ADDITION OF XANTHAN GUM, WHEAT STARCH, AND WATER
TO ANGEL FOOD CAKE WITH A
REDUCED EGG WHITE LEVEL

by

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INTRODUCTION

The cost of each ingredient in a given food product must be carefully evaluated by the food processor with respect to current economic conditions. Egg products are only one of a number of ingredients used, but they appear to have an inelastic demand. Opportunities to adjust formulations for the cost of eggs are limited, yet bakers and food processors are being forced to consider alternatives for such functional, but costly, ingredients (Voss, 1963; Enochian and Saunders, 1963).

A manufacturer of xanthan gum, the Kelco Company (1979), has proposed the replacement of all or a portion of certain functional ingredients in cake systems with xanthan gum. Some possible ingredients to be replaced include whole eggs, yolks, whites, nonfat dried milk, high cost flours, fats, and emulsifiers.

Egg whites, sugar, and flour are the three basic ingredients in angel food cake, of which egg whites are probably the most important functionally. The egg white proteins are whipped to a foam; proteins are denatured in the process, to form a relatively stable aerated structure capable of supporting other ingredients (Pyler, 1973).

Christianson, Kulp, and their co-workers (Christianson et al., 1974; Kulp et al., 1974) have used xanthan gum, a hydrophilic colloid, in starch breads. Christianson (1976) hypothesized that gelatinized starch binds with xanthan gum and forms a complex lattice-structured wall that retains gas. The Kelco Company (Anonymous, 1980) reported a 15 to 20 per cent reduction in egg white with the addition of xanthan gum in angel food cakes, which resulted in a savings of 2.5 to 3.5 cents per pound without noticeable volume or textural differences in the cakes.

This study was undertaken to determine the minimum amount of egg white necessary for structure in angel food cake. The selected egg white level was then used for further studies of angel food cake with and without added xanthan gum, wheat starch, and water to improve volume and textural properties of the reduced egg white cake.

REVIEW OF LITERATURE

Xanthan Gum

Xanthan gum is a hydrophilic colloid produced from a pure culture fermentation of glucose by Xanthomonas campestris. It is an anionic heteropolysaccharide composed of repeating blocks of five sugar units: two glucose, two mannose, and one glucuronic acid as a mixed potassium, sodium, and calcium salt. Acetyl and pyruvic acid side chains, also present, are thought to be responsible for some of the unique and desirable properties of the gum. The molecular weight is reported in the order of two million (Hodge and Osman, 1976; Anonymous, 1978; Anonymous, undated).

General properties of the gum include hot and cold water solubility, high viscosity at low concentrations, pseudoplasticity, and stability to pH and temperature variations and the presence of salts. Xanthan gum generally is considered chemically inert with respect to other ingredients in a system and is compatible with most other hydrocolloids, including starch (Rocks, 1971; Anonymous, 1974; Hodge and Osman, 1976; Anonymous, 1978; Anonymous, undated).

Xanthan gum has been the subject of extensive toxicity testing. It has been established that xanthan gum is resistant to degradation in the digestive system and in major part passes through an animal unchanged (Rocks, 1971; Anonymous, 1974; Anonymous, 1978). Thus in 1969, the Food and Drug Administration approved xanthan gum for general use in foods where Standards of Identity do not preclude such use (Federal Register, 1969).

Several studies have reported the use of xanthan gum as an additive to baked products. Christianson and co-workers (1974) used xanthan gum in protein-fortified starch bread. Xanthan gum was used to bind starch granules and give a breadlike structure comparable in appearance, mouthfeel, loaf volume, and staling to most commercial breads. Breads baked without xanthan gum did not rise and remained flat, brittle, and coarse in texture. The addition of xanthan gum improved both loaf volume and crumb structure.

Christianson (1976) further investigated the use of xanthan gum--starch breads and suggested that gelatinized starch binds with the gum and forms a complex lattice-structured wall that retains gas. The addition of xanthan gum increases dough absorption and time for dough development because more water and time are required for the hydration of the gum. A 55 to 70 per cent moisture level is required to fully hydrate the starch and gum. Free granular starch also must be present in the system for optimum gelatinization and complexing with the gum to retain the gas during baking. Xanthan gum added to unbleached and soft wheat flours increased dough stability, indicating that the gum was effective as a gluten substitute during the mixing stage. He suggests that xanthan gum can provide the visco-elastic properties of gluten in the development of yeast-leavened bakery products prepared from wheat, potato, or corn starch (Christianson, 1976).

Kulp and co-workers (1974) also looked at gluten substitutes: pre-gelatinized starch, xanthan gum, and carboxymethyl cellulose (CMC) in the preparation of gluten-free bread. Native, untreated, starch lacks the ability to bind sufficient water at the dough stage for gelatinization during baking. A binding agent is necessary to retain gas and increase the water binding capacity of the system. All three starch binding agents produced acceptable bread products, varying in effectiveness at different percentages and with or without the addition of an emulsifier. However, the breads containing only 2.1% xanthan gum were superior in volume, general properties, and flavor.

Another study (Anonymous, 1975) reported that xanthan gum gives starch doughs and batters the strength and elasticity to rise by forming foam cells and expanding with air and the carbon dioxide generated by yeast or leavening agents. Ranhotra and his co-workers (1975) used xanthan gum to form a stable dough structure in the preparation of a soy-fortified gluten-free bread.

Gunter (1974) reports an apparent stabilizing and emulsifying effect in cake batters as a result of the use of gums. He used CMC and xanthan gum in lean formulation yellow cakes to correct a tunneling effect caused by the decreased sugar and shortening and the lack of an emulsifier.

Other hydrophilic colloids have been used to improve the quality of white layer cakes. Young and Bayfield (1963) found that levels of 0.1 to 0.2%, flour weight basis, of 7HP CMC, gum tragacanth, gum arabic, Irish moss, ammonium alginate, or 7LP CMC plus 5 to 10% additional water, flour weight basis, produced better cakes than the control with no additives when evaluated after 16 and 48 hours storage. The hydrocolloids increased total score and eating-quality score when compared to the control at both periods. Menger and Ludewig (1977) also found that 0.05 to 0.3% additions of certain hydrocolloids improve pore structure, water binding, and gas retention; control batter viscosity; and increase the tolerance to recipe variation in bakery products.

In work conducted by a producer of xanthan gum, the Kelco Company

(1979), a level of 0.05%, dry ingredient basis, of the gum was used to replace one-fifth of the egg white in a bakery type angel food cake formula containing approximately 40% egg white. While similar to the 100% egg white control cakes in texture and flavor, the cake made with the gum exhibited a slightly finer cell structure.

Angel Food Cake

Angel food cake from the standpoint of formulation is one of the simplest cakes. A typical formula might consist of 42% each of egg whites and sugar, 15% flour, and minor amounts, less than 1%, of cream of tartar, salt, and flavorings (Pyler, 1973). Mixing the cake involves making an egg white foam and then carefully folding in the other ingredients. When this foam is subjected to heat, the air trapped within the bubbles of the foam expand, increasing the volume of the foam. The foam structure and volume are maintained when, during heating, the gas release and bubble expansion cease, starch gelatinizes, and proteins coagulate to set the cake structure (Mizukoshi et al., 1980).

Ingredients

Egg white. Chemical fractionation of egg white into its principal protein constituents has helped demonstrate the importance of the globulins, ovomucin, and ovalbumin in the preparation of angel food cake. MacDonnell and co-workers (1955) proposed the function of the individual proteins. The globulins are extremely good foamers, important in forming a batter with a large volume and small bubbles. Ovomucin stabilizes egg white foams at short whipping times, presumably because of its rapid insolubilization at the surface of the bubbles. It appears that all other egg white proteins furnish heat-denaturable bulk which on heating insolubilize to form the supporting matrix of the cake.

The work of others seems to support the importance of these three egg white proteins in angel food cake. Nakamura and Sato (1964a) found the levels of ovomucin and globulin to decrease in egg white foam drainage after successive whippings. They believe that ovomucin, which is coagulated during whipping, acts to stablize the foam, and the other egg white proteins act in foam formation.

In a subsequent study, Nakumura and Sato (1964b) found that the foaming power of egg white was little affected by a 1% or 4% addition of ovalbumin, increased by a 1% or 2% addition of globulin, and decreased with a 1.2% addition of ovomucin. By adding various egg white protein fractions to the whole egg white, they found the foam stability was increased, most markedly with the addition of ovomucin. This, they postulated, supports their assumption that ovomucin acts as a foam stabilizer instead of a foam producer.

Cunningham (1976) found by examining egg white foam drainage that ovalbumins are not altered greatly by whipping. Ovomucin, lysozyme, globulins A_1 and A_2, and to a lesser extent, conalbumin are retained in the foam of beaten egg whites.

Sugar. Sugar is important not only for its contribution to the sweetness of angel food cake, but also for its control of batter viscosity, degree of starch gelatinization, and coagulation of egg white proteins (Shepherd and Yoell, 1976). Various studies have reported the beneficial effect of adding sugar to egg white prior to heating (Bernard et al., 1948; Slosberg et al., 1948; Lowe, 1955; and Seideman et al., 1963). Sugar increases the temperature at which the adverse effects of heating egg white (coagulation) occur. Lactose, dextrose, and maltose raised the temperature of coagulation more than sucrose. However, a rapidly dissolving sucrose is recommended for angel food cake; the optimum amount depends somewhat on the flour. Excess sugar will alter or prevent coagulation during baking. The cake will fall, and the crust will be sugary, crystalline, and rather dry (Palmer, 1972).

Flour. The flour used in angel food cake acts as a binder and provides starch which gelatinizes in the oven and supplements the egg protein in forming the cake structure (Palmer, 1972). Dubois and Bryson (1959) studied the use of raw wheat starch to angel food cake to replace a maximum of 30 per cent of the wheat flour. A 20 to 30 per cent replacement of flour by starch resulted in cakes with improved volume, grain, texture, and shelf life.

Acid. Acid is necessary to adjust the pH of the egg whites, which normally have a pH range of 7.6 to 8.9, and improve their foam stability (Bernard et al., 1948; Slosberg et al., 1948; Seideman et al., 1963; and Palmer, 1972). Barmore (1934) found that the addition of acids and acid salts, notably potassium acid tartrate, increased the stability of egg white foams by changing the protein concentrated at the liquid-air interface of the foam. The increased foam stability allows time for heat to penetrate the foam and coagulate the proteins before the foam collapses, thus preventing shrinkage of the cake during the last part of baking and during cooling. Grewe and Child (1930) reported a change in color and grain of angel food cake due to acidity. Cakes made with the addition of acid potassium tartrate were white and fine-grained; without the acid the cakes were yellow and coarse-grained. An optimum pH range of 5 to 6.5 is recommended (Pyler, 1973).

Foam Formation

The structural and desired eating qualities of angel food cake rely heavily on the formation of an optimum and stable egg white foam. The egg whites plus added acid and some sugar are beaten to an aerated state. The foam at this stage is very sensitive to mechanical handling; therefore, the remaining sugar and flour are carefully folded in so as not to lose the air held in the foam (Shepherd and Yoell, 1976).

A liquid with high tensile strength or elasticity is necessary for stable foam formation. As egg white is beaten, an unfolding of the protein molecules occurs so that the polypeptide chains exist with the long axes parallel to the surface. This change in molecular configuration results in partial coagulation of the ovomucin which collects at the liquid-air interface of the foam as an elastic film to stabilize the foam. The elasticity of this film is of greater importance when the foam is subjected to heat. With the expansion, on heating, of the air bubbles trapped in the foam, the egg white must either stretch or break. Stretching of the film with bubble expansion results in optimum leavening of angel food cake (Baldwin, 1973).

Low surface tension is essential to foaming. Le Clerc and Bailey (1941) added water to the thick portion of egg white in order to reduce its viscosity to that of the thin white. The thinner portion could be whipped more readily to a proper consistency, and an improved angel food cake resulted. They reported as much as a third of the egg white in angel food cake could be replaced with water without appreciably affecting cake quality.

Baldwin (1973), however, suggests that high viscosity and low vapor pressure are more important than low surface tension for foam stability.

Foam drainage is unlikely in foams made with a viscous liquid, and evaporation is unlikely in foams made with liquids with a low vapor pressure. Globulins are excellent foamers. They lower surface tension, which is helpful in the initial stages of foaming, and also contribute to viscosity, decreasing the tendency for the liquid to drain from the air bubbles (MacDonnell et al., 1955). Powrie and Tung (1976) also recognize the importance of viscosity of the system to foam stability. They suggest that gums and proteins, such as gelatin, are excellent stabilizing agents which, at low concentrations of 0.5 to 2%, markedly increase the viscosity of a solution. Sometimes sugars are used in foams to increase viscosity and enhance foam stability.

Chemical additives affect foam formation and stability. Gardner and Cotterill (1961) found anionic additives at a specific concentration increase the functional efficiency of egg whites in foam formation. The maximum increase in efficiency was at an additive concentration high enough to complex proteins but not precipitate them. The combined effects of lowering surface energy and protein complexing enhanced foam formation and increased cake volume. Sodium lauryl sulfate (SLS) is an anionic surfactant which has found wide use in improving the foaming of egg white. Electrophoretic studies indicate that SLS complexes with lysozyme in addition to lowering surface energy. Additions of small quantities to egg whites used in making angel food cake result in increased cake volume (Gardner, 1960).

Examination of electron micrographs of egg white with and without sodium hexametaphosphate and triethyl citrate plus trisodium citrate led Meyer and Potter (1975) to conclude that these additives improve foam stability by crosslinking proteins. They saw less protein denaturation in unwhipped and whipped egg whites containing the additives than in egg whites without them. Crosslinking would be expected to cause egg white to resist denaturation. Triethyl citrate improves foamability by denaturing ovalbumin.

Thermal Setting

Foam setting during baking involves protein coagulation and starch gelatinization which Mizukoshi and co-workers (1979, 1980) found to occur at approximately the same temperature range, 79° to 96°C. Based on work with a sponge cake system, they proposed a model scheme for the formation of cake structure during baking. The initial increase in batter volume occurs with the expansion of bubbles due to the increase in vapor pressures of water and air in the bubbles caused by the increased baking temperature. As the temperature continues to increase starch swelling occurs, which they observed as an increase in light transmission of the model system. As the cake batter begins to change from a sol to a gel phase, starch gelatinization is almost complete and protein coagulation is accelerated. The gel phase formation depresses bubble expansion so cake batter expansion ceases. Further coagulation of egg and flour proteins occurs, strengthening the cake structure until the end of the baking period. The temperatures at which gas release, starch gelatinization and the cessation of batter expansion, and protein coagulation occur were increased with the addition of sugar.

Egg white coagulation. Parkinson (1966) reports that all egg white proteins except ovomucoid are heat-coagulable. The heat setting of egg white is a complex process involving at least three separate stages: denaturation, aggregation, and gelation (Shepherd and Yoell, 1976). Coagulation begins at about 62°C, and the egg white ceases to flow when it reaches a temperature of about 65°C; however time, temperature, pH, dilution, and added ingredients alter the coagulation temperature of egg white. Dilution of the proteins increases the coagulation temperature, as does the addition of sucrose (Seideman et al., 1963; Baldwin, 1973). Lowe (1955) found the increased coagulation temperature proportional to the amount of sugar added.

Starch gelatinization. The role of starch in the thermal setting of cake batters is well recognized as an important one (Miller and Trimbo, 1965; Howard et al., 1968; Hoseney et al., 1978; Lineback and Wongsrikasen, 1980; and Mizukoshi et al., 1980). In their studies of starch isolated from baked products, several workers have shown that the degree of starch gelatinization is greatest for angel food cake. Whether measured as loss of birefringence, enzymatically, or by examining scanning electron micrographs, starch gelatinization in angel food cake appears essentially complete (Hoseney et al., 1977; Hoseney et al., 1978; Lineback and Wongsrikasen, 1980). The extent of gelatinization is affected by temperature, available water, and other ingredients, such as sugar, present in the system (Derby et al., 1975; Hoseney et al., 1977). Hoseney and his co-workers (1978) suggest that the starch in angel food cake undergoes the greatest change of all baked products they investigated due to the high percentage of water present during baking. Derby and his co-workers (1975) suggest the differences in moisture content which affect starch gelatinization also influence product volume.

MATERIALS AND METHODS

Ingredients and Preparation

The AACC Method 10-95 for testing baking quality of angel cake flour (Kissell and Bean, 1978) was modified for use in preparing test cakes.

A commercial soft wheat patent cake flour [Pillsbury Sno Sheen; 9.3% protein (N x 5.7), 0.54% ash, 0.86% fat, 14% moisture basis] was used throughout the study. Other ingredients and specifications are listed in the Appendix, Table A-1. Ingredients in sufficient quantities were procured at the beginning of each of the two parts of the study.

Xanthan gum was sifted with the first portion of sugar, acid salt, and sodium chloride before being added to the rehydrated egg whites. Wheat starch was sifted with the flour-sugar mixture and folded into the egg white foam. Additional water, when used, was added to the rehydrated egg white before beating to a foam. A Hobart N-50 mixer (speed 1, 68 rpm; speed 2, 132 rpm; speed 3, 256 rpm) was used. Foam specific gravity was standardized at 0.14 ± 0.01. The flour-sugar mixture was incorporated into the foam by 29 strokes with a hand-held whip instead of a mixer. The bowl was turned one-quarter turn at each stroke, and the whip was brought up from the bottom of the bowl through the center of the foam every fourth stroke. Baking was done in a Reed Company gas-fired reel oven. Cakes were cooled 90 minutes, wrapped loosely with plastic wrap in the pan, and stored overnight at room temperature before evaluations.

A. Angel Food Cakes Made With Varying Levels of Egg White and Xanthan Gum

In order to determine the levels of egg white and of xanthan gum to use in angel food cakes, a 3 x 4 factorial design of gum level (0%, 0.2%, and 0.4%, flour weight basis) and egg level (100%, 80%, 65%, and 50% total egg in formula) was used. To ensure having enough batter, levels of all ingredients for the 65% and 50% egg white cakes were increased by 25%. Specific gravity of batter, batter temperature, batter pH, standing height of cakes in and out of the pan, and width measurements of the cakes were monitored.

B. Angel Food Cakes Containing 65% Egg White Made With and Without Xanthan Gum, Water, and/or Wheat Starch

Cakes with 65% egg white and 0.4% xanthan gum were used for further investigations with added water and/or wheat starch. Preliminary work established that 50% additional water and 25% wheat starch, flour weight basis, were beneficial in producing cakes with better structure. A randomized complete block design plus a 100% egg white control cake was used. Specific gravity of batter, batter temperature, batter pH, crumb pH, foam stability as indicated by foam drainage, standing height of cakes in and out of the pan, width of cakes, crust hardness, and crumb firmness and springiness were measured. Levels of ingredients for the 65% egg white cakes were increased by 25% to ensure having enough batter. The baked cakes were placed upright on a funnel to prevent some cakes from falling out of the pan during cooling.

Physical Measurements of Cakes

Batter and crumb pH, foam stability, standing height, cake width, and crust hardness were determined according to procedures given in the Appendix, Table A-2.

The Instron Universal Testing Machine (IUTM), model no. 1122, was used to evaluate firmness and springiness or elasticity of the cake crumb. The 50 cm^2 compression anvil, A372-17, was used with the 500 kg load cell. Three 2.5 cm cubes taken from the mid-section of the cakes were compressed to 0.1 cm (compressibility ratio = 40%) using a 0.2 kg scale load. Crosshead and chart speeds of 200 mm/min were used. Two force compression curves were recorded. The peak height of the first curve, converted to kg units, represents the resistance of the crumb to compression, or firmness. The distance, in cm, to the peak of the second curve expressed as a ratio in per cent of the distance to the peak of the first curve is an indication of springiness or elasticity of the crumb (Neukom and Rutz, 1980; see Appendix, Figure A-1).

Crust color was evaluated using the HunterLab spectrophotometer, model no. D54-P. Approximately 2 cm of the top crust was placed in an optically clear cup, 6 cm in diameter. Using Illuminant C, three readings per sample of L, lightness; a^+, redness; and b^+, yellowness were taken, rotating the sample after each reading, and means reported.

Sensory Evaluation of Cakes

Sensory evaluation of angel food cakes was conducted by a six member experienced panel of faculty and graduate students from the Foods and Nutrition Department. The panel was trained to evaluate contour, grain, cell walls, crumb tenderness, elasticity, sweetness, and moisture adsorption of the cakes. A 5-point category scale, with the ideal score indicated for each attribute, determined during panel training, was used (Appendix, Figure A-2). Panelists were allowed to assign half points in their evaluation and were asked to note any non-characteristic or off-flavors. Three samples per session were evaluated.

A three inch slice of cake was evaluated visually by the panel for contour. Slices of cake, with an outside width of one inch, tapering to one-half inch inside width, were evaluated for the other characteristics. The slices were perforated with a knife one-half inch from the outside crust and one inch down from the top crust to facilitate removal of a section to evaluate elasticity. A water rinse was provided.

Statistical Design and Analysis

Data for each physical measurement from three replications of the first study were analyzed by analysis of variance (ANOV), as follows, to determine the levels of egg white and xanthan gum for further testing:

Source of Variation	D/F
% Total Egg White	3
% Xanthan Gum	2
Egg White x Xanthan Gum	6
Error	24
Total	35

Least squares means were compared to determine treatment effects.

A randomized complete block design was used to study treatment effects of xanthan gum, water, and wheat starch in the 65% egg white cake compared to a 100% egg white control cake. Data for physical measurements and sensory characteristics from three replications of the second study were analyzed by ANOV.

Source of Variation	D/F
Treatment	8
Replication	2
Error	16
Total	26

Least squares means were compared to determine treatment effects.

RESULTS

A. Angel Food Cakes Made With Varying Levels of Egg White and Xanthan Gum

Table 1 reports ANOV of physical measurements of angel food cakes made with four levels of total egg white in the formula: 50, 65, 80, and 100%, and three levels of xanthan gum: 0, 0.2, and 0.4%, based on the flour weight. No significant differences in foam specific gravity due to level of egg white, level of xanthan gum, or an egg white and

Table 1. F value and level of significance from ANOV of physical measurements of angel food cake made with four levels of egg white and three levels of xanthan gum[a].

Physical Measurement	F value and level of significance[b]		
	Egg White Level	Xanthan Gum Level	Egg x Xanthan Gum
Foam specific gravity	0.44	0.17	1.94
Batter specific gravity	16.27***	0.65	1.26
Batter pH	61.96***	2.41	1.76
Standing ht.--in (cm)	51.66***	0.62	0.26
Standing ht.--out (cm)	180.48***	0.12	1.47
Width (cm)	80.86***	1.00	1.06

[a]Three replications.

[b]Values without a superscript are not significantly different ($p \leq 0.05$); ***, indicates significance at $p \leq 0.001$.

xanthan gum interaction were found since this was a controlled factor. No significant differences for physical measurements were attributed to the level of gum or to an interaction of egg white and xanthan gum. However, significant differences in physical measurements were found when the level of egg white was varied.

The least squares means of physical measurements of angel food cake made with four levels of egg white are reported in Table 2. All measurements for the cake containing a 50% level of egg white are significantly different ($p \leq 0.05$) from measurements for all other cakes. The batter specific gravity of the 50% egg white cake is higher ($p \leq 0.05$) than for the other cakes; less air was incorporated into the batter. Batter pH is lower, probably because of the quantity of the alkaline egg white removed. Standing height in and out of the pan and width measurements are considerably lower for the 50% egg white cake than for all other cakes.

The measurements for the cake with 65% of the egg white are also significantly different ($p \leq 0.05$) from all other cakes except in batter pH and width measurements. Batter specific gravity is significantly lower and both standing height measurements are significantly higher than for cakes with 50% egg white, but specific gravity is significantly higher and standing height measurements are significantly lower than the 80 and 100% egg white cakes which were not different ($p \leq 0.05$) from each other. Width measurements for the 65, 80, and 100% egg white cakes were not significantly different. A 20% egg white removal does significantly decrease batter pH, and a 50% egg white removal further significantly decreases batter pH, probably a result of the increased quantity of egg white removed.

Table 2. Least squares means[a] of physical measurements of three replications of angel food cake made with four levels of egg white.

	% Total Egg White			
Physical Measurement	50	65	80	100
Batter specific gravity	0.36[a]	0.31[b]	0.28[c]	0.28[c]
Batter pH	5.07[a]	5.30[b]	5.37[b]	5.55[c]
Standing ht.-in (cm)	2.19[a]	6.11[b]	7.38[c]	7.58[c]
Standing ht.-out (cm)*	0.44[a]	5.59[b]	6.91[c]	7.14[c]
Width (cm)*	0.86[a]	8.56[b]	8.95[b]	8.97[b]

[a]Means in a row with same letter do not differ significantly ($p \leq 0.05$).

*Cakes with 50% total egg white fell out of pan during cooling. Measurements are the means of some of the larger pieces.

Since the 80 and 100% egg white cakes were not significantly different except for batter pH, a 20% egg white reduction appears possible without major formula adjustments. A 50% egg white reduction results in a cake significantly different from the control cake, with 100% egg white, in every physical measurement. On the other hand, the 65% egg white cake is significantly different from the 80% egg white cake except in batter pH and width measurements. Apparently the 35% egg white reduction was not enough to significantly decrease batter pH; and some cake structure, as indicated by width measurements, was retained even though standing height measurements were decreased significantly. Based on these results the 65% egg white level was selected for further experimentation. Formula adjustments seemed more likely to be beneficial at this level than at the 50% egg white level.

Xanthan gum alone did not cause significant differences in physical measurements of angel food cakes (Table A-3). However, Christianson (1976) reported additional water and the presence of free granular starch necessary to produce xanthan gum--starch breads. Thus, xanthan gum, additional water, and wheat starch were chosen for formula changes in the 65% egg white experimental cakes. The higher level, 0.4%, of xanthan gum was selected based on reports of its use in angel food cake (Kelco Company, 1979; Anonymous, 1980). Preliminary work established that levels of 50% additional water and 25% wheat starch, based on the flour weight, structurally improved the 65% egg white cakes.

B. Angel Food Cakes Containing 65% Egg White Made With and Without Xanthan Gum, Water, and/or Wheat Starch

The ANOV of physical measurements of angel food cake containing 65% egg white made with and without the selected levels of xanthan gum, water, and/or wheat starch reported in Table 3 reveals a significant difference ($p \leq 0.05$) for all physical measurements due to treatment. Significant differences for sensory characteristics as a result of treatment are reported in Table 4. A comparison of least squares means for physical measurements is reported in Table 5, for sensory characteristics in Table 6.

Comparison of 100% Egg White Cake and 65% Egg White Cake Without Added Ingredients

Egg white is a polyfunctional ingredient. A 35% reduction of egg white with no other formula adjustments, in angel food cake causes significant physical and sensory differences from a 100% egg white control cake. Trends noted in the first part of the study (Table 2) were confirmed in the second part of the study (Table 5). In both instances, significant differences in batter specific gravity, batter pH, and standing height measurements as a result of a 35% egg white reduction are seen. The egg white reduction did not cause significantly different ($p \leq 0.05$) width measurements earlier, but a significant decrease in width, or increased shrinkage is reported for the reduced egg white cake in Table 5. Additional physical measurements reported in Table 5 which are significantly different ($p \leq 0.05$) for the control and 65% egg white cakes include crumb pH, foam stability, crust hardness, and L, or lightness of crust values.

Removing 35% alkaline egg white significantly decreases batter and crumb pH from those of cakes containing 100% egg white. With a 35% reduction of egg white, less air is incorporated into the batter as evidenced by the significantly higher batter specific gravity of the 65% egg white cake; however, foam stability of the reduced egg white cake is significantly greater than that of the 100% egg white control

Table 3. F value and level of significance from ANOV of physical measurement of control, 100% egg white, angel food cake and cakes containing 65% egg white made with and without xanthan gum, water, and wheat starch.[a]

Physical Measurement	F value and level of significance[b] Treatment	Replication
Batter specific gravity	5.71**	1.07
Batter pH	5.32**	0.14
Crumb pH	7.99***	0.17
Foam stability (Drainage, g)	27.62***	2.81
Standing ht.-in (cm)	18.65***	0.37
Standing ht.-out (cm)	19.13***	0.98
Width (cm)	13.75***	0.01
Crust hardness	12.12***	2.93
L	4.97**	2.10
a^+	3.22*	0.70
b^+	2.93*	3.62
Firmness (kg)	13.25***	1.72
Springiness	3.63*	4.09*

[a]Three replications.

[b]Values without a superscript are not significantly different ($p \leq 0.05$). Level of significance is indicated as follows: *, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$.

Table 4. F value and level of significance from ANOV of sensory characteristics of control, 100% egg white, angel food cake and cakes containing 65% egg white made with and without xanthan gum, water, and wheat starch.[a]

	F value and level of significance[b]	
Sensory Characteristic	Treatment	Replication
Contour	13.00***	0.83
Grain	27.88***	0.05
Cell Walls	12.28***	0.70
Crumb Tenderness	6.10**	1.92
Elasticity	9.78***	5.13*
Sweetness	3.34*	4.24*
Moisture adsorption	14.28***	1.95

[a]Three replications.

[b]Values without a superscript are not significantly different ($p \leq 0.05$). Level of significance is indicated as follows: *, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$.

Table 5. Comparison of least squares means[a] of physical measurements of control, 100% egg white, angel food cake and cakes containing 65% egg white made with and without xanthan gum, water, and wheat starch.

Physical Measurement	100% Egg White Control	Wheat Starch 0, Water 0, Xanthan Gum 0	Wheat Starch 0, Water 0, Xanthan Gum 0.4	Wheat Starch 0, Water 50, Xanthan Gum 0	Wheat Starch 0, Water 50, Xanthan Gum 0.4	Wheat Starch 25, Water 0, Xanthan Gum 0	Wheat Starch 25, Water 0, Xanthan Gum 0.4	Wheat Starch 25, Water 50, Xanthan Gum 0	Wheat Starch 25, Water 50, Xanthan Gum 0.4
Batter specific gravity	0.26^{a}	0.32^{cde}	0.32^{de}	0.29^{abc}	0.28^{ab}	0.34^{e}	0.33^{e}	0.28^{ab}	0.29^{abcd}
Batter pH	5.47^{b}	5.22^{a}	5.27^{a}	5.16^{a}	5.20^{a}	5.21^{a}	5.22^{a}	5.21^{a}	5.19^{a}
Crumb pH	5.70^{c}	5.38^{ab}	5.48^{b}	5.33^{a}	5.38^{ab}	5.39^{ab}	5.43^{ab}	5.42^{ab}	5.41^{ab}
Foam stability (Drainage,g)	29.20^{c}	6.18^{a}	1.47^{a}	19.37^{b}	1.47^{a}	3.63^{a}	0.17^{a}	18.77^{b}	1.07^{a}
Std. ht.-in (cm)	6.92^{f}	4.73^{bc}	4.17^{ab}	4.26^{ab}	3.90^{a}	5.45^{de}	5.23^{cd}	6.11^{e}	4.63^{bc}
Std. ht.-out (cm)	6.31^{e}	4.37^{abc}	4.01^{ab}	4.11^{ab}	3.81^{a}	4.94^{d}	4.83^{cd}	5.78^{e}	4.43^{bcd}
Width (cm)	9.24^{d}	8.46^{c}	8.17^{bc}	7.64^{a}	7.35^{a}	8.60^{c}	8.60^{c}	8.54^{c}	7.70^{ab}
Crust hardness	4.67^{b}	2.50^{a}	1.50^{a}	3.83^{b}	3.67^{b}	2.00^{a}	1.50^{a}	4.00^{b}	3.83^{b}
L	52.75^{a}	61.51^{b}	63.76^{b}	60.69^{b}	65.09^{b}	65.75^{bc}	72.92^{c}	60.33^{b}	65.90^{bc}
a^{+}	8.14^{d}	6.46^{bcd}	5.67^{abc}	6.95^{cd}	5.43^{abc}	5.29^{abc}	4.47^{a}	6.59^{bcd}	4.91^{ab}
b^{+}	16.90^{a}	17.44^{abc}	17.10^{ab}	18.20^{c}	18.10^{bc}	17.15^{ab}	17.49^{abc}	17.45^{abc}	18.74^{c}
Firmness (kg)	0.17^{a}	0.57^{ab}	1.03^{cd}	1.47^{de}	1.87^{e}	0.50^{ab}	0.77^{bc}	0.47^{ab}	1.43^{de}
Springiness	8.0^{bc}	8.3^{bc}	7.0^{ab}	7.0^{ab}	6.0^{a}	8.0^{bc}	8.3^{bc}	8.7^{c}	7.3^{ab}

[a]Means in a row with same letter do not differ significantly ($p \le 0.05$).

Table 6. Comparison of least squares means[a] of sensory characteristics of control, 100% egg white, angel food cake and cakes containing 65% egg white made with and without xanthan gum, water, and wheat starch.

		Wheat Starch 0				25			
		Water 0		50		0		50	
Sensory Characteristic	100% Egg White Control	Xanthan Gum 0	0.4	0	0.4	0	0.4	0	0.4
Contour	3.61^{de}	2.03^{ab}	1.58^{a}	2.47^{bc}	3.06^{cd}	2.67^{bc}	2.39^{b}	3.94^{e}	3.58^{de}
Grain	3.92^{d}	1.89^{b}	1.33^{a}	1.94^{b}	1.56^{ab}	2.72^{c}	2.61^{c}	3.69^{d}	2.61^{c}
Cell walls	3.39^{d}	2.69^{bc}	1.92^{a}	1.97^{a}	1.47^{a}	2.81^{bc}	2.58^{b}	3.19^{cd}	2.75^{bc}
Crumb tenderness	3.08^{ab}	3.11^{abc}	2.78^{a}	2.61^{a}	2.64^{a}	3.67^{cd}	3.86^{d}	3.50^{bcd}	3.56^{bcd}
Elasticity	3.72^{d}	2.61^{ab}	2.00^{a}	2.58^{ab}	2.08^{a}	3.08^{bc}	3.53^{cd}	3.69^{cd}	3.17^{bcd}
Sweetness	2.61^{a}	3.17^{b}	3.17^{b}	2.67^{a}	2.69^{ab}	2.47^{a}	2.39^{a}	2.58^{a}	2.39^{a}
Moisture adsorption	3.14^{bc}	2.89^{b}	2.06^{a}	2.22^{a}	2.25^{a}	3.94^{d}	3.86^{d}	3.72^{cd}	3.42^{bcd}

[a]Means in a row with same letter do not differ significantly ($p \leq 0.05$).

cake. Standing height and width measurements of the control cake are significantly higher than those of the 65% egg white cake, indicating the control cake had greater volume and less shrinkage during baking than the 65% egg white cake. The crust color of the control cake was significantly darker than the crust of the reduced egg white cake, but no significant differences were found in the a^+, redness, or b^+, yellowness, values of the two cakes. The crust of the angel food cake made with 100% egg white was significantly more firm, but tender, than the crust of the cake made with 65% egg white. No significant differences were found in IUTM readings for firmness and springiness of the two cakes (Table 5).

As can be seen from sensory data reported in Table 6, cakes made with 100% egg white have a significantly more symmetrical contour, more open grain, and thinner cell walls; are more elastic; and are less sweet than those cakes made with 65% egg white without any other additions. No significant differences in crumb tenderness and moisture adsorption are reported for the two cakes.

The addition of water, xanthan gum, and wheat starch alters the 65% egg white angel food cake; in some instances one ingredient is more beneficial than in others. The specific combinations of additives also influence their functionality in the 65% egg white cake; therefore, the addition of water, xanthan gum, and wheat starch will be discussed as to their effects, separately and in combination with each other, in the 65% egg white cake.

Effect of Added Water

<u>Physical measurements</u>. The addition of only water to the cakes made with 65% egg white resulted in a significantly decreased foam

stability and increased shrinkage or decreased cake width. Crust hardness was increased ($p \leq 0.05$) by the added water, and this was no longer significantly different from the control cakes, made with 100% egg white. Firmness was significantly increased by the added water compared to the 65% egg white cakes without any additions.

Water in the presence of xanthan gum or wheat starch or a combination of xanthan gum and wheat starch significantly decreased batter specific gravity and increased crust hardness so that these measurements were not significantly different from those of the control cake. In the presence of xanthan gum alone, water significantly decreased cake width, even further than in cakes with no added ingredients. Water and xanthan gum significantly decreased the width and inside standing height of these cakes compared to those cakes made without added ingredients. The outside standing height also was decreased although the decrease was not significantly different from the 65% egg white cake without added ingredients. With xanthan gum and water an increase ($p \leq 0.05$) in firmness and decrease in springiness resulted.

Water in the presence of wheat starch resulted in a significantly decreased foam stability compared to foams with no added ingredients, but the foam was more stable ($p \leq 0.05$) than that of the 100% egg white control cake. This combination increased ($p \leq 0.05$) standing height outside the pan to a value which was not significantly different from the 100% egg white control cake.

Water in the presence of xanthan gum and wheat starch together significantly increased shrinkage or decreased width measurements compared to both the 65% egg white cake with no additives and the 100% egg white control cake. Firmness of the crumb also was increased significantly by the addition of water, xanthan gum, and wheat starch. These cakes were significantly more firm than either the 100% egg white control or the 65% egg white cake with no additives.

No significant differences in batter and crumb pH, L, a^+, b^+, or springiness measurements for the 65% egg white cake with added water, alone or with xanthan gum or wheat starch or a combination of xanthan gum and wheat starch, were found.

Sensory characteristics. Water added to the 65% egg white cakes resulted in cell walls significantly thicker than those of the 100% egg white control or the 65% egg white cakes with no additives. The added water also made the 65% egg white cakes significantly less sweet than the 65% egg white cake with no additives, but the sweetness was not significantly different from that of the 100% egg white control cake. The reduced egg white cakes with added water were significantly more moist than either the 100% egg white control or the 65% egg white cake with no added ingredients.

The presence of xanthan gum, wheat starch, or their combination when water was added, significantly improved contour scores compared to those cakes with no additives. The cakes with xanthan gum, wheat starch, or xanthan gum and wheat starch were more symmetrical than the 65% egg white cakes without those ingredients and were not significantly different from the 100% egg white control cake. Cells were more open than the 65% egg white cakes without added ingredients and not significantly different from the cells of the 100% egg white control cake when water was added in the presence of wheat starch.

No significant differences in crumb tenderness and elasticity were found with the addition of water, alone or with xanthan gum, or a combination of xanthan gum and wheat starch. Elasticity of cakes with wheat starch and water was significantly higher than for the 65% egg white cakes with no additives.

Effect of Xanthan Gum

Physical measurements. The addition of xanthan gum alone significantly increased firmness of the cake crumb, making the crumb more firm than that of either the 100% egg white control cake or the 65% egg white cake with no added ingredients, which were not significantly different from each other. No significant differences in other physical measurements were attributed to the gum alone, and xanthan gum in the presence of wheat starch did not significantly change any physical measurement. Xanthan gum in the presence of wheat starch resulted in cake crusts significantly lighter in color and less red than those of the 65% egg white cakes with no additives, but other physical measurements were not significantly different between the xanthan gum/wheat starch combination and the 65% egg white cake with no additives. The cakes with xanthan gum added in the presence of wheat starch were significantly different from the 100% egg white control cake except for the yellowness score, the positive b values reported, and the springiness values, neither of which were significantly different from the 100% egg white control.

Sensory characteristics. With the addition of xanthan gum the grain was significantly less open, cell walls were significantly thicker, and the cakes were significantly more moist than 65% egg white cakes with no additives. Contour, crumb tenderness, elasticity, and sweetness were not significantly altered with the addition of only xanthan gum. All characteristics, except crumb tenderness, were significantly different from those of the 100% egg white control cake. No significant differences for any sensory characteristics were found with the addition of xanthan gum in the presence of wheat starch as compared to the 65% egg white cakes without added ingredients.

Effect of Wheat Starch

Physical measurements. Wheat starch alone significantly increased standing height measurements compared to the 65% egg white cake with no additives, however, the increased standing height was still significantly lower than the standing height of the 100% egg white control cake. Compared to the 65% egg white cake with no additives, no significant differences in the other physical measurements could be attributed to wheat starch alone.

Sensory characteristics. The addition of wheat starch alone made the grain significantly more open than the grain of the 65% egg white cake with no additives. Wheat starch alone made the cakes significantly less sweet and significantly drier than the 65% egg white cake with no additives; however, the sweetness and moisture adsorption were not significantly different from the 100% egg white control cake. No significant differences in contour, cell walls, crumb tenderness, and elasticity were found due to the presence of wheat starch alone.

DISCUSSION

The addition of water to the 65% egg white cake lowers surface tension of the egg white so that more air can be incorporated into the batter (Le Clerc and Bailey, 1941) as evidenced in the lowered ($p \leq 0.05$) batter specific gravity of those cakes with added water. The air incorporated into the batter was not held though, as those foams with only added water were significantly less stable than the foams of the 100% egg white control cake, or the foams of the reduced egg white cake with added water in the presence of xanthan gum. The protein films are weakened (diluted) because water alone is not viscous enough to prevent drainage from the air bubbles of the foam (Baldwin, 1973). Xanthan gum and wheat starch are both hydrophilic colloids and would be expected to increase the viscosity of a water system; however, with wheat starch this occurs mainly during gelatinization with heating. On the other hand, xanthan gum is hot and cold water soluble and exhibits a high viscosity at low concentrations both before and after heating (Rocks, 1971; Anonymous, 1974; Hodge and Osman, 1976; Anonymous, 1978; Anonymous, undated). No significant differences in foam stability of the reduced egg white cake with added water were found due to the presence or absence of xanthan gum.

Foam instability is further evident in the increased shrinkage or decreased width measurements ($p \leq 0.05$) of the reduced egg white cakes with added water. With expansion of the air bubbles in the foam on heating, the foam's leavening power was lost because the film containing the air bubbles was not elastic and able to expand (Baldwin, 1973). The cakes collapsed, resulting in a significantly firmer cake crumb with thicker ($p \leq 0.05$) cell walls.

The addition of water was structurally beneficial in the reduced egg white cakes when xanthan gum or wheat starch was present. Cake contour was significantly more symmetrical when water was added in the presence of either or both hydophilic colloids. Wheat starch appears to have been more effective in improving standing height of the 65% egg white cake with added water; standing height outside the pan was not significantly different from that of the 100% egg white control cake. Also, no significant differences in width were found when wheat starch was present and water was added; but if xanthan gum or xanthan gum and wheat starch were present, width measurements were significantly decreased, indicating greater shrinkage during baking. Christianson (1976) reported the need for an increased moisture level in xanthan gum--starch breads to fully hydrate the starch and the gum. Since xanthan gum and wheat starch are both hydrophilic and compete for available water, the water level may not have been sufficient to fully hydrate both additives in the 65% egg white cake. A structural improvement was found in the cakes when wheat starch was added with sufficient hydration to gelatinize during baking, but the detrimental effect which resulted when xanthan gum and wheat starch were present may be related to insufficient water for complete hydration of both.

Christianson (1976) has suggested the formation of a xanthan gum--starch complex to retain gas during baking of starch breads. No evidence of the existence of such a complex in these angel food cakes also may be related to an insufficient water level in the reduced egg white cakes.

Xanthan gum without added water appears ineffective in the reduced egg white cakes. The addition of xanthan gum alone to the reduced egg white cakes results in a significantly more firm cake crumb, more collapsed grain, and thicker cell walls. Xanthan gum seemingly competes for available water at the expense of the structure formers, proteins and starch, resulting in a collapsed structure during baking. No significant differences in physical measurements or sensory characteristics were found when xanthan gum was added in the presence of wheat starch. These results seem to agree with Kim (1980) who used the amylograph to test gelatinization temperatures of cake flour/sugar/water/xanthan gum suspensions and showed that xanthan gum does not affect the initial temperature of starch gelatinization.

Wheat starch alone added to the reduced egg white cakes significantly increased standing height measurements, and the grain was more open. Wheat starch with added water resulted in a cake similar to the control cake. The removal of 35% alkaline egg white did decrease ($p \leq 0.05$) pH and crust browning. Foam stability was improved significantly. Standing height in the pan and width measurements were significantly lower but no significant differences in standing height out of the pan compared to the 100% egg white cake were found. The importance of starch gelatinization and the extent to which it occurs in angel food cake has been reported (Hoseney et al., 1977; Hoseney et al., 1978; Lineback and Wongsrikasen, 1980). Derby, Hoseney, and their co-workers (1975; 1977) emphasized temperature, available water, and other ingredients present in the system are important in determining the extent of gelatinization. Derby (1975) suggested that differences in moisture content which affect starch gelatinization also influence product volume. Based on results obtained when water was added to a reduced egg white cake containing wheat starch, it seems possible to restore volume of the cake equal to that of the 100% egg white control cake, provided optimum levels of both ingredients are present. This cake did not differ significantly from the 100% egg white control for any sensory measurement.

CONCLUSION

Egg white is a polyfunctional ingredient. Particularly important functions in the production of angel food cake are its foaming and coagulating abilities. A 35% reduction of egg white in angel food cake causes significant differences from a 100% egg white control cake. The addition of xanthan gum, water, and wheat starch improve the reduced egg white cake; in some instances, one ingredient is more beneficial than in others. Added water is important in lowering surface tension of the egg white so that more air can be incorporated into the decreased egg white batters. Xanthan gum enhances foam stability by holding the added water in the foam. Wheat starch contributes to structure by its gelatinization during baking. Based on results of this study no one of the added ingredients: xanthan gum, water, or wheat starch, can successfully replace 35% of the egg white in angel food cake. However, the reduced egg white cake made with wheat starch and added water is similar to the 100% egg white control cake.

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APPENDIX

Table A-1. Formulation and ingredient specifications for angel food cakes.

Ingredient	Control Cake	Egg and Xanthan Gum Level Varied	65% Egg White Cake
		%, flour weight basis	
Flour, soft wheat patent (SnoSheen, Pillsbury)	100	100	100
Sugar, bakers' special (Domino, Amstar)	285	285	285
Rehydrated egg albumen[a] (Type P-20[b], Henningsen)	305	[c]	198
Acid salt (Monocalcium phosphate, monohydrate, Regent 12XX, Stauffer Chemical)	1.4	1.4	1.4
Sodium chloride	2.7	2.7	2.7
Additional water	--	--	50
Xanthan gum (Keltrol F, Kelco Co.)	--	0.2 or 0.4	0.4
Wheat starch, unmodified (Paygel P, General Mills[d])	--	--	25

[a] 12% dried egg solids to 88% distilled water rehydration ratio.

[b] Includes approximately 0.1% sodium lauryl sulfate added to dried egg solids by processor.

[c] Cakes containing 80, 65, and 50% of egg white of control cakes contained 244, 198, and 152% rehydrated albumen, respectively, on a flour weight basis.

[d] Now available from Henkel Laboratories.

Table A-2. Procedures for physical measurements of cakes.

1. pH of batter and crumb

The AACC 02-52 hydrogen-ion activity (pH)-electrometric method (AACC, 1962) was modified for use. A 15 g sample of batter or a 15 g sample of crust-free crumb broken into small pieces was mixed in 100 ml distilled water, stirred with a magnetic bar approximately two minutes, and pH recorded by a Beckman 3560 pH meter.

2. Foam stability

A 50 g sample of batter was transferred to a 75 mm diameter funnel with a 2.5 cm glass wool stopper, covered with plastic wrap, and allowed to sit overnight (18 $\pm$ 2 hours) over a dry, weighed 100 ml graduated cylinder. The foam stability was indicated by the difference in weight of the cylinder before and after drainage (Lowe, 1955).

3. Standing height

Standing height, an index to volume, was found by using a thin metal skewer to measure the depth of the cake at five places across a radius, then reading directly in cm on a ruler. An average of these values was recorded as standing height in the pan. The cake was ringed with a metal spatula, turned out onto the counter in an upright position, and depth measurements immediately taken across a radius. An average of these five values was recorded as standing height out of the pan.

4. Width

Using a thin metal skewer, the width of the radius was measured in seven randomly selected places and read directly in cm on a ruler. An average of these seven values was recorded as width.

Table A-2. (Continued)

5. Crust hardness

Crust hardness was determined by the investigator the day after baking. The three middle fingers were used to touch the crust of the intact cake and evaluate hardness on a 5-point scale; 1, too tender, crumbly to 5, tender, firm.

Table A-3. Least squares means[a] of physical measurements of angel food cake with three levels of xanthan gum.

Physical Measurement	Level of gum (%)		
	0	0.2	0.4
Foam specific gravity	0.14	0.14	0.14
Batter specific gravity	0.31	0.31	0.30
Batter pH	5.30	5.30	5.36
Standing ht.-in (cm)	6.00	5.55	5.90
Standing ht.-out (cm)	5.00	5.09	4.96
Width (cm)	6.84	7.22	6.45

[a]Three replications.

Table A-4. Least squares means[a,b] of physical measurements of angel food cake made with four levels egg white and three levels xanthan gum.

Physical Measurement	Level of egg white (%)											
	50			65			80			100		
	Level of xanthan gum (%)											
	0.0	0.2	0.4	0.0	0.2	0.4	0.0	0.2	0.4	0.0	0.2	0.4
Batter specific gravity	0.39^{a}	0.34^{bc}	0.35^{ab}	0.31^{bcde}	0.32^{bcd}	0.31^{bcde}	0.26^{e}	0.29^{cde}	0.27^{e}	0.29^{cde}	0.28^{de}	0.27^{e}
Batter pH	5.11^{ab}	5.05^{a}	5.04^{a}	5.22^{bd}	5.28^{cd}	5.39^{ce}	5.38^{ce}	5.29^{cd}	5.42^{e}	5.50^{ef}	5.56^{f}	5.58^{f}
Standing ht.- in (cm)	2.89^{a}	1.76^{a}	1.93^{a}	6.16^{b}	5.93^{b}	6.25^{bc}	7.45^{bc}	7.09^{bc}	7.61^{bc}	7.51^{bc}	7.43^{bc}	7.80^{c}
Standing ht.- out (cm)	0.00^{a}	1.32^{b}	0.00^{a}	5.88^{cdf}	5.46^{c}	5.42^{c}	6.96^{de}	6.66^{ef}	7.10^{e}	7.17^{e}	6.93^{ef}	7.31^{e}
Width (cm)	0.00^{a}	2.57^{b}	0.00^{a}	8.98^{c}	8.30^{c}	8.40^{c}	9.25^{c}	8.98^{c}	8.63^{c}	9.12^{c}	9.02^{c}	8.76^{c}

[a]Means in a row with same letter do not differ significantly ($p \leq 0.05$).

[b]Three replications.

Table A-5. Significance[a] of difference from control of least squares means[b] of physical measurements of angel food cake containing 65% egg white with and without xanthan gum, water, and wheat starch.

Physical Measurement	Control	Wheat Starch 0				25			
		Water 0		50		0		50	
		Xanthan Gum 0	0.4	0	0.4	0	0.4	0	0.4
Batter specific gravity	0.26	0.32**	0.32**	0.29	0.28	0.34***	0.33***	0.28	0.29
Batter pH	5.47	5.22***	5.27**	5.16***	5.20***	5.21***	5.22***	5.21***	5.19***
Crumb pH	5.70	5.38***	5.48***	5.33***	5.38***	5.39***	5.43***	5.42***	5.41***
Foam stability (Drainage, g)	29.20	6.18***	1.47***	19.37**	1.47***	3.63***	0.17***	18.77**	1.07***
Std. ht.-in (cm)	6.92	4.73***	4.17***	4.26***	3.90***	5.45***	5.23***	6.11*	4.63***
Std. ht.-out (cm)	6.31	4.37***	4.01***	4.11***	3.81***	4.94***	4.83***	5.78	4.43***
Width (cm)	9.24	8.46**	8.17***	7.64***	7.35***	8.60*	8.60*	8.54**	7.70***
Crust hardness	4.67	2.50***	1.50***	3.83	3.67	2.00***	1.50***	4.00	3.83
L	52.75	61.51*	63.76**	60.69*	65.09**	65.75**	72.92***	60.33*	65.90**
a^+	8.14	6.46	5.67*	6.95	5.43**	5.29**	4.47***	6.59	4.91**
b^+	16.90	17.44	17.10	18.20*	18.10*	17.15	17.49	17.45	18.74**
Firmness (kg)	0.17	0.57	1.03**	1.47***	1.87***	0.50	0.77*	0.47	1.43***
Springiness	8.0	8.3	7.0	7.0	6.0*	8.0	8.3	8.7	7.3

[a]Level of significance is indicated as follows: *, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$.

[b]Three replications.

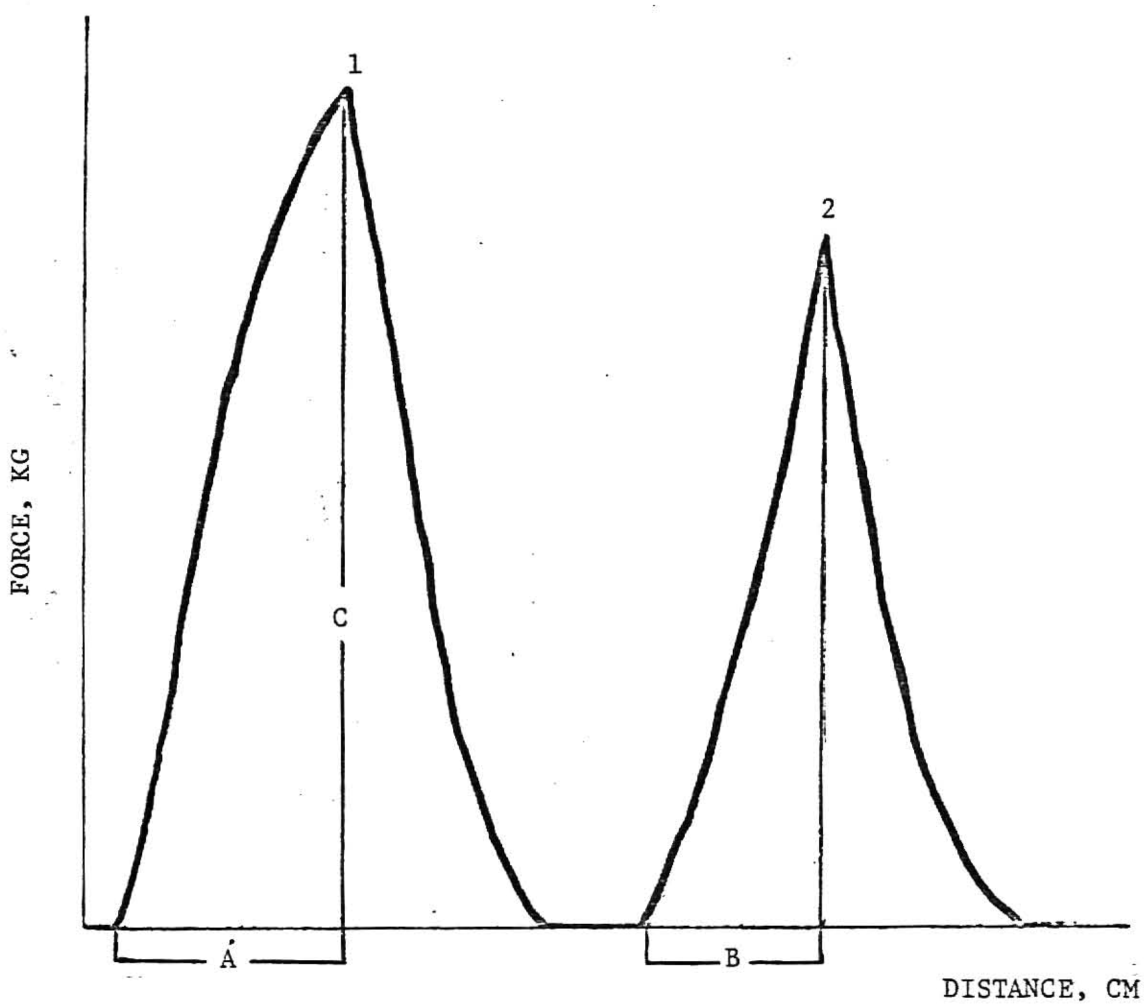
Table A-6. Significance[a] of difference from control of least squares means[b] of sensory characteristics of angel food cake containing 65% egg white with and without xanthan gum, water, and wheat starch.

		Wheat Starch 0				25			
		Water 0		50		0		50	
Sensory Characteristic	Control	Xanthan Gum 0	0.4	0	0.4	0	0.4	0	0.4
Contour	3.61	2.03***	1.58***	2.47**	3.06	2.67**	2.39**	3.94	3.58
Grain	3.92	1.89***	1.33***	1.94***	1.56***	2.72***	2.61***	3.69	2.61***
Cell walls	3.39	2.69*	1.92***	1.97***	1.47***	2.81*	2.58**	3.19	2.75*
Crumb tenderness	3.08	3.11	2.78	2.61	2.64	3.67*	3.86**	3.50	3.56
Elasticity	3.72	2.61**	2.00***	2.58**	2.08***	3.08*	3.53	3.69	3.17
Sweetness	2.61	3.17*	3.17*	2.67	2.69	2.47	2.39	2.58	2.39
Moisture adsorption	3.14	2.89	2.06**	2.22**	2.25**	3.94**	3.86*	3.72	3.42

[a]Level of significance is indicated as follows: *, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$.

[b]Three replications.

Figure A-1. Typical compression curves obtained from the Instron UTM for determining firmness and springiness of baked products.



B/A X 100 = springiness or elasticity
C = firmness

(Neukom and Rutz, 1980)

Figure A-2. Scales used by trained panel for evaluating angel food cake.

Evaluation of Angel Food Cake

Name ______________________ Date ______________________

Directions: Use the scale given below to evaluate the angel food cake samples. You may assign half points.

Sample No.	Contour	Grain	Cell Walls	Crumb Tenderness	Elasticity	Sweetness	Moisture Adsorption

Scales:

Contour	Grain	Cell Walls	Crumb Tenderness
1 uneven	1 collapsed cells	1 thick cell walls	1 too tender
2	2	2	2
3	3	3	*3 tender
4	4	*4	4
*5 symmetrical	*5 open cells	5 thin cell walls	5 tough

Elasticity	Sweetness	Moisture Adsorption
1 does not return to original shape	1 slightly sweet	1 does not require much saliva-most moist
2	2	2
3	*3	*3
*4	4	4
5 returns to original shape	5 too sweet	5 requires much saliva-driest

*This would be considered ideal.

Note: Please describe any non-characteristic or off-flavors.

ADDITION OF XANTHAN GUM, WHEAT STARCH, AND WATER TO ANGEL FOOD CAKE WITH A REDUCED EGG WHITE LEVEL

by

LOUISE LYNETTE MILLER

B. S., University of Tennessee, 1976

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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Xanthan gum has been suggested as a replacement for certain ingredients in cake systems. Additions of 0.4% xanthan gum, 50% water, and/or 25% wheat starch, based on flour weight, were made to angel food cakes containing 65% total egg white. A randomized complete block design, plus a control cake with 100% egg white, was used to study treatment effects. Physical measurements of the cakes included batter specific gravity, batter and crumb pH, foam drainage as a measure of stability, standing height as an index to volume, width of the cakes, and crust hardness. The Instron Universal Testing Machine was used to evaluate firmness and springiness of the cake samples. Sensory characteristics were analyzed by a six member experienced and trained panel using a five point category scale.

Analysis of variance of physical and sensory data revealed significant differences ($p \leq 0.05$) in cakes due to treatment. Added water lowered surface tension of the egg white so that more air could be incorporated into the batter. Xanthan gum increased ($p \leq 0.05$) foam stability, and wheat starch contributed to the structure of the reduced egg white cake. The wheat starch addition resulted in cakes with significantly increased standing height and a more open grain compared to the reduced egg white cakes with no additives. Cakes with 50% added water and 25% wheat starch were considered most similar to the 100% egg white cakes.