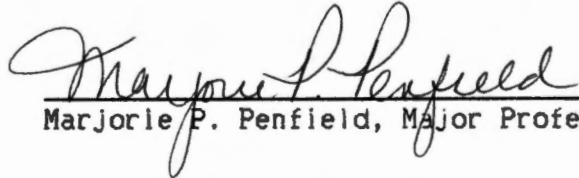
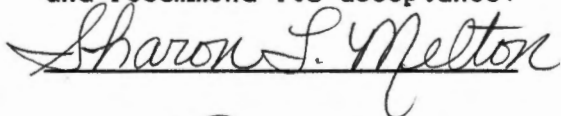


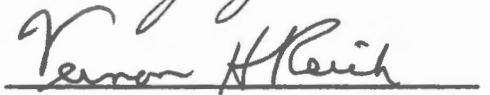
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I am submitting herewith a dissertation written by Marsha Anne McNeil entitled "The Effects of Combinations of Gum, Starch, and Water on Batters and Microwave-Baked Cakes." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Food Technology and Science.

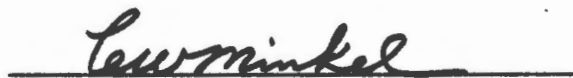

Marjorie P. Penfield, Major Professor

We have read this dissertation
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Accepted for the Council:


Vice Provost
and Dean of The Graduate School

THE EFFECTS OF COMBINATIONS OF GUM, STARCH, AND WATER ON BATTERS
AND MICROWAVE-BAKED CAKES

A Dissertation
Presented for the
Doctor of Philosophy
Degree
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Marsha Anne McNeill

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Thesis

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DEDICATION

This dissertation is dedicated to Hoyle and Betty McNeil, parents
of the author.

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ABSTRACT

In order to investigate the effects of microwave-baking of cakes, 60 combinations of hydroxypropyl methycellulose (1.8, 2.0, 2.2% fw), modified pregelatinized potato starch (3.2, 4.2, 5.2, 6.2% fw), and deionized water (137.5, 150.0, 162.5, 175.0, 187.5% fw) were used in a modification of the AACC layer cake formulation. The study was a balanced incomplete block. Batter tests included pH, specific gravity, and viscosity. Cake and crumb tests included weight loss and moisture content. Shrinkage, volume, symmetry, and uniformity also were determined. A modified texture profile analysis was done. Gum level was not significant ($p < 0.05$) for most of the objective measurements. Starch content was a significant factor ($p < 0.05$) for pH, viscosity, and chewiness. Water levels influenced all of the objective batter and cake tests except weight loss and uniformity.

A lexicon of sensory terms and reference standards were developed. Twenty descriptors were grouped into surface appearance, resistance to cut with fork, crumbliness, springiness, texture in the mouth, first bite with the molars, breakdown, ease of chewing, ease of swallowing, and residual. A 7-member panel evaluated the cake formulas using 15-cm scales anchored with bipolar terms. Water influenced ($p < 0.05$) more of the sensory parameters than gum or starch.

Response surface methodology was used to plot the data and help choose formulas for selected studies. The four formulas chosen for these studies represented the extremes on the response surfaces. The selected studies included scanning electron microscopy (SEM) of the

crumb, flow patterns of the batter during baking, microscopic evaluation of the fat, subjective crumb evaluation, and a consumer panel. The SEM micrographs clearly showed the potato starch granules. The flow patterns were similar for the four microwave formulas, but were different from the flow in the conventional oven. There was not an obvious difference in the size and distribution of the fat cells among the four batters. The crumb cell size, however, decreased noticeably as starch and water levels increased. Finally, the consumer panel evaluated two of the four formulas and an "ideal" cake. Both of the formulas were similar to the ideal.

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CHAPTER I

INTRODUCTION

The phenomenal changes that occur during the conventional baking of batter into cake always have been of interest to cereal chemists. These chemical and physical changes take place in the batter as heat is applied. Carlin (1944) defined a shortened plain cake batter as "a foam of air dispersed in fat and this foam is distributed in a medium of flour in liquid." The fluid batter contains a mixture of flour, sugar, shortening, water, leavening, and other ingredients. Layer cakes contain 20-50% fat (flour weight basis, fw) (Chung and Pomeranz, 1983). The batter sets during conventional baking at 90°-92°C and bakes from the periphery to the center and from the bottom to the top of the batter (Yamazaki and Kissell, 1978).

An alternative to baking cake in the conventional oven is using the microwave oven. In the 1980's, commercial cake mixes have been introduced that are designed specifically for baking in the microwave oven. However, there is little information available in the literature pertaining to the technology and baking process of these cake mixes. Microwave baked layer cakes offer convenience in terms of time, but exhibit different sensory characteristics when compared to conventionally baked cakes.

Hill and Reagan (1982) and Stinson (1986a,b) investigated the quality of microwave-baked cakes. Hill and Reagan (1982) found that microwave-baked cakes were satisfactory to a sensory panel but received

lower sensory scores than conventionally baked cakes. Stinson (1986a,b) baked devil's food cake in a microwave/convection oven and obtained acceptable sensory scores for these cakes. She (1986a,b) reported that the basic differences observed in the microwave-baked cakes compared to conventionally baked cakes were inferiority in crust color, texture, and surface contour and less moisture. Other researchers have supported Stinson's findings (Hill and Reagan, 1982; Lorenz et al., 1973; Martin and Tsen, 1981; Neuzil and Baldwin, 1962; Proctor and Goldblith, 1948; Street and Surratt, 1961). Van Zante (1973) pointed out that the rapid heating of batter by microwaves may produce a porous cake which exhibits poor texture. Also, carbonyl-amine browning does not occur in cake baked in the microwave (Van Zante, 1973).

A delicate balance exists among the ingredients in cake (Campbell et al., 1979). Therefore, ingredient changes could improve the quality of microwave cakes. Further, by altering ingredients and studying the quality, the underlying causes for the less desirable attributes of microwave cakes may be explained. Three ingredients often used in cake mixes are gums, starches, and water. Gums are used in many commercial conventional and microwave cake mixes. Gums serve several purposes such as thickening, emulsifying, and stabilizing. Gums also affect batter properties and add to the quality of the cake. Lee et al. (1982) and Lee and Hoseney (1982) worked with the development of a single-stage cake mix for the conventional oven and studied the effects of emulsifiers and gums upon the mix. When 1% xanthan gum, fwb, was added to the premix, the batter and cake were comparable to a commercial batter and cake. Methocel F (hydroxypropyl methylcellulose) is another

gum that can aid cake production by increasing air entrapment and gas retention (Anon., 1988a).

In addition to gums, starch and water are two other important ingredients in layer cakes. Ghiasi et al. (1982) referred to baked products as "limited-water-systems." The quality of baked products depends in part upon the gelatinization of starch which is influenced by many factors including temperature, sugar, and water level. Alpha Biochemical Corporation (Richland, WA) has developed a modified pregelatinized food potato starch (Alphajel K3000) that is applicable to cake mixes.

Potato starch contains phosphorus which forms a monoester with glucose causing this starch to have very rapid water uptake, high solubility, high viscosity, high water-holding capacity, long body retention, and to be transparent (Anon., 1988b). These characteristics make this starch suitable for a rapid heating system, such as microwave cakes.

An alteration of ingredients or baking method can affect the sensory properties of cake. Meilgaard et al. (1987) reported that trained panelists can identify and quantify product attributes. In descriptive evaluation, the development of terminology is critical. Civille and Lawless (1986) emphasized the importance of terminology to the goal of a sensory evaluation project. Deming and Setser (1988) listed terms for conventionally baked layer cakes. However, a comprehensive lexicon of cake terms with definitions and reference standards is not available in the literature.

Since there is little information available pertaining to the characteristics of microwave batter and cake, a study was undertaken to develop a layer cake formulation for the microwave oven. By altering key ingredients, gum, starch, and water, information could be obtained to explain the underlying causes for the characteristics of microwave cake. Also, descriptive sensory work for cake will supplement the evaluation procedures now available. The objectives of the study were:

1. To investigate the effects of gum levels on batter and cake.
2. To investigate the effects of the starch levels on batter and cake.
3. To investigate the effects of the water levels on batter and cake.
4. To investigate the interactions of gum, starch, and water levels, and effects of the interactions on the characteristics of the batter and crumb.
5. To select a layer cake formulation for the microwave oven, based on the results of ingredient interactions studies.
6. To develop a lexicon of cake descriptors.

CHAPTER II

REVIEW OF LITERATURE

I. LAYER CAKE FORMULATION AND FORMATION

Yamazaki and Kissell (1978) described cake as a semidry foam. Campbell et al. (1979) referred to shortened cake, those cakes other than angel food and sponge cakes, as baked wheat mixtures that contain shortening and leavening agents. The ingredient balance is essential to layer cake formation.

Lawson (1965) discussed the history and importance of cake formula balance. In the "pre-emulsifier era" (1926 to 1933) the rules for cake formulas were different from those used in 1933 with the advent of emulsifiers. The "pre-emulsifier era" rules included that the weight of the sugar was not more than the weight of the flour, that the weight of the shortening was not more than the weight of the eggs, and that the weight of the liquid ingredients was equal to the flour weight (Lawson, 1965).

The "monoglyceride emulsifier era" began in 1933 and the rules for cake formula balance changed. The changes included that the weight of the sugar for white and yellow cakes could be 140% of the flour weight, and that the weight of the liquid ingredients could be more than the weight of the sugar (Lawson, 1965). Lawson (1965) mentioned a third era called the "new emulsifier era" in which the amount of liquid was increased in relation to the amount of flour.

The "monoglyceride emulsifier era" rules are similar to the rules for the high-ratio cakes. The rules for high-ratio cake include the weight of the sugar is 1.1-1.8 times the flour weight; the weight of the egg is equal to or more than the weight of the shortening; the weight of the shortening is 30-70% the weight of the flour; and the weight of the liquid ingredients is 25-35% more than the weight of the sugar (Matz, 1960).

Howard (1972) reviewed ingredients necessary for layer cake formation and indicated that cake batter is a complex system that undergoes many changes due to the interactions of ingredients. The essential ingredients are identified as soluble and insoluble proteins, soluble and insoluble starch, and inorganic salts. Howard (1972) defined a cake batter as a fat-in-water emulsion. The bulk phases of the batter are aqueous, fat, vapor, and starch granules. In describing the role of emulsifiers in cake batter, Howard (1972) reported that the partially hydrogenated mono- and diglycerides do not help with aeration, but stabilize the batter during baking by dispersing the shortening. Aeration, with these types of emulsifiers, is dependent upon the shortening used. Small air bubbles are trapped in the shortening. The batter is a water-in-fat emulsion until all of the liquid has been added and the emulsion inverts to fat-in-water. Alpha-tending emulsifiers, such as 1-acetyl-3-monostearin and propylene glycol monostearate, help indirectly with aeration and help directly with fat dispersion. However, Howard (1972) pointed out that soluble protein is the necessary ingredient for air incorporation and the emulsifiers stabilize the batter. The alpha-tending emulsifiers form a tough film around fat

droplets at the oil/water interface in single stage mixing. This film restrains the fat and the proteins can exhibit foaming properties.

Howard (1972) noted that when the aerated batter from two-stage mixing is placed in a heated oven, further ingredient interactions occur. The vapor phase is made up of bubbles of carbon dioxide and water vapor that are released as the fat melts. If the vapor/aqueous interface is stable, the other batter ingredients do not separate out.

In a batter made from single-stage mixing, the vapor phase initially is dispersed throughout the aqueous phase. When the alpha-tending emulsifiers melt during baking the batter becomes unstable. Howard (1972) reported that soluble proteins, polyvalent cations, and surface active lipids were essential for cake formation. Howard (1972) further reported that egg whites add significantly to batter and cake structure. Polyvalent cations from flour, egg, milk, and leavening agents also are necessary for good batter and cake performance. Calcium chloride, 2855mg/440g of batter, helps stabilize batter. Surface-active lipids, such as stearic acid, are high temperature batter stabilizers.

Interfacial tension studies performed by Howard (1972) showed that batter containing cottonseed oil, stearic acid, egg white CaCl_2 , and water, displayed a strong interfacial tension between oil/water and resulted in a successful cake. Microscopic examination of this batter showed fat droplets encapsulated by a thick, tough film. During baking this film prevents the fat from interfering with the vapor/aqueous interface.

During thermal setting the fluid batter becomes a solid structure that is porous (Howard, 1972). Gelatinization of starch is pertinent for the batter to set up. The water in the batter is absorbed by the starch. The ability of the starch to absorb the water is compounded by sugar level, protein level, presence of surface active lipids, pH, temperature of baking, length of baking, and type of starch.

In 1950, Hunter et al. conducted a thorough study of shortened cakes which included indentifying the relationships between the fundamentals of the structure of the batter and the quality of the cake. The variables were formula (low-sugar, medium-sugar, high-sugar), mixing method (conventional, pastry-blend, dump), baking powder levels (4, 6, 8% fwb), types of fat (hydrogenated shortening, margarine, lard), and temperature of ingredients (8°, 22°, 30°C). The tests performed during this study were density of batter, electrical resistance and conductivity of batter, relative viscosity of batter by linespread, microscopic examination of batter with and without stained fats, specific volume of cake by rapeseed displacement, compressibility of cake, and subjective testing including comments about the batter and cake. A sensory panel judged the cakes for size of cell, distribution of cells, crumb characteristics, tenderness, moisture, and flavor. The design of the study was a modified factorial and the results were analyzed by analysis of variance.

Density of the batters and specific volumes of the cakes were considered to be the most useful objective measurements. The formula, mixing method, and fat influenced batter and cake characteristics.

Initial temperature contributed only to batter structure. Only cake quality was influenced by level of baking powder.

As the levels of sugar and fat increased and flour level decreased, the batter density decreased and relative viscosity increased. The rich formulas resulted in cakes which were velvety and tender. The low-sugar formula did not result in good quality cakes if mixed by the pastry-blend or dump methods. The batters containing hydrogenated shortening and margarine were well aerated. The batters containing lard were not well aerated. The shortening and lard were dispersed readily in the batters, whereas the margarine was not.

Kissell and Yamazaki (1979) pointed out that the kinetic phase of baking which includes thermal expansion, leavening expansion, structure setting, contraction, and shrinkage is not monitored easily due to the lack of methodology.

Gordon et al. (1979) used a controlled environmental oven to bake cakes with varying flour/starch ratios, 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50. The purposes of this study were to observe water-loss rates, temperature rates, and structures of the batter and cake. In the early stages of baking, Gordon et al. (1979) reported that temperature gradients through the batter are not well established. During this period, the surface of the batter cools as evaporations takes place, while the pan transfers heat from the oven to the edges and bottom of the batter. Also, the batter begins to expand and move. The authors found maximum water-loss to occur between 6 and 9 min for the six cakes. The 50:50 ratio cakes had maximum water-loss at 6 min and the 100:0 cake at 9 min. These researchers proposed that gelatinization and/or

evaporation influenced the rate of water-loss. After the maximum water-loss occurs and temperatures reach at least 81°C, the temperature gradients as well as the moisture gradients are well established. Water tries to move through the porous structure to the surface. In these cakes, scanning electron microscopy showed that starch gelatinization was nonuniform with distorted granules and an uneven matrix.

Cake structure affects water-loss. water-loss occurs faster in an open cake structure than in one with a closed structure. On the other hand, the structure is dependent upon gelatinization which is dependent upon the temperature and thermal diffusivity. Hsu et al. (1980) continued water-loss rates studies in cakes by using emulsified cakes.

Cloke et al. (1984a) studied the effects of monoglycerides (saturated, SMG and unsaturated, USMG) on crumb of cake. Specific gravity, water-loss, temperature of batter, and cake weight were measured. The crumb was examined by scanning electron microscopy (SEM). Water-loss appeared to occur at 4 distinct rates T^0-T^1 , from 0-6 min; T^1-T^2 from 6-11 min; T^2-T^3 from 11-17 min; and T^3-T^4 from 17-23 min. Plateaus were observed due to batter formula. The T^2-T^3 rate was most affected by batter make-up. The emulsifier type and level affected the length of T^2-T^3 plateau. During the T^2-T^3 rate, crumb changes were noticed also. SMG at levels of 5-10% and USMG at levels of 1-3% caused a nonuniform crumb, tunneling, and air cavities.

The distribution of air cells also was dependent upon presence and type of emulsifier. In cakes with no emulsifier the air cells were small and the cake was rubbery. The cakes with 5% SMG or greater had larger air cells and tunnels. The USMG cakes also had tunneling, but as

the level of USMG increased the air cells decreased in size. The batter in the unemulsified cakes contained lipid droplets of various sizes. The starch granules were most easily distinguishable in the SMG cakes by SEM. The lipid droplets in SMG cakes were elongated and ropelike. In the USMG cakes, the lipid droplets were smaller than in the SMG cakes. The authors concluded that air incorporation is not associated always with final cake volume. Tunneling and uneven cell structure of crumb also affect cake volume. Water-loss and heat transfer were thought to be related to the emulsive system and also to other physical and chemical changes that happen during baking. Levels of 4% of SMG and USMG were considered optimal for crumb structure.

II. INGREDIENT VARIATIONS

Through the years, researchers have varied ingredients in cakes. The reasons for the alterations in formulation are as numerous as the possible ingredients (Hess and Setser, 1983; Ebeler and Walker, 1984; Pearce et al., 1984; Neville and Setser, 1986; Ngo and Taranto, 1986). For example, gums are added to batters as thickening and stabilizing agents (Lee et al., 1982). Standard ingredients in cake are cake flour, leavening agents, egg, sugar, and liquid (Campbell et al., 1979). Cake flour provides protein and starch which are structural components. Kissell (1959) developed a cake formula in which the structural components of the cake are provided solely by the flour. Flour has been studied extensively in terms of chlorination and particle size (Kissell et al., 1979; Chaudhary et al., 1981; Clements and Donelson, 1982;

Gaines and Donelson, 1982a; Gaines, 1982; Ngo et al., 1985; Donelson and Clements, 1986).

Chlorination of flours not only gives the flour better color, but also improves the tolerance of flour for high sugar levels. Chlorinated flours produce cakes of better volume than untreated flours, as a strong gel is formed in the latter stage of baking that does not collapse when the air bubbles burst. Heat treated flour performs similarly to chlorinated flour. Guy and Pithawala (1981) studied the structure of batter at temperatures between 70° and 90°C to observe gel strength. The batter was made from untreated, chlorinated, and heat treated flour. They also studied the effects of other ingredients on gel strength. These authors found untreated flours formed weaker gels in batter systems and sucrose solutions when compared to treated flours. Egg proteins also contributed to gel strength.

Varriano-Marston (1985) reviewed the effects of chlorination upon flour, with the emphasis being upon the starch fraction. The chlorinated starch fraction is considered to be the component most responsible for improving flour properties. Dry starch undergoes oxidative polymerization when chlorinated.

Campbell et al. (1979) pointed out that shortening has several functions in cake, such as tenderizing, influencing moistness, and affecting characteristics of the crumb. Pohl et al. (1968) observed cake batter to be "an emulsion of fat in an aerated aqueous phase." The fat particles and the air bubbles were dispersed throughout the aqueous phase, which was a starch-protein system. This matrix allows for the movement of water vapor and carbon dioxide.

Painter (1981) reported that shortening provides for air entrapment, tenderizes the crumb, and aids water incorporation into cake mixes. Emulsifiers help with air entrapment and dispersion of the shortening into smaller particles. Lee et al. (1982) pointed out that the emulsifier and fat components should be treated as a "coordinated system" and are used in many commercial cake mixes.

Van Zante (1973) pointed out that saturated fatty acids do not absorb heat as quickly as unsaturated fatty acids of the same chain length in the microwave. The longer saturated fatty acids also heat slower than shorter chain.

The other ingredients in cake also have specific functions during baking and provide desirable characteristics to the final cake. The chemical leavening systems used in cake produce carbon dioxide which migrates into the air cells and expands as heated. The components of the egg provide different functions. The egg protein aids in structure. The egg lipids tenderize and the lipoprotein acts as an emulsifier. Sugar contributes to flavor, moistness, and tenderizing.

Gum studies

Hydrocolloids, or gums, are used in commercial mixes. Gunther (1974) pointed out that gums help with the retention of moisture in cakes. Increasing the levels of leavening agent and water and adding gum to a cake formula will improve the moistness and texture.

Glicksman (1963) reported that the modification of cellulose to hydroxypropyl methylcellulose by substitution of the methyl groups with propylene oxide results in a gum that has unique properties. This

hydrocolloid is soluble in cold water and its viscosity increases as the temperature of the solution increases. Hydroxypropyl methylcellulose can be used as a film former, protective colloid, stabilizer, suspending agent, thickener, and an emulsifier. The purposes of this gum in cakes are to increase water absorption, mixing tolerance, and improve volume (Glicksman, 1963).

Gums serve many purposes as well as affecting batter properties and adding cake quality. Lee et al. (1982) and Lee and Hosney (1982) worked on the development of a cake mix and the effects of emulsifiers and gums upon the mix. Xanthan gum was used at 0.1, 0.5, and 1.0% (fwb). Five premixes differing in processing were developed and were compared to a commercial cake mix. Mono- and diglycerides and propylene glycol monostearate (PGMS) found in commercial cake mixes also were used in this study. The method of adding the emulsifiers to the fat was investigated. As the level of PGMS increased from 2 to 7 g, the number of incorporated air cells increased, the size of the air cells decreased, and the cake volume increased. Further, as the processing temperature of the fat-emulsifier system decreased, the level of emulsifier could be decreased and a good volume cake still could be obtained. Also, the temperature of processing had more influence upon fat crystal size than did emulsifier. When 1% xanthan gum was added to the premix the batter and cake were comparable to a commercial batter and cake.

Lee and Hosney (1982) used response surface methodology (RSM) to optimize ingredient levels in a cake mix in order to develop a single-stage white layer-cake mix. The ingredients varied in one

experiment were fat-emulsifier systems: D10, PGMS, and mono- and diglycerides (MONOD). In another experiment, levels of water, xanthan gum, and dry egg whites were varied. The optimal levels of shortening, PGMS, and MONOD were 2.5, 4, and 3% (fwb), respectively. In the water, xanthan gum, and egg white system, xanthan gum thickened the batter as level of gum increased. As xanthan gum increased and water level decreased, cake volume increased. Less cake shrinkage was observed when xanthan gum levels were 2.6% (fwb) and egg white levels were 3.5% (fwb) than at other levels.

Miller and Setser (1982) used xanthan gums in white angel food cake to replace part of the egg white. Xanthan gum, water, and wheat starch were used at various levels. Sixty-five percent of the total egg white and 0.4% xanthan gum were found to be necessary in preliminary work to produce an acceptable cake. Xanthan gum increased foam stability, although it could not totally replace the egg whites.

Starch studies

The starch from flour and added starch contribute to cake structure. Many types of starch exist but not all perform the same in cake (Campbell et al., 1979). Howard et al. (1968) baked layer cakes containing no cake flour but different types of starches. Among the types of starch investigated was unmodified potato starch. Potato starch cakes set early in baking and had low volumes. Granular starch was found to be important in the early stages of baking and also in the thermal setting of the batter. During both stages, the granules absorb water.

Mizukoshi et al. (1979) used a sponge cake batter to observe starch gelatinization and egg protein coagulation. These authors reported that lack of equipment and the complexity of cake batter have contributed to the lack of information pertaining to the heat setting of cake batter. Mizukoshi et al. (1979) developed a model baking system to simulate the continuous baking at the center of a cake. The system was used to monitor temperature, viscosity, and light transmission, and to take photomicrographs under polarized light. The gelatinization of starch occurred between 79° and 88°C and egg protein coagulation happened between 82° and 96°C.

Mizukoshi et al. (1980) used the baking model developed by Mizukoshi et al. (1979) to study expansion and heat setting of cake batter. Bubble expansion, the increase in size of the incorporated air cells, causes batter expansion. As baking continues and temperatures increase the starch gelatinizes. At maximum light transmission the gelatinization ceases and protein coagulation occurs rapidly. Also, at the same instant the cake structure becomes gel-like inhibiting bubble expansion, and the bubbles pop to release gas. Therefore, the authors stated that starch gelatinization completion, acceleration of protein coagulation, bubble expansion completion, and gas release happen at approximately the same temperature.

Kulp and Lorenz (1981) investigated the effects of heat-moisture treatments on characteristics of wheat and potato starches. Starches had moisture contents of 18, 21, 24 and 27% before heat treatment. The characteristics evaluated were water-binding capacity, swelling power, solubilities, enzyme susceptibility, and pasting properties.

Water-binding capacities and enzyme susceptibilities increased with heat treatment. However, swelling power decreased while the solubility of the wheat starch increased as moisture content increased. Pasting properties decreased for both treated starches. In a follow-up report Lorenz and Kulp (1981) explored other properties of heat-moisture treated starch cakes. As the moisture level of the wheat starch increased, the volume of the cakes decreased. As the moisture level of the potato starch increased, however, the quality decreased more rapidly than with wheat flour.

Spies and Hosney (1982) studied the effect of sugar on starch gelatinization. Gelatinization was defined as when 50% of the starch granules had lost birefringence. Proposed mechanisms for sugar delaying starch gelatinization are the lowering of water activity as sugar levels increase and the interaction between the amorphous regions of the starch granules and sugar.

Varriano-Marston et al. (1980) studied starch gelatinization in several baked goods, including cakes. Since starch gelatinization influences the initial and keeping quality of a baked good, the extent of gelatinization is important to know. However, the literature is not consistent concerning the extent of starch gelatinization due to misconception of gelatinization and methodology. Varriano-Marston et al. (1980) used four methods to determine starch gelatinization. The methods used were amylograph, enzyme attack, x-ray diffraction, and polarization microscopy. Polarization microscopy, x-ray diffraction, and enzyme attack were the most useful of the methods. Moisture levels and moisture gradients also are important to starch gelatinization.

Varriano-Marston et al. (1980) drew a parallel between amount of moisture and extent of starch swelling and gelatinization. As moisture increased, so did starch swelling. Results from polarization microscopy and x-ray diffraction suggest that starch granules can be deformed and elongated, due to swelling, and still have birefringence and crystallinity. Polarization microscopy of cake crust showed granules to be unswollen, whereas the starch granules in the center of the cake were swollen and had lost birefringence. X-ray diffraction showed the granules at the center of the cakes to have a high degree of crystallinity that is different from that of unheated starch granules.

Water studies

The liquid in batter, which acts as a solvent, is supplied by the eggs and water or milk. The liquid is necessary for hydration of the proteins and starch gelatinization (Campbell et al., 1979). Wilson and Donelson (1963) baked Kissell's lean cake formula and a balanced complete formula with varying water levels. Volume, crumb, and contour were evaluated. As the water level increased in the lean cakes, the volume increased to a maximum and then decreased. Crumb structure also changed as the water content increased; the cake cells changed from open and irregular to small and uniform to compact. The top contour changed from sunken to rounded to peaked as water content increased. The volume, crumb, and contour of the cakes with a balanced complete formula followed the trends of the lean cakes, but not as severely, possibly due to the presence of the other ingredients.

Street and Surratt (1961) also varied water content of cake mixes baked in a microwave oven. They found that an increase of 40 g of water over what manufacturers instructed resulted in tunnels.

Howard et al. (1968) stated that the gelatinization of the starch was necessary for successful cake formation, and that starch gelatinization was dependent upon water absorption. A proper water-starch balance is essential in order to have a successful acceptable cake product.

III. MICROWAVE AND HEATING STUDIES

The quality of cake can be affected by the type of oven used to bake the batter. Stinson (1986a) reported that most microwave-baked cakes were of inferior quality compared to conventional cakes. Microwave/convection ovens (M/C) ovens may offer a mode of baking that results in cakes equal to conventionally baked cakes. Stinson (1986a) investigated the use of M/C oven and different baking pans in the production of devil's food cake from a commercial mix. The variables were the number of layers of cake baked at a time (one or two) oven temperature, and pan material. All cakes were found to be acceptable but quality was affected by baking conditions. The single layer M/C cakes had a stickler crumb than the other cakes. The cakes baked in microwave pans were more symmetrical than cakes baked in aluminum pans; this difference possibly occurred due to pan depth. Objective and subjective tenderness values did not vary with treatment. The single layer M/C cakes were rated lower by the sensory panel than the other

cakes. Stinson (1986b) baked devil's food and yellow cakes in a microwave/convection oven (M/C) and conventional oven (CON). Single M/C layer cakes were of lower quality than the single M/C layer cakes and the CON cakes. The double M/C layer cakes and CON cakes were rated similarly by the sensory panel.

Van Zante (1973) reported that butter cakes baked in the microwave have higher volume, lower moisture loss, and are more tender than conventionally baked butter cakes. Martin and Tsen (1981) reported that little information is available pertaining to cakes baked in the microwave. In their experiment, the AACC formula for high ratio white layer cake was baked in the conventional (CON) and microwave ovens (MW). Ingredients varied for the microwave oven were baking powder blend and water levels (115-160% fwb). Full power (100%) in the microwave was determined to yield higher quality cakes than 70% power. The formula containing 137.5% (fwb) water gave the most acceptable volume, specific volume, crumb compression, and internal score. This amount was not the optimum for each test but represented a compromise as the optimum water levels varied for each test. The levels of sodium aluminum phosphate and monocalcium phosphate ranged from 0% of each to 100% of each. Response surface methodology was used to determine the leavening agents and baking times. Again, the levels and times reached were a compromise.

Differences were observed in batter flow and with scanning electron microscopy (SEM) between microwave and conventional ovens. Batter flow and scanning electron microscopy (SEM) were different for cakes baked in each oven. There was no flow in the CON oven but the MW batter had

internal and surface flow. The crumb with from the MW cakes was coarser when compared to CON cake crumb, as examined using SEM.

Hill and Reagan (1982) compared yellow cakes baked in the conventional oven to cakes baked in the microwave oven. In the microwave, one cake was cooked on a turntable and the other cake was manually rotated at intervals. Several objective measurements were made and sensory testing was done. The conventionally baked cakes were more tender than either of the microwave-baked cakes as determined by a Warner-Bratzler shear apparatus on the Instron. No significant differences were found for weight loss or volume among any of the cakes. The sensory panel evaluated the conventional cakes as more appealing in appearance, texture, tenderness, mouthfeel, and flavor when compared to the two types of cakes baked in the microwave. The cake baked in the microwave with the turntable was evaluated as having better appearance and flavor than the cake cooked in the microwave without the turntable. There were no other differences between the two microwave-baked cakes in texture, tenderness, and mouthfeel. Hill and Reagan (1982) reported that the conventionally baked cakes were of higher quality but the cakes baked in the microwave were satisfactory. The authors also correlated shear values with sensory scores. As shear values increased, sensory scores decreased. Shear values were thought to be a predictor of sensory scores in this study.

IV. OBJECTIVE MEASUREMENTS OF BATTER AND CAKE

Objective measurements of batter can be indications of cake quality. For example, Ash and Colmey (1973) described the importance of pH in a cake system. Cake batter is a buffer to a certain degree and also an emulsion that is affected by pH. Funk et al. (1969) suggested measuring the specific gravity and consistency of batter. The specific gravity is an indication of the air mixed into the batter. Batter viscosity also is an indication of air incorporation with higher viscosity indicating greater air incorporation. Furthermore, the makeup of the batter can be examined microscopically. Hsieh et al. (1981) discussed the application of the cryofixation freeze-etch method to the study of cake batter which they state is made of macroemulsive systems. Sample preparation for cryofixation freeze-etch method involves freezing the batter at -150° to -160°C , fracturing the sample, etching and shadowing with platinum and carbon. Then the sample is destroyed and the replica is studied.

Light microscopy studies, using low level magnification, and scanning electron microscopy (SEM) are not as informative as transmission electron microscopy (TEM) in batter examination. Hsieh et al. (1981), however, used cryofixation freeze-etch method and TEM to view batter systems. The components of the batter were observed easily.

Voisey et al. (1979) reported that the change of a cake batter to a solid structure is somewhat a mystery. The actual transition is difficult to follow because of limited methodology. Several

investigators have altered ovens in order to study the baking of cake batter (Godsalve et al., 1977; Voisey et al., 1979; Paton et al., 1981).

Objective measurements of cake batter during baking include expansion and viscosity methods. Clements and Donelson (1981) invented a device for measuring batter expansion while baking. The device is a balsa wood scale placed in the batter and is secured by a magnet to the side of the pan. The device does not compromise cake volume. Gaines and Donelson (1982b) used a modified viscograph to monitor viscosity of cake heated to 100°C.

Objective measurements of the cake include volume, moisture content by drying, cell structure, and compressibility (Funk et al., 1969). Volume can be measured by seed displacement (Funk et al., 1969) or as an indice (AACC, 1983). Cloke et al. (1984b) presented formulas for the measurements of the volume of cake. The formulas are dependent upon the shape of the cake, with the cake shape generally considered to be cylindrical. The cake shape determines the formula used. The 3 shapes were defined as cylindrical, cylindrical with a spherical, or symmetrical cap. Cell structure can be evaluated subjectively on ink prints and photography of the cake crumb. SEM is very useful in evaluating crumb; TEM involves higher magnification than SEM but requires thin sections of the cake and is a more difficult technique than SEM (Hsieh et al., 1981).

Compressibility can be measured using several instruments such as the penetrometer, Kramer shear press (Funk et al., 1969), and the Instron to obtain Texture Profile Analysis (TPA) (Bourne, 1978). TPA involves compressing the sample twice to simulate chewing.

Fracturability, hardness, cohesiveness, adhesiveness, springiness, gumminess, and chewiness can be determined (Bourne, 1978). Walker et al. (1987) investigated cake firmness by adapting the bread firmness method for the Instron (AACC, 1983).

V. SENSORY REVIEW

Sensory tests also are an indication of cake quality. However, in many studies the details of sensory evaluation are not elaborated upon. Deming and Setser (1988) do cite sensory terms applicable to layer cake.

The development of terminology for a sensory evaluation is critical. In order for a sensory evaluation to be of the utmost value in the scheme of food technology, the language of the evaluation has to reflect the purpose of the evaluation, and the panelists must understand and be able to use the language. Descriptors or anchors are the language of descriptive analyses. There are no set patterns for the development of terminology but there are guidelines for descriptive tests like quantitative descriptive analysis, flavor profile analysis, and texture profile analysis.

Civille and Lawless (1986) emphasize the importance of terminology to the goal of a sensory evaluation. They state the goal to be "the objective description of a product in terms of perceived sensory attributes." Perceptions are greatly influenced by language, and the language used to describe a stimuli dependent upon perception which is of interest to the social scientist.

Civille and Lawless (1986) also pointed out that words are the tools of a language and these words represent ideas, objects, or characteristics. Civille and Lawless further stated that the development of terminology for a sensory evaluation has not been researched sufficiently. This omission was echoed by Gacula and Washam (1986). Standardized lexicons have been developed for warmed over flavor in meat (Johnson and Civille, 1986) and pond-raised catfish flavors (Johnson et al., 1987).

Civille and Lawless' (1986) criteria for selecting descriptors include that the descriptors be orthogonal, or uncorrelated with each other. The terms should not overlap in meaning. Also, the descriptors should be chosen based upon the structural aspects of the product as done with texture profile analysis. Moreover, the descriptors should have reference standards and the descriptors should be "primary" or simple in meaning. Rainey (1986) also pointed out the need for reference standards.

Moskowitz (1983) wrote that descriptive testing is a link in communication. Moskowitz goes on to say that the perfect descriptive system does not exist. He believes that a system with as few as seven descriptors is inadequate, and that an evaluation involving 500 descriptors is too cumbersome. The human ability to describe perception is limited by fatigue. Moskowitz stated a system using between 7 and 100 descriptors is possible.

Different approaches have been taken to evaluate batter and cake using sensory techniques. Investigators have evaluated batter as smooth, glossy, fluid, and curdled (Ebeler et al., 1986). Evans et al.

(1984) judged the surface of the cake as shiny, dull, or a combination of shiny and dull areas. Cracks in the surface were described as pores, small, and medium. Cloke et al. (1984a) investigated the effect of monoglycerides on crumb structure. Cake tops and cross sections were photographed. The photographs showed tunneling, if present, and crumb development.

Many investigators use the AACC Method 10-90 sensory evaluation procedure. This procedure involves assigning a numerical score to internal factors such as cells, grain, texture, crumb color, and flavor (AACC, 1983). For example, Kissell et al. (1979) investigated the role of free lipids from flour in white layer cakes. The sensory evaluation was performed by two panelists with the work being based upon the AACC Method 10-90. Cell distribution, cell size, cell-wall thickness, overall grain appearance, and color were scored (AACC, 1983). The highest score was 10 for each quality, except overall grain appearance, which could receive 16 points. The total score was adjusted to 100 points, which represented the ideal cake. Donelson et al. (1984) used the same sensory evaluation.

Lee et al. (1982) developed a white layer cake mix containing fat-emulsifier systems. The top contour was evaluated according to the AACC Method 10-90 and the grain was judged for fineness, moistness, and uniformity (AACC, 1983).

Stinson (1986b) baked devil's food cake in a microwave/convection oven. Position in the oven and type of pan were factors in the study. The experienced panel was made up of five members. The scoring was done as outlined in AACC Method 10-90 with the addition of crust color (AACC,

1983). The total score became 110. The scale was modified in that 10 represented excellent, 8 represented good, 6 represented fair, and 4 represented poor. The cake samples were taken from the same place in each cake, generally the center.

Many researchers have developed their own sensory methods. Hunter et al. (1950) used sensory evaluation as part of their classic cake study. The batters were evaluated by the researchers for "curdling" or breaking of the batter and consistency and appearance of the batter. The appearance of the cake and surface crust also were evaluated by the researchers. A sensory panel of 6 graduate students evaluated cake for size of cells (large, medium, small, very fine, compact), distribution of cells (uniform, irregular, tunnelled), crumb characteristics (velvety, slightly harsh, very harsh), tenderness (crumbly, very tender, tender, slightly tender, tough), moisture (moist, dry, wet) and flavor (well-balanced, sweet salt, bitter). The panelists indicated their perception of each quality on the scorecard. The panel orientation and/or training was not described.

Guy and Vettel (1973) looked at the use of butter, alone or in combination with emulsifier or shortening, in yellow cakes. The researchers judged the cakes for several qualities and gave each quality a numerical score. Symmetry, crumb color, crust color and grain were scored, with 10 being the score for the best quality. Texture was evaluated in terms of being soft, velvety, and resilient, and 20 points was the highest possible score for the best cake.

Hill and Reagan (1982) investigated microwave-baked butter cakes baked in microwave ovens with and without a turntable. A 4-member

trained panel evaluated appearance, texture, tenderness, mouthfeel, and flavor using descriptive terms of excellent, very good, good, fair, poor, and very poor. Excellent was assigned the highest numerical score of 6 for statistical analyses. As a reference point at each sensory evaluation, a description of high quality yellow cake was made available to each panellist.

Hess and Setser (1983, 1986) replaced sucrose in cakes with aspartame and fructose. The sensory panel evaluated the cakes for cell uniformity, moisture, tenderness, sweetness, and overall eating quality. A 5-point descriptive-quality-rating scale was used, 5.0 representing the highest score and 1.0 the lowest. Bitterness also was evaluated with 5.0 representing the least bitter and 1.0 the most bitter.

Pearce et al. (1984) made cakes containing nonfat dry milk (NFDM). The cross sections of the cakes were evaluated subjectively for color of crust, air cell size, and uniformity. As more NFDM was added the crust became browner in color. The control cakes had crusts that were cream colored.

Neville and Setser (1986) used response surface methodology to determine a formula for optimization of texture in cake containing sucrose and shortening replacements. Sensory evaluation was done for cell uniformity, moistness, gumminess, softness, and crust stickiness.

Valsey-Genser et al. (1987) used canola oil in cake. The sensory characteristics evaluated for value judgment were crumb quality, moistness, and flavor. Crumb color and tenderness were intensity judgments. The highest possible score for each characteristic was 60. The scorecard was made of line scales with descriptive anchors for each

characteristic. During training, the reference cake scores had been described for each characteristic. The scorecard also contained a description of the ideal cake for each characteristic.

VI. RESPONSE SURFACE METHODOLOGY

Response surface methodology (RSM) can be used in the optimization of time and resources (Giovanni, 1983). RSM involves identification of the independent variables, levels of the variables, and the parameters to be studied. RSM can be utilized in two ways: 1) experimental design which minimizes the combinations of the independent variables and the number of tests (Box, 1954) and 2) data evaluation. Multiple regression is done and equations are derived which are plotted as response surfaces or contour plots (Giovanni, 1983).

RSM has been used in several cake studies. Johnson and Zabik (1981) pointed out that RSM can be a tool to optimize ingredient levels. Kissell et al. (1979) used RSM in a cake volume study involving free lipids from chlorinated and unchlorinated flours. Valsey-Genser et al. (1987) used RSM to develop a cake formula containing canola oil. Box's central composite design was used to combine optimum levels of ingredients in cake formulation without testing all the possible combinations. The ingredients were canola oil, emulsifier, and water at 5 levels each. Sixteen experimental cakes were made and a positive reference cake of 100% hydrogenated emulsified shortening and a negative reference made with 100% canola oil.

VII. SUMMARY

Many aspects of batter and cake have been well studied, such as conventional baking. Other aspects such as microwave-baking have not been investigated as thoroughly. A second area in need of investigation is the standardization of sensory procedures for evaluation of cake.

CHAPTER III

PROCEDURES

I. STATISTICAL DESIGN

The statistical design used was a balanced incomplete block (Table I) (Schneider and Sanders, 1988). The cake formula is shown in Table II. Three gum levels, 4 potato starch levels, and 5 water levels were used, as determined in preliminary work, to give 60 formulations. Six formulations were made per day for 20 days. Two replications of each formulation were done and interspersed in the design. Each formula was made twice on one day in order to do batter tests and to bake cakes for further tests. One cake was used for the determination of moisture content and TPA. The other cake was used for sensory testing.

II. BAKING PROCEDURES

Mixing Method

The formulas (Table 2) and mixing method used were a modification of the Baking Quality of Cake Flour AACC Method 10-90 (AACC, 1983). The same brands of ingredients were used throughout the experiment. The flour, sugar, and salt were weighed and stored at room temperature. The nonfat dry milk and shortening were weighed and stored in the refrigerator. The egg, baking powder, gum, starch, and water were measured on the day of baking. The sugar and shortening were blended

Table 1--Experimental plan (Schneider and Sanders, 1988)

Day	Formula number					
1	1	7	4	8	36	38
2	24	37	5	40	51	39
3	27	42	52	40	21	1
4	3	17	33	2	46	49
5	23	50	49	8	32	48
6	29	35	46	5	39	23
7	54	45	7	15	21	12
8	10	32	48	44	4	41
9	54	59	58	15	2	34
10	26	3	56	59	6	53
11	55	33	13	52	38	44
12	9	45	29	51	16	28
13	42	19	53	60	24	35
14	58	27	30	17	43	37
15	43	28	26	47	18	60
16	18	20	57	41	9	13
17	19	25	34	14	30	10
18	11	47	20	14	16	56
19	12	31	22	25	11	50
20	36	6	22	57	55	31

Table 2--Cake formulations

Ingredients	Quantity	fwb, %
Flour ^a	200.00g	100
Sugar ^b	280.00g	140
Shortening ^c	100.00g	50
Fresh whole eggs ^d	100.00g	50
Nonfat dry milk ^e	24.00g	12
Baking powder ^f	11.50g	5.5
Salt ^g	6.00g	3
Potato starch ^h	variable ⁱ	variable ⁱ
Methocel gum ^j	variable ^j	variable ^k
Deionized water	variable ^l	variable ^l
Vanilla flavoring ^g	10.00ml	5
Butter flavoring ^g	5.00ml	2.5
Coloring Agent ^m	.06g	.03

^aSoftasilk, General Mills, Inc, Minneapolis, MN.

^bDomino's Extra Fine Granulated, Amstar Corp, New York, NY.

^cSuper Quick-Blend, Beatrice/Wesson, Fullerton, CA.

^dKroger Medium.

^eClassic Extra Grade, Sysco, Houston, TX.

^fCalumet, General Foods, White Plains, NY.

^gKroger, Cincinnati, OH.

^hAlphajel KS-3000 Alpha Biochemical Corp., Richland, WA.

ⁱ6.4 g (3.2%), 8.4 g (4.2%), 10.4 g (5.2%), or 12.4 g (6.2%).

^jMethocel F4M, Dow, Chicago, IL.

^k3.65g (1.8%), 4.15g (2.0%), or 4.65g (2.2%)

^l275 ml (137.5%), 300 ml (150.0%), 325 ml (162.5%),

350 ml (175.0%), or 375 ml (187.5%).

^mNew York Shade, Warner-Jenkinson, St. Louis, MO.

together for 30 sec in a Sunbeam Le Chef food processor model 14-11. The sugar and shortening mixture were mixed with the other dry ingredients and blended in the processor for 45 sec to simulate grinding or finishing of a commercial cake mix.

The batter was mixed in a Kitchen-Aid mixer model K45SS. The dry ingredients were sifted together and the egg, shortening, and 60% of the water were added to the dry ingredients and mixed for 30 sec on a very low speed (stir). The bowl was scraped, and the batter was mixed on medium speed (4) for 5 min. Twenty percent of the water was added and the batter was mixed for 30 sec; the bowl was scraped; and the batter was mixed on low (2) for 3 min. The remaining water and flavorings were added and mixed for 30 sec; the bowl was the scraped; and the batter was mixed on low for 3 minutes.

Baking and Storage

The batter was baked in 8-in round glass Pyrex pans. The pans were greased with shortening and then waxed paper was placed in the bottom of the pan. The weight of the batter in each pan was 425 g. Each pan was covered with waxed paper before baking in a White-Westinghouse countertop microwave oven (model KM540G and 750 wattage). Baking time was 4.5 min on maximum power.

After baking, the cake was removed promptly from the oven and placed on a wire rack. The waxed paper was removed from the top of the cake pan. The cake was cooled for 5 min in the pan and then was turned out onto the rack. The cake cooled on the rack for 30 min and then was

wrapped in Reynolds plastic wrap, labeled, placed on a paper plate, and placed in a plastic cake holder, sealed, and held overnight.

III. MICROWAVE OVEN OUTPUT

The microwave oven output was measured before the baking of the first layer of each treatment by heating 2 cups (475 ml) of deionized water for 1 min. The initial temperature of the water ranged from 44^o to 48^oF. The temperature of the water before and after heating was recorded. The change in temperature (^oF) was multiplied by 17.5 to determine the output of the oven in watts (Van Zante, 1973). The temperature change, ^oF, was converted to wattage since 17.5 BTU/min are equal to 1 watt when 1 pound of water is heated (Weast, 1977).

IV. BATTER TESTS

pH

The pH of the batter was determined on a Fisher Accumet pH meter model 600 (Pittsburgh, PA). The meter was calibrated to pH 7. Ten g of batter were mixed with 40 g of deionized water and the pH was measured. The pH was measured twice.

Specific gravity

The specific gravity was calculated by using the following equation:

$$\frac{\text{Weight of container filled with batter} - \text{weight of container}}{\text{Weight of container filled with water} - \text{weight of container.}}$$

A glass container of known volume was weighed and then filled with water and weighed. The container then was dried, filled with batter, and weighed (FSNFSA, 1976). Three replicates were done.

Viscosity

A Brookfield Syncro-Lectric Viscometer Model LVF (Stoughton, MA) was used for apparent viscosity measurements. Batter, approximately 6.5 cm deep, was placed into 250-ml beakers for measurement. The spindle size was 4 and the rotation speed was 6. Measurements were taken at 20 sec. Three replications were done. (FSNFSA, 1976).

V. CAKE AND CRUMB TESTS

Weight loss

The pan weight and pan weight plus 425 g of batter were recorded. Before removing the cake from the pan, the weight of the cake and pan was recorded. Then, the weight of the baked batter was subtracted from the weight of the unbaked batter.

Moisture content

Moisture content was determined by Moisture-Modified Vacuum-Oven AACC Method 44-40 (AACC, 1983). Two g of cake crumbs were dried for 5 hr in the vacuum oven. Three replications were done.

Indices

Shrinkage, volume, symmetry, and uniformity indices were calculated using the Layer Cake Measuring Template AACC Method 10-91 (AACC, 1983) template and procedure. Two cakes were cut into half and the measurements were made on 4 halves.

Instron

Texture profile analysis was done using the Instron Universal Testing Machine model 1130 (Canton, MA) with a 5000-g load cell (range of 20) which was broken half way through the experiment and was replaced by a 50-kg load cell (range of 5). The chart paper (10 cm/min) was set at twice the speed of the crosshead (5 cm/min). Three cylindrical samples, 3.5 cm in diameter, were cut from the edges and center of the cakes. The degree of compression was set to 1.5 cm. A flat compression anvil, 5.5 cm in diameter, was used to compress the samples. However, not all samples were 2.5 cm in height. Therefore, hardness actually was measured at 7.5 mm of compression. Springiness was determined as a percentage of the baselines of the 2 curves, $(S1-S2/S1 \times 100)$. Other attributes measured were cohesiveness, gumminess, and chewiness (Bourne, 1978) (Figure 1).

Sensory

A panel of 10 graduate students, 7 women and 3 men, met 3 times a week for 13 weeks to identify and define cake attributes and apply those attributes to cake samples. Initially the panel as a group used recall to generate a list of cake attributes. The subsequent sessions included

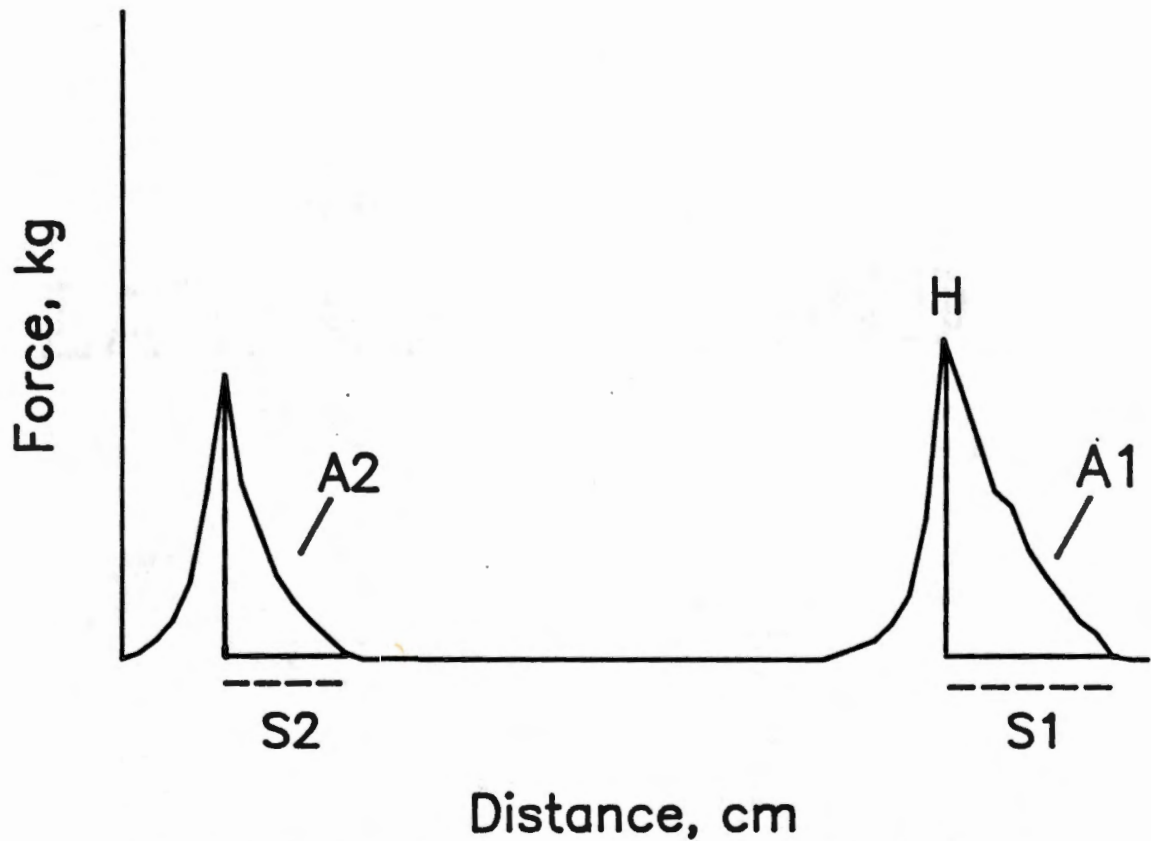


Figure 1--Typical Instron Texture Profile Analysis Curve
 (H=hardness, measured at 1.5 cm; S=Springiness,
 $S1-S2/S1 \times 100$; Cohesiveness= $A2/A1$; Gumminess= $H \times A2/A1$;
 Chewiness= $H \times A2/A1 \times S$) (Bourne, 1978).

evaluating and discussing 4 or 5 cakes made from commercial conventional and microwave oven mixes, cakes made from microwave formulas developed in-house, and bakery cakes. Panel consensus was used to determine which attributes were important and how to group the attributes for analysis (Johnson et al., 1987; Civille and Lawless, 1986). Attributes were grouped according to order of appearance during observation and consumption. The attributes then were defined by group consensus using the dictionary and Meilgaard et al. (1987) as guidelines (Appendix A).

The procedure for evaluation also was determined by the panelists. The panel agreed upon reference standards using products provided by the panel leader (Table 3). Reference standards were cake products that represented opposing ends of the 15-cm scale for each characteristic (Appendix B). The panel decided to use the 15-cm line scale anchored at each end with opposing descriptors for each characteristic. The panel practiced for several sessions using the scales in a group setting with discussion. Then the panel individually evaluated cake samples. At this point, the panel was in agreement for evaluation of 4 cake samples (Appendix C).

The panel was reduced to 7 members for the evaluation of the 60 formulas. Each panelist evaluated the samples in booths under white light and was provided with a definition sheet at every session (Appendix A). Six samples were presented, one at a time. Panelists were presented with a slice of cake 2.5 cm in width and 7.0 cm in length. The top and bottom of the samples were cut off since the panel did not evaluate the outer cake surfaces. Each panelist was given samples from the same area of each cake throughout data collection. The

Table 3--Cakes used as reference standards for sensory panel training

Cakes	Characteristics
Sara Lee Pound	Small cell size, uniform cell size uniform shape, closed appearance, smooth surface, smooth in mouth
Duncan Hines Golden ^a	Irregular cell shape, tender to fork soft for first bite, not cohesive, easy to chew
Duncan Hines Yellow Rich Recipe ^b	Large cell size, moisture release no moisture absorption, difficult to swallow
Bisquick Velvet Crumb ^c	Irregular cell size, open surface, not springy, crumbliness, no moisture release, no deformation, fracturable, moisture absorption, compact mass, difficult to chew
Jiffy Golden ^d	Rough surface, rough in mouth
Betty Crocker Angel Food	Springy, tough to fork, not crumbly not soft for first bite, deformation, not fracturable, no oily residue, easy to chew, no adhesion to teeth
Pillsbury Lemon Microwave ^e	Oily mouthcoating, adhesion to teeth

^aFollow manufacturer's instructions except overbeat on medium for 6 minutes.

^bFollow manufacturer's instructions except use 3 eggs and one can of sweetened condensed milk.

^cFollow manufacturer's instructions using 2 cups of Bisquick and overbeating 5 minutes.

^dFollow manufacturer's instructions except add 1/4 cup of cornmeal.

^eFollow manufacturer's instructions except use 1/2 cup of oil.

samples were coded with 3-digit random numbers and the order of presentation was randomized. Spring water was used as a rinse in between samples.

VI. STATISTICAL ANALYSIS

The data were analyzed by PROC GLM (SAS Institute, Inc., 1985) for the main effects and interactions gum x starch, gum x water, starch x water, and gum x starch x water. The sums of squares for block, gum, starch, water, and interactions were derived from the Type III sums of squares to determine significance for the main effects and interactions ($p < 0.05$). Type III sums of squares are conditional and were used since the design of the study was a nonorthogonal incomplete block with missing data. To partition the sums of squares into linear, quadratic, and cubic terms, Type I sums of squares were used. The partitioned sums of squares will not add to the total sums of squares due to the nonorthogonality of the experimental design. The intercept and coefficients were calculated for the response surface equations. The equations were plotted to determine predicted values. Terms were included in the equations if $p < 0.10$ (Appendix D). The data for Instron and sensory were analyzed using means instead of individual values since there were missing data and as the panel was thought to be performing as a unit.

VII. SELECTED STUDIES

Selected formulas were used in the following studies. The batters were chosen based upon response surface methodology to represent a range of batters and cakes, ranging from the optimum to the poorest. The following variables were chosen for the selected studies: 3.65 g gum, 6.5 g starch, and 275 ml water; 3.65 g gum, 12.4 g starch, and 275 ml water; 3.65 g gum, 6.4 g starch, and 375 ml water; and 3.65 g gum, 12.4 g starch, and 375 ml water.

Scanning electron microscopy of crumb

Scanning electron microscopy was done in cooperation with the Metallurgical Engineering Department of The University of Tennessee, Knoxville (McGill, 1989). Small samples, 1-3 cm, were taken from the middle of the cakes and frozen in a carbon dioxide freezer (15 min at -80° F) (Cryo-Chem., Inc., Gardena, CA) and freeze-dried (Virtis Co., Gardiner, NY) for 48 hrs. The samples were fractured (Pomeranz et al., 1984) and attached to studs with epoxy glue (Devcon). The samples were sputter-coated with gold using a Technic sputter coater and scanned using a Cambridge Instruments (Cambridge, England) scanning electron microscope at 12 kV accelerating potential. Micrographs were taken at 3 levels of magnification (50X, 350X, and 500X) of representative areas.

Flow patterns of batter

In order to observe the flow pattern of batter while baking in the conventional and microwave ovens, dyed batter was used. One-hundred g of batter was dyed with 0.5 g Warner-Jenkinson FD&C Red No. 3 (St. Louis, MO). The dyed batter was placed on top of 162.5 g of batter already in the baking dish. The dyed batter was evenly spread out with a plexiglass strip. The dyed batter was covered with batter to make the total weight of the batter 425 g. The batter was baked and the cake cooled. The cake was frozen for 3 days and cut into 9-10 strips and photocopied. The internal flow pattern was observed and characterized. Fifty g of dyed batter was placed on the bottom of 325 g of batter in order to observe flow on the bottom and 50 g of dyed batter was on the surface (Martin and Tsen, 1981). In order to observe the flow pattern one formula (275 ml of water, 3.65 g of gum, and 12.4 g of starch) was baked in the conventional oven.

Microscopic evaluation of fat

The fat was dyed with Sudan III Orange and the batter was studied under the microscope. The distribution of fat and shape of the fat cells were observed and subjectively evaluated under a Wild M20 Microscope (Wild Heerbrugg Limited, Heerbrugg, Switzerland).

Evaluation of the crumb

Photographs were taken of the cakes and the crumb was evaluated subjectively. Characteristics of the cells, both size and distribution, also were evaluated.

Consumer panel

A consumer panel composed of 26 women and 3 men, who were visiting campus for a dairy food contest sponsored by the Agricultural Extension Service, evaluated 2 of the selected formulas. These formulas were chosen based upon the response surfaces and time limitations. The panelists were seated at desks in a classroom and the samples were served together on trays. The sample size was 4.5 cm x 3.5 cm. The samples were coded with 3-digit random numbers and the order of presentation was randomized balanced. The panelists filled out a demographic sheet (Appendix E) and scorecards for the ideal cake (Appendix F) and for the samples (Appendix G). The data were analyzed by PROC GLM, Tukey's range test for means, and PROC FREQ (SAS Institute, Inc., 1985) for the demographics.

CHAPTER IV

RESULTS AND DISCUSSION

The statistical design of the study was a balanced incomplete block. Therefore, 6 different formulas were made per day, and block effects should have been significant in all analyses if there were true differences among formulas. Block effects, however, always were not significant. In order to study the differences in means, least-squares means and response surface analyses were done. Both mean separations were done since the response surfaces show trends that are not always significant at $p < 0.05$.

Three gum levels were investigated. This factor was not found to be a significant source of variation for most of the analyses. Therefore, the lowest level of 3.65 g was chosen to be held constant in the response surfaces showing the predicted values (Appendix D). The overall lack of significance for the gum levels was due possibly to the narrow range of the levels used in the presence of starch. Few interactions were seen in the objective measurements reflecting the independent effects of the individual factors of gum, starch, and water level.

I. MICROWAVE OVEN WATTAGE

The wattage of the microwave oven varied according to day of replication (Appendix E). Treatment means are shown in Table 4. The

Table 4--Treatment means as affected by oven wattage^a

Treatment ^b	Wattage	Treatment ^b	Wattage
1	517.9e ±34.0	31	587.6cde ± 6.3
2	586.5cde ±43.7	32	609.7cd ±10.9
3	671.4cd ±43.7	33	594.2cde ±11.0
4	586.5ede ±43.7	34	584.8cde ± 2.4
5	625.1c ±32.7	35	563.3cde ±11.0
6	576.7cde ±13.8	36	572.0cde ±20.6
7	571.1cde ±21.8	37	594.2cde ±32.7
8	563.3cd ±11.0	38	571.1cde ±21.8
9	584.8cde ± 2.4	39	578.8cde ±32.8
10	600.2cde ±24.2	40	540.2cde ±21.8
11	570.2cde ± 6.0	41	592.6cde ±13.4
12	588.2cde ±19.4	42	578.8cde ±10.9
13	584.0cde ±25.5	43	602.0cde ±21.8
14	536.0e ±54.6	44	594.2cde ±32.7
15	609.7cd ±10.9	45	594.2cde ±11.0
16	611.4cd ±52.2	46	571.1cde ±21.8
17	586.0cde ±00.7	47	593.3cde ± 9.7
18	617.4cd <00.0	48	578.8cde ±10.9
19	568.6cde ± 3.6	49	615.7cd ±46.1
20	600.2cde <00.0	50	567.6cde ±26.6
21	571.1cde ±21.8	51	571.1cde ±21.8
22	578.8cde ± 6.1	52	555.6cde ±21.8
23	617.4cd ±21.8	53	578.8cde ±33.0
24	594.2cde ±32.7	54	602.0cde ±21.8
25	557.4cd <00.0	55	593.3cde ± 9.7
26	602.1cde ±21.8	56	580.5cde ± 8.5
27	601.9cde ±21.8	57	591.7cde ±36.3
28	602.0cde <00.0	58	609.0cd ±10.9
29	602.0cde ±21.8	59	602.0cde ±21.8
30	577.1cde ± 8.5	60	586.5cde <00.0

^aMeans ± standard deviation; means followed by like letters do not differ (P>0.05)

^bReplicated twice.

Inconsistencies in oven output may have affected the quality of the cakes since the baking time and power were not adjusted. However, the extremes of oven wattage (517.9 and 625.1 watts) occurred for treatments 1 and 5 which both contained 4.15 g of gum, 12.4 g of starch, and 375 ml and 275 ml of water, respectively. These 2 treatments may have been affected by oven output, but response surfaces were not plotted for this gum level. The oven wattage was dependent upon the power distribution in the Food Technology Building.

II. BATTER TESTS

The pH of the batter was slightly basic. As the level of starch increased the pH increased slightly. The linear component of the sums of squares for starch was significant as was the linear water component (Table 5). This linearity was reflected in the response surface (Figure 2). As the level of water increased however, the pH decreased slightly (Table 6). The response surface showed the highest pH (7.39) at a water level of 275 ml and a starch level of 12.4 g. The lowest predicted pH (7.28) occurred when the water level of 375 ml was used and 6.4 g of starch was used, which may have been due to a dilution effect. Cake batter emulsions are affected by the pH of the batter systems. Ash and Colmey (1973) reported that stable layer cake batters have pH values of 5.0-6.0 and as the pH increases, the batter curdles and oil droplets separate out of the emulsion. Many of the batters in the present study did curdle, especially those with the higher water levels. However, a curdled batter necessarily does not mean a poor quality cake as the

Table 5--Sums of squares from analyses of variance for batter tests

Source	df	Sums of squares		
		pH	Specific Gravity	Viscosity
Block	19	.3747***	.0046	4081520254**
Gum (G)	2	.0136	.0007	309453218
G	1	.0136	.0005	186720234
G*G	1	.00001	.0002	12273983
Starch (S)	3	.0517**	.0013	1684211193*
S	1	.0478***	.0007	1553997724***
S*S	1	.0038	.0004	400138
S*S*S	1	.0001	.0001	129813331
Water (W)	4	.0521*	.0098***	17209892402***
W	1	.0352**	.0073***	17025731484***
W*W	1	.0074	.0018**	151721458
W*W*W	1	.0065	.0003	31281976
W*W*W*W	1	.0030	.0003	1157482
Error	91	.3543	.0197	8611129073
Total	119	.9380	.0197	36735470508

***P<0.001; **P<0.01; *P<0.05

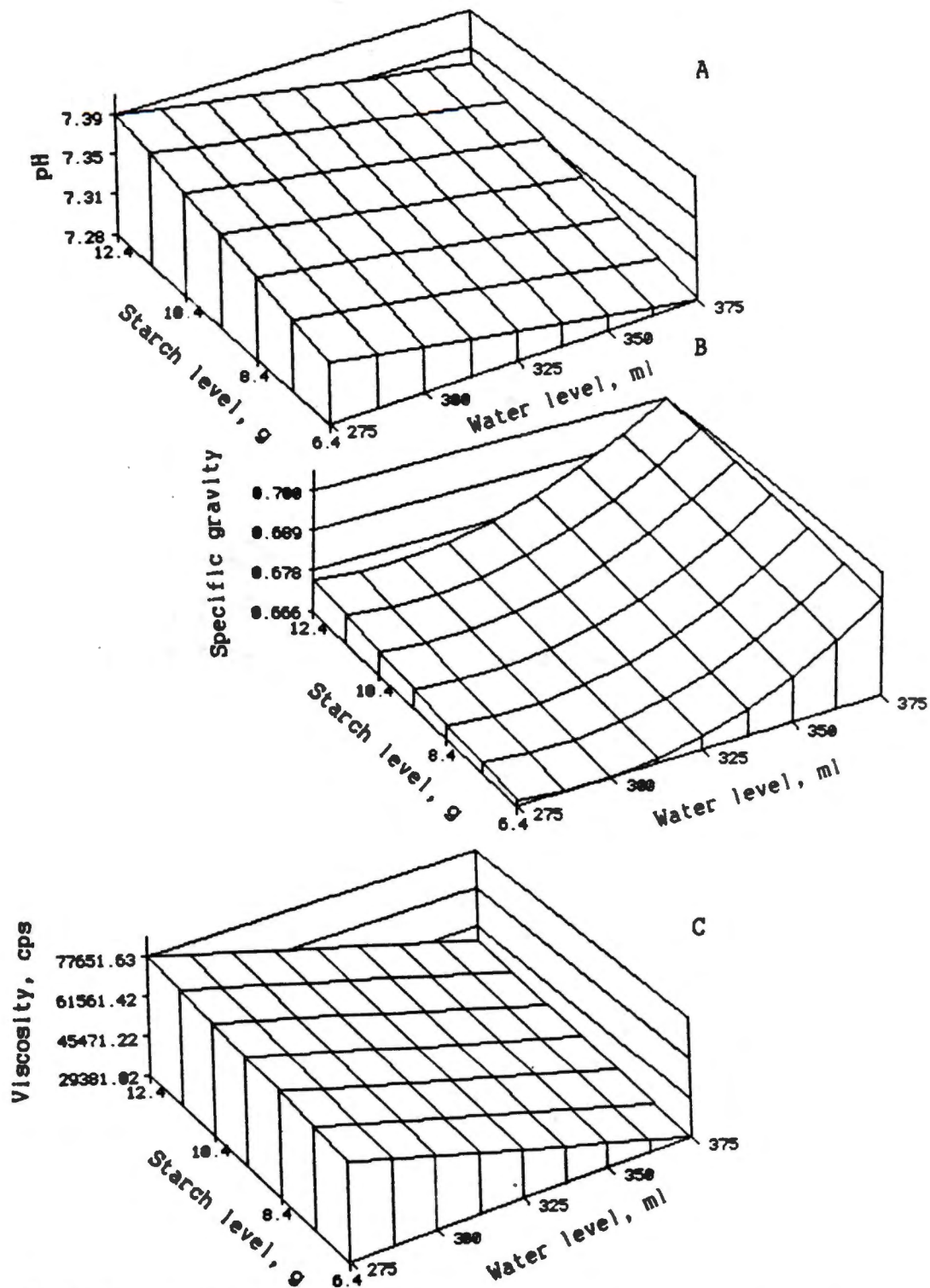


Figure 2--pH (A), specific gravity (B), and viscosity (C) as a function of starch and water levels in cakes containing 3.65 g gum.

Table 6--Least-squares means for main effects for batter and cake tests^{ab}

Main effect	pH	Specific gravity	Viscosity, cps
Gum, g			
3.65	7.33x ± .01	.678x ± .002	54274x ± 1600
4.15	7.34x ± .01	.678x ± .002	50298x ± 1629
4.65	7.36x ± .01	.672x ± .002	51145x ± 1639
Starch, g			
6.4	7.31x ± .01	.674xy ± .002	47140x ± 1896
8.4	7.34xy ± .01	.674xy ± .002	48635x ± 1918
10.4	7.36y ± .01	.673x ± .002	55272x ± 1919
12.4	7.37y ± .01	.682y ± .002	56577x ± 1837
Water, ml			
275	7.36x ± .01	.670x ± .003	71869v ± 2085
300	7.37x ± .01	.666x ± .003	61500w ± 2133
325	7.36x ± .01	.667x ± .003	50247x ± 2196
350	7.32y ± .01	.683y ± .003	41048y ± 2110
375	7.31y ± .01	.692y ± .003	34864z ± 2164

	Weight loss, g	Moisture content, %
Gum, g		
3.65	40.87x ± .23	31.67x ± .15
4.15	39.76xy ± .23	31.87x ± .15
4.65	39.48y ± .23	31.91x ± .15
Starch, g		
6.4	39.31x ± .27	31.94x ± .17
8.4	40.02xy ± .27	31.80x ± .18
10.4	40.17yz ± .27	31.54x ± .18
12.4	39.86xz ± .26	32.00x ± .17
Water, ml		
275	39.73xy ± .30	28.07v ± .19
300	40.37x ± .31	29.83w ± .19
325	39.80xy ± .32	32.19x ± .20
350	40.00xy ± .30	33.59y ± .19
375	39.34y ± .31	35.40z ± .20

^aLeast-squares means and standard error for two replications of 60 formulas.

^bLeast-squares means within a column and main effects followed by like letters do not differ ($P < 0.05$).

emulsifiers in the shortening lessen the severity of the curdling (Hunter et al., 1950).

Specific gravity is a measure of the amount of air incorporated into the batter, with low values indicating high air incorporation (Funk et al., 1969). Pyler (1988) reported that the optimum specific gravity for yellow cake with emulsified plastic shortening is 0.850. Values in this study were lower than 0.850 indicating incorporation of more air than the recommended optimum. Carlin (1944) reported that a good foam structure is important since the leavening gases spread to the air cells. Also, the specific gravity may be correlated to cake characteristics such as volume, tenderness, and grain quality. Cloke et al. (1984a) pointed out that the amount of air incorporated into cake batter may not be directly correlated to cake volume. Other factors such as cell structure and use of emulsifiers also may influence cake volume. Hunter et al. (1950) reported that an increase in sugar resulted in a decrease in batter density. Charley (1970) stated that the sugar crystals aid the incorporation of air cells into the batter. The crystalline edges of the sugar crystals help guide the air into the shortening as cells when the batter is mixed. However, the dilution effect of the higher water levels resulted in a slight increase in specific gravity (Table 6).

Block effect was not significant for specific gravity (Table 5), indicating that there were no difference due to groups of different treatment made on different days. There was no significant trend for the effect of starch level on the specific gravity (Table 6). The 2 higher water levels increased the specific gravity, indicating a lower

amount of air in the batters with 350 ml and 375 ml of water when compared to other batters with lower water levels. However, the range of means was small (.678-.692). The linear and quadratic components of water were significant as seen in the slope of the response surface (Table 4 and Figure 2). The response surface for specific gravity showed that as water increased, there was an increase in specific gravity. All batters were mixed thoroughly and the extensive mixing may have compensated for the effects of the ingredient changes on specific gravity. The extensive mixing was done in order to improve cake volume.

The viscosity of the batters was significantly affected by starch and water levels (Table 5). Each increase in water level resulted in a significant decrease in viscosity. As the water level increased the viscosity decreased (Table 6). The viscosity response surface lacked curvature reflecting the linear components of starch and water (Table 5 and Figure 2). The response surface showed a slight decrease in viscosity as starch decreased and a significant decrease in viscosity as water increased. The higher levels of water resulted in a dilution effect of batter ingredients. Hunter et al. (1950) suggested that well aerated batters have low specific gravities and high viscosities, indicating that the incorporated air is dispersed in small cells throughout the batter. The batters with the higher viscosities also had the lower specific gravities, suggesting that more air was incorporated in the batters with lower water levels (Table 5 and Figure 2).

III. CAKE AND CRUMB TESTS

For weight loss during baking the linear component of gum was significant (Table 7). The response surface (Figure 3) reflects the quadratic starch ($p < 0.10$). The batters were covered with wax paper during baking. The wax paper likely acted as a barrier for moisture loss. Street and Surratt (1961) found weight loss of microwave-baked yellow cakes made from commercial mixes with varying liquid levels to be more dependent upon cooking time than the amount of liquid in the batter. Hill and Reagan (1982) reported that yellow cakes baked in the microwave oven and yellow cakes baked in the conventional oven did not differ in weight loss. However, Street and Surratt (1961) found greater weight loss in the microwave-baked yellow cake than in conventionally baked cake, as did Neuzil and Baldwin (1962).

Moisture content was not significantly affected by the starch levels (Table 7). The moisture content increased significantly as water level increased (Table 6 and Figure 3). The linear water factor was the only significant component for moisture content, which was represented by the lack of curvature in the response surface. Street and Surratt (1961) suggested that cakes with the higher liquid contents did not lose more liquid when baked in the microwave, but retained the excess liquid and were moister when compared to cakes with less liquid. Gunther (1974) reported that when gum is used in cake batter extra water is required. However, the lack of interaction among the main effects in this study does not support Gunther's report. This extra water remains in the cake and increases the moistness of the cake.

Table 7--Sums of squares from analyses of variance for weight loss and moisture content

Source	df	Sums of squares	
		Weight Loss	Moisture Content
Block	19	204.63***	133.0951***
Gum (G)	2	11.66	1.2014
G	1	11.39*	1.0700
G*G	1	.27	.1310
Starch (S)	3	10.96	3.1512
S	1	3.81	.0004
S*S	1	7.14	2.3957
S*S*S	1	.01	.7551
Water (W)	4	11.58	648.0217***
W	1	2.12	644.5230***
W*W	1	5.39	.7824
W*W*W	1	.39	.0734
W*W*W*W	1	3.68	2.6429
Error	91	177.99	73.5232
Total	119	500.36	1037.6109

***P<0.001; **P<0.01; *P<0.05.

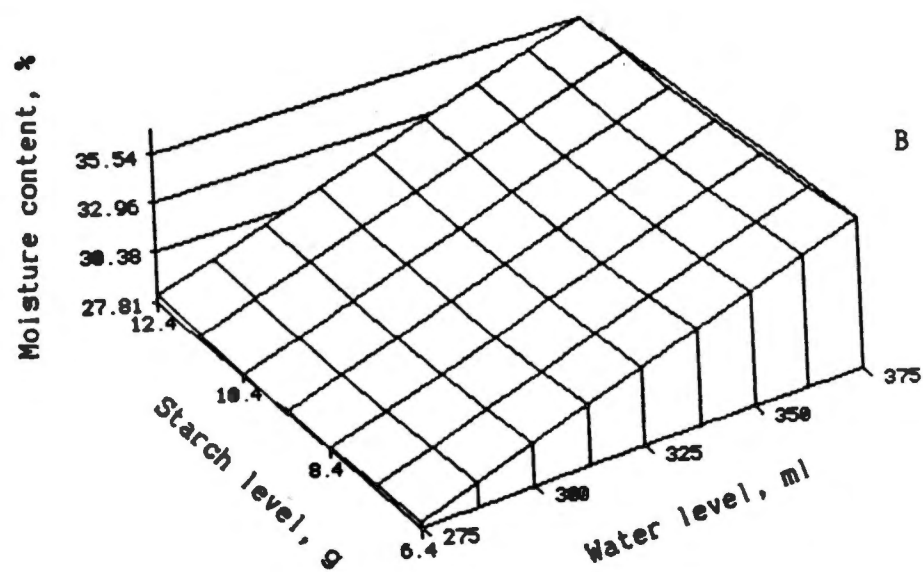
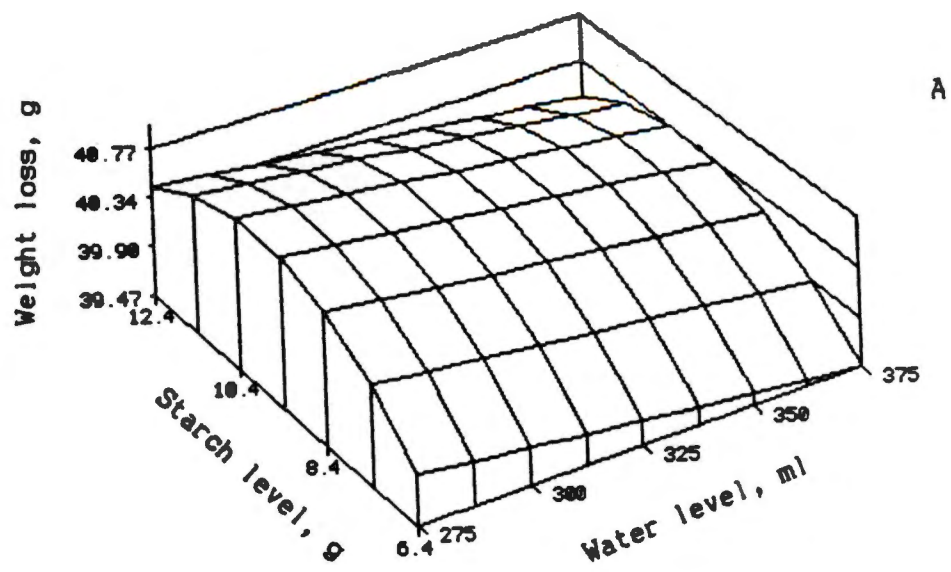


Figure 3--Weight loss (A) and moisture content (B) as a function of starch and water levels in cakes containing 3.65 g gum.

Stinson (1986a) reported that high quality cakes have low shrinkage values, high volumes, positive values for symmetry, and values of zero for uniformity. In this study, as water level increased, the shrinkage indice (a measure of decrease in diameter) increased significantly (Tables 8 and 9). For the shrinkage indice, linear water was a significant component as shown by the sums of squares. The response for shrinkage indices reflected the differences among starch levels and water levels (Figure 4). A cubic starch effect was shown by a dip in the response surface (Figure 4). Shrinkage indices at starch levels of 8.4 g and 10.4 g were significantly different, with cakes containing 8.4 g having higher shrinkage values (Table 9).

Volume indices (the sum of heights at 3 places in halve of the cake) were not affected by starch level (Table 8). As the water level increased, the volume index of the cakes decreased (Table 9 and Figure 4). The linear component of water were significant (Table 8). Street and Surratt (1961) found the volume of yellow cakes decreased as water level increased and the surface of the cakes became more irregular. Martin and Tsen (1981) also reported a decrease in volume of cake baked in the microwave at 100% power as water level in cake increased. Martin and Tsen (1981) further found that microwave-baked cakes with lower water levels had better contour than conventionally baked cakes with the same water levels. Martin and Tsen (1981) suggested that microwave-heating possibly alters the crumb by affecting all or some of the following factors: egg protein, starch gelatinization, and the starch-protein complex. The lack of a crust also may affect the crumb

Table 8--Sums of squares from analyses of variance for cake indices

Source	df	Sums of squares			
		Shrinkage	Volume Index	Symmetry	Uniformity
Block	19	1.2637***	540.78***	143.90	30.95*
Gum (G)	2	.0778	17.21	16.98	4.73
G	1	.0142	15.87	16.07*	.15
G*G	1	.0637	1.34	.92	4.58*
Starch (S)	3	.1050	32.39	13.67	.22
S	1	.0136	22.34	12.81	.11
S*S	1	.0001	8.47	.15	.02
S*S*S	1	.0912*	1.57	.70	.10
Water (W)	4	5.1704***	9747.27***	31.61	4.65
W	1	5.1327***	9674.63***	11.78	1.72
W*W	1	.0072	4.24	16.57*	2.56
W*W*W	1	.0036	11.58	2.58	.34
W*W*W*W	1	.0268	56.81	.67	.03
Error	91	1.988	644.52	336.76	76.83
Total	119	9.592	13394.21	554.37	118.46

***P<0.001; **P<0.01; *P<0.05.

Table 9--Least-squares means for main effects for cake indices^{ab}

Main effect	Shrinkage, cm	Volume index, cm
Gum, g		
3.65	1.58x ± .02	70.03x ± .44
4.15	1.61x ± .02	69.30x ± .44
4.65	1.54x ± .02	69.10x ± .45
Starch, g		
6.4	1.58xy ± .03	70.45x ± .52
8.4	1.63x ± .03	69.23x ± .52
10.4	1.53y ± .03	69.15x ± .51
12.4	1.57xy ± .03	69.07x ± .51
Water, ml		
275	1.26v ± .03	83.60v ± .57
300	1.44w ± .03	76.08w ± .58
325	1.54x ± .03	70.54x ± .62
350	1.74y ± .03	61.12y ± .57
375	1.91z ± .03	56.04z ± .58
	Symmetry, cm	Uniformity, cm
Gum, g		
3.65	-.21x ± .32	1.64x ± .16
4.15	-.52xy ± .32	2.11x ± .16
4.65	-1.19y ± .32	1.66x ± .17
Starch, g		
6.4	-.16x ± .37	1.78x ± .19
8.4	-.56x ± .38	1.83x ± .19
10.4	-.64x ± .37	1.91x ± .19
12.4	-1.18x ± .37	1.70x ± .19
Water, ml		
275	-1.70x ± .41	1.85x ± .21
300	-.32y ± .42	1.91x ± .21
325	-.29y ± .45	1.87x ± .24
350	-.31y ± .42	1.87x ± .21
375	-.56xy ± .42	1.51x ± .22

^aLeast-squares means and standard error for two replications of 60 formulas.

^bLeast-squares means within a column and main effects followed by like letters do not differ ($P > 0.05$).

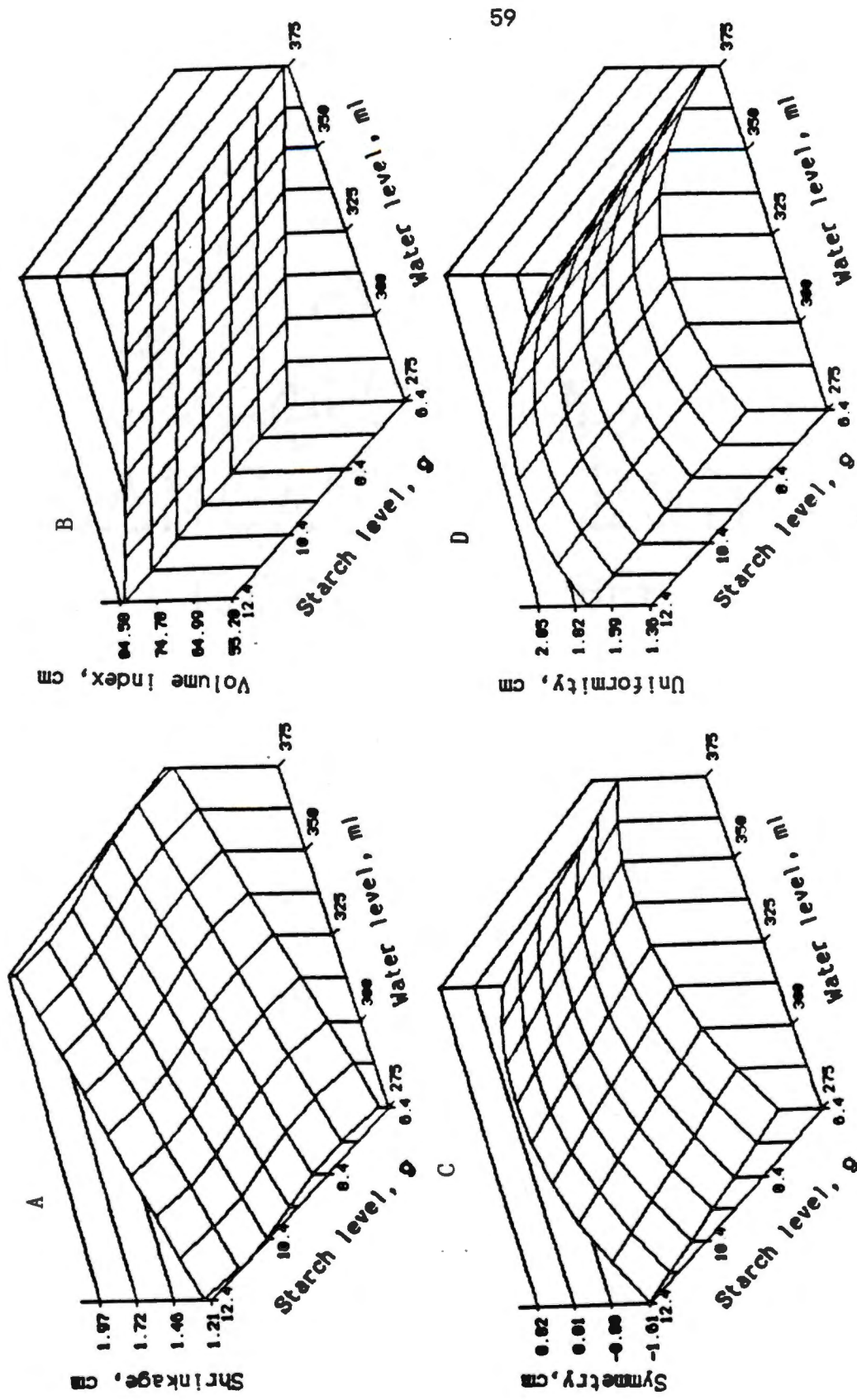


Figure 4--Shrinkage (A), volume index (B), symmetry (C), and uniformity (D) as a function of starch and water levels in cakes containing 3.65 g gum.

structure. Hill and Reagan (1982) reported no differences in the volumes of a yellow cake baked in microwave and conventional ovens.

The symmetry values (measure of contour) were negative, indicating sunken surfaces for all cakes (Table 9). Linear gum was a significant factor (Table 8). The cakes with 4.65 g of gum were more sunken than cakes with 3.65 g of gum (Table 9). Starch level did not affect the symmetry of the cakes. The lowest water level caused the cakes to have different symmetry indices from the other cakes except for the cakes containing the highest water level. The response surface for symmetry showed a trend of decreased symmetry as starch increased and an increase in symmetry (toward positive values) as water levels increased to approximately 340 ml and then a decrease in symmetry values began as water continued to increase (Figure 4). The quadratic water was reflected in the curve of the response surface. Stinson (1986a,b) found the number of layers baked simultaneously and the beginning temperature of the oven affected cake symmetry. Also, yellow cakes baked in the microwave/convection oven were flatter on the surface than conventionally baked cakes.

The uniformity indice (a difference in height from one side of the top surface to the other) was not significantly affected by starch or water levels (Table 8). The quadratic term for gum was significant (Table 8). All uniformity values were positive, indicating that all cakes were lop-sided (Table 9). The response surface reflected a trend of uniformity values to increase with starch and water levels (Figure 4). Stinson (1986a,b) found uniformity was not affected by type of oven, microwave/convection or conventional.

IV. TEXTURE PROFILE ANALYSIS

A modified texture profile analysis (TPA) (Bourne, 1978) was done with hardness and springiness being the modified parameters. Generally, the curves were not smooth and flowing. Possibly, this lack of flow was related to the numerous small air cells and the degree of compression used. Since there were many air cells the compression may not have occurred completely. The curves also reflected fracturability, which may have been due to the puncture of the surface of the cake. Walker et al. (1987) reported that when cake is compressed, compression occurs underneath the plunger and tension/shear occurs around the sides of the plunger. Hardness was measured at 7.5 mm of compression because the cake samples were not of the same height, causing variation in the degree of compression. Hardness was influenced by water (Table 10). As the water level increased, the hardness values increased significantly (Table 11 and Figure 5). The response surface reflected the quadratic water component. Martin and Tsen (1981) found crumb compression values to initially decrease as water levels increased, and then the values increased as water levels increased.

To determine springiness the distance compressed in the second bite was expressed as a percentage of the distance compressed in the first bite. Springiness values were lower for the cake samples with 4.65 g gum when compared to cakes with 3.65 g gum (Table 11). Starch did not influence springiness. Springiness values decreased as water levels increased, but were not significantly different between the 2 highest water levels (Table 11). However, linear gum, linear water, and

Table 10--Sums of squares from analyses of variance for Instron texture profile analysis

Source	df	Sums of squares				
		Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
Block	19	325406.15**	10010.067***	.03712	92738.48	11084678.64
Gum (G)	2	26441.15	73.341	.00149	16337.02	936341.97
G	1	22553.54	70.422*	.00140	13430.40	1907168.83
G*G	1	3887.61	2.919	.00010	2906.62	4026437.46*
Starch (S)	3	44631.46	22.574	.00691	26107.35	9757670.23***
S	1	14390.07	21.653	.00275	9920.84	2177005.60***
S*S	1	25752.45	.001	.00004	11423.41	381530.24
S*S*S	1	4488.94	.921	.00412	4763.10	156977.43
Water (W)	4	3235421.68***	3925.461***	.39803***	1665761.12***	868161.88
W	1	3081447.50***	3759.543***	.39426***	1558084.27***	51085096.05***
W*W	1	153837.39***	156.112**	.00045	107592.06***	47350.91
W*W*W	1	.02	7.032	.00271	81.92	560018.44
W*W*W*W	1	136.77	.00062	2.87	734736.51	2.773
S*W	12					17859035.10***
S*W	1					5962814.51**
S*W*W	1					397173.84
S*W*W*W	1					418752.61
S*S*W	1					750035.13
S*S*S*W*W	1					687.23
S*S*S*W	1					168854.28
S*S*S*S*W*W*W	1					165968.61
Error	90	621672.30	1471.291	.14273	336490.07	39294682.00(78) ^a
Total	118	4948719.10	8119.978	.71800	2525110.97	279365180.45

***P<0.001; **P<0.01; *P<0.05.

^adf for error

Table 11--Least-squares means for main effects for Instron texture profile analysis^{ab}

Main effect	Hardness, g	Springiness, %	Cohesion
Gum, g			
3.65	406.25x $\pm$ 13.74	25.56x $\pm$.67	.53x $\pm$.006
4.15	438.11x $\pm$ 13.92	24.23xy $\pm$.68	.54x $\pm$.006
4.65	441.87x $\pm$ 14.37	23.53y $\pm$.70	.54x $\pm$.007
Starch, g			
6.4	399.47x $\pm$ 16.21	24.98x $\pm$.79	.54x $\pm$.007
8.4	429.23x $\pm$ 16.61	24.74x $\pm$.80	.53x $\pm$.008
10.4	459.10y $\pm$ 16.41	24.07 $\pm$.80	.55x $\pm$.007
12.4	427.18x $\pm$ 15.70	23.84x $\pm$.76	.54x $\pm$.007
Water, ml			
275	218.42v $\pm$ 17.83	34.55w $\pm$.86	.45v $\pm$.008
300	278.14w $\pm$ 18.51	28.63x $\pm$.90	.48w $\pm$.009
325	380.04x $\pm$ 18.77	22.63y $\pm$.91	.54x $\pm$.009
350	534.96y $\pm$ 18.03	19.03z $\pm$.88	.59y $\pm$.008
375	732.16z $\pm$ 18.50	17.20z $\pm$.90	.63z $\pm$.009
	Gumminess, g	Chewiness, g	
Gum, g			
3.65	226.31x $\pm$ 10.11	2120.61x $\pm$ 90.03	
4.15	252.06x $\pm$ 10.24	2352.37x $\pm$ 91.28	
4.65	253.68x $\pm$ 10.56	2445.37x $\pm$ 94.16	
Starch, g			
6.4	223.02x $\pm$ 11.92	1432.14x $\pm$ 106.47	
8.4	240.03xy $\pm$ 12.22	1989.98y $\pm$ 108.86	
10.4	268.45y $\pm$ 12.07	2784.76z $\pm$ 107.97	
12.4	244.59xy $\pm$ 11.55	3017.60z $\pm$ 102.67	
Water, ml			
275	999.54w $\pm$ 13.12	955.65v $\pm$ 116.87	
300	134.46w $\pm$ 13.61	1225.96w $\pm$ 121.50	
325	204.64x $\pm$ 13.80	1919.58x $\pm$ 123.74	
350	314.82y $\pm$ 13.26	3013.52y $\pm$ 117.84	
375	466.62z $\pm$ 13.61	4415.88z $\pm$ 121.26	

^aLeast-squares means and standard error for two replications of 60 formulas.

^bLeast-squares means within a column and main effects followed by like letters do not differ ($P > 0.05$).

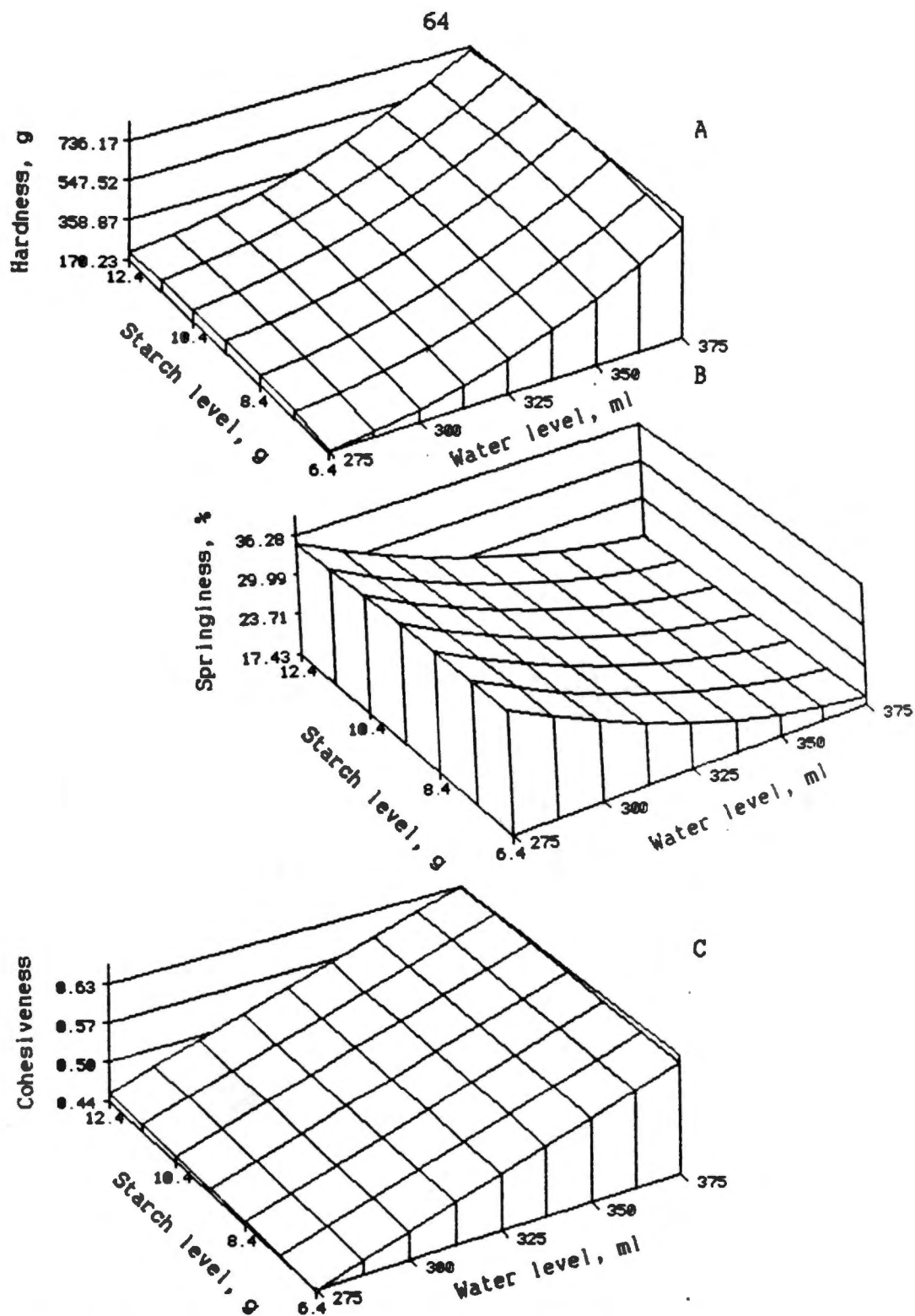


Figure 5--Hardness (A), springiness (B), and cohesiveness (C) as a function of starch and water levels in cakes containing 3.65 g gum.

quadratic water were significant (Table 10). The response surface reflected the quadratic effect of the water (Figure 5). Similarly, Sych et al. (1987) found that elasticity (springiness) of cakes decreased as initial moisture increased.

Cohesiveness did not differ among starch levels, but increased significantly as the amount of water increased (Table 11 and Figure 5). Linear water was significant resulting in a response surface which lacked curvature (Figure 5). In contrast, Sych et al. (1987) reported that initial moisture content of cake in a storage study did not influence cohesiveness.

Increasing water levels increased gumminess (Table 10). Although, cakes with 275 ml and 300 ml of water had similar gumminess values, the cakes with the other 3 water levels had significantly different gumminess values (Table 10). Linear and quadratic water components were significant (Table 10). The curviness of the response surface for gumminess shows the quadratic water level effect (Figure 6).

Levels of starch and water and the interaction of starch and water levels were significant factors for chewiness (Table 10). In general, chewiness increased with an increase in starch level. Although, an increase from 10.4 g to 12.4 g of starch did not increase chewiness values (Table 10). Similarly, an increase in water was related to an increase in chewiness. However, the samples with the lowest water levels did not differ in chewiness. Quadratic gum, linear starch, linear water, and the linear starch and water interaction were significant for chewiness (Table 10 and Figure 6). Chewiness is a complex characteristic and is affected by levels of gum, starch, and

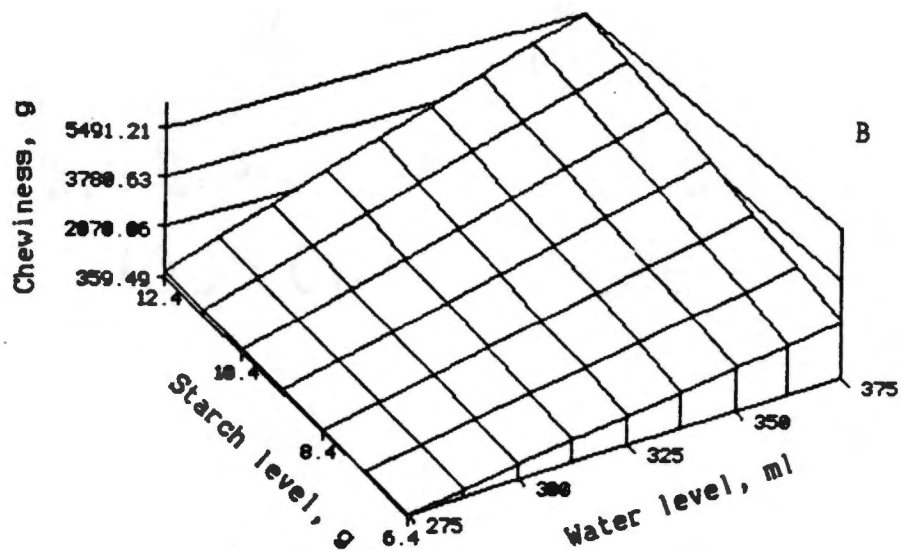
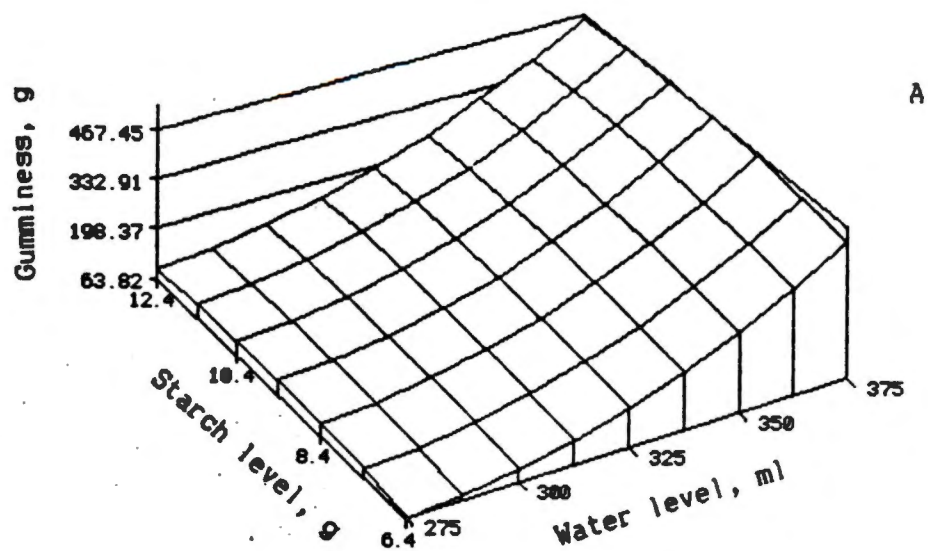


Figure 6--Gumminess (A) and chewiness (B) as a function of starch and water levels in cakes containing 3.65 g gum.

water. The response surface reflected the significance of the linear components and the interaction as the response surface was tilted (Figure 6), indicating that the cakes with the highest levels of starch and water had maximum chewiness while cakes containing the lowest water level at any starch level were the least chewy.

Objective crumb tests done using instrumentation can help assess the quality of cake. In this study responses to variation in gum, starch, and water levels seem to be rather independent and generally not involved in interactions.

V. Sensory Evaluation

The sensory panel developed the lexicon and definitions to be used in the sensory evaluation (Appendix A and Appendix B). The 15-cm line was anchored with bipolar terms. Analyses of the data were based on panel means. Panelist was not used as a main effect since there was a great deal of variability among panelists. Statistical analysis (not reported) showed the variability of the panelists to be scattered; therefore, none of the panelists could be dropped from the study. This variability may have been due to panelists' individual perception, dental state, and/or the variability in the cake samples. To help control the variability of the cake samples, each panelist received samples from the same position in the cake for every evaluation. Possibly, the cakes in this experiment may not have represented a wide range of differences. As for objective measurements, predictive response surfaces were plotted with gum held constant at 3.65 g.

Cell size was defined as the spaces or holes in the cakes and the scale increased from small to large. Cell size was not affected significantly by gum or starch level (Table 12). In general, as water level increased the mean cell size decreased. However, an increase in water level from 350 ml to 375 ml did not significantly effect cell size (Table 13). The scores for cell size were toward the lower end of the scale, representing small. Water had significant linear and quadratic effects on cell size (Table 12). The quadratic effect of the water was observed in the response surface. As the level of the water increased the cell size decreased in a quadratic fashion (Figure 7).

Street and Surratt (1961) reported that the cell size of yellow cake baked in a microwave oven and evaluated by a sensory panel was not affected by the formula liquid level. Neuzil and Baldwin (1962) baked white, plain, and devil's food cakes in the microwave and conventional ovens. A sensory panel evaluated the cakes for cell size, and the cells of the white cake baked in the microwave were considered to be larger than the cells of a white cake baked in the conventional oven. The cell size of the plain and devil's food cakes did not differ with oven. Stinson (1986a,b) reported no significant differences in cell size between yellow and devil's food cakes baked in the microwave/convection oven.

The uniformity of the cell size was evaluated from uniform to irregular. The main effects were not significant (Table 12). The least-squares means were toward the middle of the scale suggesting a mix of cell sizes (Table 13). The response surface, which contained a significant linear water effect ($p < 0.10$), depicted a trend toward the

Table 12--Sums of squares from analyses of variance of sensory scores for surface appearance characteristics

Source	df	Sums of squares		
		Cell size	Cell size Uniformity	Shape
Block	19	43.52***	76.761*	59.71**
Gum (G)	2	1.01	2.780	.60
G	1	.24	2.420	.27
G*G	1	.78	.350	.34
Starch (S)	3	.52	4.338	11.47
S	1	.10	2.903	4.77
S*S	1	.07	.086	6.62*
S*S*S	1	.35	1.348	.07
Water (W)	4	119.91***	7.076	18.27
W	1	107.44***	6.520	17.88***
W*W	1	11.22***	.004	.11
W*W*W	1	.55	.528	.09
W*W*W*W	1	.69	.018	.18
Error	91	56.38	174.370	135.31
Total	119	234.47	256.630	23.96

Source	df	Compactness	Appearance
Block	19	33.64***	49.34***
Gum (G)	2	.31	.15
G	1	.01	.02
G*G	1	.30	.13
Starch (S)	3	.30	3.81
S	1	.09	.02
S*S	1	.08	1.77
S*S*S	1	.13	2.02
Water (W)	4	176.95***	144.71***
W	1	165.72***	136.32***
W*W	1	8.97***	7.90**
W*W*W	1	1.00	.44
W*W*W*W	1	1.25	.05
Error	91	57.72	68.87
Total	119	274.56	287.40

***P<0.001; **P<0.01; *P<0.05.

Table 13--Least-squares means for main effects for sensory scores for surface appearance^{ab}

Main effect		Cell size ^c	Cell size uniformity ^d	Cell shape ^d
Gum, g	3.65	3.41x ± .13	4.95x ± .20	4.30x ± .19
	4.15	3.17x ± .13	4.95x ± .21	4.47x ± .19
	4.65	3.32x ± .13	5.29x ± .21	4.40x ± .20
Starch, g	6.4	3.30x ± .16	4.94x ± .24	4.37xy ± .23
	8.4	3.18x ± .16	4.97x ± .24	4.02x ± .23
	10.4	3.37x ± .16	5.43x ± .24	4.27x ± .23
	12.4	3.36x ± .15	5.30x ± .23	4.90y ± .22
Water, ml	275	5.24w ± .17	4.78x ± .26	3.86x ± .25
	300	3.65x ± .18	5.10x ± .27	3.98xy ± .26
	325	3.04y ± .18	5.10x ± .28	4.41xz ± .27
	350	2.40z ± .17	5.24x ± .26	4.67yz ± .26
	375	2.20z ± .18	5.60x ± .27	5.04z ± .26

		Compactness ^e	Appearance ^f
Gum, g	3.65	3.54x ± .13	4.24x ± .15
	4.15	3.45x ± .13	4.19x ± .15
	4.65	3.57x ± .14	4.27x ± .15
Starch, g	6.4	3.53x ± .16	4.15xyz ± .18
	8.4	3.50x ± .16	4.16xyz ± .18
	10.4	3.60x ± .16	4.57y ± .18
	12.4	3.46x ± .15	4.06z ± .17
Water, ml	275	5.80w ± .17	6.28v ± .20
	300	4.01x ± .18	4.81w ± .21
	325	3.35y ± .18	3.86xy ± .21
	350	2.46z ± .17	3.36yz ± .20
	375	2.00z ± .18	2.86z ± .21

^aLeast-squares means and standard error for two replications of 60 formulas.^bLeast-squares means within a column and main effects followed like letters do not differ (P>0.05).^c1=small, 15=large.^d1=uniform, 15=irregular^e1=closed, 15=open.^f1=smooth, 15=rough.

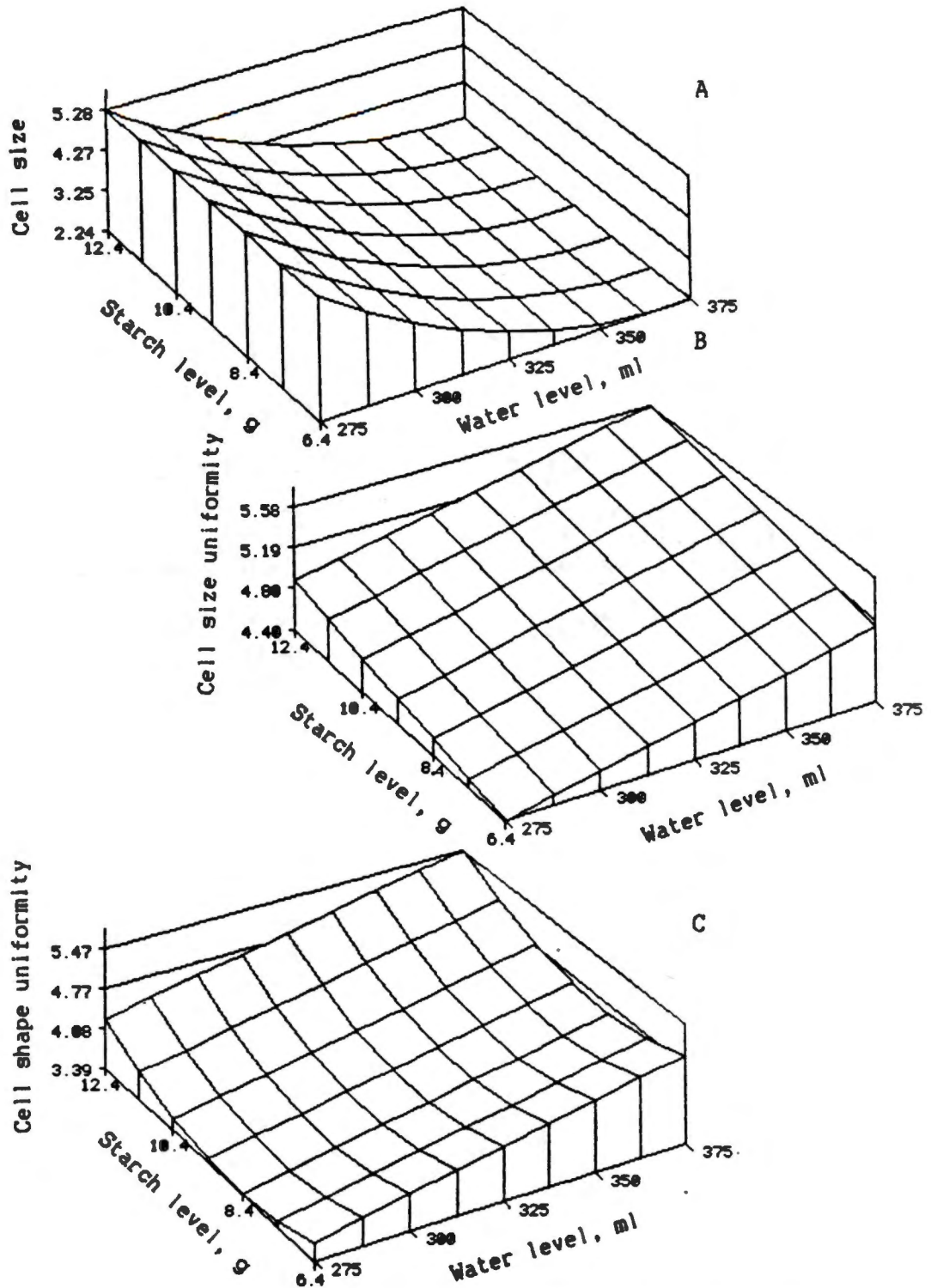


Figure 7--Cell size (1=small, 15=large) (A), cell size uniformity (1=uniform, 15=irregular) (B), and cell shape uniformity (1=uniform, 15=irregular) (C) as a function of starch and water levels in cakes containing 3.65 g gum.

greatest irregularity of size at the highest water and starch levels (Figure 7).

The uniformity of the types of shapes of the cells was judged from uniform to irregular. Quadratic starch and linear water were the significant terms in the model for cell shape (Table 12). The response surface reflected the quadratic starch and linear water effects (Figure 7). The least-squares means for cell shape were on the lower end of the scale suggesting uniformity of cell shape. The highest level of starch in the cakes affected the cell shape more than the 8.4 g of starch but there was no difference between the 6.4 g and 12.4 g levels. As water levels increased there was a decrease in uniformity (Figure 7). Looking at least-squares means, the 275 ml was different from the 350 ml and the 375 ml, but not from the 300 ml and 325 ml levels. Street and Surratt (1961) estimated that an increase in liquid of 20 g per layer of cake beyond manufacturer's instructions produced cakes with uniform cell distribution. However, an increase of 40 g of liquid per layer was believed to cause tunnel formation. Neuzil and Baldwin (1962) found no significant oven effects on cell uniformity for white, plain, or devil's food cakes baked in the microwave and conventional ovens. Stinson (1986a,b) reported similar results as Neuzil and Baldwin (1962).

Compactness and appearance, both pertaining to perception of the surface of the cakes, were affected significantly by water, linear water, and quadratic water (Table 12). The response surface for compactness and appearance were similar (Figure 8). As water level increased the values for compactness and appearance decreased in a quadratic form. The scale for compactness ranged from closed to open.

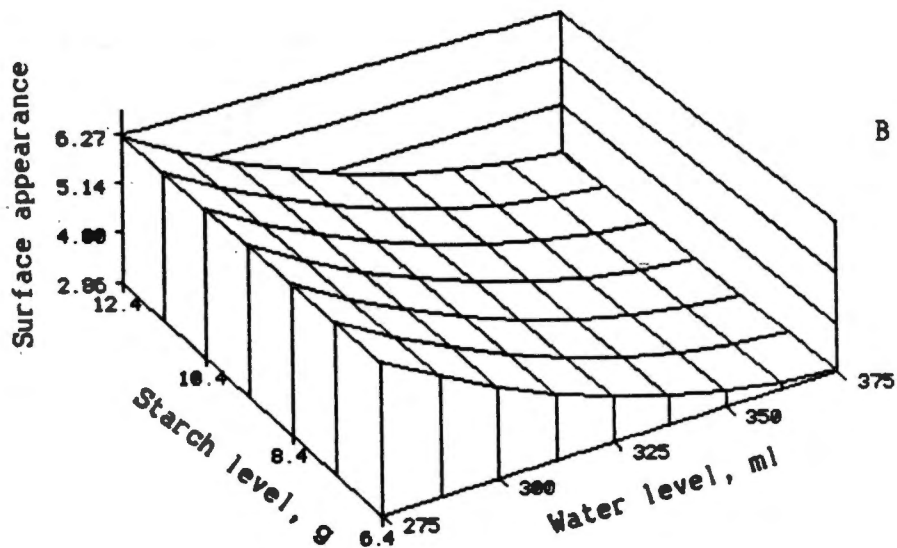
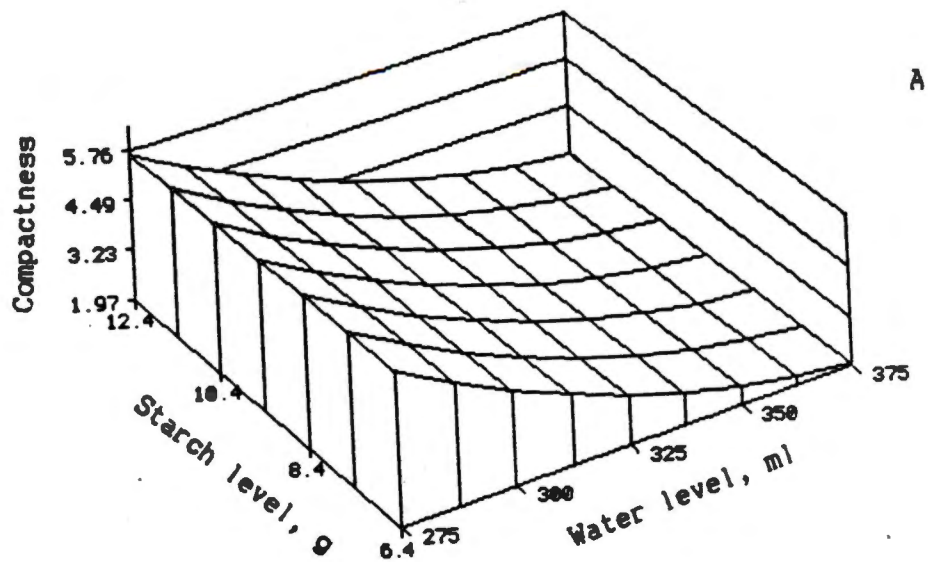


Figure 8--Compactness (1=open, 15=large) (A) and surface appearance (1=smooth, 15=rough) (B) as a function of starch and water levels in cakes containing 3.65 g gum.

The scale for appearance ranged from smooth looking surface to rough looking surface. Scores for both were on the lower ends of the scales (Table 13). The sensory panel used by Street and Surratt (1961) to evaluate yellow cake did not find any significant differences in crumb character based on formula liquid levels. Hill and Reagan (1982) evaluated appearance of yellow cakes made from a laboratory formula that was baked conventionally and in microwave ovens with and without a turntable. The appearance of the conventional cakes was given the highest score, followed by the cakes baked on a turntable, and then the cakes baked without a turntable. Uneven surfaces and tunnels were present in the microwave-baked cakes. Martin and Tsen (1981) postulated that commercial double-acting baking powder was not designed for use in the microwave oven. The heating process differs from the conventional oven and causes cake cells to be coarse, irregular, and to have thick cells. Stinson (1986b) reported similar sensory results for cell wall thickness and grain for devil's food and yellow cakes baked in the conventional and microwave/convection ovens.

Tenderness was defined as the resistance of the cake to the force of the fork to cut through the sample. The scale was anchored from tender to tough at the higher end of the scale. Gum, linear gum, starch, linear starch, water, linear water, and linear gum x starch interaction were significant factors for tenderness (Table 14). As the level of gum increased, tenderness scores increased (Table 15). The scores were close to the middle of the scale (Table 15). The response surface reflected the increases in tenderness scores with increases in starch and water levels (Figure 9).

Table 14--Sums of squares from analyses of variance of sensory scores for texture before biting

Source	df	Sums of squares		
		Tenderness	Crumbliness	Springiness
Block	19	49.787**	24.090**	34.68
Gum (G)	2	7.601*	2.016	.31
G	1	7.18*	.316	.53
G*G	1	.91	2.313*	.08
Starch (S)	3	25.506***	6.156*	4.51
S	1	25.585***	5.850*	2.95
S*S	1	.013	.011	.50
S*S*S	1	.002	.046	1.04
Water (W)	4	92.313***	158.358***	197.53***
W	1	89.843***	182.218***	183.91***
W*W	1	2.127	2.124*	11.76**
W*W*W	1	.731	.405	2.26
W*W*W*W	1	1.762	.038	7.44*
G*S	6	15.877*		24.23*
G*S	1	6.234*		1.40
G*S*S	1	.750		.01
G*S*S*S	1	2.003		3.00
G*G*S	1	3.201		10.00**
G*G*S*S	1	3.652		.18
G*G*G*S*S*S	1	.036		9.65*
G*S*W			30.770(50)* ^a	
G*S*W			.909(1) ^a	
G*S*W*W			.334(1) ^a	
G*S*W*W*W			.131(1) ^a	
G*S*S*W			.006(1) ^a	
G*S*S*S*W			.180(1) ^a	
G*G*S*W			1.553(1) ^a	
G*G*G*S*W			.124(1) ^a	
Error		90.987(85) ^a	15.08(41) ^a	121.23(85) ^a
Total	119	285.108	286.35	390.59

***P<0.001; **P<0.01; *P<0.05.

^adf for error.

Table 15--Least-squares means for main effects for sensory parameters evaluated with fork and initially in the mouth^{ab}

Main effect		Tenderness ^c	Crumbliness ^d	Springiness ^e
Gum, g	3.65	5.70x ± .18	5.34x ± .20	9.17x ± .25
	4.15	6.20xy ± .20	5.04x ± .20	9.05x ± .26
	4.65	6.30y ± .20	5.36x ± .20	9.04x ± .26
Starch, g	6.4	5.41x ± .22	5.57x ± .23	8.89x ± .30
	8.4	5.85xy ± .22	5.31xy ± .23	9.06x ± .31
	10.4	6.27yz ± .22	5.17xy ± .23	9.01x ± .30
	12.4	6.71z ± .21	4.93y ± .22	9.40x ± .30
Water, ml	275	4.91w ± .24	7.32w ± .25	10.61x ± .33
	300	5.28wx ± .25	6.25x ± .26	10.21x ± .34
	325	5.66x ± .26	5.03y ± .27	9.95x ± .35
	350	6.91y ± .24	4.11z ± .25	7.82y ± .33
	375	7.54y ± .25	3.50z ± .26	6.85z ± .34

		Texture ^f	Moisture release ^g
Gum, g	3.65	5.17x ± .17	7.15x ± .16
	4.15	4.72x ± .17	7.40x ± .17
	4.65	4.83x ± .17	7.52x ± .17
Starch, g	6.4	4.86x ± .20	7.34xz ± .20
	8.4	4.97x ± .20	6.93x ± .20
	10.4	4.84x ± .20	7.67z ± .20
	12.4	4.96x ± .19	7.51zy ± .19
Water, ml	275	7.10w ± .22	4.37v ± .22
	300	5.24x ± .22	5.76w ± .22
	325	4.76x ± .23	7.31x ± .23
	350	3.92y ± .22	8.82y ± .22
	375	3.52y ± .23	10.52z ± .22

^aLeast-squares means and standard error for two replications of 60 formulas.

^bLeast-squares means within a column and main effects followed by like letters do not differ ($P > 0.05$).

^c1=tender, 15=tough.

^d1=none, 15=complete.

^e1=no recovery, 15=complete.

^f1=smooth, 15=rough.

^g1=dry, 15=moist.

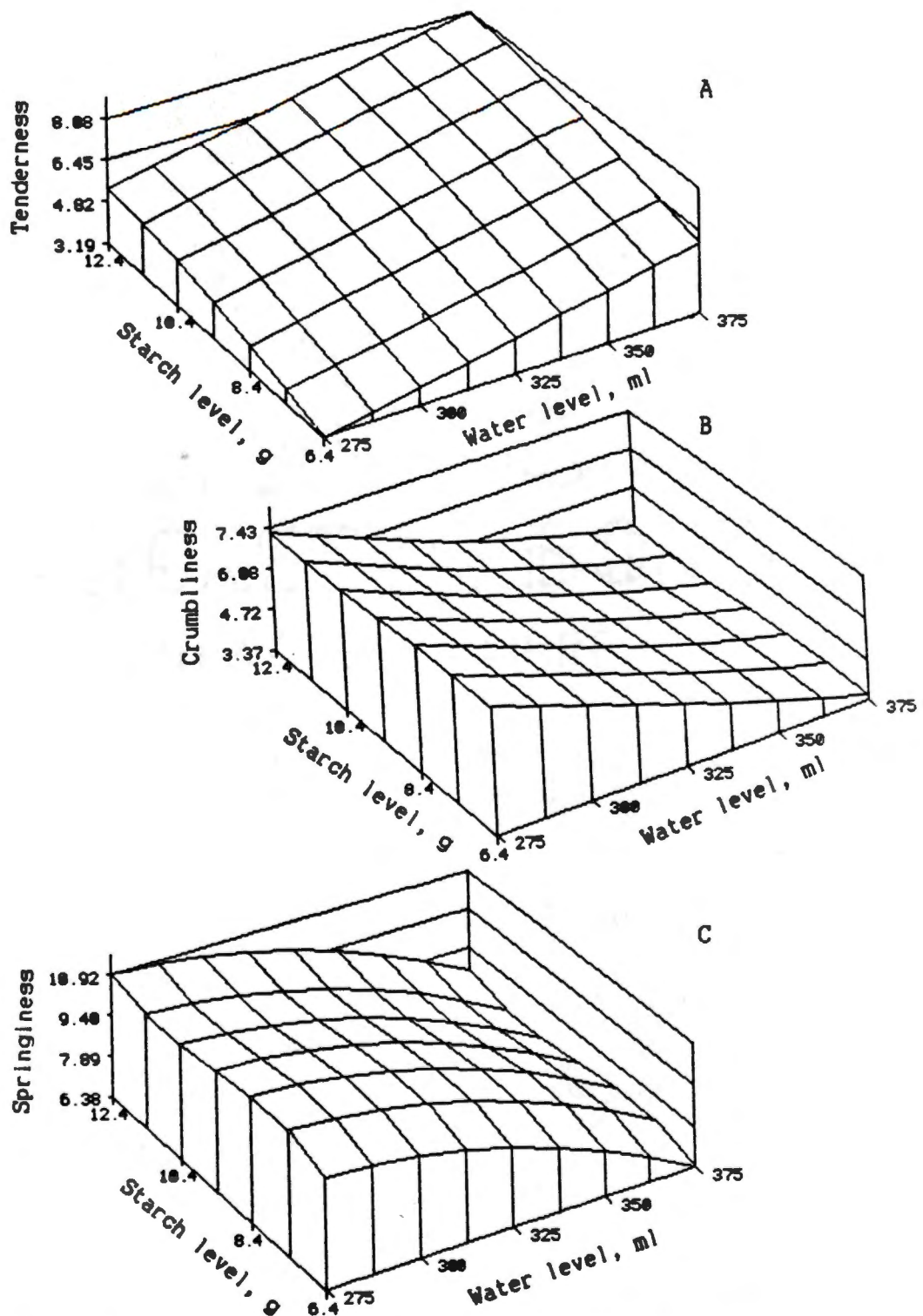


Figure 9--Tenderness (1=tender, 15=tough) (A), crumbliness (1=none, 15=complete) (B), and springiness (1=no recovery, 15=complete) (C) as a function of starch and water levels in cakes containing 3.65 g gum.

Crumbliness of the cakes was determined after cutting with the fork. The scale ranged from none to completely. Quadratic gum, starch, linear starch, water, linear and quadratic water, and the three-way interaction were the significant factors (Table 14). The scores were generally in the middle of the scale (Table 14). Least-squares means revealed significant differences for starch levels (Table 15). As starch level increased, crumbliness decreased. As water levels increased, the cakes became less crumbly with no significant difference between the 350 ml and 375 ml levels (Table 15 and Figure 9).

Springiness was evaluated as the panelists pressed down on the cake samples with a fork. All water components except cubic water were significant. The interaction between gum and starch was significant also (Table 14). The contour of the springiness response surface reflects the second order variable and the interaction (Figure 9). Individually gum and starch levels did not significantly affect springiness. The scores were above the middle of the scale, suggesting that the cakes were moderately springy (Table 15). As water levels increased the springiness scores decreased. Springiness, as determined by the TPA, was similarly affected by the main effects (Table 10, p. 62), except the interaction was not significant.

The texture of the sample when placed initially in the mouth was evaluated on a continuum of smooth to rough. Linear and quadratic water were significant factors. The response surface for this characteristic and the visual evaluation of the surface texture were similar (Figure 4, p. 59 and Figure 10). Starch level did not significantly affect the texture in the mouth. As water levels increased, a trend occurred for

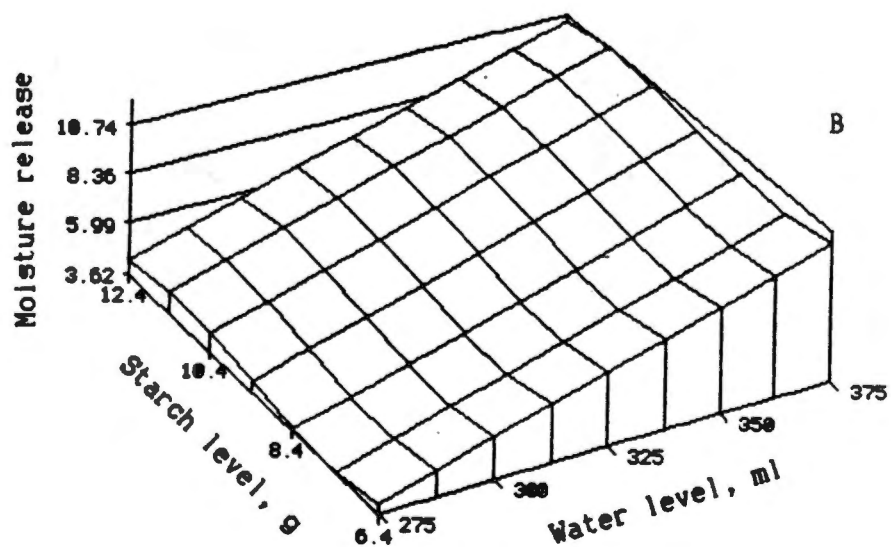
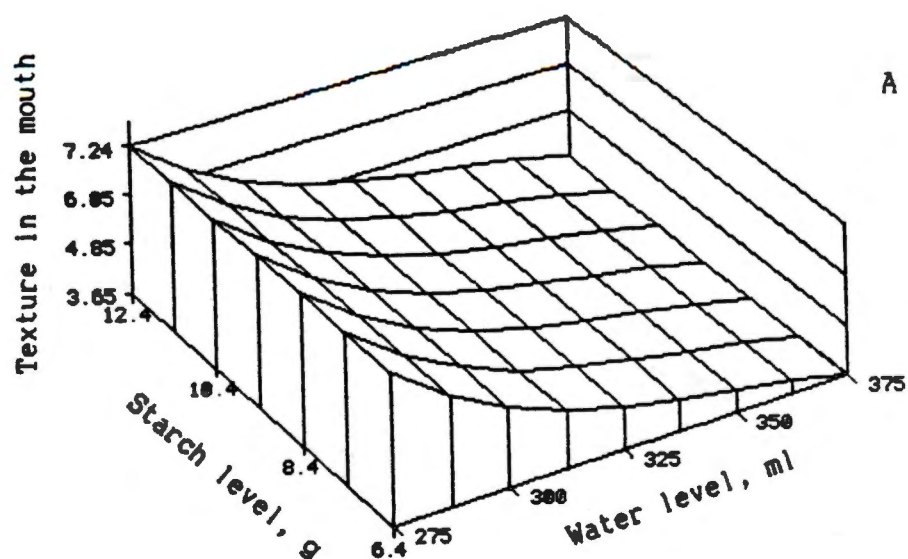


Figure 10--Texture in the mouth (1=smooth, 15=rough) (A) and moisture release (1=dry, 15=moist) (B) as a function of starch and water levels in cakes containing 3.65 g gum.

samples to become smoother (Table 15). Hill and Reagan (1982) reported that the mouthfeel of microwave-baked yellow cakes was inferior to conventionally baked cakes.

Moisture release increased significantly as water level increased (Table 15). This increase corresponds to the increase in moisture content as water level increased (Table 6, p. 50). Starch levels were significantly different (Table 15). Starch, cubic starch, water, and linear water were the significant factors for moisture release (Table 16). The cubic starch component can be seen in the response surface for moisture release (Figure 10).

Degree of softness was the phrase used to describe the amount of pressure and effort necessary to initially bite through the cake sample with the molar teeth. The scale increased from soft to not at all soft. Linear starch and linear water were the significant factors for degree of softness (Table 17). The linear effects of the starch and water are visualized in the response surface (Figure 11). Hardness, as determined by the Instron, increased significantly as water level increased (Table 10, p. 62). As the water levels increased in the study by Street and Surratt (1961) no difference was found in tenderness of cakes. Generally, microwave-baked cakes have been judged to be less tender than conventionally baked cakes (Neuzil and Baldwin, 1962; Hill and Reagan, 1982); however, Stinson (1986b) found no significant difference for tenderness in conventionally baked cakes and cakes baked in the microwave/convection oven.

Deformation, the degree of change while chewing until the structure of the sample fails, was not affected by water levels (Table 17). The

Table 16--Sums of squares from analyses of variance of sensory scores for texture in mouth

Source	df	Sums of squares	
		Texture in mouth	Moisture release
Block	19	15.702	108.642***
Gum (G)	2	3.616	2.413
G	1	2.112	2.327
G*G	1	1.504	.086
Starch (S)	3	.340	7.718*
S	1	.042	2.314
S*S	1	.004	.392
S*S*S	1	.291	5.011*
Water (W)	4	155.179	445.822***
W	1	140.883***	445.359***
W*W	1	10.523***	.445
W*W*W	1	1.875	.003
W*W*W*W	1	1.897	.027
Error	91	59.726	86.146
Total	119	271.433	640.518

***P<0.001; **P<0.01; *P<0.05.

Table 17--Sums of squares from analyses of variance of sensory scores for first bite with molars

Source	df	Sums of squares		
		Degree of softness	Deformation	Fracturability
Block	19	17.24	29.88	36.26
Gum (G)	2	.06	1.40	2.35
G	1	.04	1.23	.8
G*G	1	.02	.17	1.56
Starch (S)	3	8.98	8.42	8.90
S	1	.13*	7.96*	8.21*
S*S	1	.83	.28	.12
S*S*S	1	.01	.18	.56
Water (W)	4	12.34	6.19	48.13***
W	1	9.90**	.42	41.33***
W*W	1	1.83	.32	.11
W*W*W	1	.36	5.01	2.59
W*W*W*W	1	.24	.44	4.10
Error	91	81.86	161.53	163.61
Total	119	122.20	207.41	257.75

***P<0.001; **P<0.01; *P<0.05.

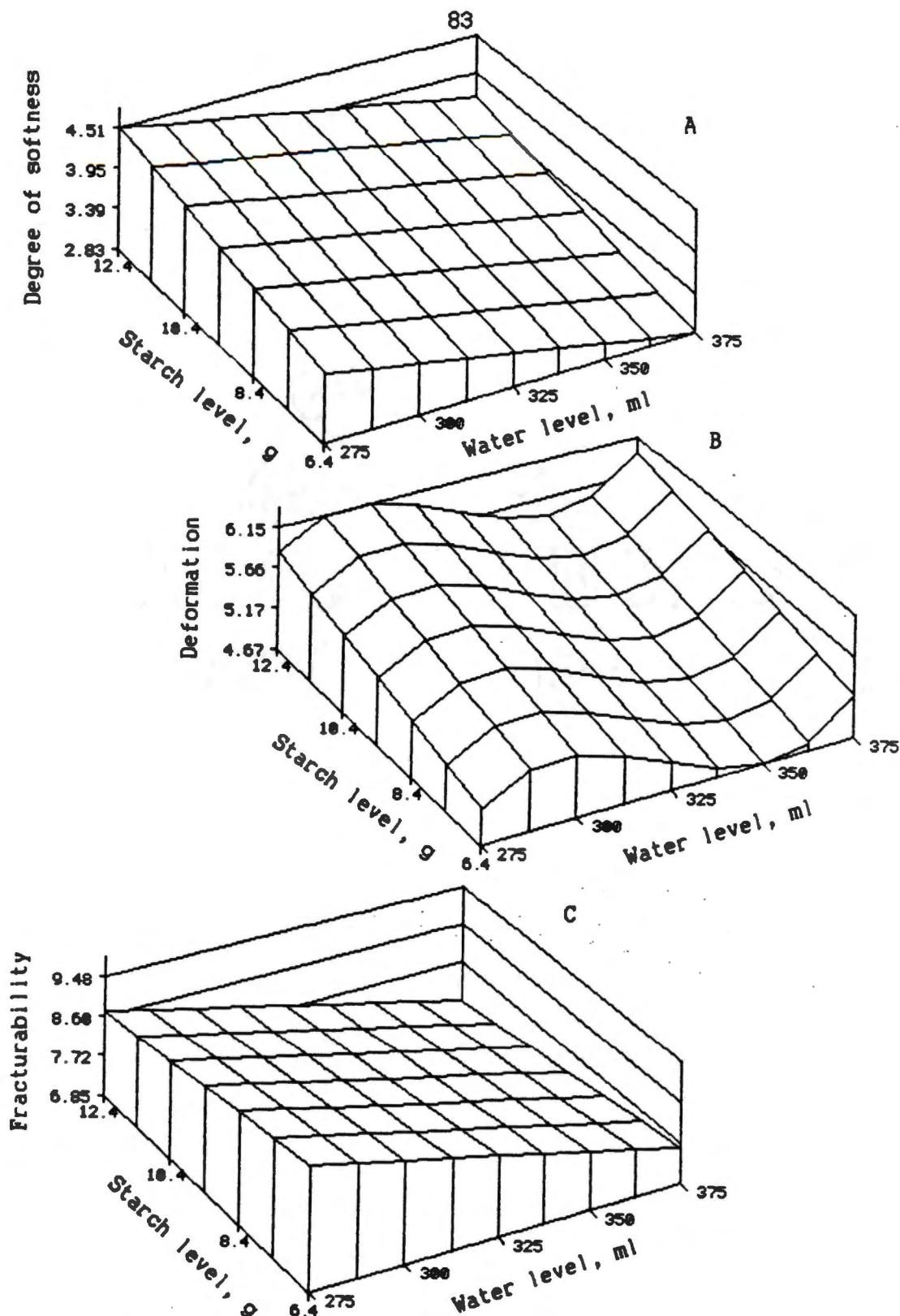


Figure 11--Degree of softness (1=soft, 15=not at all soft) (A), deformation (1=none, 15=complete) (B), and fracturability (1=none, 15=complete) (C) as a function of starch and water levels in cakes containing 3.65 g gum.

deformation scores for the 6.4 g and the 12.4 g levels of starch were significantly different (Table 18). Starch was the only significant factor at $p < 0.05$. Linear, quadratic, and cubic water components are shown in the response surface equation (Figure 11), since the cubic water was significant at $p < 0.10$. The response surface showed a linear increase in deformation as the starch increased and a cubic effect for the water levels.

Fracturability, which was defined as the crumbling of the sample as chewed, was related to deformation in that if a sample held together it did not crumble during chewing. Fracturability also similar to deformation in that block and gum level were not significant and linear starch was significant (Table 17). In addition, water and linear water also were significant for fracturability. The lowest and highest starch levels differed significantly in fracturability (Table 18).

Fracturability scores were significantly higher at 275 ml water than at 300, 350, or 375 ml but not at 325 ml, and the scores at 275 ml was also higher than at 375 ml (Table 18). However, the fracturability scores were not significantly different among 300, 325, and 350 ml of water, or between 350 and 375 ml. There was a significant trend for fracturability to decrease as water level increased (Figure 11). The mean scores were slightly above the middle of the scale (Table 18).

Molsture absorption was defined as the amount of saliva absorbed by the cake during the breakdown of the mass. The scale ranged from none to absorbs most of the molsture in the mouth. Starch level did not affect this characteristic (Table 19). The scores for this characteristic were significantly different among the 5 water levels

Table 18--Least-squares means for main effects for sensory parameters evaluated in the mouth^{ab}

Main effect		Degree of softness ^c	Deformation ^d	Fracturability ^d
Gum, g	3.65	3.65x ± .15	5.41x ± .22	8.26x ± .21
	4.15	3.65x ± .16	5.62x ± .22	7.90x ± .22
	4.65	3.60x ± .26	5.65x ± .22	8.10x ± .22
Starch, g	6.4	3.36x ± .18	5.22x ± .26	8.44x ± .26
	8.4	3.40x ± .18	5.45x ± .26	8.12xy ± .26
	10.4	3.70xy ± .18	5.57x ± .26	8.10xy ± .26
	12.4	4.08y ± .18	6.01x ± .25	7.64y ± .25
Water, ml	275	4.91w ± .24	5.58x ± .28	9.081x ± .28
	300	5.28wx ± .25	5.93x ± .30	8.14y ± .30
	325	5.66x ± .26	5.36x ± .30	8.45xy ± .30
	350	6.91y ± .24	5.24x ± .29	7.67yz ± .28
	375	7.54y ± .25	5.69x ± .30	7.03z ± .29

Breakdown of mass

		Moisture absorption ^e	Cohesion ^f	Texture ^g
Gum, g	3.65	7.61x ± .20	8.16x ± .21	3.00x ± .13
	4.15	7.21x ± .20	8.46x ± .22	3.00x ± .13
	4.65	7.21x ± .20	8.21x ± .22	3.00x ± .13
Starch, g	6.4	7.30x ± .30	7.93x ± .25	2.90x ± .15
	8.4	7.40x ± .23	8.03x ± .25	2.79xy ± .15
	10.4	7.30x ± .23	8.31xy ± .26	3.10xy ± .15
	12.4	7.41x ± .23	8.84y ± .24	3.16y ± .15
Water, ml	275	9.70v ± .25	6.90x ± .28	4.34w ± .17
	300	8.81wx ± .26	7.66x ± .28	3.27x ± .17
	325	7.69x ± .27	8.56y ± .30	2.81y ± .18
	350	5.91y ± .26	9.00y ± .28	2.27y ± .17
	375	4.62z ± .27	9.30y ± .29	2.20y ± .17

^aLeast-squares means and standard error for two replications of 60 formulas.

^bLeast-squares means within a column and main effects followed by like letters do not differ ($P > 0.05$).

^c1=soft, 15=not at all soft.

^d1=none, 15=complete.

^e1=none, 15=absorbs most of moisture.

^f1=loose, 15=compact.

^g1=smooth, 15=rough.

Table 19--Sums of squares from analyses of variance of sensory scores for breakdown when chewing

Source	df	Sums of squares		
		Moisture absorption	Cohesion of mass	Texture
Block	19	78.14***	61.33*	15.401*
Gum (G)	2	3.42	1.59	.006
G	1	2.52	.16	.372
G*G	1	.72	1.43	.031
Starch (S)	3	.27	14.24*	3.075*
S	1	.02	12.73**	1.628*
S*S	1	.03	1.48	.228
S*S*S	1	.22	.02	.369
Water (W)	4	324.57***	74.43***	59.761***
W	1	319.70***	72.01***	56.188***
W*W	1	2.64	1.93	5.686***
W*W*W	1	1.39	.28	.039
W*W*W*W	1	.83	.21	.449
S*W	12			8.496*
S*W	1			.831
S*W*W	1			.091
S*W*W*W	1			3.410**
S*S*W	1			.044
S*S*W*W	1			.036
S*S*S*W	1			2.732**
Error	91	117.40	152.81	25.156(79) ^a
Total	119	502.98	288.77	116.405

***P<0.001; **P<0.01; *P<0.05.

^adf for error.

except between 300 and 325 ml. As the water level increased, the score decreased, indicating that the moisture absorption was less when the water levels were highest (Table 18). The actual objective moisture content of the cakes also increased as water level increased (Table 6, p. 50). Linear water was a significant factor (Table 19). The response surface reflected the linear water trend (Figure 12).

Cohesion of the mass was the second characteristic of the breakdown process. The cohesion of the mass was anchored with loose on a continuum to compact. The 2 lower starch levels resulted in less cohesion than the highest level (Table 18). Cakes made with the 2 lowest water levels had lower cohesion scores than cakes made with the 3 highest water levels. As starch and water level increased, the mass became more cohesive. Scores were slightly over the middle of the scale (Table 18). Linear starch and linear water were significant factors (Table 19). The linear trends for starch and water are seen in the response surface (Figure 12).

The texture of the chewed mass was evaluated as smooth and increasing to rough on the scale. In general, as starch levels increased, the samples were perceived as rougher (Table 18). As water levels increased, the mass was considered to become smoother (Table 18). Starch, linear starch, water, linear water, quadratic water, the starch and water interaction, and the starch and cubic water interaction were significant factors (Table 19). The response surface reflected the linear starch trend and the presence of the second and third order polynomials (Figure 12).

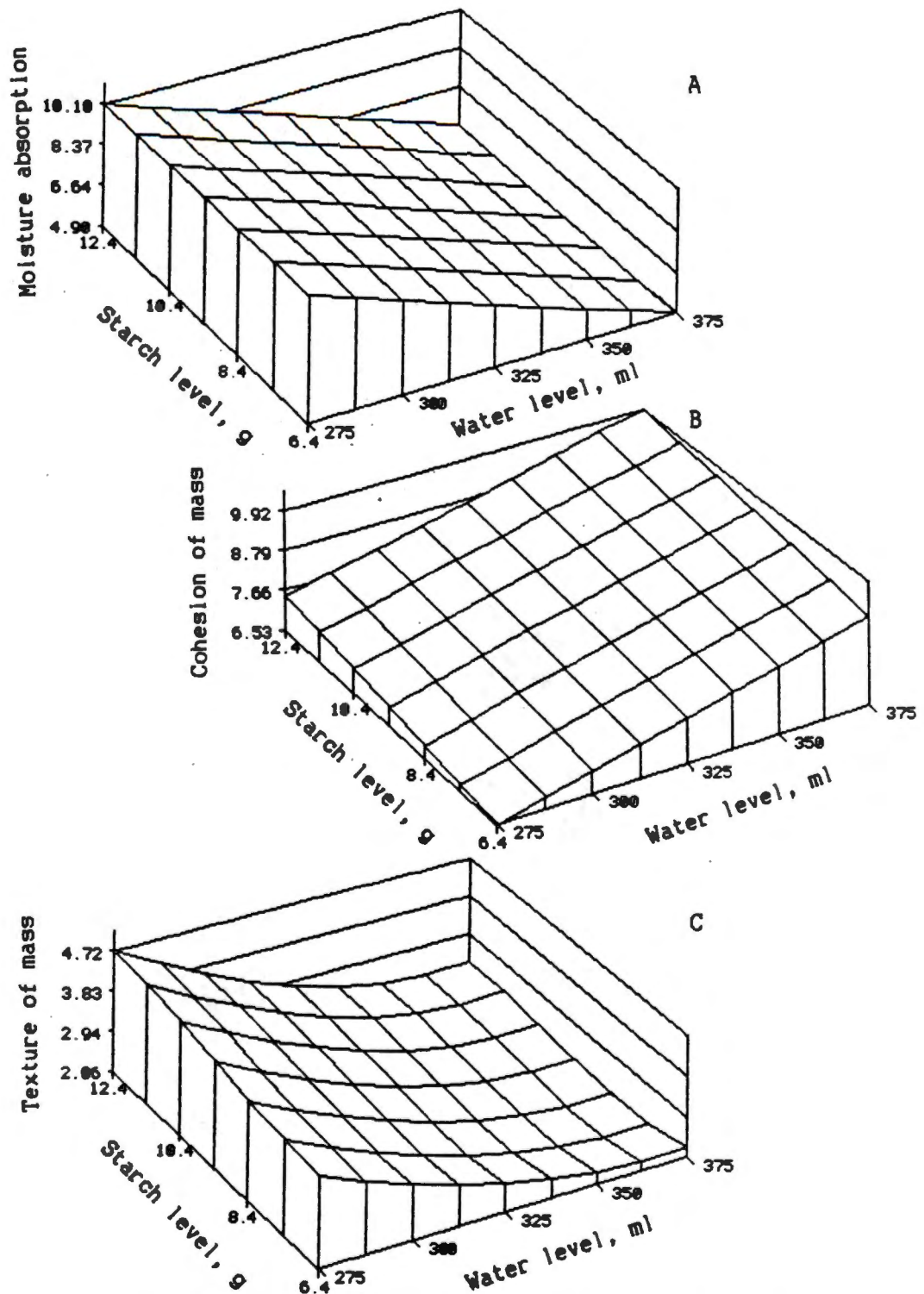


Figure 12--Moisture absorption (1=none, 15=absorbs most of moisture) (A), cohesion of mass (1=loose, 15=compact) (B), and texture of mass (1=smooth, 15=rough) (C) as a function of starch and water levels in cakes containing 3.65 g gum.

The ease of chewing was defined as the force and effort required to prepare the cake for swallowing. The ease of swallowing was defined as the force required to swallow. The scales for both characteristics were anchored with easy increasing to difficult. After swallowing, the amount of oily residual in the mouth was considered on a scale anchored with none and heavy. Finally, the adhesion to teeth parameter was evaluated after swallowing and was evaluated in terms of no adhesion to compact mass on or in the teeth.

Ease of chewing was influenced by starch and linear starch component. Linear starch was a significant factor for ease of swallowing (Table 20). As the amount of starch increased the cake became more difficult to chew (Table 21). The scores for ease of swallowing were toward the center of the scale (Table 21). Oily residue was influenced by linear starch, water level, and the interaction between gum and starch components (Table 22). As water level increased, the amount of oily residue increased in the panelists' mouths (Table 21). The oily residue from the cakes with the highest water level was considered to be in the middle of the scale. The interaction of gum and starch also was significant for adhesion to teeth, as was the linear water component (Table 22). The scores for adhesion to teeth were slightly above the middle of the scale (Table 21).

The response surfaces for ease of chewing and swallowing were influenced by a linear starch component (Figure 13). As starch level increased the ease of chewing and swallowing decreased slightly. The response surface for oily residue showed the effect of the linear starch and linear water and also, was slightly curved, reflecting the

Table 20--Sums of squares from analyses of variance of sensory scores for chewing and swallowing

Source	df	Sums of squares	
		Ease of chewing	Ease of swallowing
Block	19	14.450283	33.8526*
Gum (G)	2	.490632	.20768
G	1	.090031	.0007
G*G	1	.406012	.2069
Starch (S)	3	4.373353*	6.4257
S	1	4.149242**	4.6880*
S*S	1	.014970	.0009
S*S*S	1	.209141	1.7370
Water (W)	4	.612286	1.6972
W	1	.000002	.8130
W*W	1	.239560	.2260
W*W*W	1	.015659	.0104
W*W*W*W	1	.357064	.6478
Error	91	41.307754	82.3556
Total	119	63.468238	129.0001

***P<0.001; **P<0.01; *P<0.05.

Table 21--Least-squares means for main effects for sensory scores for ease of chewing and swallowing and residual^{ab}

Main effect	Ease of chewing ^c	Ease of swallowing ^c
Gum, g		
3.65	4.41x ± .20	6.90x ± .25
4.15	4.50x ± .20	7.00x ± .25
4.65	4.31x ± .20	6.90x ± .26
Starch, g		
6.4	4.14x ± .23	6.58x ± .30
8.4	4.36xy ± .24	7.00x ± .30
10.4	4.42xy ± .24	6.86x ± .30
12.4	4.70y ± .23	7.28x ± .30
Water, ml		
275	4.46x ± .26	6.85x ± .33
300	4.33x ± .27	6.75x ± .34
325	4.43x ± .27	7.00x ± .35
350	4.31x ± .26	6.90x ± .33
375	4.50x ± .26	7.17x ± .34
	Orally mouthcoating ^d	Teeth adhesion ^e
Gum, g		
3.65	6.10x ± .22	7.73x ± .23
4.15	6.24x ± .23	7.81x ± .23
4.65	6.02x ± .23	7.90x ± .23
Starch, g		
6.4	5.90x ± .27	7.51x ± .27
8.4	6.04x ± .26	8.00x ± .27
10.4	6.12x ± .27	7.78x ± .27
12.4	6.42x ± .25	8.00x ± .26
Water, ml		
275	4.63w ± .30	7.40x ± .30
300	5.13wx ± .30	7.75x ± .30
325	5.87x ± .30	8.00x ± .31
350	6.91y ± .30	7.74x ± .30
375	8.05z ± .30	8.18x ± .30

^aLeast-squares means and standard error for two replications of 60 formulas evaluated by 7 panelists.

^bLeast-squares means within a and main effects column followed by like letters do not differ (P>0.05).

^c1=easy, 15=difficult.

^d1=none, 15=heavy.

^e1=none, 15=compact mass.

Table 22--Sums of squares from analyses of variance of sensory scores for residuals after swallowing

Source	df	Sums of squares	
		Oily residue	Adhesion to teeth
Block	19	22.816	23.14
Gum (G)	2	1.060	.35
G	1	.001	.79
G*G	1	.777	.03
Starch (S)	3	4.851	5.92
S	1	4.305*	2.27
S*S	1	.175	.31
S*S*S	1	.198	1.99
Water (W)	4	138.538***	5.13
W	1	139.701***	5.43*
W*W	1	3.829	.18
W*W*W	1	.050	1.38
W*W*W*W	1	.033	.70
G*S	6	15.208*	30.01**
G*S	1	2.369	6.87*
G*S*S	1	1.915	1.03
G*S*S*S	1	2.930	8.54*
G*G*S	1	4.871*	13.28*
G*G*S*S	1	.719	.05**
Error	85	82.831	116.29
Total	119	300.610	183.49

***P<0.001; **P<0.01; *P<0.05.

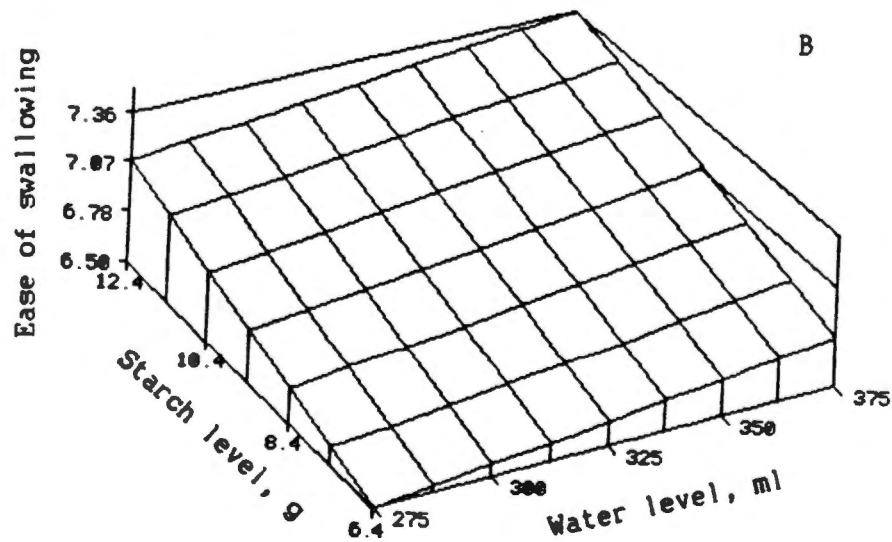
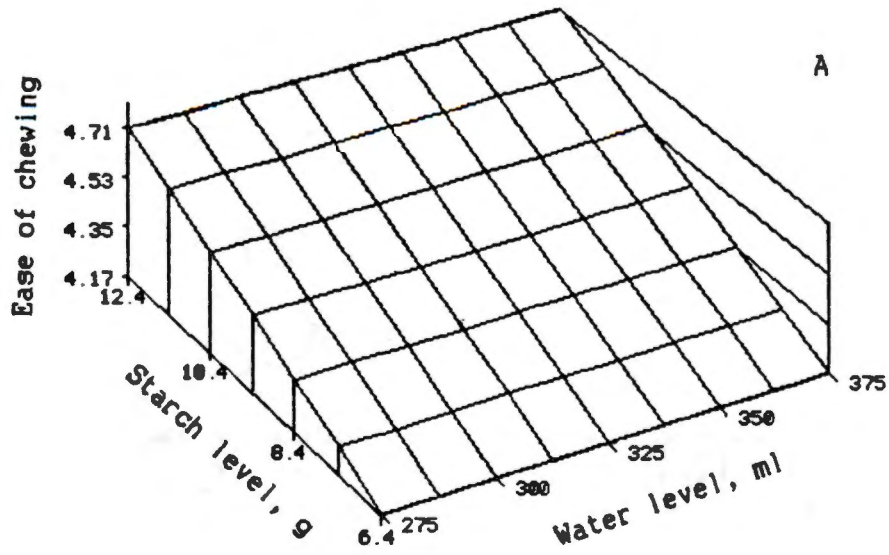


Figure 13--Ease of chewing (1=easy, 15=difficult) (A) and ease of swallowing (1=easy, 15=difficult) (B) as a function of starch and water levels in cakes containing 3.65 g gum.

interaction (Figure 14). The response surface for adhesion to teeth reflected the linear water component and the interaction of starch and gum (Figure 14).

The sensory evaluation of cake revealed that ingredient changes in the cake formulas affected many characteristics in the baked cake. The information can be used as a guide to additional ingredient changes and also, the quality of the cake.

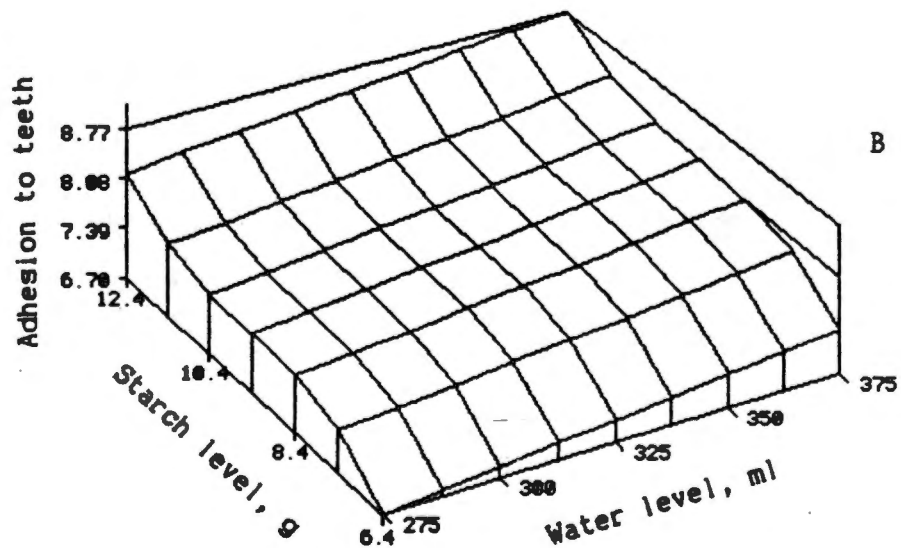
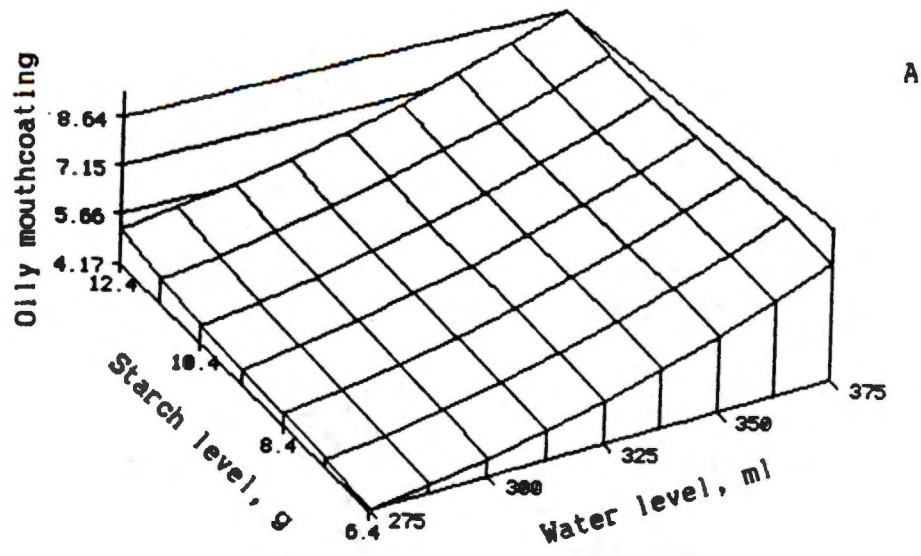


Figure 14--Oily mouthcoating (1=none, 15=heavy) (A) and adhesion to teeth (1=none, 15=compact mass) (B) as a function of starch and water levels in cakes containing 3.65 g gum.

VI. SELECTED STUDIES

In the 5 selected studies, 4 of the 60 treatments were studied. These 4 treatments were chosen because they often represented the extremes on the response surfaces. Gum was held constant at 3.65 g with combinations of the water levels, 275 ml and 375 ml, and 2 starch levels, 6.4 g and 12.4 g.

VII. SCANNING ELECTRON MICROSCOPY

Scanning electron microscopy is used primarily to study the structure of components and the integration of the components in a system such as cake crumb (Hsieh et al., 1981). The micrographs taken at low magnification (50X) showed the surface of the cake crumb as an intact system (Plate 1). The surface of the samples for the low-water cakes (A and B) appeared rougher than the surface of the high-water, low starch cakes (C). The micrograph for the surface of the high-water, high-starch (D) sample appeared similar to those of the 2 low-water samples (A and B); these micrographs showed a rough looking cell wall and large and small open spaces, representing air pockets and air cells. The high-water, low-starch cake (C) micrographs showed the cake surface to be fairly smooth with smooth indentations and air cells. This difference in the contour of the cells could be due to increased gelatinization resulting in a film, since more water was present. Cloke et al. (1984a) found unemulsified cakes to have a "knobby" appearance and small air cells, possibly similar to the high-water, low-starch cake

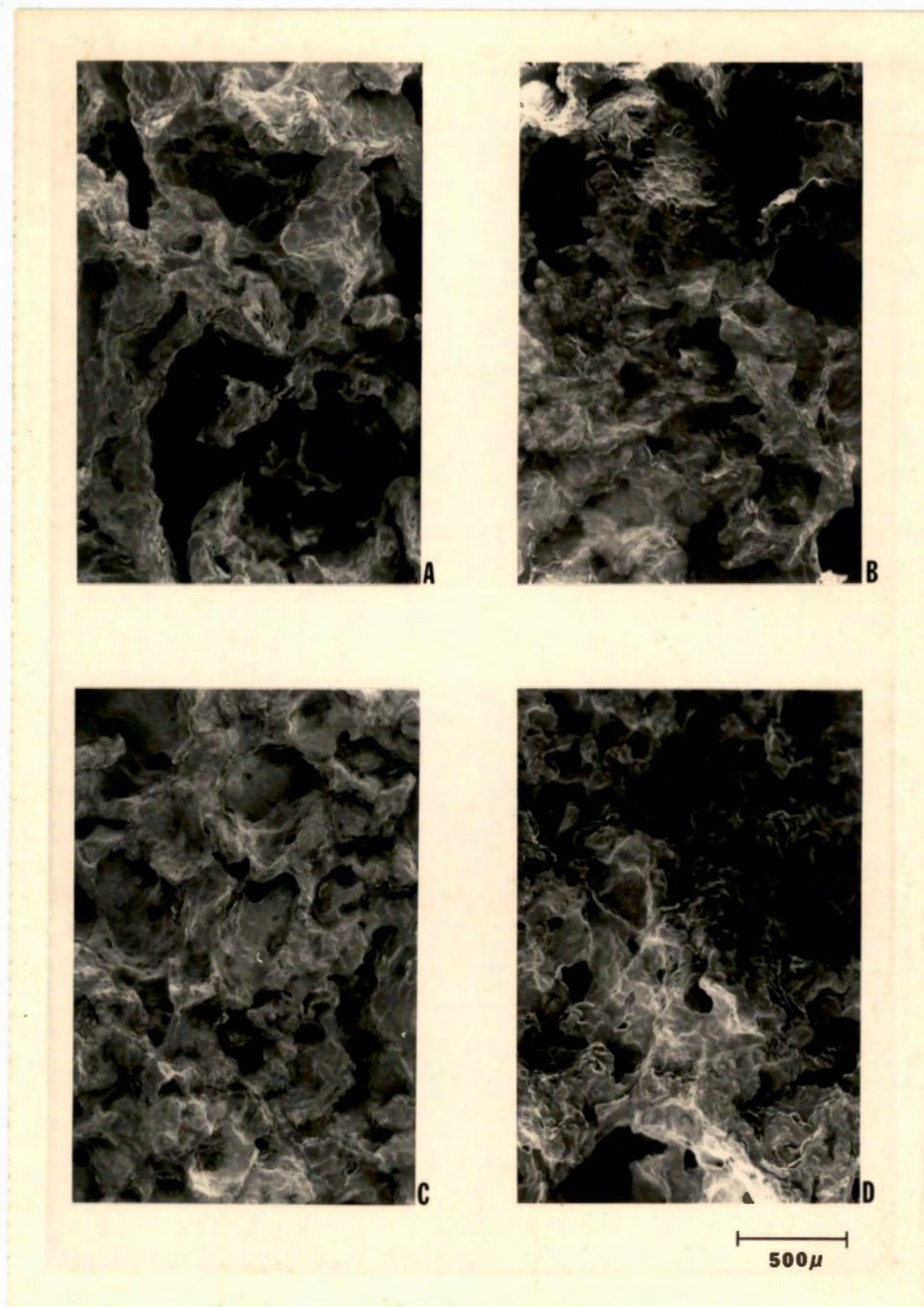


Plate 1--Scanning electron photomicrographs (50X) of cake containing: 3.65 g gum, 6.4 g starch, and 275 ml water (A); 3.65 g gum, 12.4 g starch, 275 ml water (B); 3.65 g gum, 6.4 g starch, and 375 ml water (C); 3.65 g gum, 12.4 g starch, and 375 ml water (D).

surface. The crumb with 2.5% saturated monoglyceride in the study by Cloke et al. (1984a) resembles the crumb of the cake with low water (Plate 1). Martin and Tsen (1981) reported that microwave-baked cake surface had more irregularity among the air cells and the air cells had thicker cells walls than conventionally baked cakes.

The sensory panel results coincided with the SEM micrographs. The sensory panel considered the cell size of the cakes to be the largest when the formulation contained 275 ml of water at any starch level (Figure 7, p. 71). Cell size and cell shape were considered most irregular at a water level of 375 ml and a starch level of 12.4 g. The compactness of the cake surface was more open at a water level of 275 ml of water and more closed at 375 ml of water, regardless of the starch level (Figure 8, p. 73). The surface seemed to be roughest at 275 ml of water and smoothest at 375 ml of water, without regard to starch level.

Some of the individual components of cake crumb can be visualized at higher magnifications (350X). Starch granules can be seen embedded in the matrix (Plate 2). The matrix is most likely made of starch, fat, and protein (Hsieh et al., 1981). The starch granules appear to be more numerous and elongated in the crumb with 375 ml of water and 6.4 g of starch (C) as compared to the crumb with 275 ml of water and 6.4 g of starch (A). There do not appear to be more starch granules in the crumb with 375 ml of water and 12.4 g of starch (D) when compared to the crumb with 375 ml of water and 6.4 g of starch (C). The high-water level may have a dilution effect upon the starch. However, the starch granules in the higher water cake micrographs (C and D) seem plumper than in the lower water cake crumb (A and B). Potato starch is distinguishable with

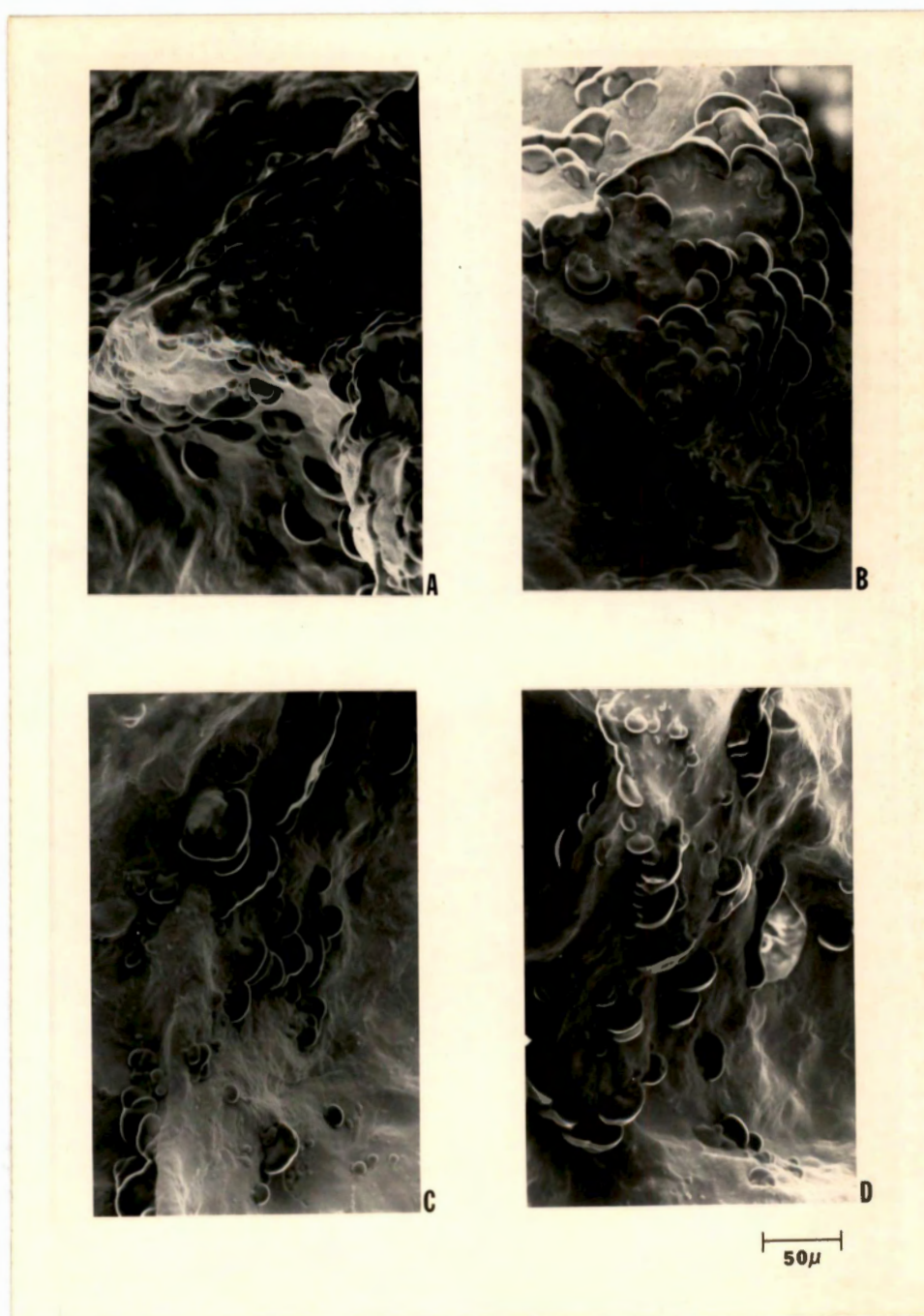


Plate 2--Scanning electron photomicrographs (350X) of cake containing: 3.65 g gum, 6.4 g starch, and 275 ml water (A); 3.65 g gum, 12.4 g starch, 275 ml water (B); 3.65 g gum, 6.4 g starch, and 375 ml water (C); 3.65 g gum, 12.4 g starch, and 375 ml water (D).

its characteristic oyster shell shape (Osman, 1972). Wheat starch also can be seen with its small, round shape (Osman, 1972).

Higher magnification (500x) emphasized the patterns viewed at 350X (Plate 3). Oil droplets also were visible. The striations of the starch granules were seen. The starch granules, largely potato, were smooth looking and often clumped together.

The method used to prepare the samples for scanning electron microscopy was an adaptation of a method used by Pomeranz et al. (1984) for bread. The method involved freeze-drying and fracturing the samples. Artifacts may have been caused by retrogradation of the starch, drying out of the crumb, and the fracturing technique. The samples containing 375 ml of water were extremely hard and therefore, difficult to fracture. The hardness may have been caused by increased starch gelatinization as compared to the lower water cakes.

VIII. BATTER FLOW

In comparison of the batter flow in a conventional cake to the batter flow in microwave-baked cakes, there were differences in top, bottom, and internal patterns of flow. The conventional cake appeared to have little batter flow on the surface, and only a slight amount of flow on the bottom (Figure 15). Expansion of the strips of dyed batter was observed on the top and bottom. However, the 4 microwave-baked top surfaces showed batter flow that was similar. The initially straight lines of the strips were curved toward the center of the batter after baking in all 4 formulas (Figures 16-19). There was less curvature of

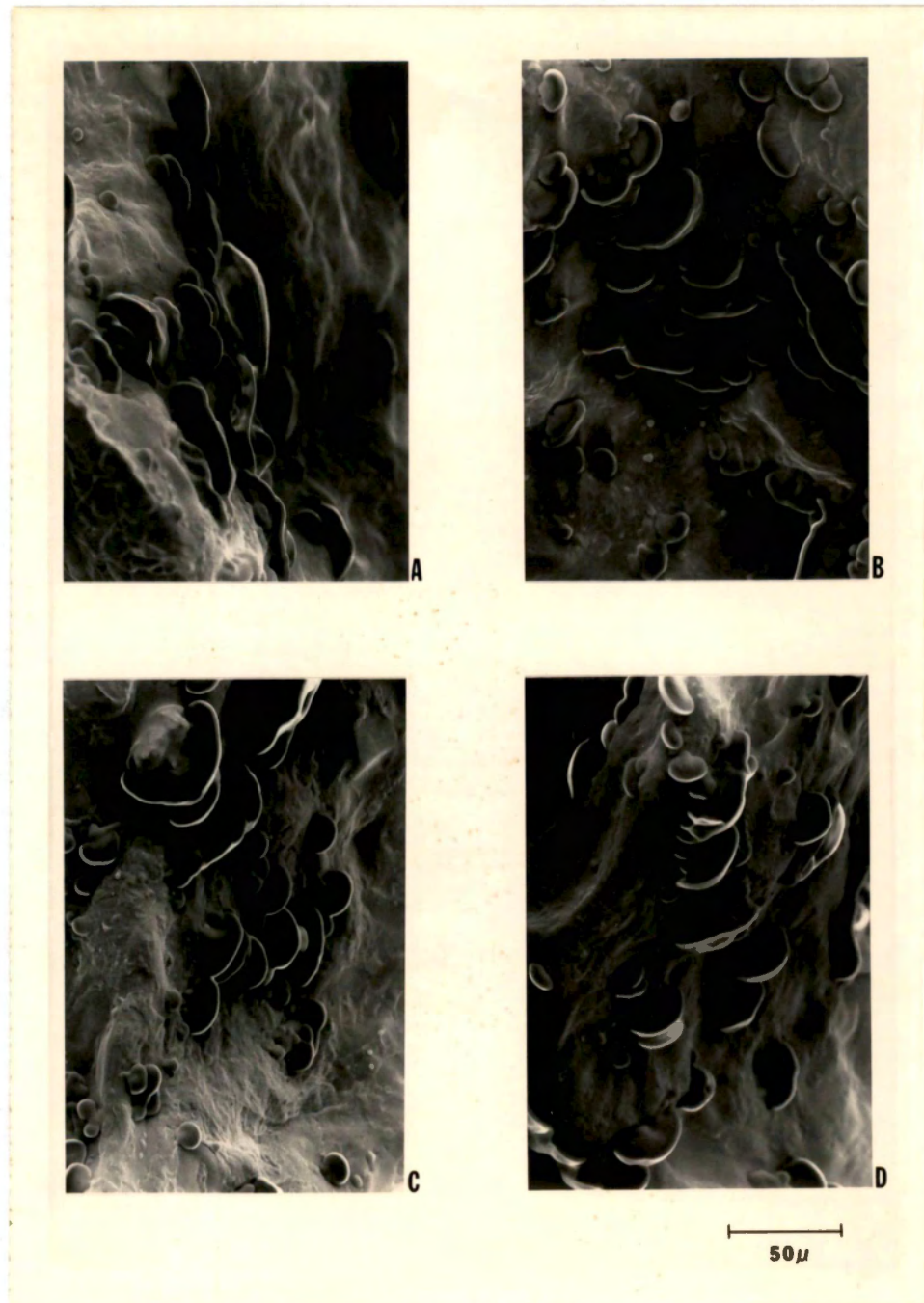


Plate 3--Scanning electron photomicrographs (500X) of cake containing: 3.65 g gum, 6.4 g starch, and 275 ml water (A); 3.65 g gum, 12.4 g starch, 275 ml water (B); 3.65 g gum, 6.4 g starch, and 375 ml water (C); 3.65 g gum, 12.4 g starch, and 375 ml water (D).

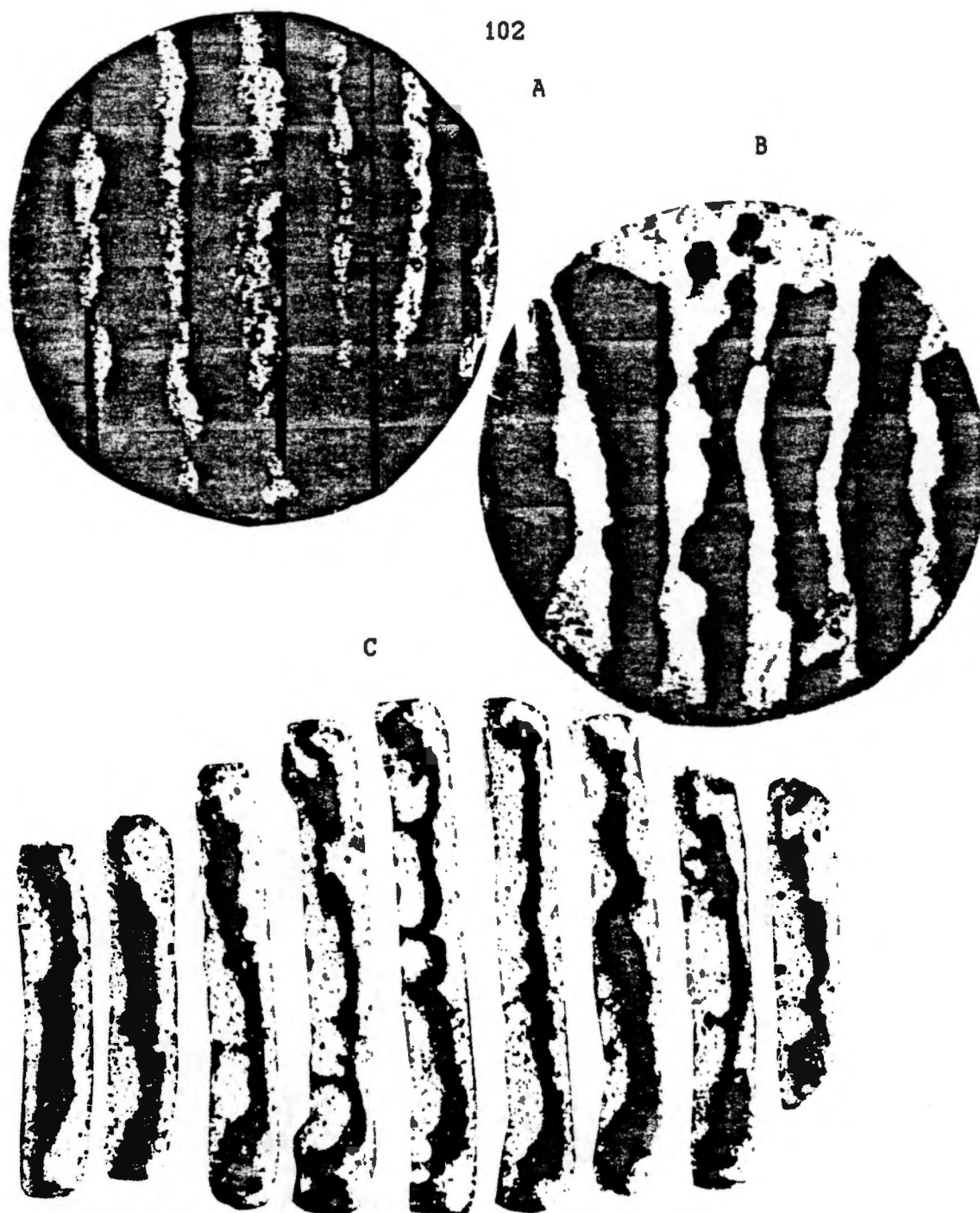


Figure 15--Batter flow of surface (A), bottom (B), and internal (C) in conventionally baked cake containing 3.65 g gum, 6.4 g starch, and 275 ml water.



Figure 16--Batter flow of surface (A), bottom (B), and internal (C) in microwave-baked cakes containing 3.65 g gum, 6.4 g starch, and 275 ml water.



Figure 17--Batter flow of surface (A), bottom (B), and internal (C) in microwave-baked cakes containing 3.65 g gum, 12.4 g starch, and 275 ml water.

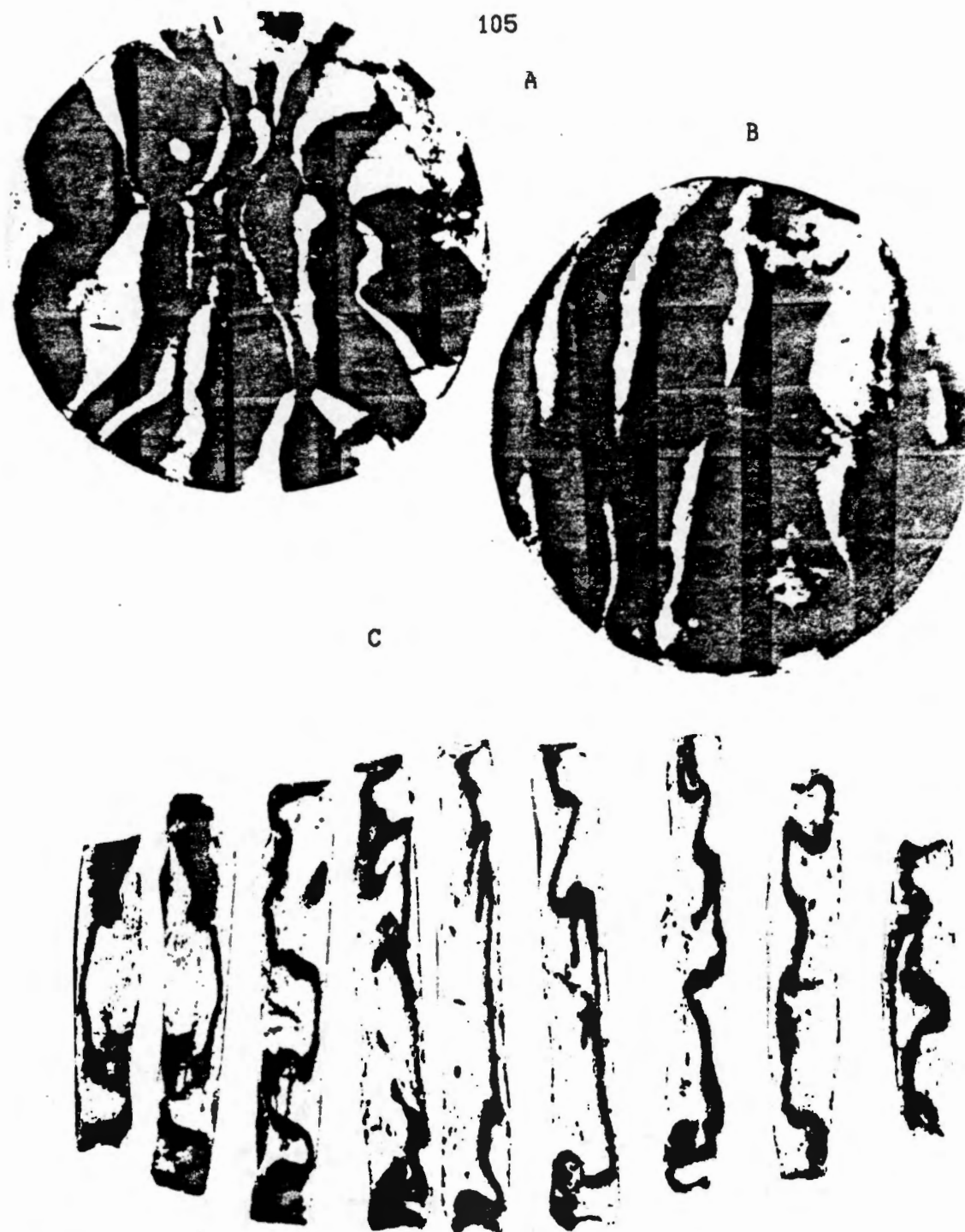


Figure 18--Batter flow of surface (A), bottom (B), and internal (C) in microwave-baked cakes containing 3.65 g gum, 6.4 g starch, and 375 ml water.

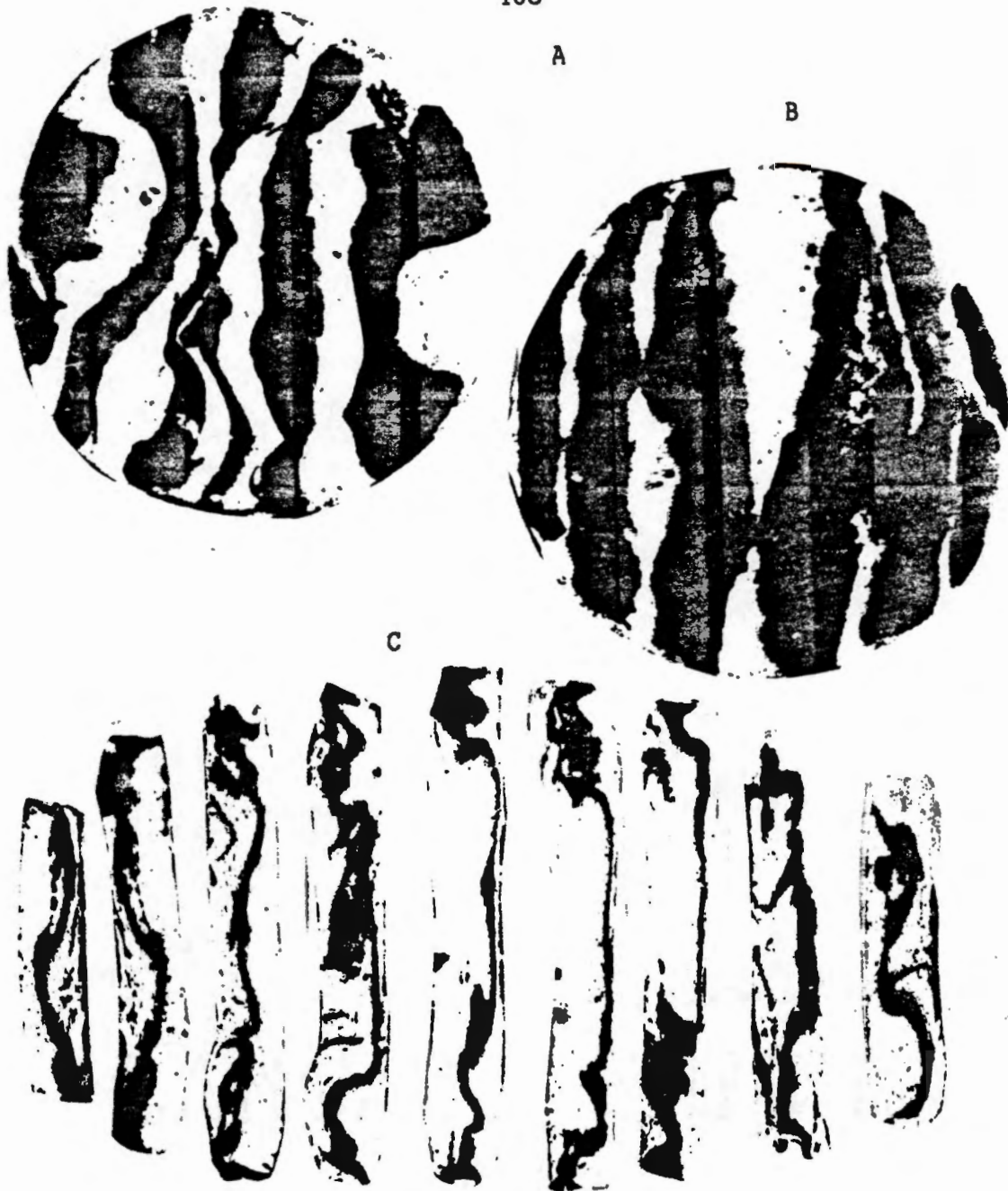


Figure 19--Batter flow of surface (A), bottom (B), and internal (C) in microwave-baked cakes containing 3.65 g gum, 12.4 g starch, and 375 ml water.

the strips on the surfaces of the cake with 275 ml and 12.4 g of starch, than on the other surfaces.

On all microwave surfaces, there was merger of dyed strips or disappearance of parts of the strips. The expansion of the batter would contribute to the merging and loss of the strips. Martin and Tsen (1981) reported similar results for batter flow. They stated that the difference in flow between the 2 types of ovens was brought about by convection currents and rapid microwave heating. Martin and Tsen (1981) found that microwave-baking resulted in cakes with peaked surfaces in the center and a grain that was more open in the center. The center of the batter possibly baked after the edges. Therefore, in the later stages of baking, the center of the batter expanded laterally and convection currents caused batter flow. Yamazaki and Kissell (1978) observed that the sides of the batter heated before the middle in conventionally baked batter. Peaked centers were not observed in this present study (Table 9, p. 58), but the heating pattern may have been similar to what Martin and Tsen (1981) described since there was merger of strips in the center of the cakes (Figures 16-19).

The strips on the bottom of all of the cakes possibly expanded laterally due to the weight of the batter. Batter flow was negligible on the bottom of the conventional cake (Figure 15); however, the ends of the middle strips on one side of the cake flowed upward into the batter. Trimbo et al. (1966) reported that in cake with surface rings the batter flow began on the bottom along the side of the pan. The formulas with 275 ml of water appeared to have the most movement as the strips were curved outward (Figures 16 and 17). There was disappearance of almost

all of a strip in the middle of the batter in the formula with 275 ml of water and 6.4 g of starch (Figure 16). The strips in the formula with 375 ml of water and 6.4 g of starch underwent the most expansion (Figure 18).

Internal batter flow occurred in the conventionally baked cakes (Figure 15) but to a lesser extent than in the microwave-baked cakes (Figures 16-19). In the conventionally baked cake the flow was limited to the middle of the cake generally. The middle of the cake had internal batter rising to near the surface.

The 4 microwave batters were alike in that the dyed batter often sank toward the bottom (Figures 16-19). There was also dyed batter that flowed toward the top, especially along the edges. The dyed batter appeared to have sunk lower in the cakes with 12.4 g of starch than in the cakes with 6.4 g of starch, possibly indicating increased starch hydration or starch gelatinization. The viscosity of the batter was influenced mostly by water (Table 5, p. 48). Trimbo et al. (1966) thought that the addition of gum to increase the viscosity of batter would prevent batter flow. In some cakes the increased viscosity did prevent flow, but it was not found to work in all cakes.

IX. FAT EVALUATION

The size and distribution of fat cells was evaluated subjectively (Plate 4). Air cells were surrounded by the dyed fat. There did not appear to be a difference in the size and distribution of fat cells in the 4 selected formulas. The size of the air cells was approximately 50

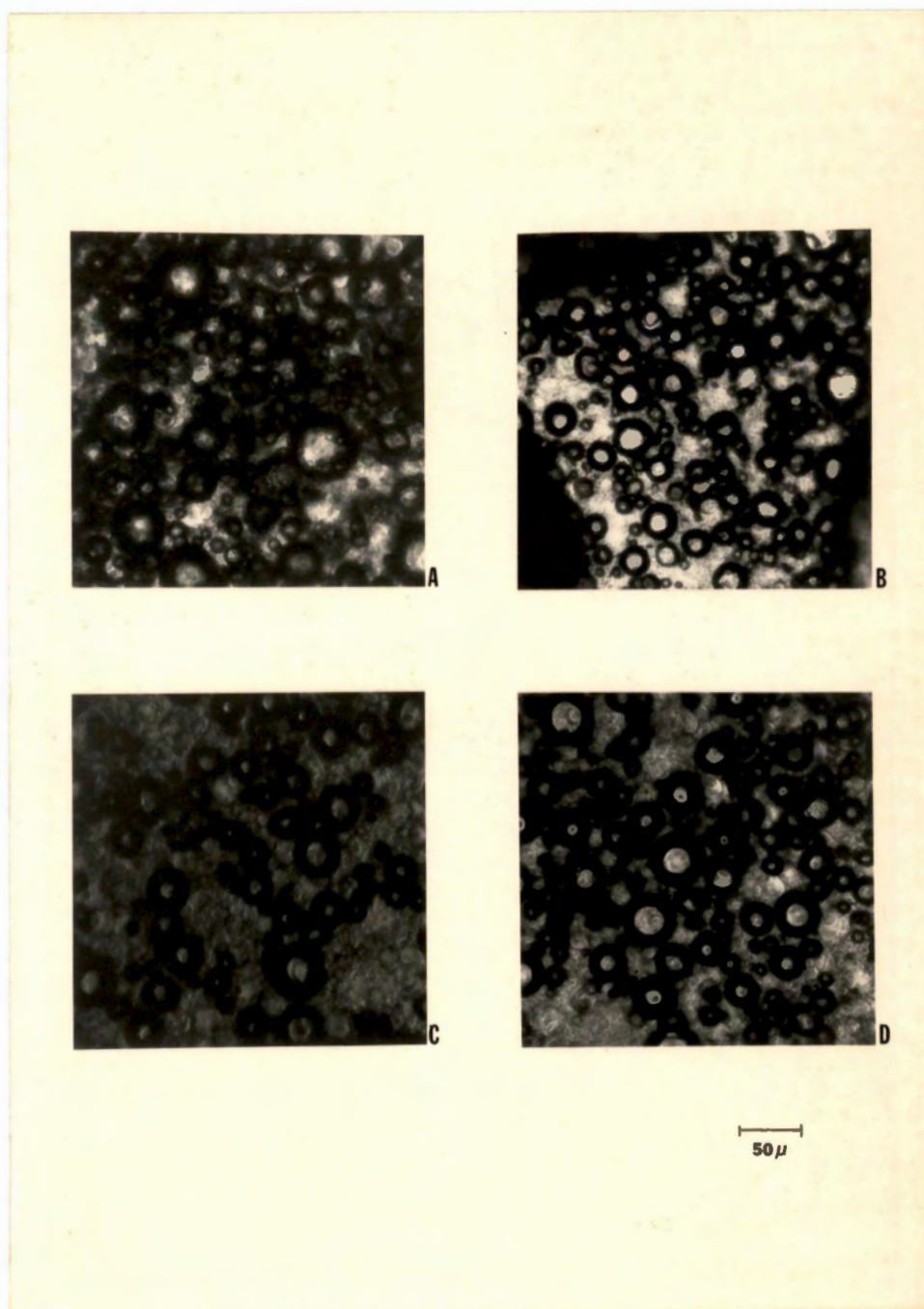


Plate 4--Photomicrographs (10X) of batter containing dyed fat: 3.65 g gum, 6.4 g starch, and 275 ml water (A); 3.65 g gum, 12.4 g starch, and 275 ml water (B); 3.65 g gum, 6.4 g starch, and 375 ml water (C); 3.65 g gum, 12.4 g starch, and 375 ml water (D).

microns. The thorough mixing procedure may have overcompensated for any differences due to formulation.

X. CRUMB EVALUATION

As the levels of starch and water increased, the cell size of the cakes decreased (Plate 5). The cake containing 6.4 g starch and 275 ml water had visible cells, holes, and air pockets. The cells in the cake containing 12.4 g starch and 375 ml water were extremely small. These observations correlate with the sensory evaluation.

XI. CONSUMER PANEL

A consumer panel of 29 women and men evaluated 2 samples of cake baked in the microwave. One sample contained 3.65 g gum, 6.4 g starch, and 275 ml water. The other sample contained 3.65 g gum, 12.4 g starch, and 375 ml water.

The age of the panel ranged from over 18 to over 55 years, with the largest percentage of 34.5% in the 55 or over group (Appendix F). Fifty-five percent of the women baked cakes several times a year and 10.3% of the men baked cakes several times a year. All but one panellists owned a microwave. Most of the panelists used both scratch and commercial cake mixes when baking conventionally. Sixty percent of the panellists had baked cakes in the microwave. Over 50% of the panellists had used both scratch and commercial cake mixes in the

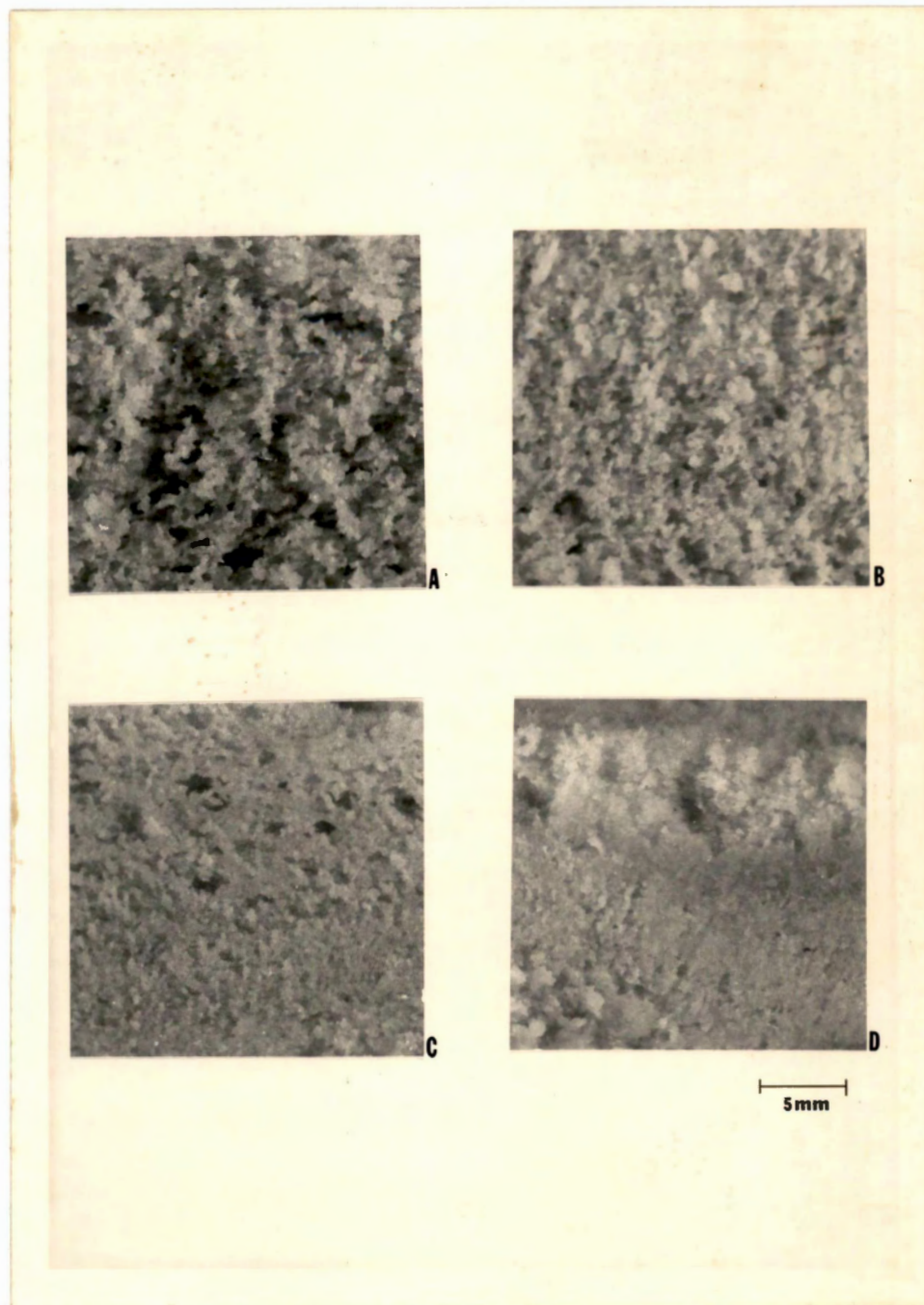


Plate 5--Photographs of cake containing: 3.65 g gum, 6.4 g starch, and 275 ml water (A); 3.65 g gum, 12.4 g starch, and 275 ml water (B); 3.65 g gum, 6.4 g starch, and 375 ml water (C); 3.65 g gum, 12.4 g starch, and 375 ml water (D).

microwave. Fifty percent of those that had used commercial cake mixes in the microwave liked the product.

The ideal scorecard (Appendix G) included cell distribution, crumbliness, hardness, crumb harshness, moistness, and toothpacking. The sample scorecard (Appendix H) was similar to the ideal and also included acceptability of appearance, taste, texture, and overall acceptability.

Both samples were comparable to the ideal yellow cake (Figure 20). Cell distribution was on the uniform end of the scale for the ideal and the sample with low water. The ideal cake and the sample with high-water were considered to be slightly crumbly. The ideal and the low-water sample did not differ for hardness and were considered to be soft. Crumb harshness did not differ for the ideal and the 2 samples. The low-water sample was less moist than the ideal cake and the sample with high-water. Toothpacking was less for the ideal cake and the sample with low-water than for the sample with high-water. The low-water sample was considered to be more acceptable than the high-water sample for appearance, taste, texture, and overall acceptability (Table 23). The sample with low-water was scored on the end of the scale toward very desirable for all 4 acceptability parameters. Even though the low-water sample was more acceptable than the high-water sample, the low-water sample was not considered to be like the ideal for crumbliness and moistness. The high-water sample, which was considered to be toward the upper middle of the scale of acceptability parameters, was like the ideal for crumbliness, hardness, crumb harshness, and moistness. The discrepancy between scores for the ideal and acceptability scores may be

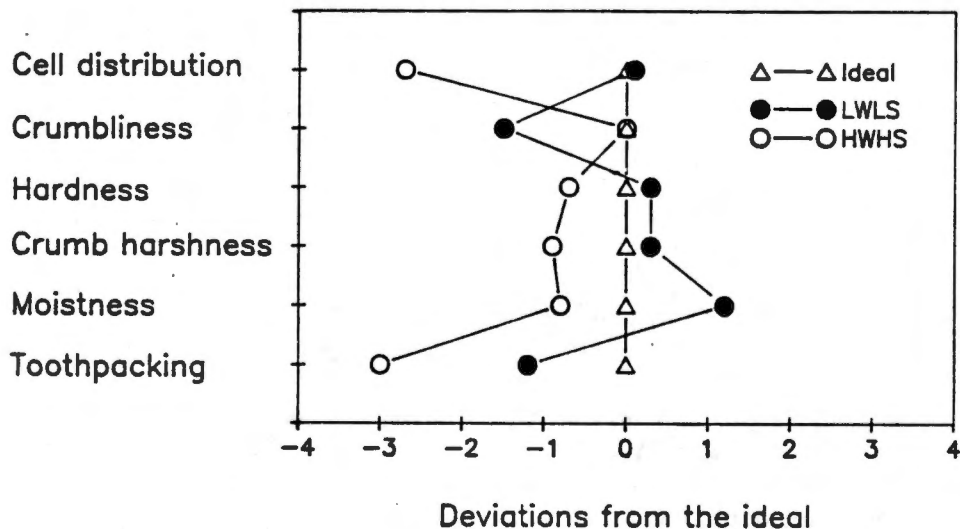


Figure 20--Comparison of consumer panel's evaluation of cakes containing 3.65 g gum, 6.4 g starch, and 275 ml water (LWLS), 3.65 g gum, 12.4 starch, and 375 ml water (HWHS) and ideal cake. Cell distribution: 1=uniform, 9=irregular; Crumbliness: 1=holds together, 9=crumbles easily; Hardness: 1=very soft, 9=very hard; Crumb harshness: 1=smooth, 9=rough; Moistness: 1=very dry, 9=very moist; Tooth packing: 1=none, 9=very much.

Table 23--Results of consumer panel for ideal and two microwave cake samples

Treatments	Means ^a	
	Low water ^b	High water ^c
Acceptability of appearance	2.7a	6.3b
Acceptability of taste ^d	2.2a	4.7b
Acceptability of texture ^d	2.6a	5.6b
Overall acceptability ^d	3.1a	5.8b

^aMeans within rows with in same letters do not differ ($P>0.05$).

^b697 contains 275 ml water, 3.65 g gum, and 6.4 g of starch.

^c885 contains 375 ml water, 3.65 g gum, and 12.4 g of starch.

^d1=most acceptable, 9=least acceptable.

indication of the inconsistencies of panelists' desire and product perception.

XII. GENERAL OBSERVATIONS

Several general observations were made during this study. For instance, as the amount of water increased, the amount of batter increased and the amount of batter which was not baked increased with water level. This obvious observation is important since it means that the ingredients were diluted since equal weights of batter were baked. The volume of the high-water cakes was less than that of other cakes (Table 8) because of the dilution of the baking power and other ingredients that contribute to structure such as gluten and egg.

The majority of the cakes suffered from tunnels throughout the cake and/or "notches" (holes) found in the side of the cakes, generally in the middle sections. Trimbo and Miller (1973) investigated tunnels in cakes. Tunneling was defined as "development of elongated voids which start near the bottom and proceed upward, generally at an angle, toward the center of the baked cake." After experimentation with mixing time, type of oven, liquid level, oven temperature, sugar/flour ratios, pan liners, additives, and silicones the authors proposed a mechanism for tunneling. The proposal suggested that as the steam forms in the batter around the edges of the batter, crust formation begins in the same area on top of the batter. The steam can not escape and voids are formed as the steam tries to escape to the center of the batter where the temperature is lower. No system was devised to completely prevent

tunneling. Preventative tunneling measures may be at the expense of other cake characteristics. However, high density batters, near 1.0 in density, result in cakes with few tunnels. Cakes baked in 8-inch layer pans have more tunnels than those baked in 9-inch pans. High baking temperatures seem to produce more tunnels than lower baking temperatures. In Trimbo and Miller's study, cake baked in a microwave oven did not have tunnels since there was no crust formation. However, tunnels have been noted by other researchers in microwave-heated cake (Street and Surratt, 1961; Neuzil and Baldwin, 1962; Hill and Reagan, 1982). Possibly, the mechanism for tunnel formation may be similar to that proposed for the conventional oven. Even though no crust is formed, the surface was affected by the baking method. Another observation, which may be related to tunnel formation and steam release, was the porous surface of many of the cakes. The surface of most of the cakes was covered with holes several mm in diameter and many surfaces were cracked.

A layering effect occurred in the cakes in this study. Some cakes would come apart in discrete layers and have a distinct layer on the bottom of the cakes which was a starch layer and/or starch-gum layer. Horizontal tunneling occurred also. Further, most of the cakes had a film around the sides. The layering effects possibly were due to the starch. Gordon et al. (1979) refer to the "nonuniform character of the starch gelatinization" in the cakes containing different starch levels and baked conventionally. This nonuniformity may affect water-loss in the last phase of baking. Cakes baked in the microwave probably have a different rate of water-loss than conventionally baked cakes. Gordon et

al. (1979) postulated that the evaporative process is impeded by the distorted starch granules and an undeveloped matrix. Channeling would be an outlet for water loss. A compact solid layer at the bottom of the high starch cakes also contributed to the nonuniformity, as water has to escape the bottom of the batter by diffusion. The gum may have contributed to the layer on the sides, since methylcellulose gums can be used to form water-soluble films (Glicksman, 1963). Handleman et al. (1961) suggested that layering was due to the rapid rise of the air cells.

On the bottom of some of the cakes a "wet spot" would occur after baking. The area was in the middle of the cakes. These areas could have been caused by the "nonuniform character of starch gelatinization" (Gordon et al., 1979), or by the nonuniform baking that happens often with microwave heating. Another note from baking was that several of the batters, particularly those with lower levels of water, expanded and overrun was observed on the sides of the pans. The gum was supposed to prevent the overflow of the batter (Anon., 1988a).

CHAPTER V

SUMMARY AND IMPLICATIONS

Overall the objectives of the study were met. The resulting cakes may not have met completely the criteria for a high quality shortened cake. Charley (1970) described such a cake as one that "has a flat or slightly rounded top...crust should be fine grained and a uniform golden brown...grain should be small and uniform in size, the cell walls thin, and the crumb resilient, soft, and velvet...light, tender, and slightly moist...acceptably sweet and otherwise have a good flavor." The cakes studied in this project represented many of the faults associated with cake baking. Some of the faults included tunnels and low volume, poor symmetry, contour, and uniformity. The faults may be attributed in part to the ingredient combinations, the extensive mixing procedure, and the mode of baking, microwave heating. It is important to realize the source of the faults so that improvements can be made.

The objectives of this study were to investigate 60 ingredient combinations of hydroxypropyl methylcellulose, modified potato starch, and water. The starch and water levels had a more confounding effect upon the batters and cakes than the gum levels. Preliminary work demonstrated the gum to be necessary for acceptable cake formulation. However, upon further investigation the gum levels were not significant for most of the measurements. Potato starch has high viscosity at low temperatures due to its low gelatinization temperature. Possibly, the starches, potato and wheat, and the sugar competed with the gum for

water and the gum was not sufficiently hydrated. At the higher water levels, more water was available, but a dilution effect seemed to occur. The cakes with the lower levels of starch and water were considered to produce the best cakes, as evaluated subjectively by the investigators and as observed with many of the response surfaces for the sensory evaluation.

Overmixing a cake batter can result in a cake which is tough and dry, has too small cells, and a "burst" crust (Campbell, 1972). Many of the cakes had very small air cells and the surface cracked.

The microwave oven has a history of baking cakes with faults (Street and Surratt, 1961; Neuzil and Baldwin, 1962; Hill and Reagan, 1982). However, if the correct combination of ingredients is devised, a high quality cake may be baked in the microwave. As Heinze (1989) pointed out, the air above the cake surface in the microwave oven does not reach high enough temperatures to cause the surface to brown, but the quality of the crumb may be high.

The final objective of the study was to develop a lexicon of cake terms and reference standards made of cake products to correspond to the lexicon. A lexicon was developed and reference standards were made. A panel practiced diligently for weeks to master the evaluation process. However, the statistical analyses showed that the panel did not work in harmony. Therefore, the sensory statistics were analyzed using means, instead of having panel as an independent variable. This lack of consistency on the part of the panel poses several considerations when training a panel. One important consideration is that a panel can be bombarded with too many parameters to evaluate. Also reference

standards should be available for the panel whenever they evaluate.

And, the panel needs to be kept motivated throughout training and data collection.

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APPENDIXES

APPENDIX A

LEXICON OF CAKE DESCRIPTORS

I. SURFACE APPEARANCE

CELLS- spaces (holes) in the cake

UNIFORM- mostly one shape or size of cell; shapes are generally round or oblong

IRREGULAR- mostly different shapes or sizes of cells

COMPACTNESS- characteristics of structure depending upon cell size and number of cells

OPEN- cell size and number of cells make cut surface appear light/airy or not solid, dense or crowded

CLOSED- cell size and number of cells make cut surface appear solid, dense, or crowded

SMOOTH SURFACE- appears even and free of inequalities, not coarse

ROUGH SURFACE- appears coarse or has inequalities

II. RESISTANCE TO CUT WITH FORK (CUT OFF 2 CM)

RESISTANCE TO CUT- entire process of cutting 2 cm piece of cake with fork

TENDER- no resistance to force of fork

TOUGH- resistance to force of fork

III. CRUMBLINESS

CRUMBLINESS OF CAKE AFTER CUTTING- falling into small pieces

IV. SPRINGINESS (PRESS DOWN 2 CM PIECE VERTICALLY WITH FORK FOR 1 SEC, SCORE RECOVERY AFTER 2 SEC)

SPRINGINESS- degree to which cake returns to original form after 2 seconds, degree of recovery is quick

V. TEXTURE OF 1 CM IN MOUTH

SMOOTH TO TONGUE AND MOUTH- not abrasive or coarse

ROUGH TO TONGUE AND MOUTH- abrasive or coarse

MOISTURE RELEASE- amount of wetness or oilness released in mouth
by cake

DRY- no wetness or oilness released in mouth by cake

MOIST- wetness or oilness released in mouth by cake

VI. FIRST BITE WITH MOLARS (CUT OFF 1 CM)

DEGREE OF SOFT- lack of or low amount of pressure and effort
required to bite through

DEFORMATION- degree of change of shape until structure fails

FRACTURABILITY- degree to which cake breaks up into pieces, or
crumbles

VII. BREAKDOWN (CUT OFF 1 CM)

BREAKDOWN- chewing process for 8 to 10 chews with the molars

MOISTURE ABSORPTION- amount of saliva absorbed by cake

COHESIVENESS OF MASS- degree to which cake holds together for up
to 10 chews

LOOSE- mass is not compact or bound together

COMPACT- bound together

SMOOTHNESS OF CHEWED MASS- not abrasive or coarse

ROUGHNESS OF CHEWED MASS- abrasive or coarse

VIII. EASE OF CHEWING AND SWALLOWING (CUT OFF 1 CM)

Chew cake as normally would and evaluate process.

EASY TO CHEW- little force and effort required to chew up cake to
prepare to swallow

DIFFICULT TO CHEW- force and effort required to chew up cake to
prepare to swallow

EASY TO SWALLOW- little force required to swallow

DIFFICULT TO SWALLOW- force required to swallow

IX. RESIDUAL (AFTER SWALLOWING)

OILY MOUTHCOATING- amount of oil remaining in mouth surfaces

ADHESION TO TEETH- amount of cake sticking to or remaining in
teeth after swallowing

APPENDIX B

SCORECARD FOR EVALUATION OF CAKE

THERE ARE SIX SAMPLES FOR YOU TO EVALUATE. PLACE A MARK ACROSS THE LINE (--)^a INDICATING THE DEGREE TO WHICH THE CHARACTERISTIC IS PRESENT IN THE SAMPLE. PLEASE RINSE BETWEEN SAMPLES.

I. SURFACE APPEARANCE

CELL SIZE
SMALL

LARGE

CELL SIZE
UNIFORM

IRREGULAR

CELL SHAPE
UNIFORM

IRREGULAR

COMPACTNESS
CLOSED

OPEN

TEXTURE
SMOOTH

ROUGH

II. RESISTANCE TO CUT (CUT OFF 2 CM)

TENDER

TOUGH

III. CRUMBLINESS

NONE

COMPLETE

IV. SPRINGINESS (PRESS DOWN 2 CM PIECE 1 CM VERTICALLY WITH FORK, HOLD FOR 1 SEC SCORE RECOVERY AFTER 2 SEC)

NO RECOVERY

COMPLETE

V. TEXTURE IN MOUTH (CUT OFF 1 CM)TEXTURE
SMOOTH

ROUGH

MOISTURE RELEASE
DRY

MOIST

VI. FIRST BITE WITH MOLARS (CUT OFF 1 CM)DEGREE OF SOFTNESS
SOFT

NOT AT ALL SOFT

DEFORMATION
NONE

COMPLETE

FRACTURABILITY
NONE

COMPLETE

VII. BREAKDOWN (CHEW 1 CM FOR 2 TO 10 CHEWS)MOISTURE ABSORPTION
NONE

ABSORBS MOST OF MOISTURE

COHESION OF MASS
LOOSE

COMPACT

TEXTURE
SMOOTH

ROUGH

VIII. EASE OF CHEWING AND SWALLOWING (CUT OFF 1 CM)EASE OF CHEWING
EASY

DIFFICULT

EASE OF SWALLOWING
EASY

DIFFICULT

IX. RESIDUAL (AFTER SWALLOWING) IF NECESSARY USE SPRINGY SAMPLE

OILY MOUTHCOATING

NONE

HEAVY

ADHESION TO TEETH

NONE

COMPACT MASS

^aThe size of the line was 15-cm for the sensory evaluation.

APPENDIX C

Table C1--Mean scores^a for panel practice session

Attribute	Cake number ^b				
	1 ^c	2	3	4	5 ^c
Appearance					
Cell size	4.7x	6.3x	7.2x	5.2x	5.1x
Cell size, uniformity	8.6x	8.8x	3.4y	10.2x	9.4x
Cell shape, uniformity	4.4y	9.8x	2.7y	10.0x	3.4y
Compactness	5.4y	5.7y	12.3x	6.6y	6.6y
Smooth texture	5.5y	5.7y	12.3x	6.6y	6.6y
Resistance to cut	3.7y	2.8y	8.5x	4.3y	3.3y
Crumbliness	11.9x	8.3y	9.0y	10.4xy	10.2xy
Springiness	4.5y	7.5x	3.8y	5.8xy	4.6y
Texture in mouth					
Smoothness	6.4y	4.0y	12.0x	5.5y	4.2y
Molsture release	7.6xy	10.5x	3.1z	6.2yz	9.1xy
First bite with molars					
Degree of softness	3.0x	3.6x	4.9x	2.6x	2.6x
Deformation	6.4x	5.1xy	3.6y	6.7x	7.1x
Fracturability	4.7y	4.6y	11.1x	5.9y	5.5y
Breakdown					
Molsture absorption	4.6yz	3.6z	8.8y	6.9xy	4.6yz
Cohesion of mass	5.3xy	6.6x	3.0y	5.2xy	6.0xy
Smoothness of mass	3.5y	2.2y	11.1x	3.1y	2.8y
Ease of chewing and swallowing					
Ease of chewing	4.6x	2.7x	4.3x	3.9x	3.5x
Ease of swallowing	3.6xy	6.2x	3.4y	3.1y	3.8xy
Residual					
Oily mouthcoating	5.3y	9.9x	2.3z	4.5y	4.0y
Adhesion to teeth	4.1x	5.6x	3.7x	3.8x	3.8x

^aMeans in a row followed by like letters do not differ ($P>0.05$).

^b1 and 5=Kroger yellow cake; 2=Pillsbury yellow cake; 3=Jiffy yellow cake; 4=Duncan Hines yellow cake.

^cLike samples for determining repeatability.

APPENDIX D

RESPONSE SURFACE EQUATIONS

Gum=3.65 g.
 Starch=6.44 g to 12.44 g by 1.
 Water=275 ml to 375 ml by 12.5.
 (P<0.10)

Batter and Cake Tests

$$\text{pH} = 7.30837498 + (.02926577 * G) + (.00965778 * S) - (.00053628 * W).$$

$$\text{Specific gravity} = 1.025693 - (.00588492 * G) + (.00118986 * S) - (.00235449 * W) + (4.0095E-06 * W * W).$$

$$\text{Viscosity} = 172668.34215561 - (3331.172869 * G) + (1726.169324 * S) - (379.136076 * W).$$

$$\text{Weight loss} = 38.09454716 - (.7622302 * G) + (1.30941938 * S) - (.06488558 * S * S) - (.00416483 * W).$$

$$\text{Moisture loss} = 9.97389248 + (.27088265 * G) - (.726996037 * S) + (.03847375 * S * S) + (.07374078 * W).$$

Cake Indices

$$\text{Shrinkage} = -7.60985857 + (1.50887427 * G) - (.18692519 * G * G) + (1.39829196 * S) - (.15365629 * S * S) + (.00543530 * S * S * S) + (.00646821 * W).$$

$$\text{Volume} = 166.40347135 - (.86633462 * G) - (.21056917 * S) - (.28114888 * W).$$

$$\text{Symmetry} = -39.16691617 - (.91815608 * G) - (.15464059 * S) + (.26301228 * W) - (.00039013 * W * W).$$

$$\text{Uniformity} = -40.14823864 + (13.57818866 * G) - (1.66073298 * G * G) - (.01496508 * S) + (.09513030 * W) - (.00015228 * W * W).$$

Texture Profile Analysis

Hardness = $2158.86251503 + (34.99752239 * G) + (79.23186604 * S) - (3.91379203 * S * S) - (19.28017239 * W) + (.03753911 * W * W)$.

Spriginess = $216.15245807 - (1.98837611 * G) - (.20497588 * S) - (.95054941 * W) + (.00119133 * W * W)$.

Cohesion = $-.10674489 + (.00898361 * G) + (.00228932 * S) + (.00180921 * W)$.

Gumminess = $1969.519366022 + (27.14633522 * G) + (53.58121044 * S) - (2.60252805 * S * S) - (16.79645645 * W) + (.03144366 * W * W)$.

Chewiness = $-564.95535902 + (1717.67173981 * G) - (181.42692791 * G * G) - (1309.76633170 * S) - (11.47383582 * W) + (4.89193808 * W * W)$.

Sensory

Cell size = $47.00256355 - (.10534153 * G) + (.01230365 * S) - (.23973059 * W) + (.00032313 * W * W)$.

Uniformity of cell size = $.63975560 + (.35673684 * G) + (.07620825 * S) + (.00718043 * W)$.

Uniformity of cell shape = $4.26401293 + (.11787231 * G) - (1.07544279 * S) + (.06209870 * S * S) + (.01216103 * W)$.

Compactness = $45.56439787 + (.03973505 * G) - (.01483525 * S) - (.22413396 * W) + (.00028797 * W * W)$.

Texture of appearance = $43.93957045 + (.03200348 * G) - (.00808705 * S) - (.21317610 * W) + (.00027624 * W * W)$.

Tenderness = $-39.04989894 + (9.03190759 * G) + (2.75907130 * S) + (.02741050 * W) - (.05298031 * G * S) - (.03237196 * G * S * S) - (.00111319 * G * S * S * S) - (.19975496 * G * G * S) + (.01512405 * G * G * S * S)$.

Crumbliness = $34.06033012 - (12.16118491 * G) + (1.45467636 * G * G) - (.24588637 * S + (.00543747 * W) - (8.75568E-05 * W * W) + (.00403695 * G * S * W) - (1.32733E-05 * G * S * W * W) + (1.94758E-08 * G * S * W * W * W) - (.00013938 * G * S * S * W) + (5.01089E-06 * G * S * S * S * W) - (.00010586 * G * G * S * W)$.

Springiness = $-178.44833664 + (37.47015572 * G) + (38.67149811 * S) + (.18656230 * W) - (.00034726 * W * W) - (4.80418728 * G * S) - (1.52445435 * G * S * S) + (.00529543 * G * S * S * S) - (.90621894 * G * G * S) + (.3480870 * G * G * S * S) + (.01162656 * G * G * S * S * S) - (.00286579 * G * G * G * S * S * S)$.

$$\text{Texture in mouth} = 211.28503761 - (.31697023 * G) + (.00754236 * S) - (1.75059401 * W) + (.00500762 * W * W) - (4.82129E-06 * W * W * W).$$

$$\text{Moisture release} = 19.20798895 + (.34268986 * G) - (11.29874507 * S) + (1.23120356 * S * S) - (.0431076 * S * S * S) + (.06115215 * W).$$

$$\text{Degree of softness} = 5.74212084 - (.06917265 * G) + (.12556666 * S) - (.00923750 * W).$$

$$\text{Deformation} = -269.48867412 + (.24484427 * G) + (.12445459 * S) + (2.57541506 * W) - (.00803948 * W * W) + (8.30117E-06 * W * W * W).$$

$$\text{Fracturability} = 16.07741569 - (.18093177 * G) - (.12870653 * S) - (.01859628 * W).$$

$$\text{Moisture absorption} = 25.43343889 - (.32655608 * G) + (.00540296 * S) - (.05166116 * W).$$

$$\text{Cohesion of mass} = -1.59756516 + (.11147411 * G) + (.15761515 * S) + (.02441693 * W).$$

$$\begin{aligned} \text{Texture of mass} = & 15.51320902 - (.02014825 * G) - (1.03861834 * S) - \\ & (.05739632 * W) + (.00012293 * W * W) + (.01212570 * S * W) - \\ & (7.88705E-05 * S * W * W) + (8.84121E-08 * S * W * W * W) + (.00066603 * S * S * W) + \\ & (3.75194E-07 * S * S * W * W) - (2.68239E-05 * S * S * S * W). \end{aligned}$$

$$\text{Ease of chewing} = 3.83193984 - (.06787864 * G) + (.09068818 * S) + (8.68598E-06 * W).$$

$$\text{Ease of swallowing} = 5.06743491 + (.01216950 * G) + (.09611069 * S) + (.00280578 * W).$$

$$\begin{aligned} \text{Oily residue} = & 6.93054709 - (.19835436 * G) + (.18644015 * S) - \\ & (.08267038 * W) + (.00018006 * W * W) + (.70872433 * G * S) - (.06886215 * G * S * S) + \\ & (.00256532 * G * S * S * S) - (.03316393 * G * G * S). \end{aligned}$$

$$\begin{aligned} \text{Adhesion to teeth} = & -6.0366394 - (3.16773318 * G) + (2.45993625 * S) + \\ & (.00622671 * W) + (1.07572324 * G * S) - (.21407928 * G * S * S) + \\ & (.00750115 * G * S * S * S) + (.07693929 * G * G * S). \end{aligned}$$

APPENDIX E

Table E1--Least-squares means for microwave oven wattage^a

Block ^b	Wattage	
1	568.02aco	±11.95
2	599.71adkmo	±12.37
3	591.97aefghm	±11.72
4	549.52cno	±11.64
5	602.91bdegh	±12.13
6	605.56bdfg	±12.25
7	604.51bdg	±11.94
8	616.30bdh	±12.23
9	583.90aefghimo	±12.07
10	591.17aefghjmo	±11.68
11	587.74aefghjmo	±11.84
12	604.97befk	±11.80
13	599.35aefghm	±11.80
14	560.03cijlm	±11.72
15	581.31acefgho	±11.84
16	584.57acefghmo	±11.80
17	590.27afghlmo	±11.60
18	561.45cmo	±11.83
19	574.22aefglmno	±12.02
20	562.67o	±12.11

^aLeast-squares means within a column followed by like letters do not differ ($P>0.05$).

^bSix measurements made per day (block).

APPENDIX F

DEMOGRAPHIC INFORMATION FOR CONSUMER PANEL

Thank you for serving on the cake panel. You have been a valuable part of our research project. To assist in analysis of the data we need some additional information from you. Please answer the following questions.

Age: ☐ less than 18
 ☐ 18-24
 ☐ 25-34
 ☐ 35-44
 ☐ 45-54
 ☐ 55 or over

How often do you bake cakes at home?

☐ Never
☐ More than once a week
☐ Several times a month
☐ Several a times a year

Do you have a microwave? Yes ☐ No ☐ (If you checked no, please stop here.)

Have you ever baked a cake in a microwave oven? Yes ☐ No ☐
☐ Was it from scratch ☐ or a mix ☐?

When you bake cakes in the conventional oven do you?
☐ bake from scratch
☐ use a mix

If you have used a microwave cake mix, please indicate the degree to which you like it.

☐ Like extremely
☐ Like very much
☐ Like somewhat
☐ Dislike somewhat
☐ Dislike very much
☐ Dislike extremely

THANK YOU FOR BEING A PART OF OUR TASTE PANEL!

APPENDIX G

SCORECARD FOR IDEAL CAKE EVALUATION

On the scales below please indicate where you think the "ideal" yellow layer cake would be rated. Mark the scorecard by placing a check on the line to represent the degree to which the characteristic should be present in the sample.

Appearance

Cell distribution:

uniform ____:____:____:____:____:____:____:____:____ irregular

Texture

Crumbliness (when you cut through with a fork):

holds ____:____:____:____:____:____:____:____:____ crumbles
together easily

Hardness (Force required to bite through on first bite):

very soft ____:____:____:____:____:____:____:____:____ very
hard

Crumb harshness:

smooth ____:____:____:____:____:____:____:____:____ rough

Moistness:

very dry ____:____:____:____:____:____:____:____:____ very
moist

Tooth packing (How much it sticks to the teeth after
swallowing):

none ____:____:____:____:____:____:____:____:____ very
much

APPENDIX H

CONSUMER PANEL SCORECARD FOR CAKE EVALUATION

You will be given 2 samples of yellow layer cake. Please evaluate them in the same order as your scorecards are arranged. Mark the scorecard by placing a check on the line to represent the degree to which the characteristic is present in the sample. Please rinse between samples.

Appearance

Cell distribution:

uniform _____ irregular

Acceptability of appearance:

very _____ very
desirable _____ undesirable

Taste

Acceptability of taste:

very _____ very
desirable _____ undesirable

Texture

Crumbliness (when you cut through with a fork):

holds _____ crumbles
together _____ easily

Hardness (Force required to bite through on first bite):

very soft _____ very hard

Crumb harshness:

smooth _____ rough

Moistness:

very dry _____ very moist

Tooth packing (How much it sticks to the teeth after
swallowing):

none _____ very much

Acceptability of texture:

very _____ very
desirable _____ undesirable

Overall Acceptability

very _____ very
desirable _____ undesirable

VITA

Marsha Anne McNeill was born in Knoxville, Tennessee, on August 14, 1958. She attended Mooreland Heights Elementary School and Young High School, both in Knoxville. In 1976, she began her college career at Salem College in Winston-Salem, North Carolina. In 1977, she entered The University of Tennessee, Knoxville, and graduated in 1980 with a Bachelor of Science degree in Home Economics with a major in Food Science. She began working toward a Master of Science degree in Food Science in 1980 at The University of Tennessee, Knoxville, and graduated in August 1982. In 1983, she enrolled in the doctoral program at Kansas State University in Manhattan, Kansas.

In 1984, she became a pharmaceutical sales representative for The Upjohn Company in LaGrange, Georgia. After two years with Upjohn, she entered the doctoral program at The University of Tennessee, Knoxville, in the Food Technology and Science Department. Throughout her graduate work, she was a graduate research assistant. The author is a member of Phi Tau Sigma, Omicron Nu, Gamma Sigma Delta, The Institute of Food Technologists (IFT), and the Sensory Evaluation Division of IFT.