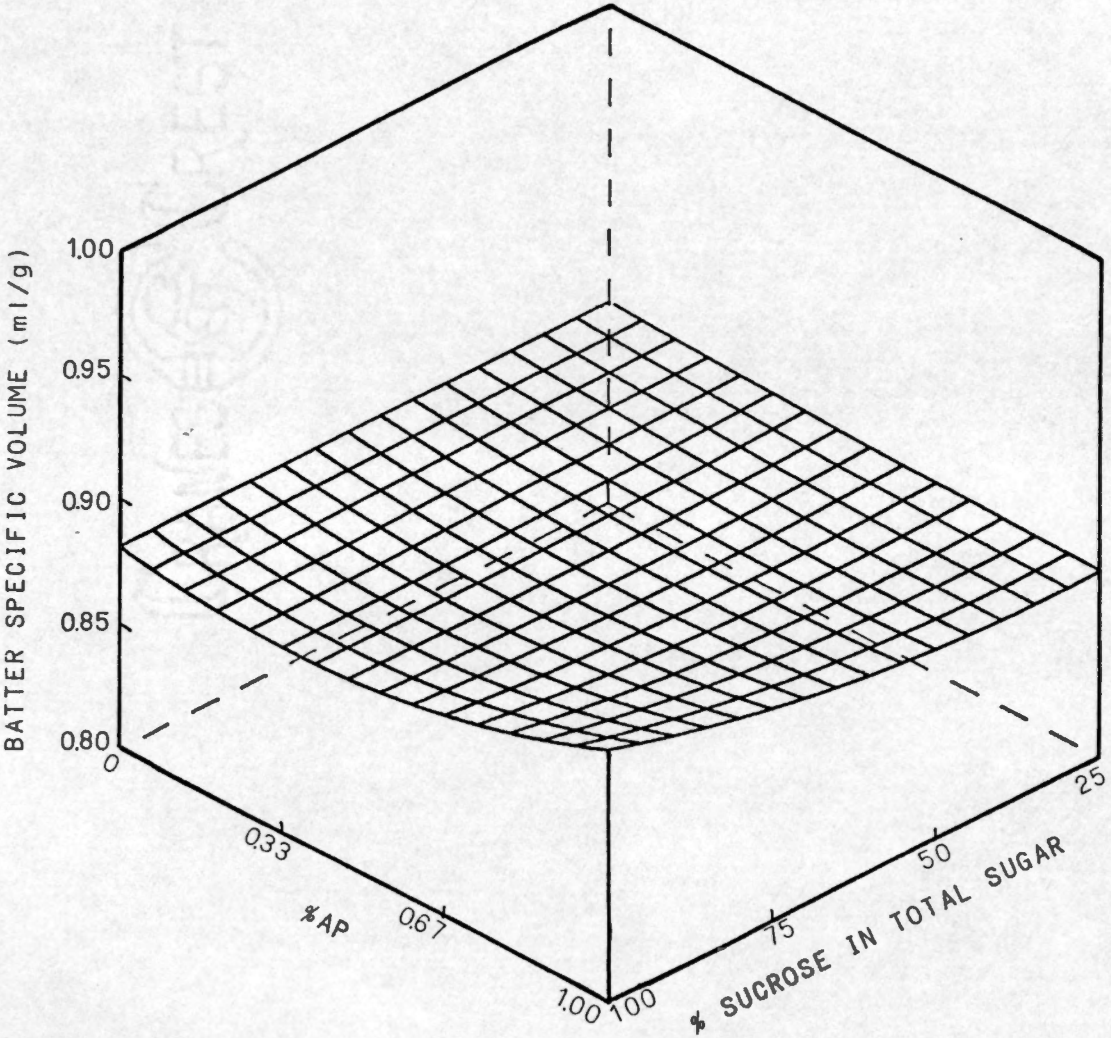

Figure 1. Batter specific volume as a function of sucrose X AP interaction.

0.67% AP, reduction of sucrose below 50% of the total sugar resulted in decreased batter aeration.

Cake Weight

Both sucrose and AP level had significant linear effects on cake weight (Table 6, page 30). At 0% AP (FWB), cake weight decreased linearly from 429.2 g at 25% sucrose in the total sugar to 425.9 g at 100% sucrose in the total sugar (Figure 2). This trend occurred at all AP levels. At all levels of sucrose, addition of ascorbyl palmitate from 0 to 1% (FWB) in the batter resulted in a linear decrease in cake weight (Figure 2). These results indicated that replacement of sucrose with fructose produced heavier cakes due to increased water binding by the fructose. Addition of ascorbyl palmitate, however, resulted in lighter cakes due to increased moisture loss during baking.

Cake Volume

Cake volume was affected significantly by sucrose level (Table 6, page 30). Volume increased from 1148 cc when sucrose was 25% of the total sugar to 1171 cc when sucrose was 100% of the total sugar (Figure 3). Substitution of fructose for sucrose in the cakes decreased the volume.

Cake Height D

For the contour or height measurement D, there was a significant quadratic sucrose effect and a significant interaction between AP and sucrose levels (Table 6, page 30). As ascorbyl palmitate level increased from 0 to 1% (FWB), the sucrose level at which a minimum

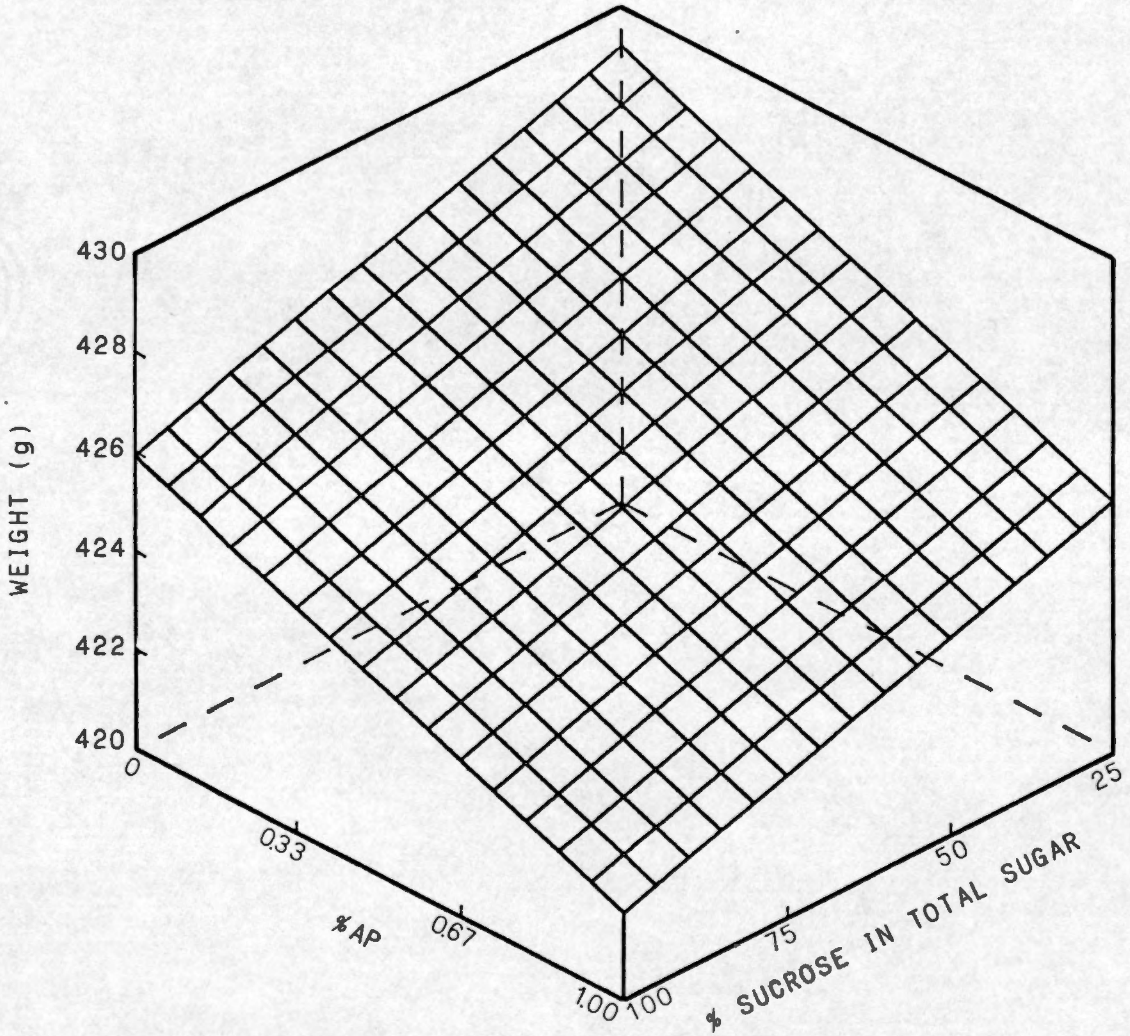

Figure 2. Cake weight as a function of ascorbyl palmitate level and sucrose level.

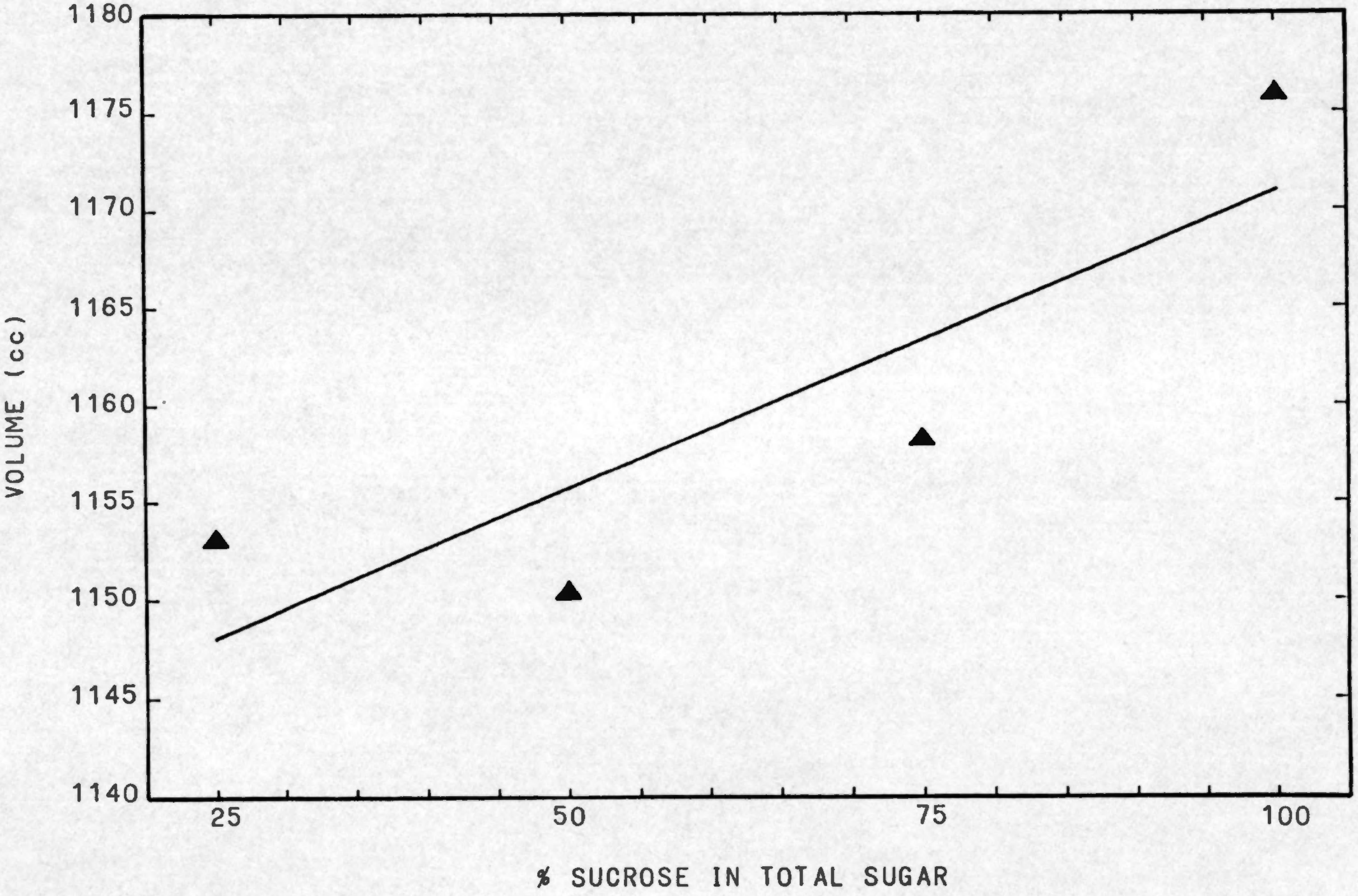

Figure 3. Cake volume as a function of sucrose level.

height measurement was observed decreased (Figure 4). In cakes containing no AP, the minimum height measurement was 3.59 cm when sucrose was 83.8% of the total sugar. In cakes made from batter containing 1% AP, the minimum cake height was 3.48 cm when sucrose was 55.4% of the total sugar. In cakes containing 25 to 83.3% sucrose in the total sugar, D decreased slightly as AP level increased from 0 to 1% (Figure 4). In cakes containing sucrose as the total sugar, however, this trend was reversed with D increasing from 3.60 cm when AP was 0% to 3.95 cm when AP was 1% (FWB) (Figure 4).

Generally, these results indicate that increasing AP levels in cakes which contain fructose in combination with sucrose decrease the height of the cake at the point at which the D measurement is made. In cakes containing only sucrose, the reverse is true. No reasons can be given for this observation at this time.

Color a_L

Ascorbyl palmitate had a cubic effect ($p<0.05$) on the color measurement, a_L (Table 6, page 30). The lowest a_L measurement of -1.31 was obtained when AP level was 0% (FWB) while the highest a_L measurement of -0.56 was obtained when AP level in cake batter was 1% (FWB) (Figure 5).

These results indicated generally that increasing AP increased the redness of the crumb color.

Cake Hardness: Force Day 0

The force required to shear a 42.25 cm^2 area piece of cake on the day of baking was affected quadratically by ascorbyl palmitate

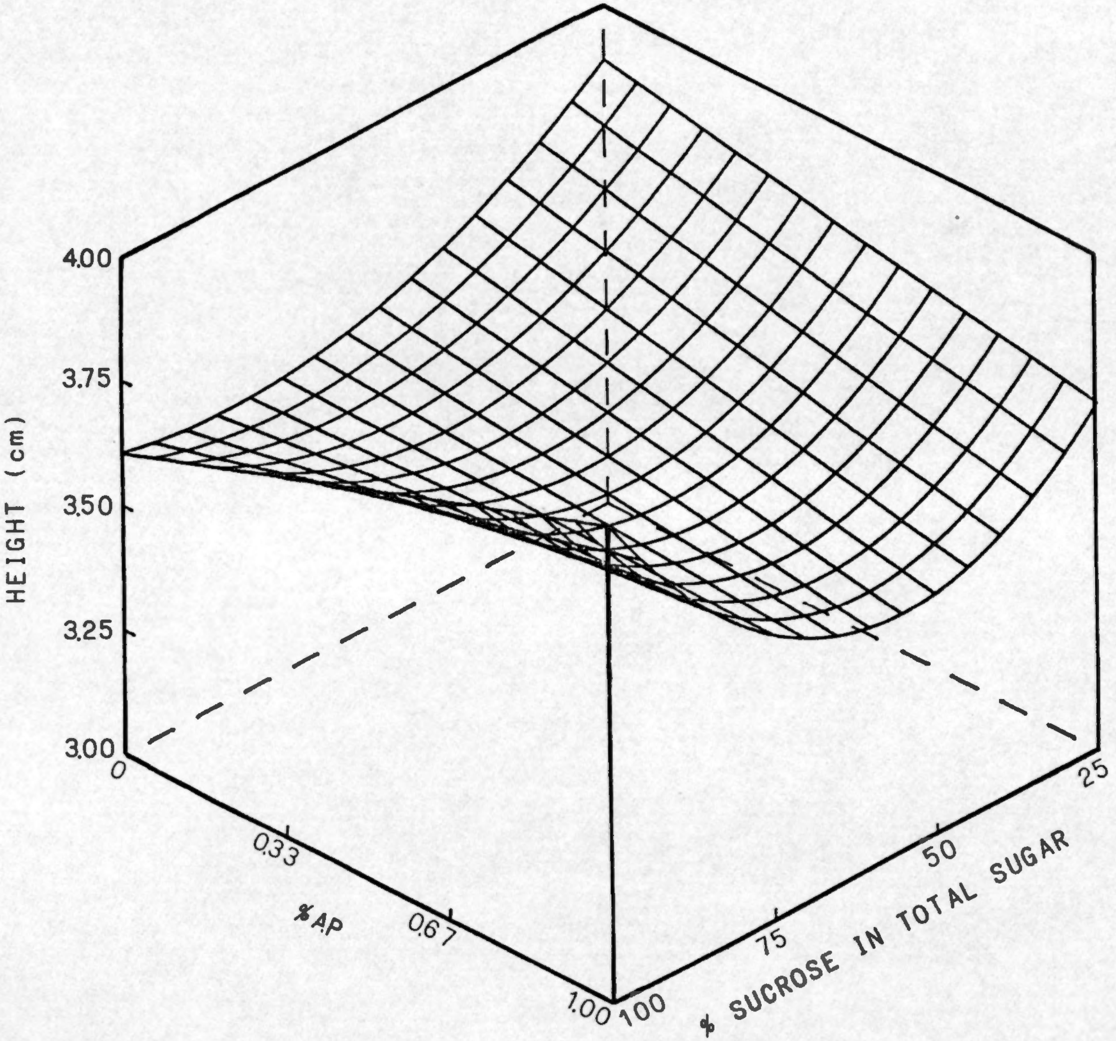

Figure 4. Cake height D as a function of sucrose level and sucrose X AP interaction.

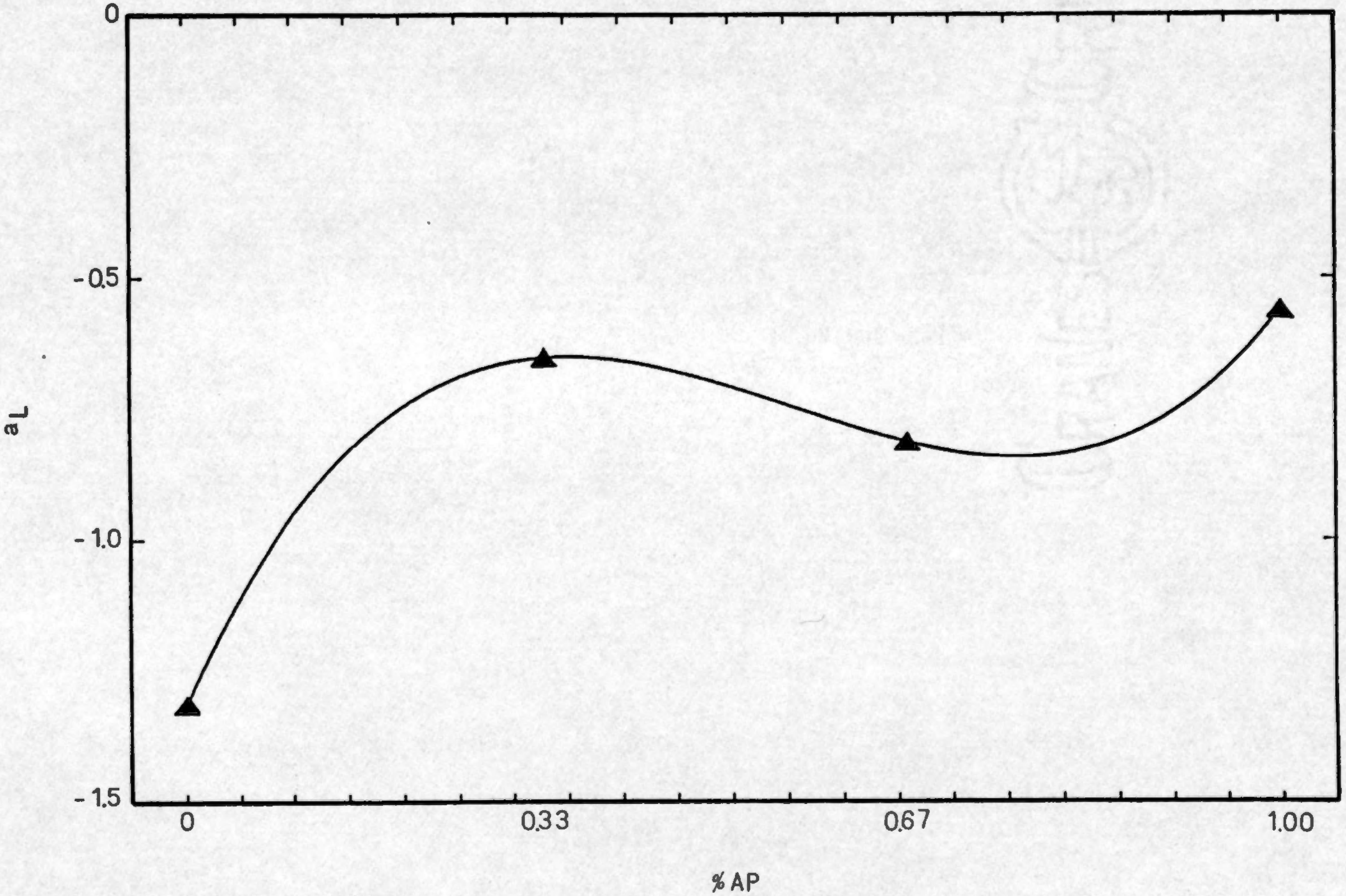

Figure 5. Color a_L as a function of ascorbyl palmitate level.

level in the cake (Table 6, page 30; Figure 6). The shear force decreased from 0.53 kg/g cake when AP level was 0% (FWB) to a minimum of 0.45 as AP level increased from 0 to 0.89% (FWB) (Figure 6).

Cake Hardness: Force Day 1

Ascorbyl palmitate had a linear effect on the shear force of the cake after one day of storage (Table 6, page 30). Shear force decreased linearly from 0.57 kg/g cake to 0.49 as AP level increased from 0 to 1% (FWB) (Figure 6).

Cake Hardness: Force Day 3

In cakes stored three days at 25°C, AP had a quadratic effect on the force required to shear the cake (Table 6, page 30; Figure 6). As AP level increased from 0 to 1% (FWB), the shear force decreased from 0.63 to a minimum of 0.53 kg/g at an AP level of 0.87% (FWB).

Cake Hardness: Force Day 5

Ascorbyl palmitate had a significant linear effect on shear force in cakes stored five days at 25°C (Table 6, page 30; Figure 6). The force required to shear the cake decreased from 0.64 to 0.53 kg/g as AP level increased from 0 to 1% (FWB).

These results indicated that the tenderness of the cake generally increased with increasing AP level in the cake batter. In addition, the cake became harder (required greater shear force) as storage time increased (Figure 6). Substitution of fructose for sucrose did not affect the hardness of the cake (Table 6, page 30).

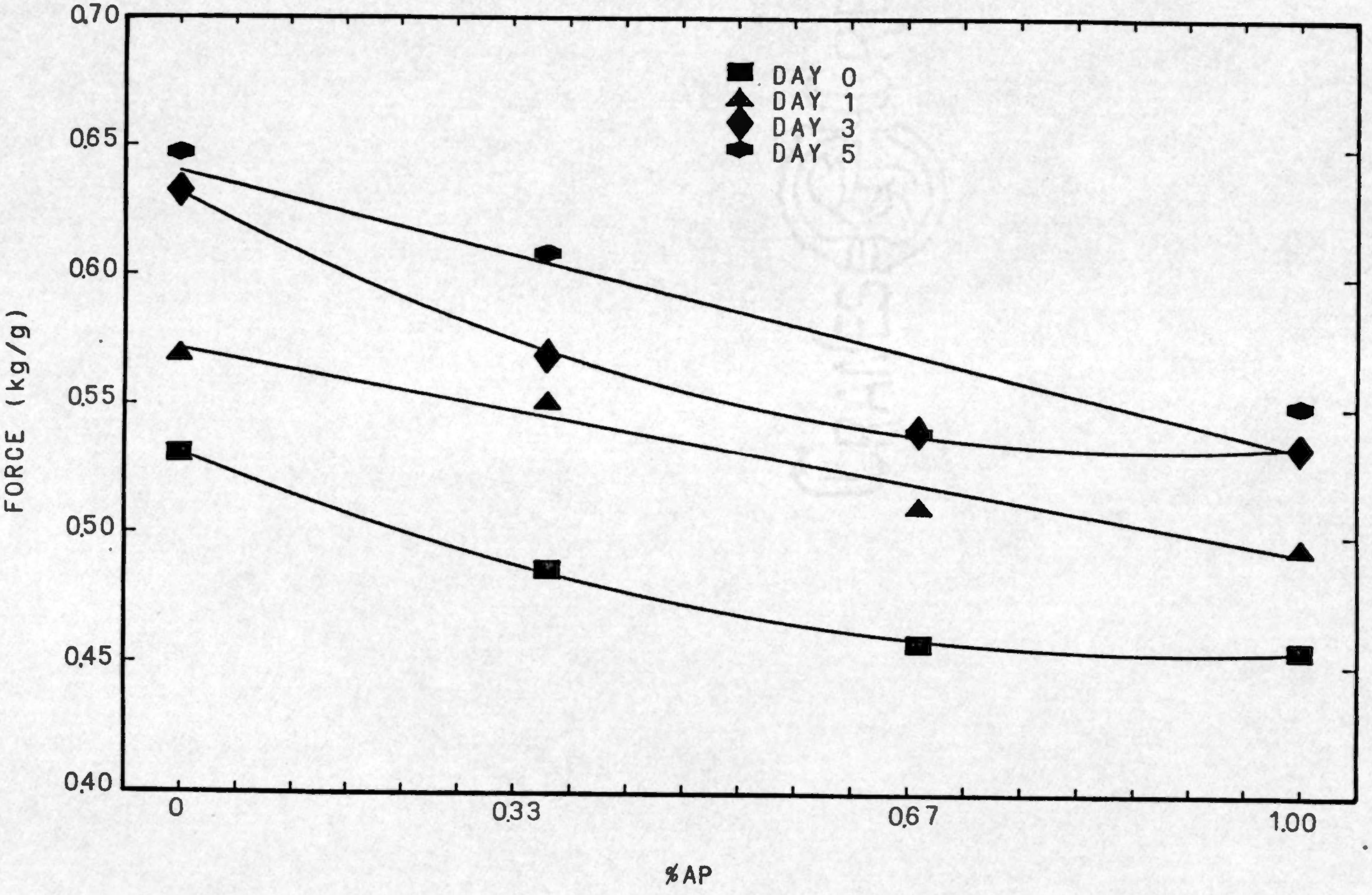

Figure 6. Cake hardness (force days 0, 1, 3, and 5) as a function of ascorbyl palmitate level.

V. STATISTICAL ANALYSIS OF SELECTED CHEMICAL ANALYSES

Moisture

Ascorbyl palmitate had a significant linear effect on moisture in the high-fiber cakes (Table 6, page 30; Figure 7). Cakes containing 0% ascorbyl palmitate had 41.33% moisture. As AP level increased, moisture content in cakes linearly decreased such that cakes made from batter containing 1% AP (FWB) had a moisture content of 40.69%. Addition of AP to the cake resulted in lighter cakes (Figure 2, page 34) with less moisture and a greater moisture loss during baking.

Fat

Sucrose level had a significant cubic effect and AP had a significant linear effect on fat extracted from cakes (Table 6, page 30; Figure 8). At all levels of sucrose in the total sugar, fat increased linearly as AP level increased from 0 to 1% (FWB). At each AP level, fat content increased to a maximum when sucrose was 86.6% of the total sugar. The minimum amount of material was extracted when sucrose level decreased to 46.75% of the total sugar. As sucrose level decreased from 46.75% to 25% of the total sugar, an increase in the amount of material extracted occurred.

The linear increase in fat content with increasing AP concentration is a result of the addition of increasing concentrations of the lipid-soluble compound, AP. The variation in fat content with decreasing sucrose content in the total sugar is harder to explain. Researchers reporting the chloroform-methanol method (Melton et al., 1979) have

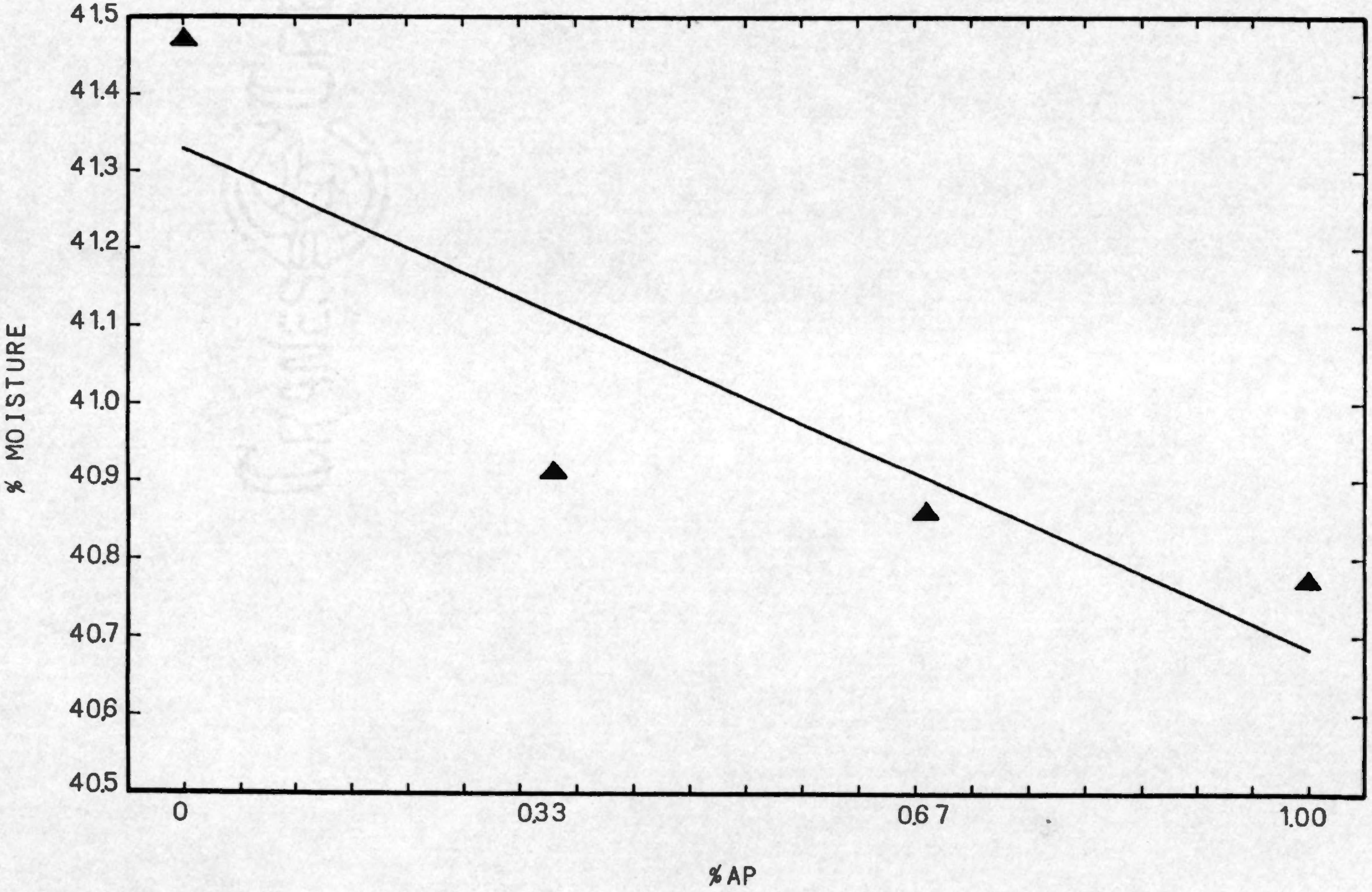

Figure 7. Moisture content of cakes as a function of ascorbyl palmitate level.

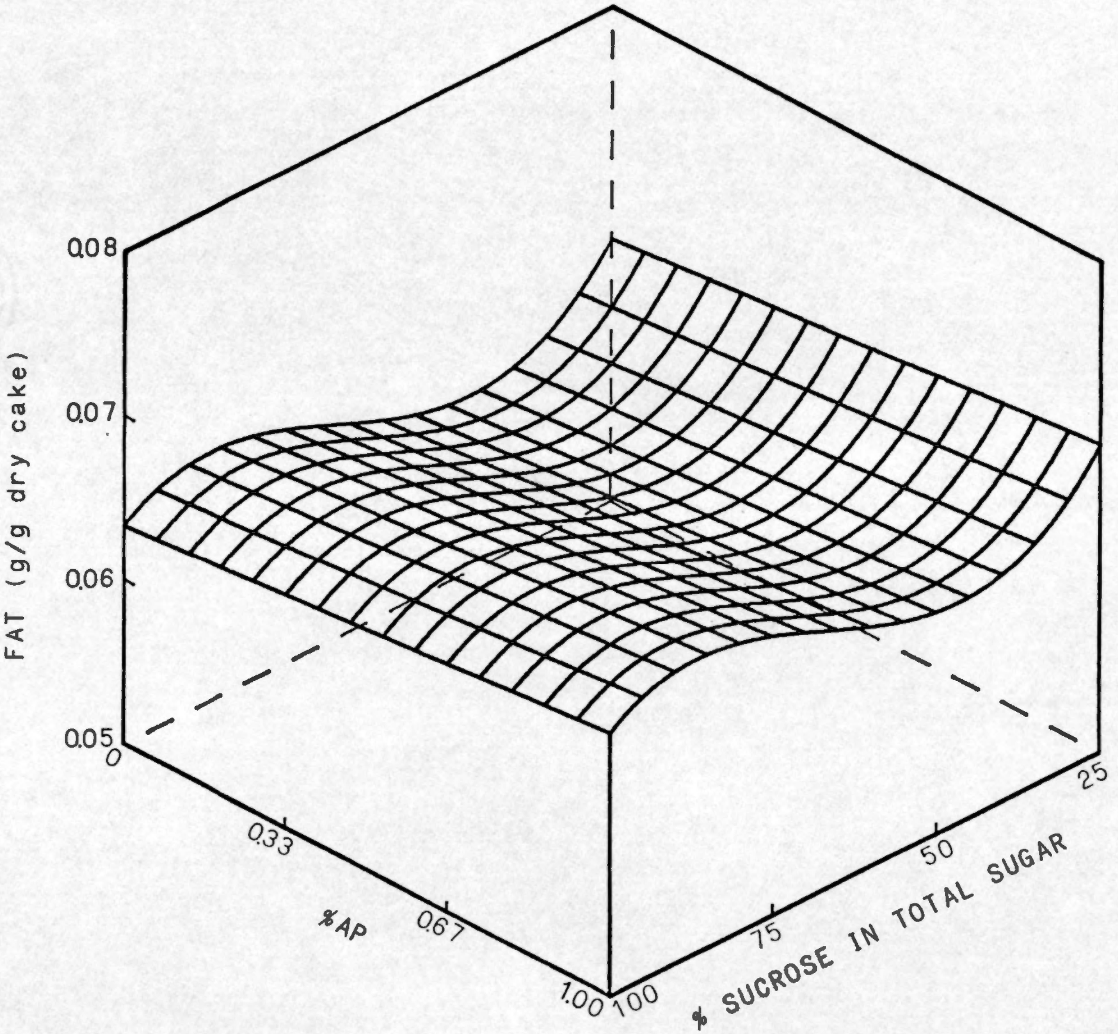

Figure 8. Fat content of cakes as a function of ascorbyl palmitate level and sucrose level.

noted the extraction of small amounts of carbohydrates with the lipid material. Fructose is much more soluble in alcohol than is sucrose; therefore, as fructose level in the total sugar increases, an increase in amount of material extracted might be expected. This trend generally has occurred in all experimental cakes except those containing 50% sucrose in the total sugar (Figure 8). No reasons can be given at the present time for this observation.

VI. CAKE ANALYSES: SUBJECTIVE ANALYSES

Softness, wall thickness, cell size, and crumb color were not affected significantly by sucrose, AP, or sucrose X AP interaction (Table 7).

Uniformity

Ascorbyl palmitate had a significant linear effect on uniformity of cell size in the cakes (Table 7; Figure 9). As AP concentration increased from 0 to 1% (FWB), the uniformity score increased linearly from 6.3 to 7.6.

The results indicated that addition of increasing amounts of AP improved cell size uniformity in the experimental cakes. These results were in agreement with those of Birnbaum (1978) who reported that surfactants (such as AP) caused more uniform dispersion or distribution of shortening in batters or doughs which resulted in larger numbers of air cells in baked goods.

Table 7. Mean squares from statistical analysis of subjective analyses

	Source								
	Sucrose		AP		Sucrose X AP		Error		Total
Variable	DF	Mean Squares	DF	Mean Squares	DF	Mean Squares	DF	Mean Squares	DF
	3		3		9		16		31
Softness		0.1027		0.2532		0.2377		0.1866	
Wall Thickness		0.0263		0.1467		0.4669		0.2457	
Cell Size		0.1837		1.0842		0.4060		0.4332	
Crumb Color		0.4823		0.1606		0.4083		0.3707	
Uniformity		0.3947		2.6863[a]		0.0899		0.3993	
Moistness		0.4558		2.3968[a]		0.6114		0.3738	
Grain		0.3912		0.5162		0.6281[c]		0.2986	
Tenderness		0.3206[c]		0.6238[b]		0.0521		0.1528	
Sweetness		0.1357[c]		0.0177		0.0713		0.0435	

[a] Significant at $p<0.01$ level.

[b] Significant at $p<0.05$ level.

[c] When partitioned, significant at $p<0.05$ level.

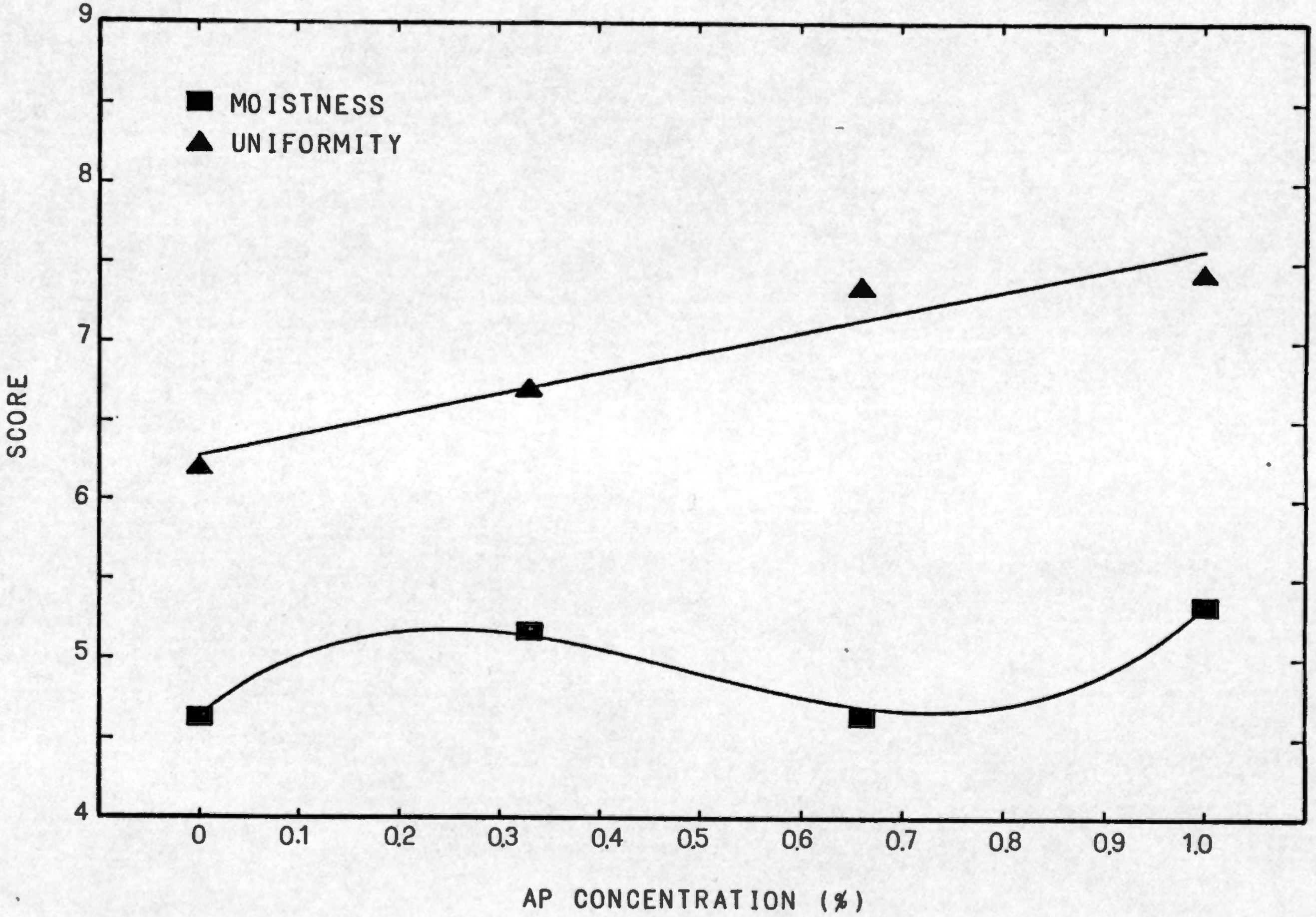

Figure 9. Uniformity of cell size and moistness as a function of ascorbyl palmitate level.

Moistness

Ascorbyl palmitate had a significant cubic effect on moistness (mouthfeel) in the experimental cakes (Table 7, page 45; Figure 9). The minimum score for moistness occurred at 0% (FWB) AP while the maximum score for moistness occurred at 1% (FWB) AP. As AP level increased from 0 to 1% (FWB), inflections in moistness scores occurred.

In cakes containing 75 to 100% sucrose in the total sugar, an increase in ascorbyl palmitate level caused an increase in the number of panelists who thought the cakes were gummy (Table 8). At a sucrose level of 50% in the total sugar, an increase in AP level from 0.00 to 0.33% caused a decrease in the number of panelists who considered the cake to be slightly gummy. When sucrose was 25% of the total sugar, cakes made from batters containing each AP level were thought to be slightly gummy or gummy by equal numbers of panelists (Table 8).

The results did not follow the same trend as total moisture (chemically determined) in the cake which linearly decreased as AP level increased. This indicated that other factors in the cakes besides the actual moisture affected the moistness as determined by mouthfeel of the cake.

Grain

Significant sucrose and AP interactions were found for cake grain (Table 7, page 45). When the cakes contained AP, the grain score increased to a maximum as sucrose decreased from 100 to 47.3% of the total sugar (Figure 10). In cakes containing no AP, grain score was the same at all sucrose levels.

Table 8. Number of panelists across replication who scored cake texture on moistness scale or as slightly gummy or gummy

AP Level (% FWB)	Score	Sucrose Level (% in Total Sugar)			
		100	75	50	25
		-------Number of Panelists--------			
0.00	Moistness	8	9	3	5
	Slightly Gummy	4	3	9	4
	Gummy	0	0	0	3
0.33	Moistness	7	8	8	5
	Slightly Gummy	5	3	4	5
	Gummy	0	1	0	2
0.67	Moistness	9	4	5	5
	Slightly Gummy	3	8	5	5
	Gummy	0	0	2	2
1.00	Moistness	4	4	5	5
	Slightly Gummy	5	6	6	5
	Gummy	3	2	1	2

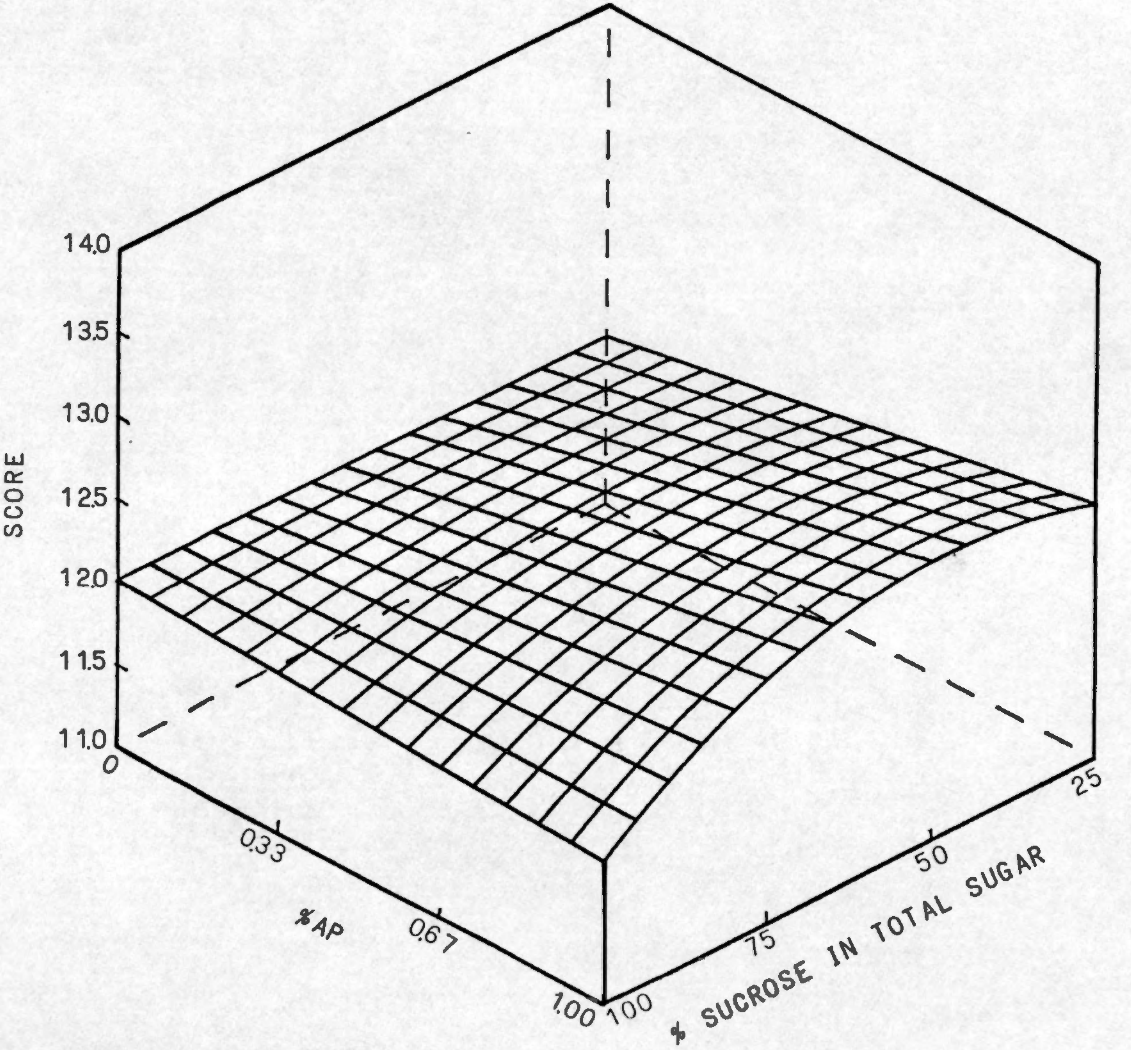

Figure 10. Cake grain as a function of sucrose X AP interaction.

At sucrose levels less than 95% of the total sugar, grain score increased linearly as AP increased from 0 to 1% (FWB), but at sucrose levels of 95% or greater, the grain score decreased linearly with increasing AP level (Figure 10). These results indicated that in cakes containing less than 95% sucrose in the total sugar, addition of AP up to 1% (FWB) in the batter improved the cake grain or caused it to be more silky (normal). This trend, however, was reversed in cakes which contained 95 to 100% sucrose in the total sugar such that AP addition caused the grain to become somewhat more coarse.

Tenderness

Both sucrose and AP had significant effects on tenderness of the cakes (Table 7, page 45). As AP level increased from 0 to 1% (FWB), the tenderness score increased linearly at any level of sucrose. At all levels of AP, as sucrose increased from 25 to 100% of the total sugar, tenderness score increased linearly (Figure 11; Note in Figure 11 that the AP and sucrose axes have been interchanged to illustrate more clearly the response surface).

These results indicated that the most tender cake with a score of 12.5, contained sucrose as the total sugar and 1% AP (FWB) in the batter while the toughest cake, with a score of 11.4, contained 25% sucrose in the total sugar and no AP (0% FWB). These results were in agreement with physical force measurements which indicated a decrease in shear force (decreased cake hardness) with increasing amounts of AP (Figure 6, page 40). The significant sucrose level effect on tenderness determined subjectively disagreed with the physical measurement since

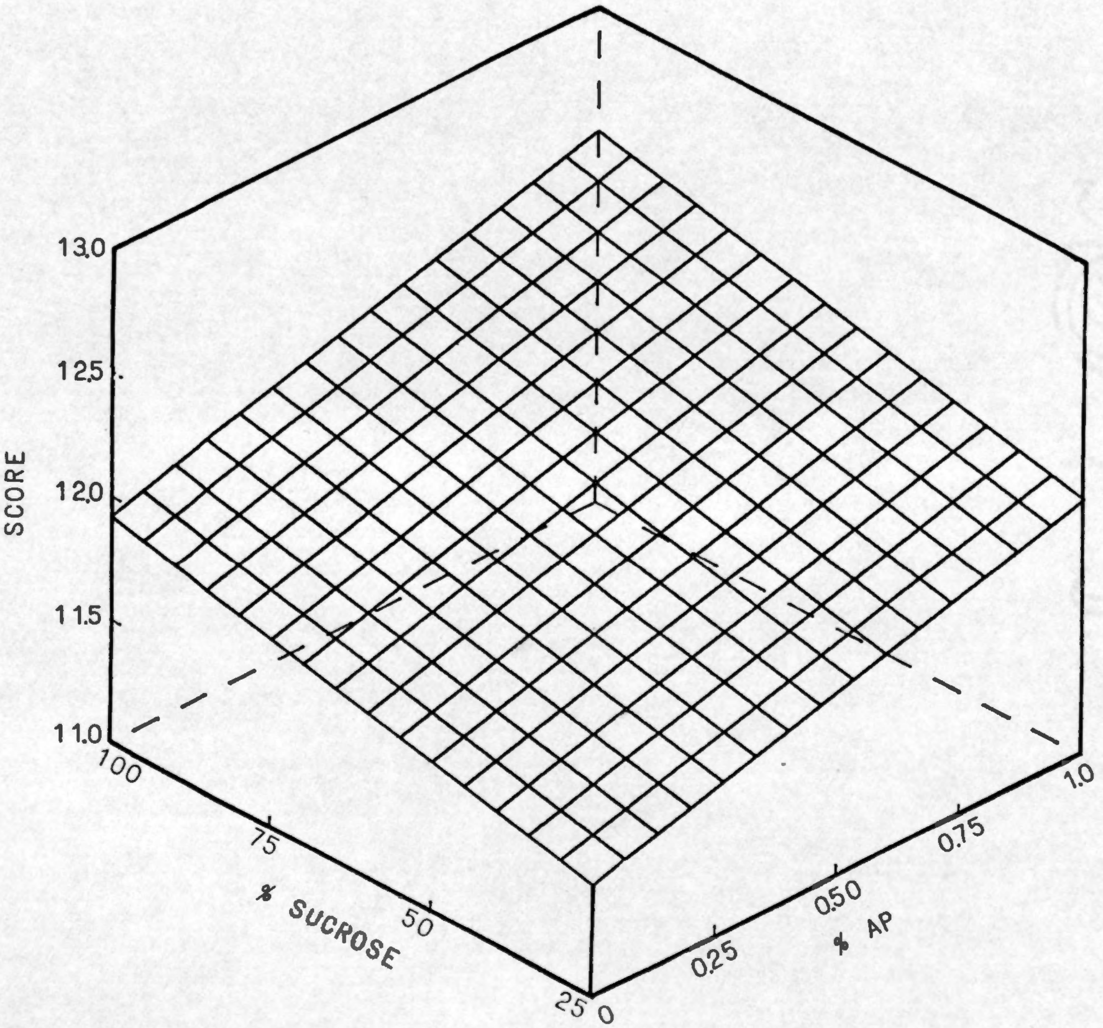

Figure 11. Tenderness as a function of ascorbyl palmitate level and sucrose level.

no significant sucrose level effect was found for the physical measurement (Table 7, page 45).

Flavor

Sucrose significantly affected sweetness score of the experimental cakes (Table 7, page 45). Across all AP levels, cakes containing 50% sucrose in the total sugar were sweetest of all cakes with an average score of 3.1 or just above moderately sweet (Table 9). As the level of sucrose decreased and AP increased, there was a general trend for the number of panelists who detected a slight off-flavor in the cakes to increase (Table 10). The exception to this observation was the cake made from batter which contained 100% sucrose and 0.33% (FWB) AP.

VII. CHEMICAL ANALYSES OF CAKES

Total moisture was determined in the experimental cakes (Table 11) and the control cakes (Table 12). Protein, ash, crude fiber, lipid, and nitrogen free extract (carbohydrate) were expressed as percentages on a dry cake basis for the experimental cakes (Table 11) and the control (Table 12).

VIII. AP RECOVERY

Ascorbyl palmitate added to cakes had a significant quadratic effect on AP extracted by the enzyme extraction method of De Stefanis et al. (1977) and quantitated by high pressure liquid chromatography (Table 13, Figure 12). The lowest AP recovery (approximately 15%) was from cakes made from batters containing 0.33% AP (FWB). The maximum

Table 9. Average cake sweetness scored by panelists across replications as a function of sucrose level and sucrose X AP interaction

AP Level (% FWB)	Sucrose Level (% in Total Sugar) 100	75	50	25
	Sweetness Score[a]			
0.00	2.5	3.0	3.1	2.9
0.33	3.0	2.8	3.0	2.9
0.67	2.8	3.2	3.2	2.8
1.00	3.1	2.9	3.2	2.8
	Average Sweetness Score[b]			
	2.8	3.0	3.1	2.8

[a] 4.0 = sweet, 3.0 = moderately sweet, and 2.0 = slightly sweet.

[b] Across AP levels.

Table 10. Number of panelists across replications who judged cake sweetness on the no off-flavor, slight off-flavor, and definite off-flavor scales

AP Level	Off-flavor Sweetness Scale	Sucrose Level (% of Total Sugar)			
		100	75	50	25
0.00	no	10	9	8	10
	slight	2	3	4	2
	definite	-	-	-	-
0.33	no	3	7	8	4
	slight	8	5	4	8
	definite	1	-	-	-
0.67	no	7	4	4	4
	slight	5	8	6	8
	definite	-	-	2	-
1.00	no	8	8	8	5
	slight	4	3	4	6
	definite	-	1	-	1

Table 11. Composition of experimental cakes (rep 1) as determined by chemical analyses

AP Level (% FWB)	Sucrose Level (% in Total Sugar)			
	25	50	75	100
	% Total Moisture			
0.00	42.41	41.74	41.56	40.99
0.33	41.30	39.71	41.16	40.63
0.67	40.67	41.23	41.61	40.08
1.00	40.55	40.60	41.66	41.02
	% Protein[a]			
0.00	8.02	8.05	8.04	8.06
0.33	8.02	8.05	7.89	8.16
0.67	8.06	7.99	7.99	7.98
1.00	8.18	7.84	7.95	7.95
	% Ash[a]			
0.00	3.05	3.04	3.15	2.97
0.33	3.34	3.14	3.21	3.05
0.67	3.11	3.18	3.10	3.19
1.00	3.12	3.06	3.19	2.96
	% Crude Fiber[a]			
0.00	10.31	10.66	9.29	9.87
0.33	10.19	9.70	10.22	10.23
0.67	9.98	9.97	9.92	9.46
1.00	9.55	9.81	10.18	9.85

Table 11. (Continued)

AP Level (% FWB)	Sucrose Level (% in Total Sugar) 25	50	75	100
	% Lipid[a]			
0.00	6.81	5.75	5.96	5.60
0.33	6.06	6.19	6.05	5.72
0.67	6.68	6.01	6.36	5.79
1.00	7.39	5.77	5.97	5.95
	% Nitrogen Free Extract[a]			
0.00	71.82	72.50	73.55	73.50
0.33	72.39	72.93	72.64	72.84
0.67	72.16	72.85	72.63	73.58
1.00	71.76	73.52	72.70	73.30

[a] All percentages were determined on a dry matter basis.

Table 12. Composition of control cakes (average of reps 1 and 2) as determined by chemical analyses

Component	Amount (%)
Total Moisture	26.85
Protein[a]	6.60
Ash[a]	0.27
Crude Fiber[a,b]	---
Lipid[a]	14.13
Nitrogen Free Extract[a]	52.15

[a] Percentages were determined on a dry matter basis.

[b] Fiber was assumed to be 0%.

Table 13. Mean squares from statistical analysis of AP recovered from cakes by enzyme extraction and HPLC analysis

Source	Degrees of Freedom	Mean Squares
Sucrose	3	119.9235
AP	2	1594.2587[a]
Sucrose X AP	6	136.5699
Replication	1	0.6667
Error	11	99.0203

[a] Significant at $p<0.001$ level.

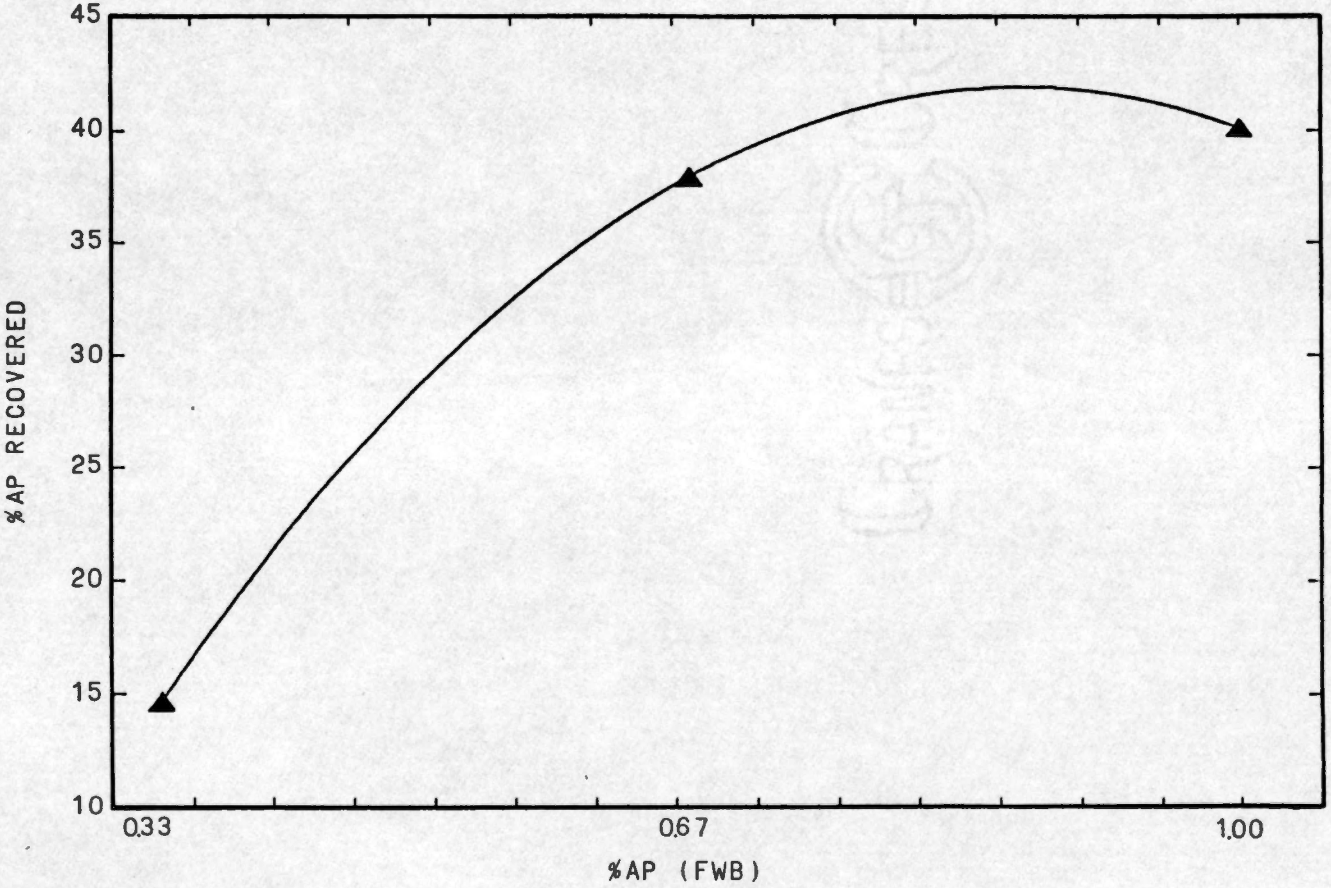

Figure 12. Ascorbyl palmitate recovery as a function of ascorbyl palmitate level.

recovery of AP (approximately 40%) occurred when AP level in the cake batter was 1.00% (FWB).

The results indicated that as AP level in cake batter increased from 0.33 to 1.00% (FWB), the amount of AP which survived baking and was extracted increased. The absence of a measurable AP peak in high pressure liquid chromatograms of chloroform-methanol extracts of experimental cakes showed that no AP was recovered by that method. The method of sample preparation (drying at room temperature and grinding in a Wiley mill) prior to chloroform-methanol extraction probably caused oxidation of the AP surviving cake mixing and baking since Harrison and coworkers (1981) reported AP recoveries of 50% from flour-AP mixtures using that extraction procedure. Cake samples which were extracted by the enzyme procedure of De Stefanis et al. (1977) were freeze-dried and ground in a water-cooled mill which could have increased the percentage of AP recovered by preventing AP oxidation.

IX. COMPARISON OF CONTROL AND EXPERIMENTAL CAKES

Physical Analyses

Control cake batter was lighter and more viscous than experimental cake batter containing cellulose (Table 14). A greater amount of experimental cake batter was needed to obtain the same volume as the control cake. Shrinkage during cooling in the control cake was slightly more than in the experimental cakes. Crumb color in the control cake was a very light yellow compared to a darker golden yellow crumb in the experimental cakes due to beta-carotene in the experimental cakes.

Table 14. Comparison of means from physical and selected chemical analyses of control cakes and experimental cakes

Variable	Cakes Control (n=2)	Experimental (n=32)
Batter Specific Volume (cc/g)	1.275	0.880
Batter Viscosity[a]	49.45	5.02
Volume (cc)	1154.17	1159.50
Weight (g)	284.15	425.50
Height B (cm)	3.90	3.58
Height C (cm)	4.85	4.51
Height D (cm)	4.15	3.66
Diameter (cm)	19.15	19.24
Shrinkage (cm)	1.15	1.06
Color L_L	81.35	76.35[b]
Color a_L	3.30	-0.83[b]
Color b_L	17.35	30.60[b]
Hardness Day 0 (kg/g)	0.663	0.483
Hardness Day 1 (kg/g)	0.911	0.532
Hardness Day 3 (kg/g)	0.869	0.569
Hardness Day 5 (kg/g)	1.181	0.587
Moisture	26.85	41.01
Fat (g/g dry cake)	0.14	0.06

[a] Value listed is directly from viscometer scale.

[b] Beta-carotene was added to experimental cakes to produce a rich, golden color.

Experimental cakes stored up to 5 days were more tender because they required less force to shear than did the control cake (Table 14). This increased softness in the experimental cakes probably was due to their higher moisture content compared to the control cake (Table 14).

Subjective Analyses

The control cake was subjectively evaluated to be softer and more tender than the experimental cakes (Table 15). In addition, the control cake had smaller, more uniform cells with thinner walls and a silkier grain than the experimental cakes (Table 15). The experimental cakes, however, had a more moist texture than the control cake.

The control cake was scored just above moderately sweet, and the average sweetness score of the experimental cakes was just below moderately sweet (Table 15). The slightly greater sweetness level in the control cake was expected since the control cake contained 120% sugar (FWB) compared to 66.67% (FWB) in the experimental cakes. However, if only the experimental cakes which contained 50% sucrose in the total sugar were compared with the control cake, only a slight difference in sweetness score existed.

As a result of beta-carotene addition in the experimental cake formula, the experimental cakes had a golden yellow crumb color compared to an off-white crumb color in the control cake when subjectively analyzed (Table 15).

Table 15. Comparison of means from subjective analyses of control cakes and experimental cakes

Variable	Cakes Control (n=2)	 Experimental (n=32)
	Score[a]	
Softness	9.9	7.8
Tenderness	11.6	12.0
Moistness	2.2[b]	4.9
Flavor[c]	3.2	2.9
Uniformity	8.7	6.9
Cell Size	9.8	6.4
Wall Thickness	9.3	7.3
Grain	15.4	12.2
Color	1.3	8.9[d]

[a] See Appendix A and B.

[b] One panelist judged the control cake to be gummy.

[c] See page 20.

[d] Beta-carotene was added to experimental cakes to produce a rich, golden color.

X. CALORIE ESTIMATION

The sweetest experimental cakes contained 50% sucrose in the total sugar. Addition of ascorbyl palmitate at 0.33% (FWB) increased cake moistness in the mouth. Increasing AP also increased tenderness, reduced cake hardness, and caused the size of cells in the cake crumb to be more uniform. In addition, in cakes containing 50% sucrose of the total sugar, AP increased fineness of cake grain. AP addition, however, at levels of 0.67 to 1.00% (FWB) in the batters of cakes containing 50% sucrose in the total sugar increased the number of panelists who scored cake texture as gummy. Because of these observations, cakes containing 50% sucrose in the total sugar and 0.33% AP were judged to have the best quality of all experimental cakes. The estimated calories of a 100 g serving of this cake was 229 calories compared with 344 calories/100 g of the control cake when calories were estimated using established caloric values (Anon., 1981b). The cake made from batter containing 50% sucrose and 50% fructose in the total sugar and 0.33% AP (FWB) had 33.4% fewer calories than its normal counterpart.

XI. COST ESTIMATION

The cost for dry ingredients needed to make two 20.32 cm diameter layers of the experimental cakes was estimated to be $0.56 compared to $0.38 for regular yellow cakes (Melton, 1981). This increase in the cost of the experimental cake over a regular yellow cake was due mainly to the cost of cellulose ($0.48/454 g) which was substituted for flour ($0.22/454 g) and the higher cost of fructose ($0.95/454 g) which was substituted for sucrose ($0.22/454 g). Additional batter was required to obtain good volume in the experimental cakes and thus increased the cost.

CHAPTER V

CONCLUSION

Investigation of several formulations and conditions of preparation resulted in the development of a basic mix formula used to investigate the effects of fructose replacement of sucrose at levels of 0, 25, 50, and 75% of the total sugar and ascorbyl palmitate as a shortening-sparing agent at levels of 0.00, 0.33, 0.67, and 1.00% (FWB) on cake quality. Optimum conditions of preparation were a mixing time of 3 minutes using a portable mixer on mix speed, batter increment of 475 g per 20.32 cm diameter pan, and baking temperature of 218.3°C in a rotary despatch oven.

Statistical analysis of physically and subjectively evaluated characteristics indicated that neither sucrose, AP, nor sucrose X AP interaction significantly affected batter viscosity, cake heights B and C, diameter, shrinkage, or crumb color (Hunter values L and b) as physically evaluated and softness, wall thickness, cell size, and crumb color as subjectively evaluated. Results indicated that addition of ascorbyl palmitate generally increased batter specific volume when fructose was 0 to 50% of the total sugar and AP level was greater than 0.33% (FWB). Addition of AP generally decreased cake weight, cake hardness, and moisture content and increased redness of crumb color and uniformity of cell size as AP levels increased from 0 to 1% (FWB) at all levels of fructose. In cakes containing 5-75% fructose in the total sugar, addition of AP up to 1% (FWB) generally improved cake grain causing it to be more silky. Addition of AP at fructose levels of 50% of the total sugar resulted in minimal detection of a slight off-flavor. As fructose level increased to 75%, however, off-flavor detection with AP addition also increased.

Results indicated that replacement of sucrose with fructose generally decreased cake volume from 1171 to 1148 cc and increased cake weight from 425.9 to 429.2 g as fructose level increased from 0 to 75% of the total sugar. Addition of fructose generally increased sweetness in cakes from slightly sweet to moderately sweet but resulted in the detection of a slight off-flavor at 25 and 75% replacement. Addition of fructose generally decreased tenderness as subjectively evaluated.

Results of chemical analyses indicated that addition of AP at levels of 0 to 1% generally decreased moisture in the cakes and increased fat extracted from the cakes. High pressure liquid chromatographic analysis of enzymatically extracted AP from cakes indicated that percentage recovery of AP which survived cake mixing and baking increased from approximately 15 to 40% as AP level increased from 0.33 to 1.00% (FWB).

Comparison of the experimental formula containing cellulose to the control formula indicated that the control cake batter was lighter and more viscous than the experimental cake batter. More experimental cake batter was required to obtain the same volume in the finished cake as the control cake. Results indicated that the control cake had a silkier grain, more uniform cell size, and greater tenderness (subjectively analyzed) than the experimental cake. The experimental cakes, however, required less force to shear and had a more moist texture. Both cakes were moderately sweet.

From all results obtained, the experimental cake made from batter which contained 0.33% AP (FWB) and 50% fructose in the total sugar was judged to have the most acceptable quality. Using percentages of carbohydrate, protein, and fat determined by chemical analyses, calories/100 g of experimental and control cakes were determined. Caloric content of the control cake was calculated as 344 calories/100 g while that of the experimental cake was calculated as 229 calories/100 g. This decrease in calories represented a 33.4% reduction based on the control cake. It was concluded that the experimental cake mix could, therefore, be labeled as a decreased calorie yellow cake mix.

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APPENDICES

APPENDIX A

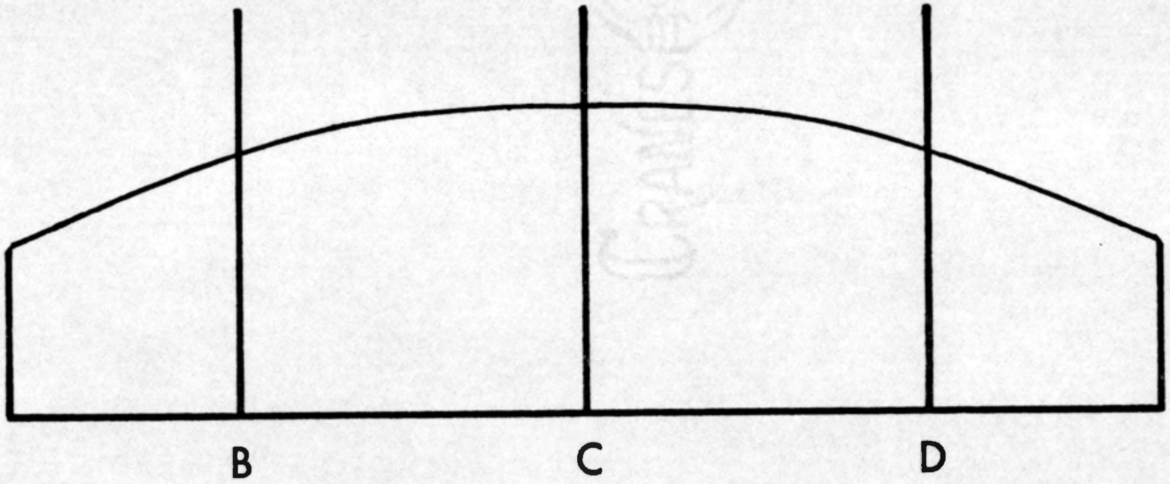

Figure 13. Height measurements B, C, and D as taken on cake center section.

APPENDIX B

NAME______________________________ SCORE SHEET FOR CAKES DATE__________________________

You will be given _______ cake samples. Taste each sample carefully and evaluate the following characteristics:

SOFTNESS or how easily the cake is compressed prior to the penetration of the teeth; TENDERNESS or the force required for the teeth to penetrate the cake sample; MOISTNESS or mouth-feel after cake has been chewed; and FLAVOR, evaluation of the sweetness of the cake and the presence and absence of off-flavors. Evaluate each characteristic by writing the number from the scales for each characteristic below that best describes your judgement by the correct cake sample number. Rinse mouth carefully between each cake sample with water provided. A cup is provided for expectoration of sample if you so desire.

Scale for Softness (10 points)

10 Soft
9
8 Slightly firm
7
6 Firm
5
4
3 Hard
2
1 Very hard

Scale for Tenderness (14 points)

14 Very tender
13
12 Tender
11
10 Sl. tough
9
8
7 Mod. Tough
6
5
4
3 Very Tough
2
1

Scale for Moistness (10 points)[a]

10 Moist
9 Slightly moist
8 Slightly dry
7 Slightly gummy
6 Gummy
5 Mod. Dry
4 Dry
3
2 Very dry
1

Scale for Flavor[a] (10 points)

10 Sweet, no off flavor
9 Sweet, sl.off flavor
8 Mod. Sweet, no off flavor
7 Mod. Sweet, sl.off flavor
6 Sl. Sweet, no off flavor
5 Sl. Sweet, sl.off flavor
4 Sweet, def. off flavor
3 Mod. Sweet, def. off flavor
2 Sl. Sweet, def. off flavor
1 Not sweet at all

Sample	Softness	Tenderness	Moistness	Flavor

COMMENTS: ______________________________

---

[a] See p. 23.

APPENDIX C

NAME____________________ SCORE SHEET FOR APPEARANCE OF CAKES DATE____________________

Outside of the sensory taste booths in Room _________, _________ cake samples are set up for visual evaluation of the characteristics listed below: Evaluate each characteristic by writing the number from the scales for each characteristic that best describes your judgement by the correct cake sample number. Try to be objective and do not be influenced by other judges who may be present in the room at the time of your evaluation.

Scale for Uniformity of Cell Size (10 points)	Scale for Cell Size (10 points)	Scale for Cell Wall Thickness (10 points)	Scale for Grain (16 points)	Scale for Crumb Color (10 points)
10 Even (normal)	10 Dense (V.small)	10 Thin(normal)	16 Silky (normal)	10 Yellow
9	9	9	15	9
8	8 Close (Small)	8	13	8
7	7	7	12	7 Moderately yellow
6 Slightly uneven	6 Sl.Close(med.)	6 Sl.Thick	11	6
5	5	5	10 Harsh	5
4	4 Open (large)	4	9	4 Light yellow
3	3	3	8 Coarse (cornbread)	3
2 Uneven	2 V.open(V.large)	2 Thick	7	2
1	1	1	6	1 Light cream

SAMPLE	UNIFORMITY	CELL SIZE	WALL THICKNESS	GRAIN	CRUMB COLOR

COMMENTS:____

____

____

____

APPENDIX D

EQUATIONS

Batter Specific Volume $= 0.8812 - 0.0004SA + 0.000006S^2A^2$

Cake Weight $= 430.3239 - 0.0441S - 4.1686A$

Cake Volume $= 1140.4390 + 0.3050S$

Cake Height D $= 4.2125 - 0.01509S + 0.00009S^2 - 0.0115SA$
$+ 0.00015S^2A$

Color $a_L = -1.3125 + 4.4817A - 9.3520A^2 + 5.6203A^3$

Cake Hardness (Force):

Day 0 $= 0.5313 - 01722A + 0.0964A^2$

Day 1 $= 0.5713 - 0.0783A$

Day 3 $= 0.6315 - 0.2267A + 0.1304A^2$

Day 5 $= 0.6399 - 0.1068A$

Moisture $= 41.33 - 0.6447A$

Fat $= 0.0933 - 0.0017S + 0.000028S^2 - 0.00000014S^3$
$= 0.0026A$

Uniformity $= 6.2810 + 1.2987A$

Moistness $= 4.6400 + 4.9636A - 13.4543A^2 + 9.1840A^3$

Grain $= 12.0128 + 0.0284SA - 0.0003S^2A$

Tenderness $= 11.2909 + 0.0062S + 0.5878A$

Sweetness $= 2.4675 + 0.0194S - 0.0002S^2$

AP Recovery $= -29.5250 + 165.4771A - 95.8450A^2$

VITA

Judy Ann McKee Harrison was born in Hartsville, Tennessee on March 20, 1954 to William and Edna McKee. She graduated from Trousdale County High School in 1972. In the fall of 1972, she entered Tennessee Technological University and received a Bachelor of Science degree in Secondary Education-Biology in 1976. In September of that year, she began working as a laboratory technician in the Food Technology and Science Department of The University of Tennessee. She was later given a graduate research assistantship in that department and began study toward a Master of Science degree. The degree was awarded in December 1981.

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