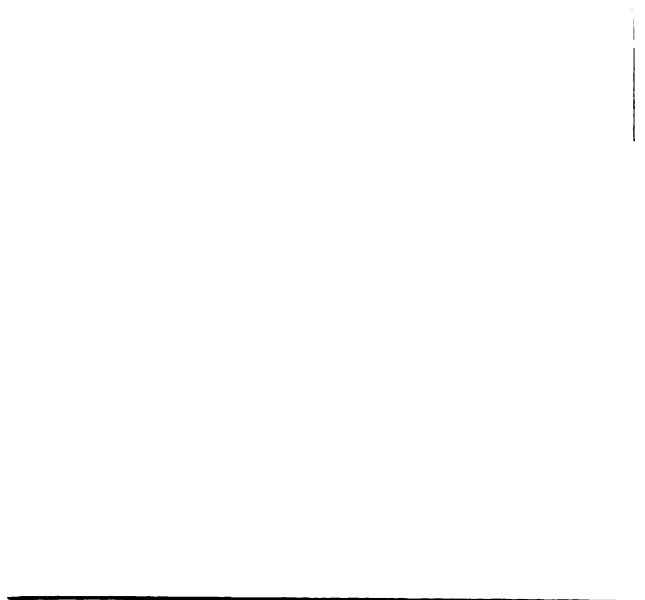


SUBSTITUTION OF FOAM SPRAY-DRIED ACID WHEY
SOLIDS FOR BUTTERMILK SOLIDS IN CHOCOLATE CAKE

Thesis for the Degree of M. S.
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Mary Stelson Parks

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ABSTRACT

SUBSTITUTION OF FOAM SPRAY-DRIED ACID WHEY SOLIDS FOR BUTTERMILK SOLIDS IN CHOCOLATE CAKE

by Mary Stelson Parks

This investigation was initiated to determine the effect of substituting various quantities of foam spray-dried acid whey solids for buttermilk solids on the quality characteristics of a standard quick-mix chocolate cake. The original buttermilk solids in the cake formula were replaced with 25%, 50%, 75%, and 100% foam spray-dried acid whey solids. To determine the amount of substitution consistent with good quality, the cakes in which foam spray-dried acid whey solids were substituted were compared by subjective evaluation and objective measurement with those prepared with 100% buttermilk solids. Five replications of each of the four variables and the control were tested and collected data were statistically analyzed by a computer.

The results of this research suggested that foam spray-dried acid whey solids may be feasibly substituted for buttermilk solids under certain conditions. When increasing percentages of foam spray-dried acid whey solids

were substituted for buttermilk solids, batters became significantly less viscous and cake volumes became significantly smaller. It is suggested that a probable relationship exists between batter viscosity and cake volume and that dissimilarity in these physical properties are attributed primarily to differences in composition between foam spray-dried acid whey solids and buttermilk solids.

Statistical analyses indicated that there were no significant differences between cake samples for the objective measurements of pH of the batter and cake, specific gravity of the batter, and volume, tenderness, compressibility, tensile strength, and color of the cakes. No significant differences existed between cake samples for subjective evaluations of outside attributes and inside characteristics of the cake. The fact that so few cake characteristics were altered by this substitution indicates that foam spray-dried acid whey solids are a feasible substitute for buttermilk solids. In addition to retaining many of the original cake characteristics, the use of foam spray-dried acid whey solids would offer considerable savings in ingredient cost to the food manufacturer.

Although this investigation has indicated that foam spray-dried acid whey solids may easily and more economically be substituted for buttermilk solids, inquiry in the following areas might also be useful: (1) a search for procedures or substances to be incorporated with foam

spray-dried acid whey solids in cake formulas to increase batter viscosity and cake volume; (2) an investigation of additional ingredients such as other acid or milk products for which foam spray-dried acid whey solids could be effectively substituted; and (3) a study of the advantages and limitations of substituting foam spray-dried acid whey solids for buttermilk solids in other products.

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By

Mary Stelson Parks

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INTRODUCTION

Acid whey is an acceptable food product, but problems arising from past processing techniques and its inherent composition have previously limited its incorporation into food products. Cottage cheese companies are concerned with disposing of whey as a waste product or with finding uses for the whey because increased cottage cheese production has resulted in increased quantities of acid whey by-product. The United States Department of Agriculture reported that in 1964, 623 million pounds of cottage cheese curd were produced in the United States. From the production of this quantity of cottage cheese, nearly 216 million pounds of dried acid whey solids could have been processed if there had been outlets for its use.

In the past, excess whey was disposed of by emptying it into natural water ways, a practice which has become unlawful in many states (Alesch, 1958). Emptying fluid whey into sewage disposal systems is expensive and many companies will be forced to discontinue cottage cheese production unless cheaper means of disposal or new methods of utilization of the acid whey by-product are developed.

Although acid whey has been spray-dried for years, its high lactic acid content causes whey to dry less

readily than sweet whey and to form lumps in the spray-drying equipment (Hanrahan and Webb, 1961). In 1961, Hanrahan and Webb developed a more efficient method of foam spray-drying cottage cheese whey. However, without feasible outlets for the product, there is no reason to produce quantities of dried whey. Research is needed to discover new possibilities for utilizing this by-product.

Some research has been directed toward utilizing sweet whey, but the inherent compositional differences between sweet and acid whey may preclude effective utilization of the latter by similar techniques. The effect of the addition of sweet whey to a basic cake is to produce a cake with improved flavor, browning, and keeping qualities and a cake crumb which is more moist and tender (Hanning and de Goumois, 1952). Due to the acidity and the distinctive flavor and odor, uses of acid whey may be substantially different and more limited than those of sweet whey. Recently the suitability of using foam spray-dried acid whey solids as a source of serum solids in fruit sherbets was demonstrated by Blakely (1964). However, research concerning the use of foam spray-dried acid whey solids in other products for human consumption has been limited.

Because of some similarities in composition, foam spray-dried acid whey solids may approximate the functional properties of buttermilk solids. Moreover, Habighurst and Singleton (1965) have found that the use of acid

whey at normal levels greatly accentuated the flavor of chocolate. Substitution of foam spray-dried acid whey solids for buttermilk solids would offer economy in the manufacture of certain foods since currently buttermilk solids cost approximately 15¢ per pound, and foam spray-dried acid whey solids sell for about 9-1/2¢ per pound (Stine, 1965). The baking industry is a large consumer of milk products. In bakery foods ordinarily prepared with buttermilk solids, the substitution of foam spray-dried acid whey solids might make possible retaining product quality at reduced cost. This investigation was initiated to add dimensions to the knowledge about the feasibility of substituting foam spray-dried acid whey solids for buttermilk solids in a quick-mix chocolate cake formula.

REVIEW OF LITERATURE

Milk By-products--Whey and Buttermilk

Whey and buttermilk are residual by-products from the manufacture of cheese and butter, respectively. As by-products derived from milk, both are good sources of high quality protein. Although these products are similar in composition, important differences exist.

Whey (Whittier and Webb, 1950)

Whey is the residual fluid remaining after coagulated curd is removed from skim or whole milk. Cottage cheese may be rennin or acid coagulated; differences in composition of the resulting whey are due in part to the method of casein coagulation. If the casein is coagulated by rennin, calcium and phosphorus remain in the curd. When the coagulating agent is acid, added per se or developed by fermentation of the lactose, part of the phosphorus and most of the calcium remain in the whey. During the fermentation process, lactic acid is formed by bacterial action from lactose; but, due to the simultaneous formation of gases and volatile acids, the increase in lactic acid is not equal to the decrease in lactose content. The typical composition of whey is found in Figure 1.

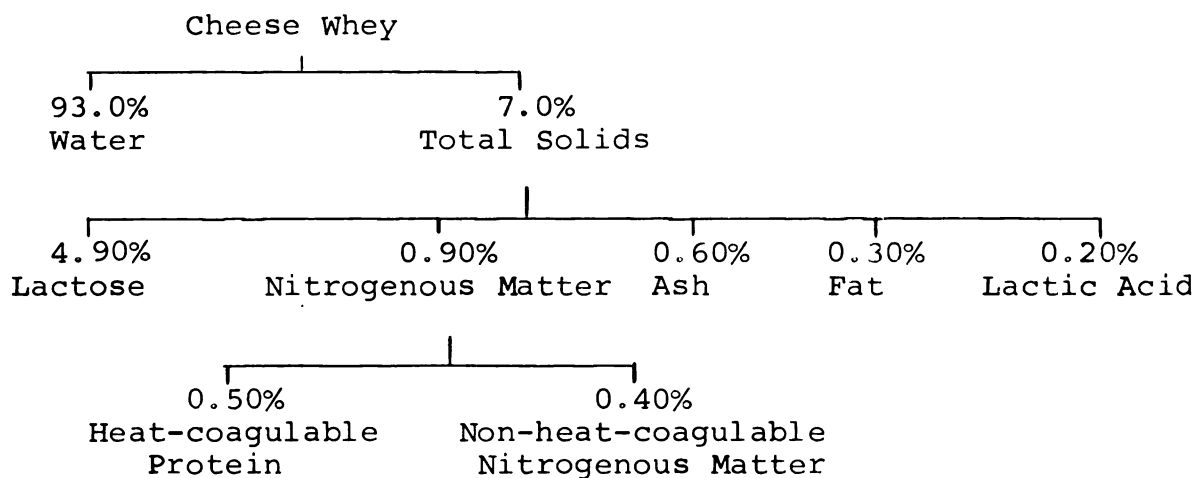


Figure 1. Typical whey composition (Whittier and Webb, 1950).

Buttermilk (Whittier and Webb, 1950)

Buttermilk, a by-product of butter production, is generally classified as sweet cream or sour cream buttermilk. Sour cream buttermilk contains an average of 0.5 per cent lactic acid and less lactose than sweet cream buttermilk. Figure 2 shows the typical composition of sweet cream buttermilk.

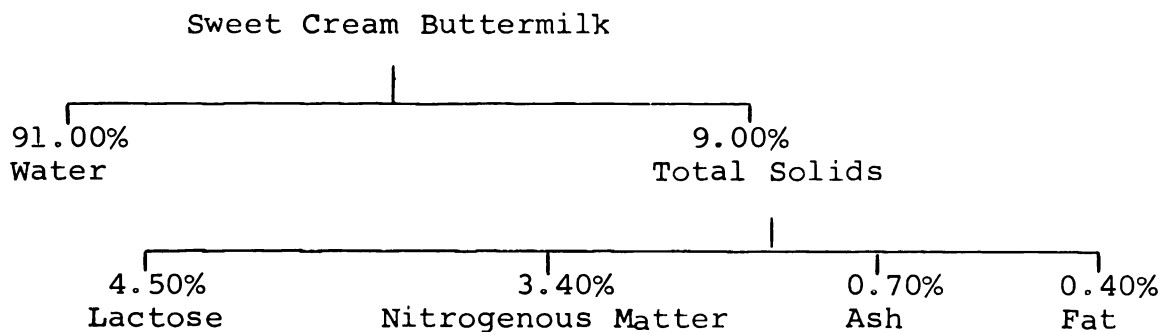


Figure 2. Typical composition of sweet cream buttermilk. (Whittier and Webb, 1950).

Spray-drying of buttermilk and whey

Sweet cream buttermilk is condensed and spray-dried without further treatment unless it is to be used for bakery products. Fluid buttermilk intended for use in bakery products is processed through an additional supplementary heat treatment (Coulter and Jenness, 1964). If whey is condensed and spray-dried in the same manner as the buttermilk, the resulting product is not completely satisfactory for commercial use: upon exposure to air, the dried whey absorbs moisture and the lactose component crystallizes, causing the powder to cake.

Various procedures and equipment have been designed and patented for producing a free-flowing dry whey (Coulter and Jenness, 1964). These methods generally involve crystallization of the lactose. As early as 1933, Eldredge patented the process of mixing the spray-dried whey with 8 per cent water, allowing the mixture to stand for 2-3 hours to form a cake, and then grinding the cake to form small particles. Today, Cheddar cheese whey is generally condensed to 50-55 per cent solids and spray-dried so that the powder contains approximately 10 per cent moisture. Lactose is then allowed to crystallize for a period of time and the powder is redried to not more than 5 per cent moisture to meet top (extra) grade requirements.

If cottage cheese whey is dried in the same manner as the Cheddar cheese whey, the resulting product is sticky

and clings to the walls of the drier. A method for producing free-flowing acid whey solids was developed by Hanrahan and Webb (1961). Briefly, this process involves pumping a nontoxic gas, such as nitrogen, at high pressure into the whey just before it reaches the spray nozzle. As soon as the whey is atomized, it loses the increased pressure brought about by nitrogen injection, and this expansion of the gas forms particles of foam. Whey dried in this manner is very porous, has increased surface area, is only slightly hygroscopic, and can be more easily handled.

Compositional differences between foam spray-dried acid whey solids and sweet cream buttermilk solids

Both foam spray-dried acid whey solids and sweet cream buttermilk solids contain similar components, but the proportion of the components differ. Foam spray-dried acid whey solids contain less fat and protein and more lactose, lactic acid, and ash (Table 1) than do sweet cream buttermilk solids. The by-products differ substantially in the nitrogenous matter, particularly the type of protein present. In the manufacture of cottage cheese, the lactalbumin and lactoglobulin remain in the fluid whey, whereas the casein is coagulated and precipitated in the curd (Whittier and Webb, 1950). Increased amounts of protein remain in the buttermilk by-product because casein is not precipitated in the production of butter.

Table 1. Average composition of dried sweet cream buttermilk solids and foam spray-dried acid whey solids.

	Sweet Cream Buttermilk ^a	Acid Whey ^b
	%	%
Moisture	3.0	3.0
Fat	5.0	1.0
Protein	36.0	11.9
Lactose	46.7	63.7
Lactic Acid	1.4	8.4
Ash	7.9	11.02

^aWebb and Johnson, 1965.

^bStine and Sargent, 1963.

Types and Uses of Dried Whey Solids

Dried whey solids are usually classified according to three types: (1) regular or sweet; (2) fortified or modified; (3) acid. Each type contributes certain distinct characteristics and advantages to food products in which they are incorporated.

Regular or sweet whey

Regular or sweet whey is the residual by-product from the manufacture of Parmesan, Swiss and Cheddar type cheeses (Habighurst and Singleton, 1965). This type of whey has been used successfully for years, because its low acid content allows the fluid whey to atomize readily and to dry without the formation of lumps in the spray-drying

equipment (Hanrahan and Webb, 1961). Properly processed, the dried powder resists moisture pickup but readily absorbs water when reconstituted (Habighurst and Singleton, 1965). Regular or sweet dried whey solids are versatile and improve quality characteristics of many products at a reduced cost to the food manufacturer.

Sweet whey can be easily and profitably incorporated into baked products. Heat coagulable proteins, lactalbumin and lactoglobulin, contribute to product structure during baking: lactose promotes desirable browning (Alesch, 1958). Incorporating 15% dried sweet whey in cakes containing 20-40% fat and 100% sugar, based on the weight of flour, gave the cakes improved crumb characteristics as well as promoted more desirable flavor, browning, and keeping quality (Hanning and de Goumois, 1952). Cakes containing whey were larger in volume and scored higher for texture, tenderness, and flavor at all fat levels. Taste panel evaluation indicated a reduction in fat content of cakes from 40 to 30%, 30 to 25% or from 25 to 20% could be adequately compensated for by the addition of 15% whey to the cakes of lower fat content.

More recently, proteins and lactose of Cheddar cheese whey have been separated and individually added to baked goods in an effort to determine the separate contributions of these two main components of whey to the quality characteristics of baked products. Hofstrand et al., (1965) found whey proteins and lactose to have opposite

effects on cake doughnut quality. Added whey proteins resulted in a more elastic dough, a firmer crumb, and decreased fat absorption, compressibility, and general eating quality. Addition of the lactose component of whey decreased dough elasticity and increased compressibility and fat absorption. The volume was markedly decreased when whey proteins were used but little affected when additional lactose was used. The researchers postulated that the reduced volume with increased amounts of protein was the result of lowered initial coagulation temperature, causing the protein to coagulate before the doughnut had expanded to maximum volume.

Fortified or modified whey

Fortified or modified whey is produced by adding protein such as milk protein (casein), NFDM, or soya protein to regular or sweet whey (Singleton et al., 1965). With the addition of these hydrophilic substances, the water binding capacity of the products in which they are incorporated is increased. Addition of this type of whey to the bread formula produces a dough which is more elastic and easier to handle in the equipment, and which has less chance of being overmixed. Fortified or modified whey can be used in place of NFDM at a savings in production cost. From the nutritional standpoint fortified whey exceeds NFDM in thiamine, riboflavin, calcium, sodium,

lactose, Vitamin A, pantothenic acid, and choline; and because of the increased amounts of whey proteins, lactalbumin and lactoglobulin, it is richer in lysine and tryptophan. Bread in which this type of whey is incorporated has the added advantages of softer crumb, improved texture, even crust color, and more flavor.

Acid whey

The latest type of dried whey solids with important potential application for the food industry is the acid type (Singleton et al., 1965). Acid whey is the fluid remaining after the coagulated curd of cottage or cream cheese is removed. Since initiation of the new processing technique, commonly known as "gas injection" spray-drying, possible uses for dried acid whey have become much more extensive.

Acid whey solids, substituted for normally used milk solids, add desirable properties to sherbets and produce high quality products (Potter and Williams, 1949). These investigators found that when cottage cheese whey was used in place of milk solids in sherbets, it was unnecessary to add citric acid to sherbet mixes. By using acid whey solids instead of milk solids the manufacturer could realize a saving in ingredient cost of 10 cents per 100 pounds of sherbet base. Recent research by Blakely (1964) indicated that good quality sherbets with smooth

texture were obtained when foam spray-dried acid whey solids replaced 25, 50, 75 and 94.5 per cent of the serum solids in orange, lemon, and raspberry sherbets.

Shortened Cakes

Cakes are classified according to two types: those made without fat or chemical leavening agents, commonly known as angel food or sponge cakes, and those made with fat and generally a chemical leavening agent included, called butter or shortened cakes (Griswold, 1962). Cake batter structure of a shortened cake is considered to be a dispersion of air in fat which is distributed in a flour-liquid medium (Carlin, 1944). This foam structure and its relation to batter viscosity is of crucial importance in the production of a high quality cake. In addition to batter viscosity, some other indices related to cake quality are pH of the batter and cake, specific gravity of the batter, and textural characteristics of the cake. Production of a cake which is sufficiently tender yet rigid and one which has good body, texture, and flavor, requires the attainment of a delicate balance of ingredients. Some of the ingredients which promote this balance are flour, milk, egg, fat, and sugar.

Functioning of ingredients

Gluten developed in the flour and the proteins of milk and egg are constituents which contribute to batter

elasticity and allow the batter to stretch around gas bubbles and entrap them in the batter. Because only a minimal amount of gluten development is desirable in cake batters, soft flour with high starch and low protein content is usually chosen (Meyer, 1960). Carlin (1944) observed that very few, if any, new bubbles were formed from the chemical leavener, baking powder, but that diffusing carbon dioxide merged into the gas bubbles previously formed during the creaming of shortening and sugar or entrapped in the sifted flour. Because protein elasticity allows for retention of gas bubbles and the carbon dioxide tends to move into already existing air bubbles rather than forming new ones, overmixing and rough handling should be avoided so as to prevent loss of the bubbles formed in the batter. During baking, lightening of the batter is due to the release of carbon dioxide and expansion of the carbon dioxide and air within the bubbles, and a semi-rigid cake structure is formed by the gelatinization of the starch and the coagulation of the egg and milk proteins (Meyer, 1960).

Fat and sugar in cake recipes increase tenderness, but decrease elasticity of cake batters. By retarding the development of gluten, sugar aids in promoting cake tenderness. The emulsifying agents contained in the fat help retain gas bubbles in the batter and distribute fat more evenly throughout the batter. Fats containing added emulsifiers produce batters with less tendency to curdle and

permit the incorporation of larger proportions of sugar and liquid in the cake formula. This results in a sweeter, more moist cake (Meyer, 1960). Carlin (1944) found that cake batters made with fats containing monoglycerides were less viscous than batters made from the same fat without the monoglycerides and that the emulsified fat produced a better cake. A study of the bubble mechanics in cakes by Handleman et al., (1961) indicated that when unemulsified shortening was used in the cake formula, bubble-to-bubble diffusion was slow; therefore, since leavening gas evolved only into a relatively small number of the bubbles, these bubbles attained buoyancy, rose to the top and were lost from the batter. These authors theorized that the reduced volume observed in cakes containing unemulsified shortening resulted from the loss of gas by this bubble-to-bubble diffusion mechanism.

Cake batter viscosity

A relationship exists between the viscosity of the cake batter and the batter structure. Collins (1940) added fat soluble dyes to plain cake batters in order to study batter structure more easily. She found that thin batters contained a few large sized gas bubbles dispersed irregularly throughout the batter. Thin batters were not viscous enough to hold the air incorporated during the mixing procedure or the gas liberated by the baking powder.

Conversely, gas bubbles were small, numerous, and evenly distributed in thick batters. Thin batters were darker and more intense in color whereas the thicker batters appeared lighter in color. The amount of air held in the batters may have, in part, determined the intensity of the color as large numbers of gas bubbles increase the dispersion of the dye particles which, in turn, results in a batter of lighter color. Less viscous batters were associated with oil-in-water emulsions while more viscous batters were found to be water-in-oil emulsions.

Batter viscosity correlates with cake quality. In cake batters where the proportion of ingredients is balanced, thin, runny batters produced inferior cakes and viscous batters produced more desirable cakes (Lowe, 1955). A relationship between batter viscosity and cake volume was noted by Swickard (1941), who observed that as batter viscosity increased from thin to thick, corresponding increases in volume were noted. Cakes made from more viscous batters received higher ratings by taste panel members for tenderness, texture, moistness, and flavor.

pH of the batter and cake

As pH of the cake is varied from the alkaline to the acid range, a corresponding change in cake attributes is noted (Cathcart, 1951). If the pH of the batter or cake is alkaline, there is a tendency for the color of the cake to become darker, have a coarse, open grain, and poorer

keeping qualities. A lighter colored, denser cake with better keeping qualities is produced when the pH of the cake is acid.

Because many factors influence the pH of the batter and cake, determining optimum range of pH values for cakes is very difficult. The functioning of the baking powder as the principal leavening agent in cakes involves the reaction between the acid salt, such as monocalcium phosphate, and the alkaline baking powder base, sodium bicarbonate (Maselli and Pomper, 1960). As a result of this interaction, salts such as sodium phosphate form and the leavening gas, carbon dioxide, evolves. Because of the loss of some carbon dioxide, and consequently of acid, during mixing and baking, the pH values of the batter during the early stages of mixing tend to be lower than pH of the batter at the end of the mixing process or the final pH of the cake. Protein-containing materials such as flour, milk, and eggs tend to buffer the effect of the baking powder and minimize changes in batter and cake pH. The pH of other ingredients used in cake production have been recorded by Cathcart and can be found in the article by Maselli and Pomper (1960). Because all ingredients used in the cake formula in some way influence total pH values for cakes, ingredient pH should be considered in arriving at optimum pH ranges for cakes.

Specific gravity of batter

The specific gravity of cake batter is the ratio of the weight of a designated volume of batter to the weight of an equal volume of water (Cook, 1963). This measure can be used as a quality control factor since it indicates the amount of batter aeration. Desirable specific gravity values for certain cake batters are sponge cakes, 0.50, and layer cakes, 0.65 to 0.75. Values lower than the optimum range indicate overaerated cakes. Higher values indicate denser batter which results in cakes with lower volume and more compact texture. With changes in mixing procedure or quantity or quality of ingredients used, specific gravity readings should be taken and alterations made to obtain optimum range values since cake characteristics such as grain, texture, tenderness, and volume are readily affected by the specific gravity of the batter (Ellinger and Shappeck, 1963).

Textural characteristics

Texture of batter products refers to the size of the gas bubbles, grain, thinness or thickness of the cell walls, and sometimes includes tenderness measurements (Meyer, 1964). Measurement of tenderness is complicated because its meaning varies in relation to the type of food being evaluated (Griswold, 1962). Objective measurement of tenderness must imitate and reproduce the cutting,

grinding, and squeezing action normally made by teeth. In addition to tenderness measurements, objective evaluation of cake textural characteristics may be made by measuring the resistance to compression. Compressibility relates to the softness or firmness of the product, and is measured by determining the distance a known force or weight depresses the cake crumb or the amount of weight or force necessary to depress the cake crumb a certain distance. Compressibility is a measure of cake aeration and structural rigidity (Hunter et al., 1950).

Textural quality of cake may also be evaluated by determining tensile strength. Platt and Kratz (1933) developed the original method for obtaining tensile strength values for cakes. Tensile strength is an indication of the amount of force necessary to pull a piece of cake apart. In this measurement, an hourglass shaped piece of known dimensions is pulled apart by the weight of water flowing into a cup suspended from the bottom of the piece of cake. During the staling process of sponge cake, Platt and Kratz found that tensile strength was inversely related to compressibility: values for tensile strength increased when compressibility values decreased.

Chocolate Cakes

Chocolate cakes vary greatly in kind and quality. When cocoa or chocolate is added to a plain cake formula, the batter becomes more acid, thicker, and less sweet

(Griswold, 1962). Cocoa products may be added to a white or yellow cake formula without being detrimental to quality as long as the amount added ranges approximately from 10 to 15%, and the amount of flour is reduced by the weight of the cocoa less its fat content (DeGrood, 1959). Since the color of chocolate cake is related to pH, the proportion of ingredients affecting the pH level of the cake must be controlled to produce a cake which is acceptable both in taste and appearance.

pH of chocolate cakes

The color of chocolate cakes becomes a more desirable brown or reddish-brown as the pH is made alkaline by the addition of soda and the flavor becomes less desirable as the pH increases (Lowe, 1955). Use of sufficient quantities of sodium bicarbonate in a chocolate cake formula to give the cake a pH higher than 8.0 will cause a detrimental effect to taste (Grewe, 1930). Chocolate as a color constituent and indicator in cakes is yellow at pH 5.0 and changes to red at pH 7.5. Changes in color with the corresponding change in pH are indicated in Table 2.

Table 2. The pH of a chocolate cake as related to color (Cathcart, 1951).

pH	Color
5 - 6	cinnamon
6 - 7	brown
7 - 7.5	mahogany
7.5 - 8	red-mahogany

Color of chocolate cakes

A wide range of variation exists in the color of chocolate cakes and it is important to produce a cake which appeals to the consumer's eye. Using the Munsell system, Grewe (1930) found that as the milk acidity decreased, the color of the cakes became deeper, i.e., a dark chocolate cake was produced when sweet milk was used and a much lighter one was produced by strongly acid milk. This agrees with Lowe (1955), who stated that a deeper red or mahogany shade chocolate cake is produced with sweet milk and soda than with sour milk and soda.

The type of chemical leavener and the amount of time the batter sets before baking also influence the color of chocolate cake (Lowe, 1955). The color is always darkened with the use of soda and lightened with the use of baking powder. The type of baking powder exerts some effect on color: phosphate and tartrate type baking powders produce a reddish color and the sulfate-phosphate type produces a relatively darker brown. A deeper mahogany color results when the batter sets 10 to 15 minutes after mixing than when baked immediately after mixing. Change in cake color may be due to one factor or to a combination of factors.

Objective Measurements

Objective measurements are used to determine differences between food products because they are more reproducible and less subject to error than subjective methods. Data from any instrument used for objective testing should generally be in agreement with data from sensory evaluation. Color, tenderness, compressibility, and tensile strength are the characteristics of baked products most commonly evaluated by objective measurements.

General methods of color measurement

The color of food is often evaluated subjectively by panelists. Although vast numbers of different shades of color can be differentiated by the human eye, color perception differs with each individual. Keeping in mind a color standard from one scoring session to the next is also difficult for the panelist. Precise, objective, and reproducible measurements are needed for determining color differences (Mackinney and Chichester, 1954).

Many methods and instruments are available for color measurement. Although some are more reliable than others, they may also present many problems. The Munsell charts, containing 982 colors, and the Maerz and Paul Dictionary of Color, containing 7056 colors, are quick and fairly satisfactory methods for determining color of a food by matching the sample with a color in a book.

Color is also determined with the Maxwell discs, using the Munsell system of notation. In this method discs are slit and slipped together, spun at a rate of speed sufficient to give the appearance of a solid color, and adjusted until the spinning color matches the sample color. All of these methods, however, depend on a visual estimation of color (Triebold and Aurand, 1963).

The basic instrument, recognized by the American Standards Association as fundamental to the standardization of color, is the spectrophotometer. This instrument measures the amount of light reflected by the object in each part of the spectrum (Judd and Wyszecki, 1963). Intensity of the light is plotted on a graph against wavelength. This instrument has the advantage of being precise and objective, but it is expensive and interpretation of the data requires much time and skill (Mackinney and Chichester, 1954).

Tristimulus filter colorimeter (Gardner Color Meter)

The Gardner Color Meter determines color differences on the bases of three scales (L , a_L , and b_L in comparison with the color of a standard plate (Endres, 1965). A light source from the instrument strikes the sample at a 45° angle and is, in turn, diffused perpendicularly from the sample back into the machine. This reflected light then passes through each of three filter photocells which in turn create a current by which the light's intensity can be measured.

For a machine reading to correlate well with the visual estimate made by the eye, color should be determined on more than one coordinate (Francis, 1963). The Gardner Color Meter measures lightness of an object by the L scale so that the median point between black and white has the value 50 (Endres, 1965). Perpendicular to this white-black axis are the color solid rectangular coordinates, a_L , and b_L . A negative value on the a_L scale indicates greenness and a positive value redness; a negative value on the b_L scale indicates blueness and a positive value yellowness. Values determined by this instrument can be converted to any of the other standard systems of color measurement (Mackinney and Chichester, 1954).

Problems of color measurement

The accuracy of the tristimulus filter colorimeters depends on the accuracy of the response achieved by the combination of the filter, photocell and the light source. Difficulty in measuring occurs when a white reference point is used because a large color difference between the measured sample and the reference point usually results. As the difference between the standard and the observed color increases, the uncertainty and discrepancy in the measurement increases (Mackinney and Chichester, 1954).

Accurate color measurement is difficult with white and black. White reflects almost all of the light striking the surface, and black absorbs most of the energy falling

on its surface. Black and white are nonselective in their reflectance because they do not reflect one part of the color spectrum more than another (Judd and Wyszecki, 1963). Uncertainty in distinguishing different colors with the Gardner Color Meter increases as the extremes of black and white are approached, because the current decreases as the radiant energy falling upon the photocell decreases. Obtaining accurate readings at low intensities is impossible (Mackinney and Chichester, 1954).

The non-homogeneous character of food samples presents another problem with color measurement. Many foods are not homogeneous; consequently, a composite reading from a heterogeneous sample must be made. This can be done by using a suitable instrument or by actual physical manipulation. The Purdue Color-Ratio Meter has a series of photocells located in a circle and the reading is a composite of responses from all of the cells. With the Hunter color-difference meter, arithmetic means of several spot readings must be computed unless a specially adapted attachment is procured which spins or rotates the sample and gives one average reading. In a study on the methods of presenting raspberry and strawberry samples to the Hunter color-difference meter (Tinsley et al., 1956), a high correlation was observed between the means of spot and rotation values. Although there was a high correlation between blended samples and the rotation and spot values, the L , a_L , and b_L values were considerably lower in the case of the blended samples.

Shear press

Kramer et al. (1951) developed an instrument, the shear press, to measure the tenderness of lima beans. After his initial adaptation of the shear press to food products, researchers expanded its use to include other vegetables, meats, and baked products (Kramer, 1961). The basic component of the shear press is a hydraulic system which moves a piston with an even application of force at a pre-determined rate of speed. Resistance by a food product being tested to the force exerted is recorded on an electronic recording attachment. Proving rings, with ranges from 100 pounds for measuring soft materials to 5000 pounds for hard products, eliminate frictional error which might give inaccurate readings. The recorded time-force curves may be read as the maximum force, which is the peak shear value or as the total work, which is determined by measurement of the area-under-the-curve (Endres, 1965).

Shear press measurement of cake tenderness, compressibility, and tensile strength

Procedures for measurement of compressibility, tenderness, and tensile strength of angel cakes were developed by Funk et al. (1965). Cakes designated according to three degrees of toughness, based on the amount of flour added to a basic cake mix, were subjectively evaluated by a

taste panel for tenderness, moistness, and texture. The same cakes were objectively evaluated by the Kramer shear press for tenderness, compressibility, and tensile strength. High correlations were found between the Kramer maximum-force shear press values of tenderness, compressibility, and tensile strength and the panel evaluations of tenderness, cell wall thickness, cell size and moisture. From this investigation, the authors concluded that the quality characteristics of angel cakes could be evaluated with sufficient precision using the Kramer shear press.

Brown (1964) evaluated the functional properties of albumen by comparing angel cakes prepared from five types of albumen. She concluded that significant differences in compressibility of angel cakes resulted when the cakes were prepared with the different types of albumen. No significant differences, however, were found between the cakes for tenderness and tensile strength values. It is conceivable that because of the lack of use of an optimum range in these measurements, existing differences may not have been recorded. She also concluded that, while her findings were in conflict with those of Funk et al., (1965) the differences in her cakes may not have been gross enough to have been recorded by the shear press.

Butter cakes differ considerably in textural characteristics from foam cakes. Gruber and Zabik (1966) investigated the feasibility and limitations of using the Kramer shear press as an objective indicator of tenderness,

compressibility, and tensile strength of butter cakes. Results obtained from the study showed tenderness to be the best of the methods tested for determining textural characteristics of butter cakes; differences in compressibility and tensile strength were detected only between very tough and tender cakes. Highly significant correlations between sensory evaluations and shear press measurements indicated to these researchers that objective measurement of butter cake characteristics by the Kramer shear press could be used in lieu of sensory evaluations.

Subjective Evaluation

In food research, recognizing and identifying differences in quality characteristics of food products is necessary (Boggs and Hanson, 1949). Estimation of differences in food samples can be effectively made by a small panel of judges. Numerical scoring of product characteristics by panel members is useful for obtaining a basis by which product quality can be controlled and changes caused by methods and ingredients can be evaluated (Meyer, 1960). Qualities commonly evaluated in baked products are: appearance, symmetry, color of crust and crumb, texture, aroma, moistness, tenderness, flavor, and general eating quality.

Boggs and Hanson (1949) reported that application of particular procedural methodology will help obtain more accurate experimental results. Higher accuracy can be

obtained when there is a minimum of within-sample variation; a limited number of samples and characteristics are to be judged; all samples for which comparative data are desired are submitted at one time; and a sufficient number of replicates are included in the investigation so that trends can be repeated and so that the data can be statistically analyzed.

Past experiences condition human beings to non-objective responses, a limiting factor in food evaluation. In an experiment to estimate the extent to which memory taste affected actual taste, Dunker (1939) gave white chocolate to panelists to be evaluated for flavor. No flavor difference from regular brown chocolate was reported when panelists were blindfolded; when the blindfold was removed, the white chocolate was thought to taste less like the customary brown product. In this experiment, panelists found it difficult to isolate and examine just the aspect of flavor without being influenced by the previous visual concept of how they expected chocolate to look.

Panel evaluation is usually desirable, not as an entity in itself for evaluating food acceptability, but as a basis for correlation with chemical and physical measurements (Boggs and Hanson, 1949). Use of particular objective measurements, however, should be contingent upon agreement with sensory evaluations, and these objective tests should provide a true measurement of the quality

factor being studied (Funk et al., 1965). If objective measurements could be developed that would correlate very highly with sensory evaluations, these researchers proposed that the need for sensory evaluation might be consequently eliminated in future studies.

EXPERIMENTAL PROCEDURE

This research was initiated to determine whether foam spray-dried acid cottage cheese whey solids could be satisfactorily substituted for buttermilk solids in a chocolate cake formula. Results of preliminary experiments substituting foam spray-dried acid whey solids for buttermilk solids in a standard chocolate cake recipe indicated that an acceptable cake can be produced when foam spray-dried acid whey solids are used in part, if not completely, for buttermilk solids. To ascertain what effect substitution would have, all other factors known to affect quality of the cakes were carefully controlled.

Design of Experiment

A standard chocolate cake formula which included 90.8 g of buttermilk solids was the control cake, and subsequent variables included partial to complete replacement of the buttermilk solids by the foam spray-dried acid whey solids in the same formula according to the following schedule:

Variable	Buttermilk solids	Whey solids
1 (control)	100%	0%
2	75%	25%
3	50%	50%
4	25%	75%
5	0%	100%

Five replications of each variable were prepared and submitted to subjective evaluation and objective measurement of quality characteristics to determine maximum substitution of whey for buttermilk solids consistent with good quality.

Chocolate Cake Formula

The formula selected for use in this study was adapted from a standard quick-mix chocolate cake recipe (KitchenAid Recipes).¹ Cakes were made according to the following formula:

	Amount	% of Flour
Cake flour	672.0 g	100.0
Baking Powder	10.8 g	1.6
Soda	8.0 g	1.2
Salt	18.0 g	2.6
Sugar	800.0 g	119.0
Shortening	282.0 g	41.9
Vanilla	15 ml	2.2
Egg	288.0 g	42.8
Chocolate	170.1 g	25.3
Distilled water	900.0 g	133.9
Milk solids (buttermilk and/or whey)	90.8 g	13.5

Ingredient Procurement

Basic formula ingredients

Common lots of cake flour, baking powder, soda, salt, sugar, shortening, vanilla, chocolate, and buttermilk solids were obtained from the Michigan State University

¹KitchenAid Recipes, Hobart Manufacturing Co., Troy, Ohio (1962), p. 11.

Food Stores. Composition of buttermilk solids is listed in Table 3 (Van Winkle, 1966). Cake flour and sugar were weighed to the nearest gram on a 5-kilogram torsion balance and salt was weighed to the nearest 0.1 gram on a trip balance. Cake flour, salt, and sugar were then mixed, packaged in closed polyethylene bags, and stored at room temperature. Shortening was weighed to the nearest gram in plastic bowls, packaged in polyethylene bags and stored at 4-5°C. Vanilla, baking powder, and soda were stored at room temperature in closed containers and measured on the day they were used.

Table 3. Average composition of Chef-lac sweet cream buttermilk solids (Van Winkle, 1966).

Protein	34.0%
Butterfat	5.0% (min.)
Moisture	3.0% (min.)
Titratable acidity	1.75%(min.)
Sodium content	0.54%

The Michigan State University Poultry Department furnished a common lot of eggs which were broken, thoroughly blended, and portioned into plastic-lined cardboard freezer containers. The eggs were then blast frozen at -40°C and stored at -23°C. Before using, these frozen eggs were thawed at 4-5°C for 24 hours and warmed to 25°C before use in the cakes.

Processing the whey

The whey was dried and concentrated for ease in handling as the water content of cottage cheese whey is approximately 93.5% (Hanrahan and Webb, 1961). The Michigan State University Dairy Plant furnished the cottage cheese whey and the Food Science Department processed the whey according to the procedure designed by Hanrahan and Webb (1961). The average composition of the foam spray-dried acid whey solids used in this experiment is indicated in Table 4.

Table 4. The composition of foam spray-dried acid cottage cheese whey solids (Stine and Sargent, 1963).

	<u>Percent</u>
Protein	11.94
Fat	1.02
Moisture	3.00
Acidity	8.39
Lactose	63.70
Ash	11.02

Concentrating the whey. Whey was concentrated by the procedure outlined by Blakely (1964). In order to remove particles of curd, all cottage cheese whey used in this experiment was filtered through a single gauze faced 6 1/2-inch Rapid-Flo filter disk. Prior to foam spray-drying, whey preheated to 46°C was concentrated to approximately 50% total solids in a 16-inch Rogers vacuum pan.

Foam spray-drying. Between the main pumping tank and the spray dryer, nitrogen under a pressure of 1050 lbs./sq.in. was injected into the main line at a rate of 2.0 cu. ft./gal. and mixed with the whey. This served to expand the spray droplet and make it less dense. In a Rogers co-current horizontal inverted tear-drop dryer, equipped with a Spraying Systems type SPC 6 nozzle with a 0.040 inch orifice diameter, the expanded whey droplet was dried and collected for storage in polyethylene bags. During spray-drying, average inlet and outlet temperatures were 127°C and 85°C respectively. This foam spray-dried acid whey was refrigerated at 4-5°C until time of use.

Method of Preparation

To insure even distribution of the dry ingredients, the previously weighed cake flour, salt, sugar, and milk solids (buttermilk and/or whey depending on the variable) were dry-blended using a paddle attachment in a 12 quart bowl Hobart model A-200 for 5 minutes. Shortening, vanilla, and 450 g of distilled water were added to the dry ingredients and mixed using speed 2 (90 rpm) for 1 minute and 45 seconds. The bowl and paddle attachment were scraped. Soda and baking powder were weighed to the nearest 0.1 g, added to the mixture, and blended using speed 3 (162 rpm) for 15 seconds. The bowl and paddle were again scraped, and the chocolate, egg, and remaining portion of distilled water were mixed into the batter for

2 minutes using speed 2 (90 rpm).

Baking and Storing Procedure

Using a 5-kilogram capacity torsion balance, 1400 grams of batter were weighed into each of two 14 1/2 x 4 x 4-inch oblong aluminum loaf pans. The number of large air bubbles were reduced by cutting through the batter with a metal spatula. The 2 pans were placed side by side, approximately 4 inches apart, on the middle shelf of an Etco forced convection oven, model 1860 A, and baked for 55 minutes at 177°C. After baking, the cakes were allowed to cool on racks at room temperature for an hour. When volume measurements were obtained, the cakes were removed from pans and put on cardboard bases, then placed in polyethylene bags, labeled with predetermined coded numbers, tied and immediately frozen at -23°C.

Preparation of Samples

The two frozen coded cakes from each replication of each variable were allowed to thaw for 18 hours. Then the contour, surface, and surface color were subjectively evaluated by four judges. One of the two cakes of each replication was used for objective evaluation and the other for taste panel evaluation. To obtain identical slice thickness of cake samples for objective measurements, one of the partially thawed cakes was sliced using a Hobart electric slicer, model 410, set at 60. Shear press samples

were cut with appropriately shaped cutters for shear press evaluation. All samples were tightly wrapped in Saran to prevent dehydration. The first replication of the control and each variable were cut and tested according to the predetermined sequence presented in Figure 3. To assure randomized samples, subsequent replications were subjected to the rotational pattern described by Funk et al., (1963).

1.	CRUST
2.	pH
3.	Tenderness
4.	Compressibility
5.	Color
6.	Tensile strength
7.	Extra
8.	Tensile strength
9.	Extra
10.	Tenderness
11.	Tensile strength
12.	Compressibility
13.	Color
14.	Tensile strength
15.	Tenderness
16.	Compressibility
17.	Tenderness
18.	CRUST

Figure 3. Sequence for cutting and testing the slices of chocolate cake for objective measurement.

Since the slicer had a tendency to mask the texture, the cakes for taste panel evaluation were cut with a serrated edge cake knife to the approximate thickness of the slices made by the Hobart slicer. Again, cakes were cut according to a predetermined sequence of slicing (Figure 4). Cake slices designated for taste panel members were rotated according to the pattern used by Funk et al., (1965).

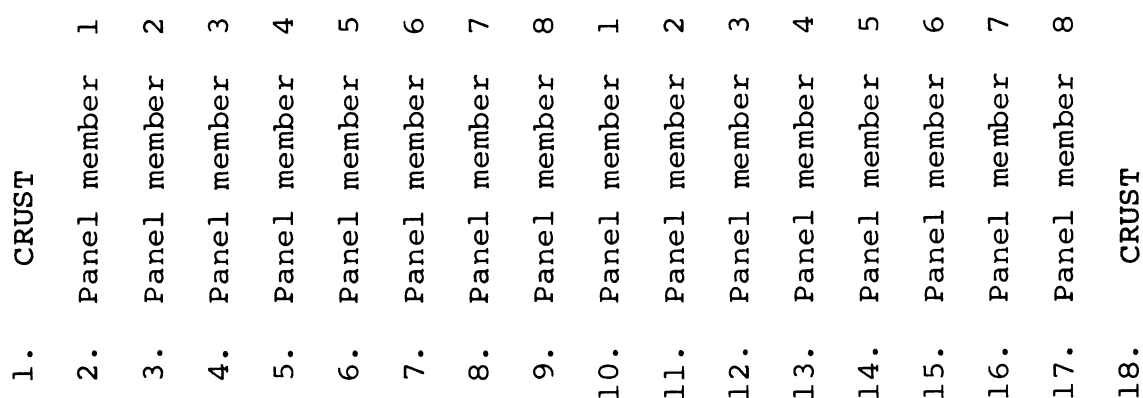


Figure 4. Sequence for cutting and testing the slices of chocolate cake for taste panel evaluation.

The taste panel consisting of eight members evaluated inside characteristics of color, texture, moisture content, tenderness, and flavor. To prevent the outside edges from affecting consideration of the inside attributes, a round cutter 5.73 centimeters in diameter was used to cut uniform samples from the center of each piece of cake. The cake samples were placed on 6-inch randomly numbered paper plates and the cake sample and plate were tightly wrapped in Saran to prevent dehydration until evaluated by the panel members.

Objective Measurements

Objective tests were used to evaluate both the batter and the cake. Measurements of the batter characteristics included pH, viscosity, and specific gravity. Prior to freezing, volume determinations were made on the cakes. Thawed cakes were evaluated for pH, inside color, tenderness, compressibility, and tensile strength.

pH of batter

The pH determinations were made on the cake batter with a Beckman Zeromatic pH meter equipped with calomel and glass electrodes. A 25-g aliquot of batter was placed in a 100-milliliter beaker and the pH of the batter was recorded. The value was obtained by averaging readings of two trials.

Specific gravity of batter

The method of Platt and Kratz (1933) was used to determine the specific gravity of the cake batter. Comparison was made of the average weight of 1/2 cup of batter at 25°C to the average weight of 1/2 cup of water at 25°C. Cake batter was poured into a metal 1/2 cup measure, leveled with a metal spatula and weighed on a balance accurate to 0.1 g. The final reading was an average of two trials.

Viscosity of the batter

Batter viscosity was determined using a Brookfield viscometer, model RVT equipped with a No. 5 spindle rotating at 200 rpm. A 300-milliliter sample of batter was placed in a 500-milliliter beaker. The spindle was submerged in the batter, with care not to entrap any air which would affect the validity of the readings. The spindle was allowed to rotate in the liquid for 10 seconds and the

first reading was taken. The spindle was then allowed to rotate in the batter for an additional 10 seconds and the second reading was taken. These two recorded determinations were averaged and multiplied by a conversion factor provided by the company to obtain the final viscosity value.

Volume of the cake

Volume was measured by the seed displacement method used by Brown (1964). While the cakes were still in the pans, Saran was molded to fit the contour of the surface of the cake. Rape seed was then poured into the cake pan to overflowing, and a metal spatula was used to level it with the top of the pan. The rape seed in the cake pan was poured carefully from the pan and measured in a 1000-milliliter graduate cylinder. The difference between the amount of seed which filled the pan when empty and the pan with the cake in it was the volume of the cake. Each value was an average of two determinations.

pH of the cake

A 25-g sample of cake was taken from the center of each cake slice and blended with 50 milliliters of distilled water for 1 minute on the low speed of an Osterizer blender. The pH was read after the electrodes had been inserted in the mixture for 1 minute. Each value was computed as the average of three cake samples.

Color measurement

The Gardner Color Difference Meter, Model AC-1, was used to measure the color of the cake samples. The instrument was standardized in preparation for determining the L (lightness), a_L (greenness), and b_L (yellowness) values with the white tile (L , 90.9; a_L , -2.0; b_L -2.5). Each slice of cake was placed on a plate glass (4 3/4 in. x 3 5/8 in. x 1/8 in.), the assembly was placed over the viewing area and readings were taken from two different positions. Color analysis was based on L , a_L , and b_L values. Each average for the control and four variables were based on four readings, two readings for each of two cake slices.

Tenderness of cake

Tenderness was measured using the standard shear-compression cell of the Allo-Kramer shear press, model SP12, equipped with an electronic recorder, model E2EZ. Cake samples, 5.73 centimeters square and 1.78 centimeters thick were weighed and placed in the lower half of the cell. The 100-pound electronic proving ring, a range of 50 pounds and a pressure of 5 pounds was used for this measurement. During a 30-second downstroke, the upper cell assembly sheared through the piece of cake and subsequently recorded values on the chart paper. The sections of the cell assembly were thoroughly washed between each

tenderness determination. The cell assembly was slightly dampened before each determination of cake tenderness.

Two factors, maximum force and area-under-the-curve index, were used as indicators of cake tenderness. Maximum force needed to shear through the sample of cake was calculated as:

$$\frac{\text{Maximum graph reading} \times \text{range.}}{\text{Sample weight}}$$

Each maximum force value was based on an average of three trials. To compute area, the graphed curve was carefully cut out and weighed on a Mettler balance, Model H15. The area was then multiplied by the particular range used in the test to obtain the index. In a study by Funk et al., (1965), a conversion factor of 174.2 for changing gram weight to area had been determined. Thus the weighed graph was changed to area readings by multiplying by the conversion factor. The area-under-the-curve divided by the original sample weight indicated the area-under-the-tenderness curve. An average of three trials was performed on each cake.

Compressibility of the cake

Compressibility was determined according to the method used by Brown (1964). The 100-pound electronic proving ring at a range of 20 pounds and a pressure of 5 pounds was used for this measurement. On a wooden platform at the base of the main column of the shear press, a sample of cake, 5.23 centimeters in diameter and 1.78 centimeters

thick, was centered and depressed by a flat plunger, 5.73 centimeters in diameter which is the upper assembly of the succulometer cell. Each cake sample was depressed to a uniform thickness of 0.72 centimeters on a 30-second downward stroke of the plunger.

Compressibility of the cake samples was indicated in two ways, maximum force and graph-curve-area-index. Maximum force compressibility was calculated as:

Maximum graph reading x range.

Total area was calculated by cutting out the area of the graph enclosed by the reading and weighing it and multiplying this value by the conversion factor. The area was then multiplied by the particular range used in the test to obtain the index. Three replicate trials were performed on each cake tested.

Tensile strength of the cake

Tensile strength was measured by the basic method of Platt and Kratz (1933), and adapted for use on the Allo-Kramer shear press by Funk et al., (1965). For this measurement, the 100 pound proving ring, a range of 1 pound, and a pressure of 5 pounds were used. Cake samples were cut in an hourglass shape which measured 2.54 centimeters across the center and 1.78 centimeters thick. The cake was inserted in clamps and the sample was pulled apart at the center section. A picture of the Allo-Kramer shear press and its operation appears in the paper by Funk

et al., (1965). Tensile strength was calculated, according to the method of Funk et al., (1965), as:

$$\frac{\text{Maximum graph reading} \times \text{range.}}{\text{Area of the break (in cm}^2\text{)}}$$

Tensile strength was based only on maximum force. Three trials were performed on each cake.

Subjective Evaluation

Before cakes were sliced, outside characteristics--contour, surface, and surface color were evaluated by a panel of four judges. After the cake had been cut, a panel of eight judges evaluated the inside characteristics using a 7-point scale. Inside color, texture, moisture content, tenderness, and flavor were considered and indication of the product's acceptability was made. A training session prior to evaluation of the test cakes was held in order to acquaint the panel members with the product and to allow them to ask questions. Directions for scoring, given to the judges, appear in the Appendix.

Outside attributes

Four cakes, two cakes for each of two variables were judged each period. The cakes were coded with previously determined randomized numbers, placed against a grey background and examined under fluorescent 15 watt cool white light bulbs. Each attribute was evaluated on a 5-point hedonic scale, with 5 considered as optimum.

Contour was evaluated for cracking and humping. Slight cracking and a small even hump was considered optimum. The surface was observed for evidence of pinholing. No pinholing was given the highest ratings; whereas, extreme pinholing was considered objectionable and given the lowest rating. Rich, even, brown or reddish-brown was considered the most desirable surface color. A score sheet appears in the Appendix.

Inside characteristics

All samples were coded according to predetermined randomized numbers and evaluated within an hour of cutting, by taste panel judges. All five attributes were scored on a 7-point hedonic scale. Judgment as to whether the product was acceptable or not was indicated and any additional comments were noted. The cake score card appears in the Appendix.

Analysis of Data

Subjective and objective data were evaluated by use of two computer programs on the CDC 3600 Computer at Michigan State University. Simple correlations were determined by the Core routine and analysis of variance by the Rand Routine (Option 1). Significant differences among the cakes made with buttermilk and/or whey were evaluated through the use of the Studentized range tests (Duncan, 1955).

RESULTS AND DISCUSSION

This investigation was initiated to determine the effect of substituting various percentages of foam spray-dried acid whey solids for buttermilk solids on the quality of chocolate cake. Objective and subjective data were examined to ascertain the effect of such substitutions. Methods were developed in the laboratory to control all other variables which might affect the quality of the product.

Objective Measurements

Numerical data from objective measurements were subjected to analyses of variance. Significant differences as indicated by the analyzed variance were further evaluated by use of the Studentized multiple range test (Duncan, 1955). Tables of replicate means, cake type means, and standard deviations for objective measurements accompany the discussion of these results.

Viscosity and volume

Replicate means, cake type means, and standard deviations for batter viscosity and cake volume appear in Table 5. Analysis of variance for batter viscosity of cakes made with varying percentages of foam spray-dried

Table 5. Viscosity, specific gravity, and pH of chocolate cake batter; pH and volume of chocolate cake.

Cake Variable	Replication					Mean/Standard Deviation				
	1	2	3	4	5					
<u>Viscosity of cake batter (cps)</u>										
100% B ^a - 0% W ^b	8480	9100	8820	7720	8560	8536	±	517		
75% B - 25% W	7840	8400	8540	7400	8220	8080	±	462		
50% B - 50% W	8660	7400	7120	7620	8080	7776	±	606		
25% B - 75% W	7020	7300	7460	7660	7560	7400	±	251		
0% B - 100% W	6500	6140	6460	5400	6780	6256	±	530		
<u>Specific gravity of cake batter</u>										
100% B - 0% W	1.19	1.17	1.18	1.17	1.18	1.18	±	.01		
75% B - 25% W	1.21	1.17	1.16	1.19	1.17	1.18	±	.02		
50% B - 50% W	1.16	1.18	1.19	1.19	1.19	1.18	±	.01		
25% B - 75% W	1.20	1.19	1.17	1.18	1.15	1.18	±	.02		
0% B - 100% W	1.17	1.20	1.17	1.15	1.19	1.18	±	.02		
<u>pH batter</u>										
100% B - 0% W	6.5	6.6	6.5	6.4	6.6	6.5				
75% B - 25% W	6.6	6.7	6.7	6.5	6.3	6.6				
50% B - 50% W	6.6	6.5	6.5	6.6	6.5	6.5				
25% B - 75% W	6.5	6.5	6.5	6.6	6.4	6.5				
0% B - 100% W	6.5	6.5	6.7	6.4	6.6	6.5				
<u>pH cake</u>										
100% B - 0% W	6.9	7.1	7.2	7.1	7.2	7.1				
75% B - 25% W	7.1	7.1	7.2	7.1	7.1	7.1				
50% B - 50% W	7.1	6.9	7.1	7.0	7.2	7.1				
25% B - 75% W	7.0	7.0	6.9	7.1	7.1	7.0				
0% B - 100% W	6.9	7.1	6.8	7.0	7.1	7.0				
<u>Volume of the cake (ml)</u>										
100% B - 0% W	2795	2870	2861	2835	2851	2842	±	30		
75% B - 25% W	2819	2839	2851	2860	2814	2837	±	20		
50% B - 50% W	2810	2813	2810	2810	2783	2805	±	12		
25% B - 75% W	2761	2750	2839	2798	2746	2779	±	39		
0% B - 100% W	2719	2799	2800	2780	2715	2763	±	42		

^aB = Dried buttermilk solids.

^bW = Foam spray-dried acid whey solids.

acid whey solids and/or buttermilk solids (Table 6) revealed highly significant differences which could be attributed to substitution of foam spray-dried acid whey solids for buttermilk solids. Comparison of cake type means for viscosity disclosed that cake batters made with buttermilk solids were much more viscous than those made with foam spray-dried acid whey solids. At the 0.1 per cent level of probability, cake batter with 0%, 25% and 50% of the foam spray-dried acid whey solids substituted for the buttermilk solids were significantly more viscous than the cake batters with complete substitution of foam spray-dried acid whey solids for buttermilk solids. Additional differences among variables occurred at the 1% and 5% levels of probability and are shown in Table 6. Batters were progressively less viscous with increasing substitutions of foam spray-dried acid whey solids for buttermilk solids.

Cake volumes analyzed for variance revealed highly significant differences among cake types (Table 7). Comparison of the cake type means indicated that cakes made with buttermilk solids had larger volumes than those made with foam spray-dried acid whey solids. At the 0.1 per cent level of probability, cakes made with complete substitution of foam spray-dried acid whey solids for buttermilk solids were significantly smaller than the control and cakes made with 25% substitution of foam spray-dried acid whey solids for the buttermilk solids. Additional differences among variables at other levels of significance can be found in

Table 6. Analysis of variance for viscosity of the chocolate cake batter.

Source of Variance	Degrees of Freedom	Mean Square	F Statistics
Cakes	4	3729184.0	17.52***
Replicates	4	339704.0	
Error	16	212884.0	
Total	24		

***Significant at 0.1 per cent level of probability.

STUDENTIZED MULTIPLE RANGE TEST^a

100% B	75% B	50% B	25% B	0% B
0% W	25% W	50% W	75% W	100% W
8536	8080	7776	7400	6256

5% level: _____

1% level: _____

.1% level: _____

^aMeans underscored by the same line are not significantly different (Duncan, 1955).

Table 7. Analysis of variance for volume of the chocolate cake.

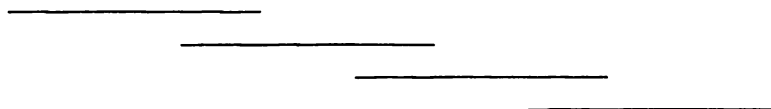
Source of Variance	Degrees of Freedom	Mean Square	F Statistic
Cakes	4	6101.86	11.25***
Replicates	4	2603.56	
Error	16	542.56	
Total	24		

***Significant at 0.1 per cent level of probability.

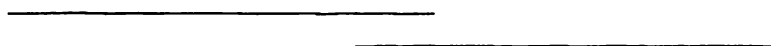
STUDENTIZED MULTIPLE RANGE TEST^a

100% B	75% B	50% B	25% B	0% B
0% W	25% W	50% W	75% W	100% W
2842	2837	2805	2779	2763

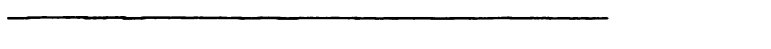
5% level:



1% level:



.1% level:



^aMeans underscored by the same line are not significantly different (Duncan, 1955).

Table 7. Cake volumes become progressively smaller when increasing amounts of foam spray-dried acid whey solids were substituted for buttermilk solids.

It is necessary to examine compositional differences between buttermilk solids and foam spray-dried acid whey solids to ascertain why these significant differences exist. Buttermilk solids contain a substantial amount of the acid or rennin coagulable milk protein, casein, which is for the most part absent in acid whey. Casein helps contribute to batter elasticity and thus allows the batter to stretch around the gas bubbles and entrap them in the batter. In addition, the buttermilk used in this investigation contained five times more natural lecithin than regular milk (Van Winkle, 1966) from which acid whey would be derived. Lecithin is an excellent emulsifier (Lowe, 1955), and helps retain moisture and disperse globules of fat (United States Department of Agriculture, 1959). Addition of emulsifying agents such as lecithin at 3 per cent of the total fat content causes an increase in volume and overall quality score of cake (Meyer, 1964). The presence of this natural emulsifier helps retain the gas bubbles within the cake batter structure. Also, the larger amounts of lactose and lactic acid present in the foam spray-dried acid whey solids may increase cake tenderness, decrease elasticity of the cake batter and thus contribute to the reduction in batter viscosity and volume.

The marked decrease in viscosity with the corresponding decrease in volume observed when acid whey solids were substituted for buttermilk solids suggests that a relationship might exist between the batter viscosity and the volume of the cake. Collins (1941) has indicated that less viscous batters are less able to retain incorporated air within the structure of the batter. Assuming this to be true, it is possible that in the less viscous batter produced by the acid whey solids, some of the incorporated air might have escaped before or during baking. In addition, leavening gas evolving into the smaller number of bubbles present in the less viscous batter might have caused some of these bubbles to become buoyant, rise to the top and be lost from the batter. Therefore, the reduced number of air cells in the less viscous batter might have been the cause for the observed reduced volume of the cake.

The pH of the batter, pH of the cake, and specific gravity of the batter

Replicate means, cake type means, and standard deviations for pH of the batter, pH of the cake, and specific gravity of the batters appear in Table 5. Analyses of variance of these factors revealed no significant differences which could be attributed directly to the substitution of acid whey solids for buttermilk solids. Due to the substantial amount of the acid constituent in the whey, changes in pH values were expected when increasing quantities

of the acid whey solids were incorporated into the formula. However, the buffering effect of the proteins may have been responsible for the small change in pH readings which occurred with the addition of the acid whey solids.

Gardner color difference measurements

Table 8 contains the replicate means, cake type means, and standard deviations for the Gardner color difference measurements. No significant differences were indicated by the analyses of variance for color differences measured by L , a_L , and b_L scales. Some problems in obtaining accurate measurements using this type of instrument are presented in the review of literature. A white reference point was used to measure the color of the cake samples; thus a large color difference existed between the reference point and the dark chocolate color being measured. The chocolate-brown color absorbed much of the machine light, thus making accurate results very difficult to obtain on this instrument at low intensity readings. Because the cake samples were slightly darker at the outside edges, samples were not completely homogeneous. Since no special adaptor was available for obtaining composite readings from rotated non-homogeneous samples, cake slices were mechanically rotated and two readings were taken. It may have been that not enough readings were obtained to get a true representation of color. The texture of the cake presented another limiting factor in obtaining accurate

Table 8. Gardner color difference measurements of chocolate cakes.

Cake Variable	Replication					Mean/Standard				
	1	2	3	4	5	Deviation				
<u>Gardner a_L</u>										
100% B ^a - 0% W ^b	3.4	3.2	3.5	3.2	3.3	3.3	+	.1		
75% B - 25% W	3.0	3.7	3.2	3.2	3.6	3.3	+	.3		
50% B - 50% W	3.9	3.3	3.1	3.4	3.5	3.4	+	.3		
25% B - 75% W	3.8	3.6	3.5	3.8	3.3	3.6	+	.2		
0% B - 100% W	3.4	3.3	3.8	3.7	3.1	3.5	+	.3		
<u>Gardner b_L</u>										
100% B - 0% W	6.2	6.2	6.5	6.2	6.4	6.3	+	.1		
75% B - 25% W	6.1	6.6	6.3	6.4	6.7	6.4	+	.2		
50% B - 50% W	7.0	7.2	6.3	6.6	6.7	6.8	+	.4		
25% B - 75% W	7.3	6.8	6.8	6.9	6.6	6.9	+	.3		
0% B - 100% W	6.9	6.2	7.3	6.9	6.6	6.8	+	.4		
<u>Gardner L</u>										
100% B - 0% W	21.1	22.5	23.8	22.4	23.6	22.7	+	1.1		
75% B - 25% W	22.2	21.4	22.6	23.3	22.3	22.4	+	.7		
50% B - 50% W	22.1	23.1	22.1	21.8	22.2	22.3	+	.5		
25% B - 75% W	22.5	21.5	22.4	22.2	21.9	22.1	+	.4		
0% B - 100% W	21.7	20.8	22.6	21.6	21.5	21.6	+	.6		

^a_B = Dried buttermilk solids.

^b_W = Foam spray-dried acid whey solids.

readings. The cake samples contained many small cells of varying size and thickness for absorbing and reflecting light instead of presenting a completely solid color block. In addition, heat from the machine caused shortening from the cake to melt on the glass plate and leave a grease film which might have masked color to some extent. Thus, it may be that there were not significant differences among the samples; or, due to difficulty in obtaining valid measurements, these color differences may not have been accurately measured by the method used.

Kramer shear press measurements

Analyses of variance indicated no significant differences among cake types for any of the shear press measurements. Replicate means, cake type means, and standard deviations for the Kramer shear press measurements appear in Table 9. Since cake samples were tender and tore immediately upon stretching, the area-under-the-curve index values for tensile strength were not obtainable. In general, values for tenderness, compressibility, and tensile strength were not substantially affected by any level of substitution of foam spray-dried acid whey solids for buttermilk solids.

Subjective Evaluation

Scores from subjective evaluation by the panelists were analyzed for variance. Tables of replicate means, cake type means, and standard deviations for the subjective

Table 9. Kramer shear press measurements of chocolate cakes based on maximum force and area-under-the-curve index.

Cake Variable		1	2	3	4	5	Mean/Standard Deviation			
<u>Tenderness</u> - maximum force (lb force/g)										
100% B ^a	-	0% W ^b	0.95	0.77	0.82	0.83	0.94	.87	±	.07
75% B	-	25% W	0.87	0.76	0.88	0.86	0.91	.86	±	.05
50% B	-	50% W	1.00	0.83	0.88	0.87	0.10	.91	±	.08
25% B	-	75% W	0.83	0.81	0.79	0.85	0.89	.83	±	.04
0% B	-	100% W	0.88	0.80	0.75	0.78	0.98	.84	±	.09
<u>Tenderness</u> - area-under-the-curve index										
100% B	-	0% W	265.1	211.4	208.8	190.8	231.4	221.5	±	+28.3
75% B	-	25% W	251.1	192.2	193.9	210.8	213.1	212.2	±	+23.7
50% B	-	50% W	320.5	224.1	186.1	189.6	239.2	231.9	±	+54.4
25% B	-	75% W	227.9	236.3	193.1	211.9	209.9	215.8	±	+16.8
0% B	-	100% W	263.9	199.5	180.9	191.0	227.9	212.6	±	+33.6
<u>Compressibility</u> - maximum force (lb force)										
100% B	-	0% W	5.07	4.11	4.86	4.29	4.67	4.60	±	.40
75% B	-	25% W	5.43	3.74	5.01	4.31	5.20	4.74	±	.70
50% B	-	50% W	5.49	4.27	5.59	6.56	5.37	5.46	±	.81
25% B	-	75% W	4.19	5.26	3.65	4.15	5.70	4.59	±	.85
0% B	-	100% W	5.11	4.06	3.84	4.71	6.15	4.77	±	.92
<u>Compressibility</u> - area-under-the-curve index										
100% B	-	0% W	20.9	19.4	17.7	19.3	19.2	19.3	±	1.1
75% B	-	25% W	26.9	16.0	18.6	17.2	22.2	20.2	±	4.4
50% B	-	50% W	25.8	18.5	20.9	30.1	21.9	23.4	±	4.6
25% B	-	75% W	20.1	26.0	16.5	18.3	22.5	20.7	±	3.7
0% B	-	100% W	24.5	18.7	15.9	22.8	24.4	21.3	±	3.8
<u>Tensile Strength</u> - maximum force (lb force/cm ²)										
100% B	-	0% W	.013	.011	.015	.018	.015	.014	±	.003
75% B	-	25% W	.010	.015	.016	.021	.020	.016	±	.004
50% B	-	50% W	.008	.017	.013	.014	.014	.013	±	.003
25% B	-	75% W	.014	.017	.018	.019	.014	.016	±	.002
0% B	-	100% W	.013	.015	.018	.018	.016	.016	±	.002

^aB = Dried buttermilk solids.

^bW = Foam spray-dried acid whey solids.

evaluations accompany the discussion of these results.

Outside attributes

Analyses of variance for outside attributes of contour, surface, and surface color revealed no significant differences due to substitution of acid whey solids for buttermilk solids in the cakes. Panelists' evaluations of outside attributes of cakes are indicated in Table 10. Cracking, humping, and pinholing appeared to be equally prominent on all types of cakes. The surface color was judged as being rich, even brown or reddish-brown for all cakes.

Taste panel evaluation

The scores from subjective evaluation by the taste panelists (Table 11) were analyzed for variance and no significant difference was found between any of the attributes considered. In the estimation of the panelists, most attributes seemed to be slightly improved by the substitution of acid whey solids for buttermilk solids. Flavor was not adversely affected by the acid constituent in the whey. There was evidence that flavor was slightly improved by the substitution.

Correlations for Objective and Subjective Measurements of Chocolate Cakes

Simple correlation coefficients were calculated among all combinations of the data. Correlations were then divided into objective and subjective measurements. Significant

Table 10. Subjective evaluation of outside attributes of chocolate cake based on a 5-point scale.

Cake Variable			1	2	Replication		3	4	5	Mean/Standard Deviation		
<u>Contour</u>												
100% B ^a	-	0% W ^b	3.6	3.6	3.8	3.8	4.4	3.8	<u>+</u>	.3		
75% B	-	25% W	4.3	3.0	3.1	4.6	2.9	3.6	<u>+</u>	.8		
50% B	-	50% W	3.6	4.6	3.9	4.3	3.9	4.1	<u>+</u>	.4		
25% B	-	75% W	3.5	3.8	4.1	3.6	3.8	3.8	<u>+</u>	.2		
0% B	-	100% W	3.6	4.5	3.9	3.6	3.6	3.8	<u>+</u>	.4		
<u>Surface</u>												
100% B	-	0% W	3.1	2.8	3.4	3.3	3.6	3.2	<u>+</u>	.3		
75% B	-	25% W	3.9	2.8	3.1	3.5	3.1	3.3	<u>+</u>	.4		
50% B	-	50% W	2.6	3.6	3.3	3.5	3.0	3.2	<u>+</u>	.4		
25% B	-	75% W	2.8	2.4	2.9	2.9	2.8	2.8	<u>+</u>	.2		
0% B	-	100% W	2.6	3.5	2.5	2.6	2.5	2.7	<u>+</u>	.4		
<u>Surface Color</u>												
100% B	-	0% W	4.1	3.9	4.6	4.0	4.1	4.1	<u>+</u>	.3		
75% B	-	25% W	3.9	4.0	4.1	3.1	3.8	3.8	<u>+</u>	.4		
50% B	-	50% W	4.0	4.0	4.3	4.4	3.6	4.1	<u>+</u>	.3		
25% B	-	75% W	4.3	4.3	4.3	4.4	4.4	4.3	<u>+</u>	.1		
0% B	-	100% W	3.9	4.3	4.5	3.5	3.9	4.0	<u>+</u>	.4		

^aB = Dried buttermilk solids.

^bW = Foam spray-dried acid whey solids.

Table 11. Taste panel evaluation of chocolate cakes based on a 7-point scale.

Cake Variable	Replication					Mean/Standard Deviation				
	1	2	3	4	5					
<u>Inside color</u>										
100% B ^a - 0% W ^b	4.1	4.3	4.7	4.4	4.6	4.4	+		.2	
75% B - 25% W	4.5	4.3	4.6	4.5	4.4	4.5	+		.1	
50% B - 50% W	4.3	4.2	4.5	4.6	4.2	4.4	+		.2	
25% B - 75% W	4.1	4.3	3.9	4.8	4.1	4.2	+		.3	
0% B - 100% W	4.5	4.1	4.7	4.7	4.6	4.5	+		.2	
<u>Texture</u>										
100% B - 0% W	3.8	3.2	3.8	3.9	4.2	3.8	+		.4	
75% B - 25% W	3.6	3.6	3.9	3.7	4.3	3.8	+		.3	
50% B - 50% W	3.4	3.6	3.6	4.0	3.9	3.7	+		.2	
25% B - 75% W	4.1	4.1	3.5	4.3	4.1	4.0	+		.3	
0% B - 100% W	4.2	3.8	4.3	4.1	4.3	4.1	+		.2	
<u>Moisture</u>										
100% B - 0% W	4.3	3.8	4.8	4.4	4.4	4.3	+		.4	
75% B - 25% W	4.3	3.8	4.4	4.1	4.7	4.3	+		.3	
50% B - 50% W	3.8	4.1	4.4	4.0	4.4	4.1	+		.3	
25% B - 75% W	3.9	4.0	4.3	4.3	4.2	4.1	+		.2	
0% B - 100% W	4.6	4.1	4.3	4.3	4.5	4.4	+		.2	
<u>Tenderness</u>										
100% B - 0% W	4.3	4.1	4.7	4.3	4.8	4.4	+		.3	
75% B - 25% W	4.5	4.4	4.7	4.1	4.8	4.5	+		.3	
50% B - 50% W	4.4	4.3	4.5	4.1	4.1	4.3	+		.2	
25% B - 75% W	4.6	4.6	4.6	4.7	4.6	4.6	+		.0	
0% B - 100% W	5.0	4.4	4.7	4.4	4.6	4.6	+		.2	
<u>Flavor</u>										
100% B - 0% W	4.6	3.9	4.3	4.8	4.7	4.5	+		.4	
75% B - 25% W	4.6	4.1	4.5	4.5	4.6	4.5	+		.2	
50% B - 50% W	4.7	4.5	4.6	4.7	4.3	4.6	+		.2	
25% B - 75% W	4.2	4.8	4.6	4.6	4.7	4.6	+		.2	
0% B - 100% W	5.1	4.6	5.0	4.3	4.3	4.7	+		.4	

^aB = Dried buttermilk solids.

^bW = Foam spray-dried acid whey solids.

correlations for objective measurements of the chocolate cakes are found in Table 12; those for subjective measurements are found in Table 13.

Correlations for objective measurements

A very highly significant negative correlation was found between the pH of the cake and Gardner b_L values (Table 12). This indicates that as the pH of the cake decreased, the yellow color constituent became more prominent. Positive correlations were found between viscosity of batter and pH of the cake ($p < 0.01$) and viscosity of the batter and volume of the cake ($p < 0.001$). This indicated that the batter became more viscous as the pH increased and that the volume became larger with increasing batter viscosity. A very highly significant positive correlation existed between Gardner a_L and b_L values. Brown is composed of many color constituents, and it is possible that increase in redness was accompanied by a corresponding increase in yellowness. Most Kramer shear press measurements correlated. Correlations among shear press values were also found by Brown (1964) and Gruber and Zabik (1966). Correlations among shear press values for cake characteristics would appear to indicate the reliability of these objective measurements for determining cake quality.

Table 12. Significant correlation coefficients of objective measurements of chocolate cakes.

[illegible]

Table 12. (Continued).

Objective Measure- ments	pH batter	pH cake	Specific Gravity	Gardner a ₁	Gardner b ₁	Gardner L	Compress- ibility force	Compress- ibility area	Tenderness force	Tenderness area	Tensile Strength	Volume	Viscosity
Tenderness force		.415*					.672**	.426*		.641**	-.346*		.347*
Tenderness area								.453*	.641**		-.590**		
Tensile Strength							-.372*	-.454*	-.346*	-.590**			
Volume					-.409*	.569*	-.421*	-.492**					.585**
Viscosity		.480**		-.364*		.390*			.347*			.585**	

*Significant at 5 per cent level of probability.

**Significant at 1 per cent level of probability.

***Significant at 0.1 per cent level of probability.

Correlations for subjective evaluations

Outside attributes, contour and surface, correlated very highly (Table 13). This indicates that there was a subsequent increase in the amount of pinholing as the amount of cracking and humping increased. The surface color did not correlate significantly with either contour or surface characteristics.

Inside quality characteristics were generally well correlated among themselves. The general acceptability of the cake samples correlated with tenderness at the 5% level of significance, with flavor at the 1% level of significance and with texture and moisture at the 0.1% level of significance. Inside color did not correlate significantly with the general acceptability of the cakes, so inside color was either not distinctively different among samples or did not seem to be a significant factor. The correlations of cake attributes with general acceptability of the product indicate that the panelists were using most facets to determine general acceptability of the cake samples.

Correlations between objective and subjective measurements

Pertinent values for objective and subjective measurements did not correlate significantly. Panelists determination of the inside color of the cakes did not correlate significantly with Gardner values. Kramer shear press values did not correlate significantly with taste panel evaluations.

Table 13. Significant correlation coefficients of subjective measurements related to chocolate cakes.

Subjective Measurements	Contour	Surface	Surface Color	Inside Color	Texture	Moisture	Tenderness	Flavor	Acceptability
Contour	*** .583								
Surface	*** .583								
Surface Color							.389*		
Inside Color					.422*	.390*			
Texture			.422*	.422*		.472**	.563***	.403*	.684***
Moisture			.390*	.390*	.472**		.537**		.516***
Tenderness		.389*			.563***	.537**		.429*	.384*
Flavor					.403*		.429*		.491**
Acceptability					.684***	.516***	.384*	.491**	

*Significant at 5 per cent level of probability.

**Significant at 1 per cent level of probability.

***Significant at 0.1 per cent level of probability.

Theories may be advanced for the lack of these significant correlations. Taste panelists may not have been using the same criteria as the shear press for determining cake tenderness quality. Also ranges of difference in cake samples may not have been great enough to expect significant correlations, even when all of the buttermilk solids in the recipe were replaced by the foam spray-dried acid whey solids.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine the effect of substituting various quantities of foam spray-dried acid whey solids for buttermilk solids on the quality of chocolate cake. To examine the amount of substitution consistent with good quality, 25%, 50%, 75%, and 100% of the original buttermilk solids were replaced with the foam spray-dried acid whey solids. These cakes were compared with the control prepared with 100% buttermilk solids. Five replications of each of the five variables were examined.

Chocolate cakes were prepared by the standard quick-mix method and submitted to a series of objective measurements and subjective evaluations. Physical properties of the batter were studied by obtaining measurements of pH, viscosity, and specific gravity. After the cakes were baked, the volume, tenderness, compressibility, tensile strength, color, and cake pH measurements were obtained. A four-member panel evaluated cakes for outside characteristics of surface, contour, and color; an eight-member taste panel evaluated cake characteristics for inside color, texture, moisture content, tenderness, flavor, and general acceptability.

Results indicated that the substitution of foam spray-dried acid whey solids for buttermilk solids brought about highly significant changes in cake batter viscosity and

cake volume. Batters were progressively less viscous and cake volumes became progressively smaller with increasing substitutions of foam spray-dried acid whey solids for buttermilk solids. It was concluded that a probable relationship existed between the viscosity of the batter and the cake volume and that compositional differences between the two by-products were the primary causes for these physical changes. The foam spray-dried acid whey solids used in this investigation contained substantially less protein and lecithin and more acid and lactose than did the buttermilk solids. These differences in composition could have caused the thinner batters which were found when foam spray-dried acid whey solids were substituted for buttermilk solids. The thinner batters apparently were unable to retain gas as well as the thicker batters; and this reduction of gas may have, in turn, caused smaller cake volumes. The addition of protein or lecithin to the cake formula containing foam spray-dried acid whey solids might help remedy the thinner batter.

All other objective measurements and subjective evaluations showed no significant differences due to this substitution. In all other respects, then, foam spray-dried acid whey solids could be successfully substituted for buttermilk solids in a quick-mix chocolate cake formula without causing any significant changes in cake properties. The particular appeal of using foam spray-dried acid whey solids as a substitute for buttermilk solids is that solids

changes so few batter and cake characteristics and in addition would provide considerable savings in ingredient cost to the food manufacturer.

Although the results of this project suggested that foam spray-dried acid whey solids are a feasible substitute for buttermilk solids under certain conditions, it is also evident that further research is needed in the following areas: (1) investigation of procedures or substances which would increase batter viscosity and subsequent cake volume with the use of foam spray-dried acid whey solids; (2) comparison of these results using the conventional mixing method and/or another basic chocolate cake formula; (3) an investigation of the effect of using cocoa instead of chocolate on cake characteristics; (4) studies to determine what additional ingredients such as other acid or milk products could be effectively substituted for by foam spray-dried whey solids; and (5) an investigation of the feasibility and limitations of substituting foam spray-dried acid whey solids into other products containing buttermilk solids.

LITERATURE CITED

- Alesch, E. A. 1958. Utilization of whey solids in food products. *J. Dairy Sci.* 41, 699-700.
- Blakely, L. E. 1964. Foam spray-dried cottage cheese whey as a source of solids in sherbets. M.S. Thesis. Michigan State University Library, East Lansing.
- Boggs, M. M., and H. L. Hanson. 1949. Analysis of foods by sensory difference tests. *Advances in Food Research* 2, 219-258.
- Brown, S. L. 1964. Effect of heat treatment on the physical and functional properties of liquid and spray-dried albumen. M.S. Thesis. Michigan State University Library, East Lansing.
- Carlin, G. T. 1944. A microscopic study of the behavior of fats in cake batters. *Cereal Chem.* 21, 189-199.
- Cathcart, W. H. 1951. Baking and bakery products in "The Chemistry and Technology of Food and Food Products, Vol. II." M.B. Jacobs, Ed. Interscience Publishers, Inc., New York. 1162-1211.
- Collins, O. D. 1940. The viscosity of cake batter as related to batter structure. M.S. Thesis. Purdue University Library, Lafayette, Ind.
- Cook, W. C. 1963. Specific gravity in the control of cake quality. *Baker's Dig.* 37 (2), 105-106.
- Coulter, S. T., and R. Jenness. 1964. Dry milk products in "Food Dehydration, Vol. II--Products and Technology." W. B. VanArsdel and M. J. Copley, Eds. The AVI Publishing Company, Inc., Westport, Conn. 591-651.
- DeGrood, J. 1959. Chocolate and cocoa in cookie and cake production. *Baker's Dig.* 33, (2) 36-40.
- Duncan, D. B. 1955. Multiple ranges and multiple F tests. *Biometrics* 11, 1-8.
- Dunker, K. 1939. The influence of past experience upon perceptual properties. *Am. J. Psychol.* 52, 255-265.

- Ellinger, R. H., and F. J. Shappeck. 1963. The relation of batter specific gravity to cake quality. Baker's Dig. 37 (6), 52-58.
- Endres, J. A. 1965. The effect of drying processes on the color and gel strength of baked whole egg and milk slurries. M.S. Thesis. Michigan State University Library, East Lansing.
- Francis, F. J. 1963. Color control. Food Technol. 17 (5), 38-45.
- Funk, K., M. Zabik, and D. Downs. 1965. Comparison of shear press measurements and sensory evaluation of angel cakes. J. of Food Sci. 30, 729-736.
- Grewe, E. 1930. Effect of variation in ingredients on color of chocolate cake. Cereal Chem. 7, 59-66.
- Griswold, R. M. 1962. "The Experimental Study of Foods." Houghton Mifflin Co., Boston.
- Gruber, S. M., and M. E. Zabik. 1966. Comparison of sensory evaluation and shear press measurements of butter cakes. Food Technol. (in press).
- Habighurst, A., and A. Singleton. 1965. Improve your products with whey solids. Food Proc. 26 (8), 74-78.
- Handleman, A. R., J. F. Conn, and J. W. Lyons. 1961. Bubble mechanics in thick foams and their effects on cake quality. Cereal Chem. 38, 294-305.
- Hanning, F., and J. de Goumois. 1952. The influence of dried whey on cake quality. Cereal Chem. 29, 176-189.
- Hanrahan, F. P., and B. H. Webb. 1961. USDA develops foam-spray drying. Food Eng. 31 (8), 37-38.
- Hofstrand, J. T., M. V. Zaehring, and R. A. Hibbs. 1965. Functional properties of two components of Cheddar cheese in bakery products: 1. Cake doughnuts. Cereal Sci. Today 10, 212-214, 233.
- Hunter, M. B., A. M. Briant, and C. J. Personius. 1950. Cake quality and batter structure. Cornell Univ. Agr. Ext. Sta. Bull. No. 860.
- Judd, D. B., and G. Wyszecski. 1963. "Color in Business, Science, and Industry." 2nd Ed. John Wiley and Sons, Inc., New York.

- Kramer, A. 1961. The shear press, a basic tool for the food technologist. *The Food Scientist* 5, 7-16.
- Kramer, A., R. B. Guyer, and H. P. Rodgers, Jr. 1951. New shear press predicts quality of canned lima beans. *Food Eng.* 23, 112.
- Lowe, B. 1955. "Experimental Cookery." 4th ed. John Wiley and Sons, Inc., New York.
- Mackinney, G., and C. O. Chichester. 1954. The color problem in foods. *Advances in Food Research* 5, 302-351.
- Maselli, J. A., and S. Pomper. 1960. The significance of pH in baking. *Baker's Dig.* 34 (5), 66-69, 87-88.
- Meyer, L. H. 1960. "Food Chemistry." Reinhold Publishing Corporation, New York.
- Platt, W., and P. D. Kratz. 1933. Measuring and recording some characteristics of test sponge cakes. *Cereal Chem.* 10, 73-90.
- Potter, F. E., and D. H. Williams. 1949. Use of whey in sherbets. *Ice Cream Trade J.* 45 (9), 54-55.
- Singleton, A. D., H. N. Haney, and A. B. Habighurst. 1965. Adapting dried whey products to present-day bakery operations. *Cereal Sci. Today* 10, 53-55, 62.
- Stine, C. M. 1965. Private communication. Department of Food Science. Michigan State University.
- Stine, C. M., and J. S. E. Sargent. 1963. Analysis of spray dried cottage cheese whey. *Mich. State Univ. Agr. Exp. Sta. Quart. Bull.* 46, 159-161.
- Swickard, M. T. 1941. The viscosity of cake batters in relation to some indices of cake quality. M.S. Thesis. Purdue University Library, Lafayette, Ind.
- Tinsley, I. J., A. P. Sidwell, and R. F. Cain. 1956. Methods of presenting raspberry and strawberry samples to the Hunter color and color-difference meter. *Food Technol.* 10, 339-344.
- Triebold, H. O., and L. W. Aurand. 1963. "Food Composition and Analysis." D. Van Nostrand Company, Inc., Princeton, New Jersey.
- U. S. Department of Agriculture. 1959. "Food, The Yearbook of Agriculture 1959." U.S. Department of Agriculture, Washington.

U.S. Department of Agriculture. Statistical Reporting Service, Crop Reporting Board. 1965. Production of manufactured dairy products, 1964. Washington, D.C.

Van Winkle, Webster. 1966. Private communication. Webster Van Winkle Corporation. Summit, New Jersey.

Webb, B. H., and A. H. Johnson. 1965. "Fundamentals of Dairy Chemistry." The AVI Publishing Company, Westport, Conn.

Whittier, E. O., and B. H. Webb. 1950. "Byproducts from Milk." Reinhold Publishing Corporation. New York.

APPENDIX

Chocolate Cake Score Card

Name _____

Date _____

Code number _____

Instructions: Check the phrase which most nearly describes the contour, surface and color.

Contour

- _____ slight cracking, small even hump.
- _____ slight cracking, moderate humping.
- _____ moderate amount of cracking and humping, slight number of cross slits.
- _____ moderate cracking, extreme humping, moderate number of cross slits.
- _____ extreme humping, extreme cracking, extreme number of cross slits.

Surface

- _____ no pinholing
- _____ 1/4 of surface covered by pinholes
- _____ 1/2 of surface covered by pinholes
- _____ 3/4 of surface covered by pinholes
- _____ extreme pinholing

Surface color

- _____ rich even brown or reddish-brown
- _____ deep brown but slightly streaked
- _____ moderate brown
- _____ medium light brown
- _____ burned spots

Comments:

Figure 5. Chocolate cake score card.

GENERAL INSTRUCTIONS TO PANEL MEMBERS

1. Please do not give any facial or vocal reactions as you evaluate your sample.
2. The samples are coded with random numbers and are presented in a randomized order. Please start with the sample in the lower left corner of the tray and proceed toward the right. The upper row should be evaluated in the same order.
3. Using a red pencil please mark the numerical score which most nearly fits your evaluation of each quality characteristic of the sample in the box at the right hand side of the score card. Score each sample independently of others. BE SURE THE PLATE CODE MATCHES THE SCORE CARD CODE. Each sample will have its own score card.
4. You may rinse your mouth between sample evaluations with the water provided.
5. Please make sure you have five numbers written on the score card and have answered the question at the end.

Figure 6. General instructions to panel members.

CAKE SCORE CARD

Name _____ Date _____

Code Number _____

	7	6	5	4	3	2	1	SCORE
	(excellent)	(very good)	(good)	(medium)	(fair)	(poor)	(very poor)	
INSIDE COLOR	Rich deep brown or reddish-brown							
TEXTURE	Cells uniform in size and structure; thin cell walls							
MOISTURE CONTENT	Slightly moist							
TENDERNESS	Tender, resilient, holds shape when cut							
FLAVOR	Delicate, sweet, well-blended flavor							

Is this an acceptable product? Yes _____ No _____

Comments:

Figure 7. Cake score card.

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