ALTERNATIVE SWEETENING SYSTEMS IN LAYER CAKES USING ASPARTAME AND FRUCTOSE

by

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In memory of my brother,

Orville "Joe" Hess

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INTRODUCTION

Man has sought sweet tasting substances since prehistoric times, and they have been used in food products for several thousand years. The earliest known sweets were fruits and honey (Inglett, 1976); however, we have become accustomed to the sweetness and desirability of sucrose.

If all individuals could and wanted to use sucrose there would be no problem. No accurate measurement exists for how much sugar the average American consumes. The best available guide for sugar use is the per capita consumption figures from the U.S. Department of Agriculture (USDA). The consumption figures indicate the amount of sugar shipped by producers for industrial and home use (Lecos, 1980). The consumption of sucrose sweeteners increased from 97.7 to 102.4 pounds per capita from 1961 to 1971. In the same ten year period, the consumption of non-caloric sweeteners increased from 2.5 to 5.7 pounds per capita, assuming the non-caloric sweeteners to be 300 times as sweet as sugar (Walter, 1974). In 1978, the consumption of sugar fell to 93 pounds, according to USDA figures. The decline of refined sugar consumption has been offset by a steady rise in corn sweetener usage--from a per capita rate of 19 pounds in 1970 to 34 pounds in 1978 (Lecos, 1980). Low calorie and dietetic foods account for almost three billion dollars annual expenditures in the U.S. (Beck, C., 1978). A Market Facts Inc. study for Calorie Council Control in 1978 found 26 per cent of the U.S. population over 13 years using artificial sweeteners in some form (Anon., 1979).

Consumption of non-carbohydrate sweeteners is increasing because a number of human disorders are attributed to excess consumption of sucrose. Numerous reports attribute dental caries to high sugar diets (Brown, 1974; Gori, 1979; Miller, 1980; Leveille, 1980). The consumption of sucrose also has been implicated as a cause of diabetes and most medical authorities are concerned with sucrose in the dietary management of diabetes (Beck, C., 1978). Sucrose is blamed for overnutrition or obesity (Pangborn and Larson, 1975). One-fourth of the American population is estimated to be avoiding, restricting or limiting their sucrose consumption to prevent, retard, or reverse obesity (Beck, C., 1978), even though total consumption of calories in excess of energy output, not sucrose alone, is the real cause of obesity (Leveille, 1980).

Commercial products without added sucrose could provide healthier products for consumers (Chase, 1979; Gori, 1979). The purpose of this study was to develop a non-sucrose sweetened layer cake that could be used by either diabetics or non-diabetics. Aspartame (APM) alone, or in combination with low levels of fructose, was used for sweetening.

REVIEW OF LITERATURE

The search for a safe non-nutritive sweetener has received much attention since the passage of the Delaney Amendment in 1958 (Hough et al., 1979). An ideal non-nutritive sweetener would have the following characteristics:

1. be at least as sweet as sucrose, colorless, odorless, pleasant, untainted sweet quality
2. not be detrimental to physical and chemical functions attributed of a wide variety of food products
3. not encourage metabolic abnormalities such as diabetes and dental caries
4. be safe for use; metabolized normally or completely excreted unchanged
5. be easy to manufacture
6. be water soluble; chemically and thermally stable
7. be economically competitive (Pangborn et al., 1975; Hough et al., 1979; Harper, 1975).

Taste of Carbohydrate and Non-carbohydrate Sweeteners

Sweetness is one of the four basic taste sensations. Carbohydrates, such as sucrose, glucose, and fructose, generally are considered sweet-tasting chemicals. Shallenberger theorized in 1963 that the sweetness of a sugar was related to the hydrogen bonding between the vicinal hydroxy group of the substance and those of the receptor site. In 1967, Shallenberger described the hydrogen bond as an AH-B system. The AH is a proton donor and B a proton acceptor, with AH and B separated by a distance of about 3 Å. Until 1969, the sweetness of D and L sugar isomers were believed different; based on the AH-B theory, the D-series of amino acids would be sweet and the L-series would not be sweet (Shallenberger et al., 1969; Shallenberger, 1980). Similar AH-B systems have been identified in saccharin, cyclamates, chloroform, inorganic compounds, and beryllium salts (Shallenberger, 1980), which are perceived as sweet (Beck, K., 1978).

Role of Ingredients

Sweetening Agents

Sucrose is responsible for functions in food other than sweetness. Reductions in volume and tenderness result when sucrose is eliminated from a baked product. The decreased volume is a result of not enough air being incorporated into the product. Sharp edges of crystalline sugars have air adhering to their sides which is then beaten into the fat. The setting of the cake's structure by starch gelatinization affects the tenderness or lightness of the finished product. High levels of sugar inhibit starch gelatinization and interfere with gluten development. In addition to volume, sweetness and tenderness, sucrose provides preservative action, humectant properties, and browning (Charley, 1970; Beck, C., 1978; Campbell et al., 1978; Bennion, 1980).

Previous research indicates sucrose delays gelatinization of starch pastes and decreases gel strength of pastes (Bean and Osman, 1960). Bean and Yamazaki (1978a) found glucose, fructose, and sucrose delay starch gelatinization, which seemed to be a major factor in determining volume and contour of layer cakes. However, sugars other than sucrose can be used if the water level is adjusted so gelatinization of starch will occur at a temperature that is optimum for the formula. In later work, Bean et al. (1978b) theorized that space and the amount of available water determine how sugar affects starch gelatinization. Ash (1979) indicated the simple substitution of high fructose corn syrup (HFCS) for sucrose would not be feasible since HFCS alters starch gelatinization and crystal growth as well as flavor response. Direct substitution of alternative sweeteners for sucrose requires starch swelling and/or gelatinization be taken into consideration (Ash, 1979; Bean and Yamazaki, 1978a; Bean et al., 1978b; Osman, 1975; Savage and Osman, 1978).

Shortening Agents

The shortening used in cakes provides for moistness, and also increases tenderness. The type of fat used in a shortened cake and the method of mixing was the subject of a study conducted by Hunter and co-workers (1950). Results indicated the kind of fat affects the structure of the cake batter and the mixing method influences the volume and distribution of air in the batter. Batters made with hydrogenated shortenings using a conventional mixing method were determined to be superior to batters with other types of fat and mixing methods. Hydrogenated shortenings were determined to be good creaming agents since they distributed air evenly throughout the batter. Hydrogenated shortenings produce batter with low specific gravity, high viscosity, and a cake with an even grain (Bennion, 1980).

Emulsifiers

Emulsifiers increase the amount of air incorporated during the creaming or mixing stage (Endres, 1967). Previous research indicates emulsifiers aid in the even distribution of fat throughout the batter (Bennion, 1980). Wooten and co-workers (1967) indicated new surface active agents improve air incorporation into cake batters, resulting in a finer grain and increased volume of cakes containing only mono- and di-glycerides. The use of hydrophilic emulsifiers resulted in cake larger in volume, more pleasing to the eye, and with improved eating qualities. Blends of emulsifiers contribute to improved volume, grain, texture, color, and shelf-life of cakes when vegetable oil was substituted for solid shortening or when HFCS was substituted for sucrose (MacDonald, 1968; Hartnett, 1979).

Bulking Agents

Generally, calorie reduction by the substitution or elimination of fat and/or carbohydrates results in a loss of appearance, texture, and mouthfeel (Beereboom, 1978). Prospective bulking agents should have similar physical and functional properties without the calories of the fat or carbohydrate being replaced (Beereboom, 1978; Beck, C., 1978). Possibilities include: cellulose derivatives, hydrocolloids, polyhydric alcohols, synthetic polymers, sucrose esters, and silica gels (Beck, K., 1978).

Hydrocolloids have been used to thicken, or gel, water and milk systems, suspend ingredients, stabilize emulsions or foams, control crystal growth and impart mouthfeel (Moirano, 1966). Gums are used often to mask or hide the after-taste of artificial sweeteners (Glicksman et al., 1966). Eating quality of standard white layer cakes has been improved by adding hydrophilic colloids. Sodium carboxymethylcellulose (CMC) has been found to improve the eating characteristics, mouthfeel and shelf-life of white sucrose sweetened layer cakes (Bayfield, 1962).

Instrumental Evaluation of Shortened Cake Texture

No current research was found reporting texture measurements using the Instron Universal Testing Machine (IUTM) in the evaluation of shortened cakes. Szczesniak and co-workers (1970) concluded most foods undergo a combination of compression, extrusion, and shear, and Voisey (1977) emphasizes the importance of correctly interpreting what occurs prior, during, and after the rupture of food.

Information obtained from the Instron Corporation indicates the initial smooth rising portion of the curve generally represents the response of the material as it is being compressed before it is sheared. Dahle and Montgomery (1978) reported on work with bread, theorizing peak resistance to deformation in grams of force was "crumb strength."

Huang and Robertson (1977) reported the middle curve section was indicative of the internal structure of frankfurters. Voisey (1977) postulated the roundness of a peak when bread is sheared is caused by the continuous rupture of the mass rather than an abrupt shearing.

Voisey (1977) interprets the peak force of bread as the maximum value of combined forces due to the resistance of the sample. The peak force of crackers can be assumed to be a reasonable index of shear strength. However, those materials each had only one peak. Huang and Robertson (1977) theorized the final peak of a frankfurter curve represented the measure of resistance of the compressed surface layer mass.

Aspartame as a Sweetening Agent

Taste of Aspartame

Aspartame (APM) is the generic name for the high potency dipeptide sweetener, L-aspartyl-L-phenylalanine methyl ester (Mazur, 1976). It is hydrolyzed in the intestinal mucosa into methanol, aspartate, and phenylalanine (Ranney et al., 1976; Stegink et al., 1977). Because it is metabolized into its amino acids, it is referred to as a nutritive substance and has not been classified as an artificial sweetener or restricted to special dietary foods (Harper, 1975). It is a white powder with a sweet taste which contains four kilocalories energy per gram; one teaspoon APM contains about three calories (Mazur, 1976; Staff Report, 1974).

APM has the most sucrose-like taste of the non-carbohydrate sweeteners discovered to date (Beck, C., 1978). Cloninger and Baldwin (1970) reported APM to be 160 times sweeter than a four percent aqueous sucrose solution; others estimate APM to be 180 to 200 times sweeter than sucrose (Mazur, 1976; Beck, C., 1974; Staff Report, 1974). The sweet taste of APM is a complete surprise since no other peptides have been found to be sweet. The constituents, aspartate and phenylalanine, are reported to be flat and bitter, respectively; however, when properly linked, the taste is sweet (Mazur and Ripper, 1979). In the research and sensory testing of APM, no one individual has failed to pick up the sensation of sweetness

(Beck, C., 1974), and some tasters prefer APM to sucrose. Untrained tasters indicated a change in sweetness is not detected even with one-half or double the concentration of APM in a beverage (Mazur and Ripper, 1979).

Early studies indicated this dipeptide has no off-flavor and/or aftertaste. More recently, Paccalin and co-workers (1980) established APM does not have associated acidity or bitterness, or any metallic aftertaste. A time-intensity relationship curve indicated a slight delay in the sweetness curve but otherwise it is similar to sucrose (Larson-Powers and Pangborn, 1978).

APM is similar to sucrose not only in its sweetness but also in its ability to influence, potentiate, or enhance flavors or their perception (Beck, C., 1974; McCormick, 1975; Pangborn and Larson, 1975; Larson-Powers and Pangborn, 1978; Beck, C., 1978). Finucane and Halik (1974) reported APM reduces bitterness of coffee at levels that are not reported to be sweet. Pangborn and co-workers (1973) reported small amounts of methyl cellulose raised the perceived sweetness of APM in a buffered aqueous solution. Beck (1974) noted APM extends the sweetness of chewing gum and improved the taste and aroma of fruit-flavored drinks and gelatin desserts. Orange-flavored sherbet (McPherson et al., 1978) or gelatin (Baldwin and Korschgen, 1979) with aspartame as the sweetening agent did not exhibit flavor synergism or potentiation. However, APM sweetened orange- and cherry-flavored beverages exhibited more intense fruit flavors than their sucrose counterparts (Baldwin and Korschgen, 1979).

Several reports state APM cannot be used in foods that require prolonged cooking (Staff Report, 1974; Beck, C., 1978). APM decomposes to diketopiperazine when subjected to temperature and pH extremes (McCormick, 1975) resulting in a loss of sweetness (Beck, C., 1974). Studies done by the G. D. Searle Co., have shown substantial but not total loss of sweetness in baked goods using APM. The amount of loss is directly related to the length of time exposed to heat. The results indicated products sweetened with APM were sweeter than products without a sweetener but not as sweet as the product using sucrose. Using APM in a baked product will require substantial creativity due to the loss of sucrose's functional properties (Beck, C., 1978).

Safety of Aspartame

Chemical substances may exert a toxic effect at very high dose levels, although age and species susceptibility will vary (Stegink et al., 1977). Olney (1975) has questioned the potential safety of aspartame's constituent amino acids, aspartate and phenylalanine. Numerous studies to determine the metabolic effects of APM on healthy children, adolescents, and adults have been initiated.

A primary use of sugar substitutes is to replace the sucrose in an individual's diet. A study on the long term effects of APM on hormonal balance indicated APM may safely be used on weight reduction diets, since no APM could be detected in any of the conventional metabolic parameters that were investigated (Knopp et al., 1976). APM administered to adult non-insulin dependent diabetics was well-tolerated (Stern et al., 1976). Ranney and co-workers (1976) found that mice, rats, rabbits, dogs, monkeys, and humans metabolized aspartame, although the rate of metabolism for each species differed. Metabolism of aspartate is rapid and the human body can handle its metabolic products (Stegink et al., 1977). Frey's double blind study (1976) using normal healthy children indicated no clinically significant laboratory differences in liver and renal function tests. Physical and eye examinations further indicated no abnormalities.

Effects of APM on adults and children diagnosed as phenylketonurics (PKU) is a primary concern. The danger involves an inability to metabolize the amino acid phenylalanine. Studies designed to look at the effect of APM on children, adolescents, and adult heterozygous PKU reported that aspartame would have no effect (Koch et al., 1976; Stegink et al., 1977).

The conclusion reached from various studies is that APM is a safe substitute for sucrose and can be recommended to the general public. A Board of Inquiry appointed by the FDA found data relating to phenylalanine and neurotoxicity to be in support of aspartame's safety. However, development of brain tumors by the ingestion of extremely high levels of APM of 100 to 6,000 mg/kg throughout the rat's life raised concern over the additive's safety. The board recommended that questions of possible "tumorgenic potential need to be resolved through experiments containing large number of animals" (Anon., 1980). The FDA commissioner will review the issue and announce a decision in the Federal Register.

MATERIALS AND METHODS

Ingredients and Methods

Whenever possible ingredients were procured in quantities sufficient for the entire study at the start of the experimental work. Fresh oranges, eggs, whole milk, and buttermilk were obtained weekly. Aspartame and Equa® were donated by G. D. Searle, Chicago, Illinois. Equa® is the granulated form of aspartame. A complete listing of ingredients, suppliers, and lot numbers appears in the Appendix, Table A-1.

Cakes were prepared according to the formulas given in Table 1. Based on preliminary testing, sodium-stearoyl-2-lactylate (SSL), an emulsifier, was added at the 0.01% level to improve texture and decrease

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

THIS IS AS RECEIVED FROM THE CUSTOMER.

Table 1. Cake formulations.

Ingredients	Cakes (%)			
	Chocolate	Lemon	Orange	Spice
Cake flour	100	100	100	100
Equa®	23.5	21	21	21
Shortening	66	66	50	50
Baking powder, double acting	10	8	8	8
Salt	1.7	1.6	1.6	1.6
Whole egg	100	60	60	60
Whole milk	--	110	110	110
Buttermilk	78	--	--	--
Aspartame[1]	0.6-1.8	0.5-1.5	0.5-1.5	0.5-1.5
Fructose[2]	0-30.1	0-25	0-25	0-25
SSL	0.01	0.01	0.01	0.01
XG	0.01	0.01	0.01	0.01
Cocoa	18	--	--	--
Vanilla extract	1.0	--	--	1.0
Lemon extract	--	1.0	--	--
Orange peel	--	--	2.5	--
Cinnamon	--	--	--	1.4
Allspice	--	--	--	0.5
Mace	--	--	--	0.375

[1]For treatment 1 and 2 1.2% for chocolate and 1.0% for all other cake flavors; for treatment 3 and 4 1.8% for chocolate and 1.5% for all other cake flavors; for treatment 5-8 0.6% for chocolate and 0.5% for all other cake flavors.

[2]For treatment 1-4 0% for all cake flavors; for treatment 5 and 6 22.3% for chocolate and 18.5% for all other cake flavors; for treatment 7 and 8 30.1% for chocolate and 25% for all other cake flavors.

size of air bubbles; xanthan gum (XG), a hydrophilic colloid, was added at the 0.01% level to enhance sweetness. Campbell et al. (1978) suggested use of baking powder at the 4% level, flour weight basis, for yellow sucrose sweetened cakes and a 5% level for chocolate cakes. Sodium aluminum sulfate, a double acting baking powder, was added at the 8% or 10% level to the non-sucrose sweetened cakes in this study for added leavening, bulking, and generally to improve textural characteristics, as determined in preliminary testing. Preliminary testing also indicated microwave cooked cakes might be sweeter than cakes baked in a conventional oven. To determine if apparent sweetness was altered by different treatments, e.g. additional carbohydrate or non-carbohydrate sweetener or type of oven, four flavors were evaluated. The carbohydrate sweetener chosen was fructose and additional aspartame was added for cakes sweetened totally by non-carbohydrate sweetener. Dietetic cake mixes presently found on the market use the carbohydrate sweetener fructose. Previous research using untrained panelists indicated individuals could not detect a change in sweetness when the concentration of APM was changed in a beverage (Mazur and Ripper, 1979). A randomized complete block design blocked for flavor was used. All treatment combinations of a flavor were evaluated in a single session. Three replications were made. The cake treatment combinations are given in the Appendix, Table A-2.

At the start of each baking period, all ingredients were weighed and sweeteners were sifted together. The eggs were broken, mixed, and weighed prior to baking. The mixing method used in this study is given in Table 2. Specific gravity and pH of batter were measured prior to baking as indicated in Appendix, Table A-3. Internal temperature of cakes was measured during baking, Appendix, Table A-3. Cakes were cooled for ten

Table 2. Mixing method for cakes.

Mixing step	Speed setting[1]	Time (min.)
1. Cream shortening.[2] Scrape.	6	1.0
2. Gradually add xanthan gum, sodium-stearyl-2-lactylate, aspartame, Equa®.[3,4] Scrape.	6	1.0
3. Cream the above ingredients. Scrape.	6	2.0
4. Gradually add egg. Scrape.	8	1.0
5. Cream all the ingredients. Scrape.	8	1.0
6. Add one-third of sifted dry ingredients[5] and one-third of milk.[6] Scrape.	1	0.25
7. Add one-third of sifted dry ingredients[5] and one-third of milk.[6] Scrape.	1	0.25
8. Add remaining ingredients. Scrape.	1	0.25
9. Mix all ingredients.	1	0.25
10. Weigh 300 g of batter into a greased and papered metal pan and bake at 350°F for 30 minutes in a conventional oven.[7]		
11. Weigh 250 g of batter into a greased and papered glass dish and bake at full power in a microwave oven[8] for 2 minutes.		

[1]Hobart mixer, Model K5.

[2]Orange peel is added, when used.

[3]Cocoa, when used, is sifted into the sweetener mixture.

[4]Fructose, when used, is premixed with SSL, XG, Equa®, and Aspartame.

[5]Cinnamon, allspice, and mace are pre-sifted with flour, salt, and baking powder, when used.

[6]Lemon or vanilla extract is premixed with the milk, when used.

[7]Oven model, Rotary Hearth Oven, Model 280C.

[8]Oven model, Amana Radarange®, Model RR-7DA.

minutes before removal from pans, then placed on wire racks for further cooling. Cooked cakes were labeled, placed in plastic bags, stored overnight at room temperature until further evaluations were made.

Sample Preparation

Two to four hours prior to serving, a center 1.27 cm wide section was removed for the standing height measurements (Appendix, Table A-3); 2.54 cm cubes, excluding crusts; and 2.54 cm squares of crust were cut and placed on white plates. Samples were coded with three digit random numbers and covered with plastic wrap to prevent drying. The remaining cake was wrapped and used for crumb pH (Appendix, Table A-3) and texture measurements with the IUTM.

Panel Selection and Training

Eating quality was evaluated 18 to 24 hours after baking at mid-morning and mid-afternoon sessions by two separate panels. Five panelists with no known carbohydrate metabolic diseases, hereafter referred to as non-diabetics, were graduate students in the departments of Foods and Nutrition and Dietetics, Restaurant, and Institutional Management. The second panel of six was composed of townspeople and students in the Manhattan community suffering from carbohydrate metabolic abnormalities of diabetes and hypoglycemia and hereafter are referred to as the diabetic panel. Training sessions were used to acquaint the graduate students with baked products. The diabetics and hypoglycemics were trained by familiarization with basic sensory techniques; sweet, sour, and bitter taste characteristics in solution and in products; and with baked products.

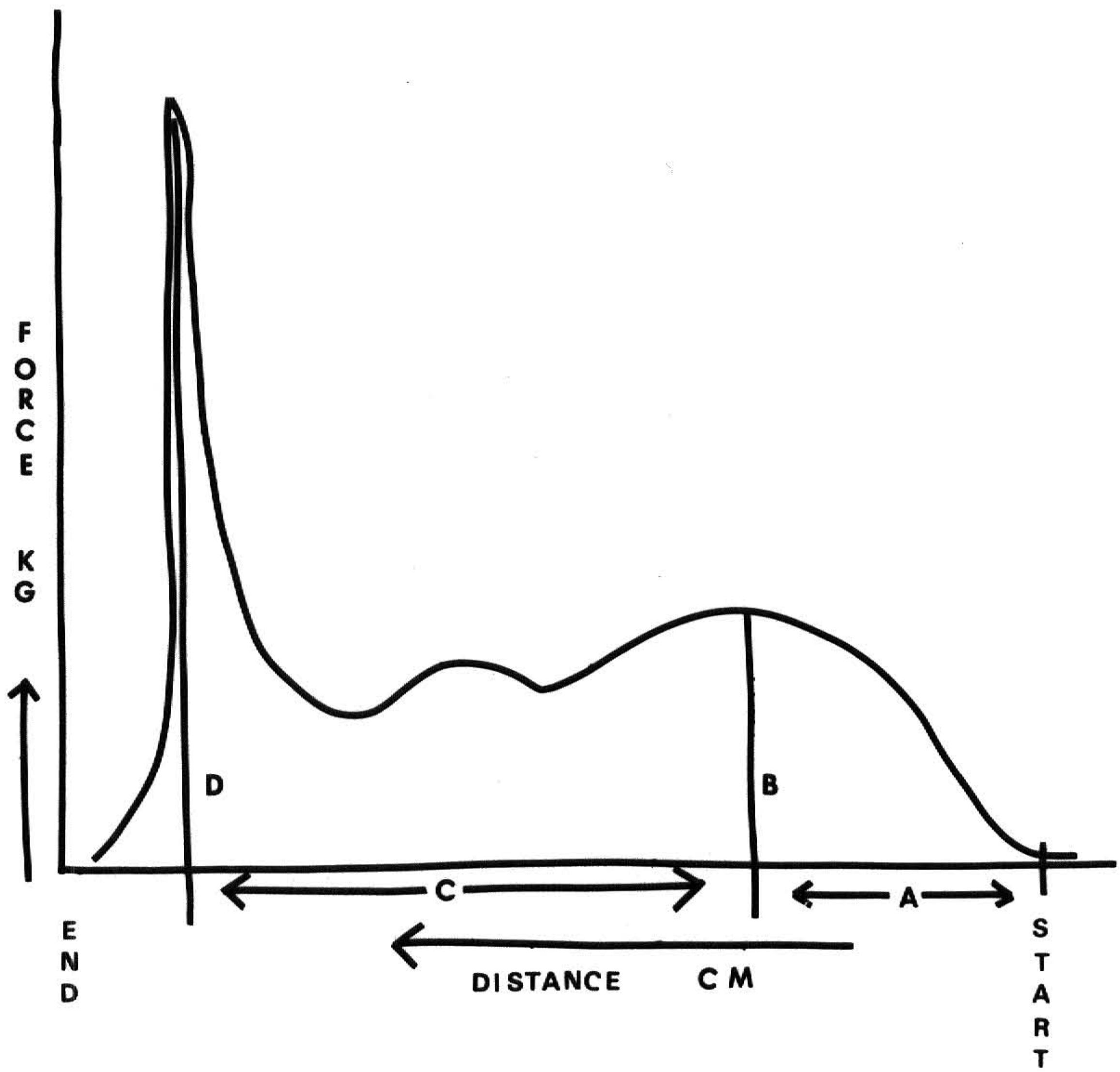
Panelists evaluated the cake texture, flavor, and overall eating quality. Cake texture was assessed by evaluation of cell uniformity, moistness, and tenderness. Cake flavor was appraised by evaluating for sweetness and bitterness of crust and crumb. A five-point descriptive rating scale for textural qualities, sweetness, and overall eating quality with 5.0, considered highest, and 1.0, lowest, was used. For bitterness, 5.0 was lowest and 1.0 was highest (Appendix, Figure A-3).

Texture Measurements

The IUTM, model 1122, was fitted with a specially designed incisor and molar attachment shown in the Appendix, Figure A-1. A 0.1 kg setting on the full scale load, a crosshead speed of 50 mm/min and a chart speed of 200 mm/min were used. Three representative 2.54 cm cubes from each cake were evaluated. The cubes were cut from the top down. Since the height of the cakes was greater than 2.54 cm, the bottom crust was removed from the samples. The upper limit was set on 33.5 mm and the minimum limit was set on 0.0 mm. There was a one mm gap between the upper and lower incisor. The upper "tooth" was immediately returned to the maximum limit. A typical force distance curve for non-sucrose sweetened cakes is shown in Figure 1.

Four measurements based on reported research using the IUTM on bread, meat, frankfurter, fruits, and vegetables were taken from each curve (Figure 1). Response of the cakes during compression, in cm, was defined as the internal resistance of the crust and crumb of the cake. Measurement B corresponds to the first break in the curve and represents the strength of the cake's crumb and appears related to Dahle and Montgomery's (1978) peak resistance to deformation of break. The

Figure 1. Typical force distance curve for non-sucrose sweetened cakes.



A--internal resistance during compression

B--crumb strength

C--breakdown of crumb structure

D--maximum force exerted

breakdown of the crumb structure, measurement C, represents the distance between the peaks or the internal resistance of the crumb to compression, and is probably related to the grain of the cake similar to the round peaks of bread (Voisey, 1977) or frankfurters (Huang and Robertson, 1977). If the grain was fine and tender with many small air cells, the structure of the crumb would be more easily ruptured. The force at the end of the compression cycle or the maximum force exerted on the cake is represented by measurement D.

Analysis of Data

All data were analyzed by analysis of variance (ANOV). Three replications of each cake flavor and treatment combination were used. ANOV for sensory data was as follows:

Source of Variation	DF
Replication (R)	2
Cake Flavor (C)	3
Treatment (T)	7
C × T	21
Panel (P)	1
T × P	7
C × P	3
T × C × P (Error)	21
Total	65

Mean values for crumb pH and standing height were analyzed by a separate ANOV.

Source of Variation	DF
Replication (R)	2
Cake Flavor (C)	3
Treatment (T)	7
T × C (Error)	21
Total	33

The ANOV for specific gravity and batter pH was:

Source of Variation	DF
Replication (R)	2
Cake Flavor (C)	3
Treatment (T)	3
T × C (Error)	9
Total	17

Data for texture measurements by the IUTM were analyzed as follows:

Source of Variation	DF
Replication (R)	2
Cake Flavor (C)	3
Treatment (T)	7
T × C	21
Rep (T × C) (Error)	64
Total	97

When treatments, cakes, or interactions were significant, least significant differences (LSD) $p \leq 0.05$ were calculated in each instance.

RESULTS AND DISCUSSION

The mean squares and probabilities from the ANOV for sensory characteristics are given in Table 3. Significant differences among cake flavors were noted for the sensory assessments of cell uniformity, tenderness, moistness, sweetness, crumb bitterness, and crust bitterness. All cake characteristics were reported to be significantly different for treatment. Significant interactions ($p \leq 0.05$) of cake flavors and treatments were found for uniformity of cells, tenderness, and overall eating quality. Type of panel resulted in significant differences for sweetness, crust bitterness, and overall eating quality. A significant interaction ($p \leq 0.05$) between cake flavors and panel type was noted for cell uniformity and between treatment used and panel type for moistness. No significant three way interaction of cake flavor, panel type, and treatment was found for any of the characteristics assessed.

ANOV for some physical measurements of the cake batter (Table 4) indicate no significant differences for cake flavor, for type of treatment, or interaction between cake flavor and treatment for batter pH. Specific gravity of cake batter, the crumb pH and standing height of the cakes were significantly different for cake flavor and type of treatment. Significant differences among replications were found for crumb pH and for standing height. The interaction between treatments and cake flavors was significant ($p \leq 0.05$) for standing height.

Significant differences were found for cake flavors for all measurements taken from the Instron curves (Table 5). Type of treatment resulted in significant differences only for the force required for the second peak. No significant interactions among cake flavors and treatments were found for any of the IUTM measurements.

Table 3. Mean squares (MS) and probabilities (PR) for cake characteristics determined by sensory analysis.

Source of Variation	DF	Analysis of Variance: Uniformity of Cells MS (PR>F)	Tenderness MS (PR>F)	Moistness MS (PR>F)	Sweetness MS (PR>F)	Crumb Bitterness MS (PR>F)	Crust Bitterness MS (PR>F)	Overall Eating Quality MS (PR>F)
Replication (R)	2	3.78 (0.7350)	29.04 (0.0542)	52.10 (0.0052)	321.79 (0.0001)	327.37 (0.0001)	473.22 (0.0001)	145.25 (0.0001)
Cake Flavor (C)	3	243.48 (0.0001)	67.79 (0.0003)	454.97 (0.0001)	84.19 (0.0001)	45.00 (0.0325)	108.49 (0.0006)	2.74 (0.8339)
Treatment (T)	7	43.30 (0.0018)	175.65 (0.0001)	462.50 (0.0001)	79.02 (0.0001)	116.49 (0.0001)	171.58 (0.0001)	152.28 (0.0001)
C × T	21	20.21 (0.0478)	32.71 (0.0001)	9.52 (0.4672)	5.22 (0.8739)	13.33 (0.6042)	12.58 (0.7995)	18.50 (0.0124)
Panel (P)	1	36.26 (0.0878)	19.48 (0.1597)	3.95 (0.5203)	39.56 (0.0283)	35.33 (0.1270)	189.87 (0.0012)	710.33 (0.0001)
C × P	3	34.62 (0.0406)	1.73 (0.9089)	10.60 (0.3465)	11.11 (0.2501)	15.09 (0.3927)	15.82 (0.4384)	9.22 (0.4083)
T × P	7	7.92 (0.7178)	16.83 (0.1072)	25.50 (0.0128)	9.24 (0.3357)	12.80 (0.5455)	30.69 (0.0979)	7.47 (0.5983)
C × P × T	21	10.84 (0.6104)	6.85 (0.8235)	9.34 (0.4900)	5.82 (0.8019)	6.14 (0.9894)	10.67 (0.9009)	7.61 (0.7104)

Table 4. Mean squares (MS) and probabilities (PR) for physical measurements of batters and cakes.

Source of Variation	DF	Analysis of Variance				DF	Analysis of Variance			
		pH Batter		Sp. Gravity			pH Crumb		Std. Ht.	
		MS	PR>F	MS	PR>F		MS	PR>F	MS	PR>F
Replication (R)	2	0.30	0.2545	0.0009	0.1287	2	0.79	0.0032	0.31	0.0092
Cake Flavor (C)	3	0.06	0.8473	0.0034	0.0005	3	3.07	0.0001	1.47	0.0001
Treatment (T)	3	0.26	0.3182	0.0031	0.0008	7	0.50	0.0012	0.85	0.0001
T × C	9	0.18	0.5706	0.0006	0.2072	21	0.12	0.5515	0.11	0.0454

Table 5. Mean squares (MS) and probabilities (PR) for texture measurement of cakes by the Instron Universal Testing Machine

Source	DF	Distance to the First Peak, cm MS (PR>F)	Force Required for the First Peak, kg MS (PR>F)	Distance Between the Peaks, cm MS (PR>F)	Force Required for the Final Break, kg MS (PR>F)
Cake Flavor (C)	3	2248.93 (0.0249)	5056.63 (0.0001)	2464.495 (0.0220)	137198.48 (0.0001)
Treatment (T)	7	221.96 (0.9380)	326.94 (0.1826)	460.442 (0.7223)	19108.36 (0.0076)
T × C	21	318.46 (0.9716)	259.84 (0.2882)	330.879 (0.9748)	1977.41 (0.9974)

Effect of Cake Flavor

Sensory Measurements

In Table 6, the mean values of sensory characteristics for the three replications pooled for treatments are reported for the combined panels according to the different flavors. ANOV indicated no difference in overall eating quality for cake flavors. For several characteristics, chocolate was significantly different ($p \leq 0.05$) from all other cake flavors, as it was the least uniform in cell structure, least tender, driest, sweetest, and most bitter for crust and crumb. Birch and Ogunmoyela (1980) reported the use of surfactants can increase the sweetness of cocoa drinks. SSL used in this study is a surfactant and may have contributed to the greater sweetness perceived in the chocolate cakes.

Lemon was evaluated as significantly the most uniform in cell structure of all cakes studied and no difference for cell uniformity was found between orange and spice cakes. Orange and spice cakes were judged the most tender ($p \leq 0.05$) with no difference noted between the two flavors; lemon was significantly more tender than chocolate. Lemon cakes were the most moist of the four cake flavors. No significant difference for moistness was noted between lemon and orange or between orange and spice cakes; however, lemon cakes were significantly more moist than spice cakes. No difference in sweetness or crumb bitterness was perceived in lemon, orange, or spice flavors. Lemon cakes had a significantly more bitter crust than orange and spice cakes; however, no difference for crust bitterness was found between the orange and spice flavors.

Table 6. Mean values for sensory[1] and physical attributes of flavors of cakes.

Measurement	Cake Flavor				LSD
	Chocolate	Lemon	Orange	Spice	
Sensory Characteristics[4]					
Cell uniformity[5]	2.97[a]	3.50[b]	3.37[c]	3.32[c]	0.09
Tenderness[5]	3.53[a]	3.69[b]	3.78[c]	3.78[c]	0.08
Moistness[5]	2.47[a]	3.15[c]	3.07[bc]	2.99[b]	0.13
Sweetness[5]	2.57[a]	2.35[b]	2.31[b]	2.28[b]	0.07
Crumb bitterness[6]	4.00[a]	4.15[b]	4.20[b]	4.21[b]	0.07
Crust bitterness[6]	3.67[a]	3.77[b]	3.98[c]	3.96[c]	0.09
Overall eating quality[5]	2.52	2.47	2.52	2.52	N.S.
Physical Measurements[4]					
Batter pH[2]	6.86	6.72	6.78	6.87	N.S.
Crumb pH[3]	6.33[a]	7.04[b]	7.09[b]	6.99[b]	0.21
Specific gravity[2]	0.7586[ab]	0.7703[b]	0.7454[ab]	0.7316[a]	0.0356
Standing height[3]	4.28[a]	3.76[b]	3.79[b]	3.81[b]	0.14

[1]Three replications, eight treatments, two panels, for total of 48 observations.

[2]Three replications, four treatments, for total of 12 observations.

[3]Three replications, eight treatments, for total of 24 observations.

[4]Mean values in same row with same letter are not significantly different ($p \leq 0.05$).

[5]Five point scale with 5.0, highest to 1.0, lowest.

[6]Five point scale with 5.0, lowest to 1.0, highest.

Physical Measurements

Chocolate cakes had a significantly ($p \leq 0.05$) more acidic crumb, and standing heights were larger indicating greater volume than the lemon, orange, or spice cakes; no differences were found among the other three cake flavors for crumb pH or standing height (Table 6). A significantly lower specific gravity, indicating greater air incorporation into the batter, was found for spice cakes compared to lemon cakes; however, lemon and spice cakes were not significantly different from either orange or chocolate cakes.

Texture Measurements

Table 7 compares the mean values by flavor for texture measurements. Significant differences were noted in the four IUTM measurements. The distance to the first peak, or the response of the cake during compression, indicated spice cakes were the most easily ($p \leq 0.05$) compressed of the four cake flavors. The force required for the first peak, or the crumb strength, indicated chocolate cakes had the greatest crumb strength ($p \leq 0.05$) of the four cake flavors. Lemon and orange cakes did not differ in the force required; however, spice cake crumb required less force than the lemon cake but no significant difference was noted between orange and spice cakes. The internal resistance of the crumb or the distance between the two peaks indicated spice cake crumb had significantly more crumb resistance than lemon and chocolate cakes. Orange cakes were not significantly different from the other flavors. The maximum force exerted on the crumb for the final break was significantly ($p \leq 0.05$) higher for chocolate cake than the other flavors. No differences were noted between lemon, orange, or spice cakes.

Table 7. Mean values[1] for texture measurements of flavors of cakes pooled for treatments.

Measurement	Chocolate	Lemon	Orange	Spice
Texture Measurement[2]				
Distance to the first peak, cm[3]	40.32[a]	38.59[a]	34.11[a]	27.43[b]
Force required for first peak, kg[3]	194.55[a]	136.71[c]	132.17[bc]	114.38[b]
Distance between the peaks, cm[3]	62.08[a]	62.21[a]	67.56[ab]	74.83[b]
Force required for the final break, kg[3]	82.67[a]	49.47[b]	40.85[b]	57.62[b]

[1]Three replications.

[2]Mean values in the same row with the same letter are not significantly different ($p \leq 0.05$).

[3]LSD values are given in the Appendix, Table A-4.

Chocolate cakes were evaluated the most acidic, having the greatest crumb strength, and were sensorily the least tender and sweetest. Ideally, chocolate cakes should have a pH range 7.2 to 7.6 (Pyler, 1979), whereas, the pH of these cakes was 6.33. Color and texture of baked products are related to pH, with toughness of a cake increasing when the pH level decreases below optimum.

Pyler (1979) indicates yellow cakes should have a pH of 6.7 to 7.1. All three other flavors were within that range. Since the pH was at its optimum, the cakes should have been tender. Orange and spice cakes were evaluated as the most tender with no differences noted between the crumb strength of the two cake flavors. Spice cakes were evaluated as having the lowest specific gravity, indicating greater air incorporation which also could have contributed to its lower crumb strength.

Effect of Treatments

The treatments used resulted in significant differences for every cake characteristic (Table 3) and significant interactions with cake flavor for cell uniformity, tenderness, and overall eating quality and an interaction for panel moistness. Table 8 compares mean values of sensory analysis for treatment effect for three replications by the combined panels pooled for cake flavor. In Table 9, mean values are compared for specific gravity, standing height, and crumb pH by oven type. ANOV indicated no difference was observed for batter pH. Comparison of treatment means of the IUTM measurements for the force required for the second peak is shown in Table 10.

Sweetening Agents

Sensory measurements. No significant differences were noted between levels of APM for cake characteristics: cell uniformity, moistness, tenderness and overall eating quality for cakes baked in either type of oven. When fructose was used as the added sweetener, no significant differences were noted between fructose levels for the cake characteristics of moistness, crust bitterness and crumb bitterness. No differences ($p \leq 0.05$) were found in cell uniformity, moistness, or sweetness between use of the higher level of APM and the lower level of fructose.

Generally, cakes made in either oven with fructose have a more uniform cell, a more tender crumb, possess a higher overall eating quality, are sweeter, and less bitter for crust and crumb than cakes with APM. Differences were significant for tenderness, crust bitterness, crumb bitterness, and overall eating quality between 2 g APM and 37 g fructose and between 2 g APM and 50 g fructose. In every case, panelists' scores

Table 8. Mean values[1] for sensory characteristics of treatments.

Cake Characteristic	Conventional Oven				Microwave Oven				LSD
	1 g APM	2 g APM	37 g Fructose	50 g Fructose	1 g APM	2 g APM	37 g Fructose	50 g Fructose	
Sensory Characteristic[2]									
Cell uniformity[3]	3.14[a]	3.14[a]	3.22[a]	3.42[b]	3.24[a]	3.27[ab]	3.39[bc]	3.50[bc]	0.14
Tenderness[3]	3.80[a]	3.74[a]	3.97[b]	4.06[b]	3.29[a]	3.36[a]	3.61[b]	3.74[c]	0.11
Moistness[3]	3.32[ab]	3.23[a]	3.32[ab]	3.45[b]	2.51[a]	2.58[a]	2.48[a]	2.51[a]	0.13
Sweetness[3]	2.08[a]	2.33[b]	2.30[b]	2.57[c]	2.25[a]	2.46[b]	2.39[b]	2.65[c]	0.10
Crust bitterness[4]	3.62[a]	3.47[b]	3.89[c]	3.81[c]	3.81[a]	3.73[a]	4.29[b]	4.17[b]	0.14
Crumb bitterness[4]	3.99[a]	3.84[b]	4.33[c]	4.36[c]	3.98[a]	3.94[a]	4.33[b]	4.35[b]	0.11
Overall eating quality[3]	2.35[a]	2.42[a]	2.76[b]	2.95[c]	2.23[a]	2.24[a]	2.53[b]	2.57[b]	0.12

[1]Three replications and eight treatments for total of 24 observations.

[2]Mean values in same row with same letter are not significantly different ($p \leq 0.05$).

[3]Five point scale with 5.0, highest to 1.0, lowest.

[4]Five point scale with 5.0, lowest to 1.0, highest.

Table 9. Mean values[1] for physical attributes of treatments pooled for cake flavor.

Measurement	Type and Level of Sweetening Agent				LSD
	1 g Aspartame	2 g Aspartame	37 g Fructose	50 g Fructose	
Batter[2]					
pH batter	6.59	6.87	6.87	6.91	N.S.
Specific gravity	0.755^{ab}	0.772^{b}	0.743^{ab}	0.735^{a}	0.036
Microwave oven cakes					
pH crumb[3]	6.80^{b}	6.96^{c}	7.17^{d}	7.15^{d}	0.15
Standing height[4]	3.61^{ab}	3.54^{a}	3.75^{bc}	3.80^{c}	0.20
Conventional oven cakes					
pH crumb[3]	6.72^{ab}	6.62^{a}	6.79^{b}	6.73^{ab}	0.15
Standing height[4]	4.14^{d}	4.05^{d}	4.18^{d}	4.21^{d}	0.20

[1]Three replications and four treatments for total of twelve observations.

[2]Mean values in same row with same letter are not significantly different ($p \leq 0.05$).

[3]Mean values in these rows with same letter are not significantly different ($p \leq 0.05$).

[4]Mean values in these rows with same letter are not significantly different ($p \leq 0.05$).

Table 10. Mean values[1] for texture measurements by Instron Universal Testing Machine of treatments pooled by cake flavor.

Measurement	Conventional Oven				Microwave Oven				LSD
	1 g APM	2 g APM	37 g Fructose	50 g Fructose	1 g APM	2 g APM	37 g Fructose	50 g Fructose	
Distance to the first peak, cm	35.28	32.69	35.42	37.67	39.33	31.39	33.78	34.59	N.S.
Force required for the first peak, kg	141.26	152.69	136.78	144.00	158.55	155.88	142.86	119.65	N.S.
Distance between peaks, cm	63.94	69.09	66.58	61.94	62.58	75.15	68.81	71.29	N.S.
Force required for the second peak, kg[2,3]	132.51 acdefg hij	141.43 abcdef ghij	117.78 abcdef ghi	109.22 bcdefg hi	157.79 abcdef gij	180.48 abcdeh ij	159.34 abcfghj	153.47 abdefg hij	

[1]Three replications.

[2]LSD values are given in Appendix, Table A-5.

[3]Mean values with same letter are not significantly different ($p \leq 0.05$).

indicated the cake characteristics more desirable when some fructose was used rather than additional APM. Panelists evaluated cakes with 1 g APM significantly less sweet than other levels and types of sweetening agents; cakes with 2 g APM ($p \leq 0.05$) less sweet than cakes with 50 g fructose; however, sweetness of cakes prepared in either oven with 2 g APM and 37 g fructose were not significantly different.

Physical measurements. Specific gravity indicated batters with 50 g fructose had more air incorporated ($p \leq 0.05$) than batters with 2 g APM (Table 9), although no differences were reported for other levels and types of sweeteners. Microwave cakes made with fructose had a greater volume ($p \leq 0.05$) than cakes with either level of APM. No significant differences for standing height were found dependent upon type or level of sweetening agents when cakes were baked in a conventional oven. Cakes containing fructose were less acidic than cakes with APM.

Texture measurements. Table 10 compares the mean values by treatment for three replications for texture measurements. The maximum force exerted reported in kg was significant ($p \leq 0.05$); however, the other texture measurements did not reveal significant differences. No differences were noted within oven type. Significant differences ($p \leq 0.05$) were noted between cakes prepared in the microwave and the conventional oven. Cakes made in the conventional oven needed less force for the crumb to break. Cakes made using either level of fructose also required less force than cakes with APM. Fructose, a crystalline sugar, undoubtedly, contributes more than APM to tenderness of cakes by its effect on gelatinization of starch and on gluten strength.

Type of Oven

<u>Sensory measurements</u>. Generally, cakes cooked by microwaves (Table 8) were more uniform, sweeter, and had a less bitter crust and crumb, but they were less moist, less tender and lower in overall eating quality than cakes baked conventionally.

Significant differences resulted between ovens for all characteristics evaluated except for crumb bitterness. For cell uniformity, no differences ($p \leq 0.05$) were noted between ovens for both levels of APM and 50 g fructose. Cakes with 37 g fructose were significantly more uniform in cell structure when baked in the microwave.

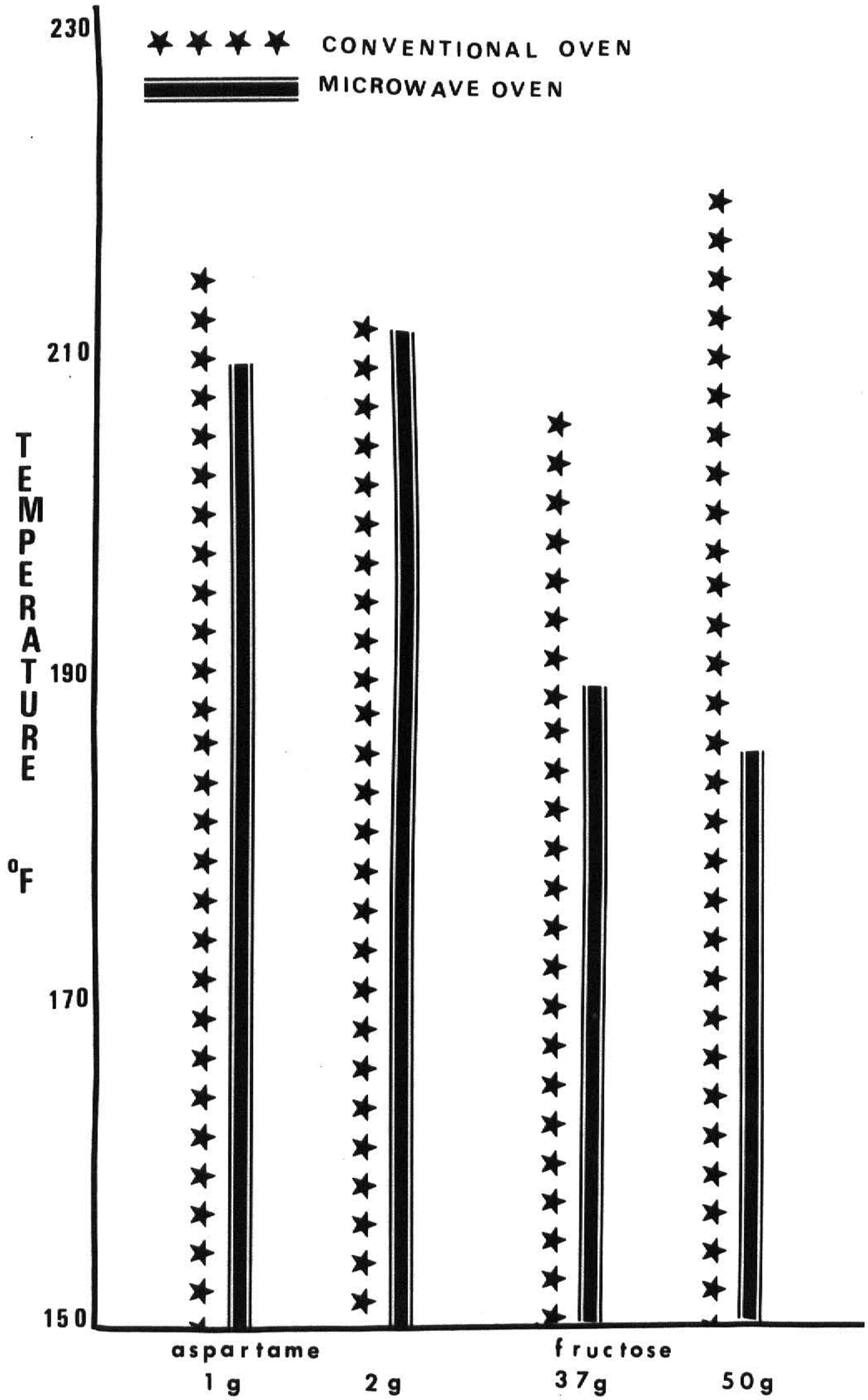
Cakes baked in the microwave oven were significantly less tender, less moist, and less bitter for crust than cakes baked in conventional oven for all levels and types of sweetening agents. No difference in sweetness between types of oven was noted for either level of fructose. However, cakes containing either level of APM were significantly sweeter when baked in the microwave oven rather than the conventional oven as was expected because of the shorter time exposed to heat. No difference in overall eating quality ($p \leq 0.05$) resulted between type of ovens when 1 g APM was used. However, cakes containing 2 g APM, 37 g fructose, or 50 g fructose were significantly lower in overall eating quality when baked in the microwave oven.

<u>Physical measurements</u>. Cakes baked in the microwave oven (Table 9) had a significantly less acidic crumb than corresponding cakes baked in the conventional oven with the exception of cakes with 1 g APM for which no difference between ovens was found. Standing height indicated microwave cooked cakes had a lower volume ($p \leq 0.05$) than conventionally cooked cakes for all types and levels of sweetening agents used.

Little work is reported in the literature comparing type of oven for baking shortened cakes. White and devil's food cakes cooked in a microwave oven were less tender and less moist than conventionally baked cakes; however, the cell structure and flavor were not altered significantly (Neuzil and Baldwin, 1962). This research agrees with those findings. However, Street and Surratt (1961) determined mix cakes were less moist but more tender when baked in a microwave oven rather than a conventional oven. They found increasing the liquid level of cakes made in the microwave oven enabled them to produce a cake with a similar cell structure, moistness, and volume of a conventionally baked cake.

Internal temperature measurements. The sweetness of non-sucrose sweetened cakes baked in microwave oven was greater than corresponding cakes baked conventionally. Beck (1978) indicated APM breaks down to the non-sweet diketopiperazine with heat and time. When cakes are cooked in the microwave oven, the internal temperature of the cake and amount of time was less than for corresponding cakes made in the conventional oven. The final temperature of conventionally cooked cakes was higher than corresponding cakes baked in the microwave oven (Figure 2), and results of evaluations given in Table 8. Cakes containing additional levels of aspartame or fructose had a lower final temperature when baked in the microwave oven than corresponding cakes baked in the conventional oven. Cakes made in the microwave oven with 50 g fructose were evaluated as sweetest ($p \leq 0.05$) (Table 8) and had the lowest final temperature (Figure 2) of the cakes evaluated. Table 8 indicate microwave cooked cakes were rated sweeter than conventionally cooked cakes.

Figure 2. Final internal temperature of spice cakes baked in microwave and conventional oven.


230
210
190
170
150
CONVENTIONAL OVEN
MICROWAVE OVEN
TEMPERATURE
°F
aspartame
1 g
2 g
fructose
37g
50g

Cake Flavor and Treatment Interactions

In Tables 11 and 12, means are given for the combined panels where the measurements between type of cake and treatment was significant. Table 11 reports means of cakes baked conventionally and Table 12 reports means of cakes baked in the microwave oven. Means where interactions for flavor and treatment were not significant appear in the Appendix, Tables A-6, A-7, A-8, A-9 and A-10.

Sensory Measurements

Conventional oven. In Table 11, chocolate cakes with 1 or 2 g added APM or 37 g fructose were significantly less uniform for cell structure than other cakes. Lemon cakes with 50 g added fructose had significantly more uniform cells than chocolate cakes with 50 g fructose. Cell structure of orange cakes with 1 g APM was significantly more uniform than for any chocolate cakes; the lemon cakes with 1 g APM or 37 g fructose; all other orange cakes; and spice cakes with either level of APM or with 37 g fructose.

Chocolate cakes with fructose and lemon cakes with APM were not significantly different from each other in tenderness but were significantly more tender than chocolate cakes made with either level of APM; however, they were significantly less tender than all other cake and treatment combinations. Orange and spice cakes with 50 g fructose were not significantly different from each other but were significantly more tender than chocolate or lemon cakes.

Overall eating quality was highest ($p \leq 0.05$) for orange and lemon cakes with 50 g fructose, and these cakes were not significantly different from each other. Chocolate cakes with 2 g APM and lemon and spice

Table 11. Comparison of mean values for cake flavor and treatment interactions for cell uniformity,[1] tenderness,[1] overall eating quality,[1] and standing height[2] of conventionally baked cakes.

Type and Level Sweetener	Cake Flavor	Cell Uniformity[3,4] LSD=0.28	Tenderness[3,4] LSD=0.22	Overall Eating Quality[3,4] LSD=0.23	Standing Height[4] LSD=0.39
1 g APM	Chocolate	2.64^{a}	3.28^{a}	2.54^{cde}	4.32^{abc}
2 g APM	Chocolate	2.76^{a}	3.25^{a}	2.16^{a}	4.01^{ab}
37 g Fructose	Chocolate	2.82^{a}	3.63^{b}	2.80^{fgh}	4.37^{bc}
50 g Fructose	Chocolate	3.24^{bcd}	3.72^{b}	2.87^{gh}	4.49^{c}
1 g APM	Lemon	3.16^{bcd}	3.79^{bc}	2.25^{ab}	4.11^{abc}
2 g APM	Lemon	3.55^{efg}	3.64^{b}	2.41^{bc}	3.95^{a}
37 g Fructose	Lemon	3.38^{def}	4.08^{de}	2.72^{defg}	4.05^{ab}
50 g Fructose	Lemon	3.64^{fg}	3.98^{cde}	3.02^{hi}	4.07^{ab}
1 g APM	Orange	3.67^{g}	3.97^{cd}	2.49^{cd}	4.03^{ab}
2 g APM	Orange	3.20^{bcd}	4.00^{cde}	2.51^{cd}	4.07^{ab}
37 g Fructose	Orange	3.34^{cde}	4.17^{def}	2.72^{defg}	4.15^{abc}
50 g Fructose	Orange	3.37^{cdef}	4.37^{f}	3.13^{i}	4.19^{abc}
1 g APM	Spice	3.09^{bc}	4.14^{de}	2.14^{a}	4.08^{ab}
2 g APM	Spice	3.04^{b}	4.07^{de}	2.59^{cde}	4.15^{abc}
37 g Fructose	Spice	3.33^{cd}	3.99^{cde}	2.80^{fgh}	4.17^{abc}
50 g Fructose	Spice	3.44^{defg}	4.20^{ef}	2.76^{efg}	4.07^{ab}

[1]Six observations.

[2]Three observations.

[3]Five point rating scale with 1.0, lowest to 5.0, highest.

[4]Mean values with same letter in the same column are not significantly different from each other ($p \leq 0.05$).

Table 12. Comparison of mean values for cake flavor and treatment interactions for cell uniformity,[1] tenderness,[1] overall eating quality,[1] and standing height[2] of microwave baked cakes.

Type and Level Sweetener	Cake Flavor	Cell Uniformity[3,4] LSD=0.28	Tenderness[3,4] LSD=0.22	Overall Eating Quality[3,4] LSD=0.23	Standing Height[4] LSD=0.39
1 g APM	Chocolate	3.12[ab]	3.43[cde]	2.49[cde]	4.21[d]
2 g APM	Chocolate	2.92[a]	3.49[cde]	2.36[bc]	4.19[d]
37 g Fructose	Chocolate	2.94[a]	3.56[defg]	2.53[cdef]	4.31[d]
50 g Fructose	Chocolate	3.34[bcd]	3.88[h]	2.39[bc]	4.34[d]
1 g APM	Lemon	3.44[cd]	3.29[bc]	2.08[a]	3.41[abc]
2 g APM	Lemon	3.57[de]	3.37[cd]	2.09[a]	3.49[abc]
37 g Fructose	Lemon	3.49[cde]	3.61[efg]	2.43[cd]	3.54[abc]
50 g Fructose	Lemon	3.77[e]	3.74[gh]	2.76[f]	3.50[abc]
1 g APM	Orange	3.26[bc]	3.36[cd]	2.16[ab]	3.55[bc]
2 g APM	Orange	3.08[ab]	3.08[ab]	2.04[a]	3.13[a]
37 g Fructose	Orange	3.61[de]	3.58[defg]	2.45[cd]	3.59[bc]
50 g Fructose	Orange	3.43[cd]	3.72[fgh]	2.63[def]	3.58[bc]
1 g APM	Spice	3.13[ab]	3.06[a]	2.16[ab]	3.29[ab]
2 g APM	Spice	3.53[cde]	3.50[cdef]	2.47[cd]	3.37[abc]
37 g Fructose	Spice	3.53[cde]	3.70[fgh]	2.71[ef]	3.55[bc]
50 g Fructose	Spice	3.48[cd]	3.61[efg]	2.50[cde]	3.76[c]

[1]Six observations.

[2]Three observations.

[3]Five point rating scale with 1.0, lowest to 5.0, highest.

[4]Mean values with same letter in the same column are not significantly different from each other ($p \leq 0.05$).

cakes with 1 g APM were not significantly different from each other. Chocolate cakes with the highest level and spice cakes with the lowest level APM were rated significantly lower in eating quality than all other conventionally baked cakes.

Microwave oven. Chocolate cakes with 2 g APM or 37 g fructose were not significantly different ($p \leq 0.05$) from orange or spice cakes with 1 g APM but were significantly less uniform in cell structure than other cakes (Table 12). Chocolate cakes with 50 g fructose were not significantly more tender than lemon or orange cakes made with 50 g fructose or spice cakes with 37 g fructose.

Microwave cakes generally are less tender and had a lower overall eating quality than conventionally baked cakes; however, chocolate cakes cooked in the microwave oven with 1 or 2 g APM or 50 g fructose were more tender than the corresponding chocolate cakes baked conventionally (Tables 11 and 12). Lemon and orange cakes cooked in the microwave oven with both levels of APM and spice cakes with 1 g APM were not significantly different ($p \leq 0.05$) from each other but were scored significantly lower in overall eating quality than other cakes. Lemon and orange cakes with 50 g fructose and spice cakes and chocolate cakes with 37 g fructose were the same ($p \leq 0.05$), but lemon cakes with 50 g fructose were scored significantly lower than other cakes.

Physical Measurements

Conventional oven. Lemon cakes (Table 11) made with the added 2 g APM were significantly lower in volume than chocolate cakes with 37 and 50 g fructose, which had the highest standing heights of all cakes baked conventionally.

Microwave oven. As with conventionally baked cakes, chocolate cakes (Table 12) had the highest standing heights and this was significantly higher than for all other microwave cooked cakes. Orange cakes with 2 g APM were significantly lower in volume than the other orange cakes, spice cakes with either level of fructose, or all chocolate cakes. Spice cakes with 1 g APM or orange cakes with 2 g APM were significantly lower in volume than chocolate cakes.

Work done by Street and Surratt (1961) reported an increased liquid level in microwave cakes resulted in cakes with a similar volume to conventionally baked cakes. In this study we did not increase the liquid level, but the emulsifier, SSL, and doubled amounts of double acting baking powder, were used to increase cake volume.

Differences Between Panels

In Table 13, the mean values for the two panels are compared for the three replications of all cake flavors and treatments for the sensory evaluation of cake characteristics. No significant differences resulted between the textural qualities: cell uniformity, moistness, or crumb tenderness. A significant difference between the panels for sweetness, crust bitterness, and overall eating quality was noted. However, no difference was found for crumb bitterness. The non-diabetics determined the cakes to be significantly sweeter, crust bitterness to be greater ($p \leq 0.05$), and the cakes to be generally higher ($p \leq 0.05$) in overall eating quality than did the diabetic panelists. Comments on the scorecards indicated sweetness was more important than cake texture when overall eating quality was evaluated by diabetic panelists.

Table 13. Mean values[1,2] for sensory attributes of cakes evaluated by separate panels of diabetics and non-diabetics.

Cake Characteristic	Panelists	
	Diabetic	Non-diabetic
Texture[3]		
Uniform cells	3.25[a]	3.33[a]
Moistness	2.93[a]	2.91[a]
Tender crumb	3.73[a]	3.66[a]
Flavor		
Sweetness[3]	2.33[a]	2.42[b]
Crust bitterness[4]	3.95[a]	3.75[b]
Crumb bitterness[4]	4.18[a]	4.10[a]
Overall eating quality[3]	2.31[a]	2.70[b]

[1]Three replications, four cake flavors, and eight treatments, for total of 96 observations.

[2]Mean values in same row with same letter are not significantly different ($p \leq 0.05$).

[3]Five point scale with 1.0, lowest to 5.0, highest.

[4]Five point scale with 5.0, highest to 1.0, lowest.

Cake Flavor

No significant interactions ($p \leq 0.05$) between panel type and cake flavor were noted for the cake characteristics: moistness, tenderness, sweetness, crust bitterness, crumb bitterness, or overall eating quality (Appendix, Table A-13). Table 14 compares the mean value of three replications for the sensory evaluation of cell uniformity for cake flavors pooled by treatment and analyzed by diabetic and non-diabetic panels. Generally, non-diabetics determined the cakes to have a more uniform cell structure than diabetics.

Table 14. Mean values[1] for sensory evaluation[2] of cell uniformity of cake flavors.

Panel Type Characteristic	Cake Flavor				LSD
	Chocolate	Lemon	Orange	Spice	
Diabetic					
Cell uniformity[3]	2.87[a]	3.39[bc]	3.44[c]	3.29[b]	0.14
Non-diabetic					
Cell uniformity[3]	3.07[a]	3.61[b]	3.30[c]	3.36[c]	0.14

[1]Three replications, eight treatments, for total of 24 observations.

[2]Five point scale with 1.0, lowest, to 5.0, highest.

[3]Mean values in same row with same letter are not significantly different ($p \leq 0.05$).

For cell uniformity, both panels indicated chocolate cakes were significantly less uniform than other cake flavors. Diabetic panelists determined orange cakes were significantly the most uniform-grained of the cake flavors; however, non-diabetic panelists considered lemon cakes significantly the most uniform of the four cake flavors. Diabetic panelists found no difference in cell uniformity between lemon or spice cake flavors or between lemon and orange cake flavors. Non-diabetic panelists found no significant differences between the orange and spice cakes.

Type of Oven or Sweetener Used

No significant interactions ($p \leq 0.05$) between panel type and treatment were found for the cake characteristics: cell uniformity, tenderness, sweetness, crust bitterness, crumb bitterness, or overall eating quality.

Table 15 shows comparison of the mean values of three replications for sensory evaluation by the two panels for moistness pooled for cake flavor. Both panels evaluated the conventionally baked cakes more moist than microwave baked cakes.

Table 15. Mean values[1] for sensory evaluation[2] of cake moistness for treatments.

Measurements[3]	Type and Level of Sweetening Agent				LSD
	1 g APM	2 g APM	37 g Fructose	50 g Fructose	
Diabetic					
Conventional					
Moistness	3.28^{ab}	3.18^{a}	3.16^{a}	3.43^{bc}	0.18
Microwave					
Moistness	2.54^{a}	2.66^{a}	2.66^{a}	2.56^{a}	0.18
Non-diabetic					
Conventional					
Moistness	3.35^{ac}	3.28^{ac}	3.47^{b}	3.46^{bc}	0.18
Microwave					
Moistness	2.48^{a}	2.45^{a}	2.30^{a}	2.46^{a}	0.18

[1]Three replications, four cake flavors, total of 12 observations.

[2]Five point scale with 1.0, lowest, to 5.0, highest.

[3]Mean values in same row with same letter are not significantly different ($p \leq 0.05$).

Cakes cooked by microwaves were significantly less moist than cakes baked conventionally although neither panel noted significant differences between types and levels of sweetening agents for microwave cakes.

Diabetics determined cakes with 50 g fructose were significantly more moist than cakes with 2 g APM and 37 g fructose; however, no differences were noted between cakes with 50 g fructose and 1 g APM or among cakes prepared with either level of APM and the low level of fructose. The non-diabetics evaluated cakes with 37 g fructose significantly more moist than cakes made with APM, and found no differences ($p \leq 0.05$) between levels of APM or between levels of fructose.

The importance of users of products participating in sensory studies cannot be overemphasized. Limited work was found using persons consuming and evaluating products not containing sucrose. One previous study used diabetics and "weight watchers" as sensory judges (Hardy and co-workers, 1979). Fructose was not found to be sweeter in sugar cookies, white cake, or vanilla pudding, they did not recommend the substitution of fructose for sucrose because of the role sweetness plays in product acceptability. Results of this study agree with those conclusions; furthermore, we found diabetics and non-diabetics perceive sweetness intensity differently.

SUMMARY AND CONCLUSIONS

Cakes prepared with aspartame were studied to determine the effect on sweetness and other sensory qualities of different cake flavors, microwave and conventional baking, and increased levels of aspartame or small levels of fructose for further sweetening. Sensory characteristics were evaluated by a panel of diabetics and a panel of non-diabetics.

Four flavors; chocolate, lemon, orange, and spice, were evaluated. The panelists assessed the cake characteristics: cell uniformity, tenderness, moistness, sweetness, crust and crumb bitterness and overall eating quality. Chocolate was evaluated as the least uniform in cell structure, least tender, driest, sweetest and most bitter for crust and crumb of all flavors studied.

Cakes cooked in the microwave oven were considered to be sweeter but lower in textural qualities than cakes baked in the conventional oven. The microwave cooked cakes were drier than conventionally cooked cakes. In this study, the chocolate cakes generally were considered more tender than corresponding cakes baked conventionally, although the other cake flavors were less tender when cooked by microwaves.

The addition of fructose and aspartame enhanced the sweetness of the cakes. The use of higher levels of aspartame alone was not as effective as the addition of small amounts of fructose to cakes made with aspartame.

The non-diabetics evaluated the cakes as sweeter and more bitter than the diabetic panelists. The two panels did not differ in their evaluation of the textural qualities, however.

Based on these results, one can conclude:

1. Non-diabetics perceived sweetness of conventionally baked cakes as higher than diabetics. The non-diabetics perceived crust bitterness as being more intense than the diabetics.
2. Chocolate flavored cakes were the sweetest and the most bitter of the flavors evaluated: chocolate, spice, lemon, and orange.
3. The addition of fructose improved the textural qualities and enhanced the sweetness of aspartame-sweetened cakes to a greater extent than did additional aspartame.
4. The cakes cooked by microwaves were evaluated as sweeter and lower in tenderness and moistness than cakes baked in the conventional oven.

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APPENDIX

Figure A-1. Equipment used to measure texture.

THIS BOOK CONTAINS NUMEROUS PICTURES THAT ARE ATTACHED TO DOCUMENTS CROOKED.

THIS IS AS RECEIVED FROM CUSTOMER.

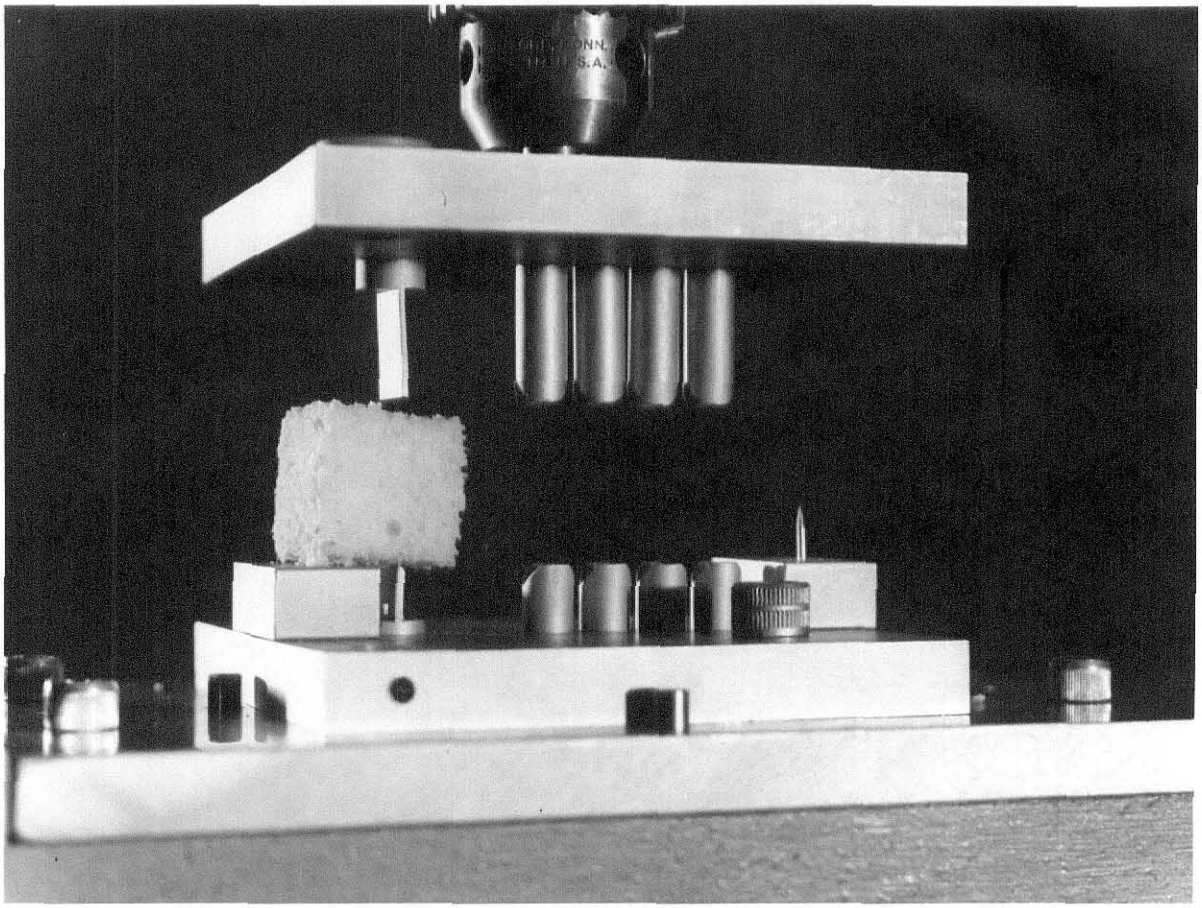

Figure A-2. Scorecard used for sensory evaluations.

EVALUATION OF LAYER CAKES

NAME ______________________________

DATE ______________________________

Place a mark for each sample at the point which best describes your evaluation of the layer cakes. Label each mark with the sample code number.

DESIRABLE CHARACTERISTICS | UNDESIRABLE CHARACTERISTICS

TEXTURE

1. Uniform cells — Irregular cells

5	4	3	2	1
	moderately uniform	neither	moderately irregular	

2. Moistness — Dryness

5	4	3	2	1
	moderately moist	neither	moderately dry	

3. Tender crumb — Tough crumb

5	4	3	2	1
	moderately tender	neither	moderately tough	

FLAVOR

1. Sweetness — Lack of sweetness

5	4	3	2	1
very		moderately	slightly	none

2. Bitterness — Very bitter

5	4	3	2	1
	slightly bitter	moderately bitter		

A. Crust___

B. Crumb___

OVERALL EATING QUALITY

5	4	3	2	1
excellent	very good	moderately good	fair	poor

COMMENTS:

Table A-1. List of ingredients, suppliers and lot numbers.

Ingredients	Supplier	Lot Number
Cake flour	Sofasilk	--
Equa®	G.D. Searle	--
Shortening	Crisco	--
Baking powder, double acting	Calumet	0-029
Salt	Good Value	--
Whole egg	All Star Dairy	--
Whole milk	All Star Dairy	--
Buttermilk	All Star Dairy	--
Aspartame	G.D. Searle	C-2556--Rep 1 and 2
		C-0075--Rep 3
SSL	Artodan	SP-50
XG	Keltrol	KTL-26360
Cocoa	Hershey	--
Vanilla Extract	French's	--
Lemon Extract	French's	--
Orange Peel	Fresh oranges obtained locally	--
Cinnamon	French's	--
Allspice	French's	--
Mace	French's	--
Fructose	Sigma	88C-0298

Table A-2. Cake treatments and combinations.

Treatment	Oven Type[1]	Additional Sweetener	
		g Aspartame (%)	g Fructose (%)
1	C	1.0 (0.5-0.6)[2]	--
2	M		
3	C	2.0 (1.0-1.2)[2]	--
4	M		
5	C	--	37 (18.5-25)
6	M		
7	C	--	50 (22.3-30.1)
8	M		

[1]C--conventional oven and M--microwave oven.

[2]Basic formulas contained 0.5% or 0.6% aspartame.

Table A-3. Methods for physical measurements.

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pH of batter. 25 grams of batter were mixed with 100 ml of distilled water in a 250 ml glass beaker. The beaker contents were stirred using a magnetic stirrer. Three readings were obtained on the Horizon, model 5998-10 and an average of the readings recorded.

Specific gravity. Specific gravity was used to indicate the amount of air incorporated into the batter. The procedure found in Campbell et al. (1978) was followed except the cup was filled, tapped six times and excess batter was removed with a spatula.

pH of crumb. 25 grams of crumb was mixed with 100 ml of distilled water in a 250 ml glass beaker. The beaker contents were stirred using a magnetic stirrer. Three readings were obtained and an average of the readings recorded.

Standing height. Standing height was used as an index to volume. Height of the center slice was measured at the outer edges, the center, and two points halfway between the center and outer edges. An average of the five measurements was recorded as an index to volume.

Internal temperature. Internal temperature of cakes was measured and recorded using the Honeywell potentiometer. One probe was placed at the center of the cake, a second probe was placed 2.54 cm (1 in.) from the center point and a third probe was situated 3.81 cm (1½ in.) from the center. Temperatures were recorded at 1 min intervals throughout the baking period in the conventional oven. For microwave cakes, the internal temperature was taken at the same positions (center, 2.54 cm and 3.81 cm from center) 1 min after removing cakes from the oven.

Table A-4. LSD values for Table 7.

Cake Flavors	Distance to the First Peak	Force Required for the First Peak	Distance Between the Two Peaks	Force Required for the Second Peak
Chocolate and lemon	5.37	5.37	9.64	28.35
Chocolate and orange	5.25	5.25	9.54	28.05
Chocolate and spice	5.29	5.29	9.60	28.25
Lemon and orange	5.21	5.21	9.46	27.84
Lemon and spice	5.25	5.25	9.53	28.03
Orange and spice	5.19	5.19	9.43	27.73

Table A-5. LSD values for Table 10.

Treatments	LSD Value	Significant
1 and 2	39.81	
1 and 3	39.22	
1 and 4	39.81	*
1 and 5	38.94	
1 and 6	40.12	
1 and 7	38.94	
1 and 8	39.50	
2 and 3	39.81	
2 and 4	40.39	
2 and 5	39.54	*
2 and 6	40.70	
2 and 7	39.54	*
2 and 8	40.09	
3 and 4	39.81	
3 and 5	38.94	
3 and 6	40.12	
3 and 7	38.94	
3 and 8	39.50	
4 and 5	38.94	*
4 and 6	40.12	
4 and 7	38.94	*
4 and 8	39.50	
5 and 6	39.86	*
5 and 7	38.67	
5 and 8	39.23	
6 and 7	39.86	*
6 and 8	40.41	
7 and 8	39.23	*

Table A-6. Comparison of mean values[1] when differences were not significant for cake flavor and treatment interactions for sensory attributes of conventionally baked cakes.

Type and Level of Sweetener	Cake Flavor	Moistness[2]	Sweetness[2]	Crust Bitterness[3]	Crumb Bitterness[3]
1 g APM	Chocolate	2.67	2.20	3.66	3.93
2 g APM	Chocolate	2.75	2.33	3.30	3.69
37 g Fructose	Chocolate	2.86	2.50	3.60	4.19
50 g Fructose	Chocolate	2.90	2.75	3.56	4.00
1 g APM	Lemon	3.56	2.11	3.55	4.08
2 g APM	Lemon	3.28	2.27	3.41	3.80
37 g Fructose	Lemon	3.80	2.27	3.92	4.31
50 g Fructose	Lemon	3.62	2.61	3.59	4.44
1 g APM	Orange	3.50	1.99	3.73	4.10
2 g APM	Orange	3.50	2.42	3.76	3.99
37 g Fructose	Orange	3.37	2.20	3.99	4.47
50 g Fructose	Orange	3.72	2.56	4.19	4.55
1 g APM	Spice	3.54	2.01	3.55	3.87
2 g APM	Spice	3.39	2.31	3.40	3.88
37 g Fructose	Spice	3.22	2.25	4.03	4.35
50 g Fructose	Spice	3.55	2.36	3.89	4.44

[1]Six observations.

[2]Five point scale with 5.0, highest to 1.0, lowest.

[3]Five point scale with 5.0, lowest to 1.0, highest.

Table A-7. Comparison of mean values[1] when differences were not significant for cake flavor and treatment interactions for sensory attributes of microwave baked cakes.

Type and Level of Sweetener	Cake Flavor	Moistness[2]	Sweetness[2]	Crust Bitterness[3]	Crumb Bitterness[3]
1 g APM	Chocolate	2.13	2.50	3.76	4.06
2 g APM	Chocolate	2.24	2.78	3.60	3.94
37 g Fructose	Chocolate	2.08	2.57	3.91	4.08
50 g Fructose	Chocolate	2.12	2.96	4.00	4.11
1 g APM	Lemon	2.82	2.27	3.60	3.79
2 g APM	Lemon	2.80	2.28	3.56	3.94
37 g Fructose	Lemon	2.73	2.35	4.33	4.33
50 g Fructose	Lemon	2.61	2.60	4.18	4.55
1 g APM	Orange	2.61	2.15	3.85	3.84
2 g APM	Orange	2.59	2.41	3.75	3.77
37 g Fructose	Orange	2.59	2.27	4.36	4.44
50 g Fructose	Orange	2.70	2.52	4.23	4.44
1 g APM	Spice	2.47	2.10	4.03	4.23
2 g APM	Spice	2.60	2.39	4.02	4.12
37 g Fructose	Spice	2.51	2.35	4.51	4.47
50 g Fructose	Spice	2.61	2.50	4.25	4.31

[1]Six observations.

[2]Five point scale with 5.0, highest to 1.0, lowest.

[3]Five point scale with 5.0, lowest to 5.0, highest.

Table A-8. Mean values[1] when differences were not significant for cake flavor and treatment interactions for physical measurements of cakes.

Type and Level of Sweetener	Cake Flavor	Batter pH	Crumb[2] pH	Crumb[3] pH	Specific Gravity
1 g APM	Chocolate	6.82	6.29	5.59	0.7568
2 g APM	Chocolate	6.83	6.24	6.58	0.8031
37 g Fructose	Chocolate	6.87	6.28	6.70	0.7423
50 g Fructose	Chocolate	6.92	6.24	6.74	0.7325
1 g APM	Lemon	5.95	6.89	7.27	0.7711
2 g APM	Lemon	6.97	6.54	7.12	0.7877
37 g Fructose	Lemon	6.98	7.02	7.33	0.7784
50 g Fructose	Lemon	6.99	6.87	7.31	0.7741
1 g APM	Orange	6.77	6.84	7.14	0.7573
2 g APM	Orange	6.81	6.92	7.12	0.7632
37 g Fructose	Orange	6.73	7.05	7.35	0.7251
50 g Fructose	Orange	6.82	6.99	7.32	0.7362
1 g APM	Spice	6.82	6.85	7.18	0.7346
2 g APM	Spice	6.87	6.77	7.01	0.7356
37 g Fructose	Spice	6.87	6.81	7.29	0.7289
50 g Fructose	Spice	6.91	6.83	7.23	0.7274

[1]Three observations.

[2]Cakes baked in conventional oven.

[3]Cakes baked in microwave oven.

Table A-9. Mean values when differences were not significant for cake flavor and treatment interactions for texture measurements by the Instron Universal Testing Machine for conventionally baked cakes.

Type and Level of Sweetener	Cake Flavor	Distance[1]	Force[2]	Distance[3]	Force[4]
1 g APM	Chocolate	34.25	49.75	57.75	209.88
2 g APM	Chocolate	32.88	57.38	66.63	215.50
37 g Fructose	Chocolate	38.44	47.56	70.56	200.22
50 g Fructose	Chocolate	43.56	54.00	59.33	178.22
1 g APM	Lemon	37.11	35.78	66.78	128.44
2 g APM	Lemon	33.67	33.11	67.11	118.78
37 g Fructose	Lemon	37.33	26.89	61.00	77.33
50 g Fructose	Lemon	39.00	31.00	59.77	85.44
1 g APM	Orange	35.67	29.00	64.11	78.33
2 g APM	Orange	35.00	32.44	64.78	94.56
37 g Fructose	Orange	32.78	29.89	68.67	76.44
50 g Fructose	Orange	35.78	28.77	61.11	68.11
1 g APM	Spice	33.89	28.33	66.44	122.00
2 g APM	Spice	29.22	31.89	73.67	145.11
37 g Fructose	Spice	33.11	32.44	66.11	117.11
50 g Fructose	Spice	32.33	30.22	67.56	105.11

[1]Distance to the first peak, cm.

[2]Force required for the first peak, kg.

[3]Distance between peaks, cm.

[4]Force required for the second peak, kg.

Table A-10. Mean values when differences were not significant for cake flavor and treatment interactions for texture measurements by the Instron Universal Testing Machine for microwave baked cakes.

Type and Level of Sweetener	Cake Flavor	Distance[1]	Force[2]	Distance[3]	Force[4]
1 g APM	Chocolate	57.75	59.13	48.25	226.00
2 g APM	Chocolate	43.63	49.13	59.63	219.13
37 g Fructose	Chocolate	36.25	37.75	62.25	218.00
50 g Fructose	Chocolate	35.63	33.88	71.50	190.75
1 g APM	Lemon	42.13	39.13	57.63	150.38
2 g APM	Lemon	38.13	38.75	59.50	152.25
37 g Fructose	Lemon	36.14	41.00	65.57	133.43
50 g Fructose	Lemon	45.00	30.33	60.22	151.67
1 g APM	Orange	36.78	35.44	63.67	104.11
2 g APM	Orange	23.75	36.88	79.63	161.38
37 g Fructose	Orange	32.89	39.78	71.56	130.56
50 g Fructose	Orange	39.11	32.56	68.33	110.11
1 g APM	Spice	21.00	25.38	80.63	157.38
2 g APM	Spice	21.33	32.00	84.22	188.22
37 g Fructose	Spice	30.25	24.50	75.13	155.75
50 g Fructose	Spice	16.75	22.50	86.88	167.00

[1]Distance to the first peak, cm.

[2]Force required for the first peak, kg.

[3]Distance between peaks, cm.

[4]Force required for the second peak, kg.

Table A-11. Internal temperature of spice cakes taken one minute after removal from the microwave oven.

	Measurement[1]		
	1	2	3
1 g APM	199	210	182
2 g APM	197	213	182
37 g Fructose	196	190	168
50 g Fructose	191	186	175

[1]Measurements 1, 2, and 3 were taken 2.54 cm (1 in.) from the center of the cake, in the center of the cake, and 3.81 cm (1½ in.) from the center of the cake, respectively.

Table A-12. Internal temperature of spice cakes taken during baking in the conventional oven.

Time (min)	1 g APM Measurement[1]			2 g APM Measurement			37 g Fructose Measurement			50 g Fructose Measurement		
	1	2	3	1	2	3	1	2	3	1	2	3
0	86	104	96	95	90	93	87	88	83	87	88	88
1	100	129	118	115	104	113	110	110	106	104	109	102
2	109	144	131	126	112	124	139	139	123	124	128	123
3	116	152	140	131	117	131	142	140	132	135	139	136
4	122	157	146	131	117	131	152	148	138	142	145	145
5	128	162	152	135	120	137	162	157	145	147	149	152
6	133	162	156	139	125	141	169	162	149	150	152	157
7	138	161	160	143	129	144	175	163	153	152	156	162
8	141	161	163	145	134	147	177	165	155	154	157	165
9	144	163	165	145	138	149	179	167	157	155	158	167
10	145	164	165	146	143	150	176	168	158	156	159	168
11	145	166	168	147	148	153	174	169	160	158	160	170
12	144	167	169	150	153	154	170	170	161	160	161	171
13	144	169	169	152	159	155	167	171	161	162	163	171
14	144	171	170	156	163	156	165	171	163	166	167	173
15	144	173	170	160	168	158	165	172	163	171	172	174
16	146	177	172	163	172	159	163	173	164	176	177	175
17	148	181	170	168	176	160	164	175	165	180	182	177
18	148	184	169	171	180	161	165	177	166	187	191	181
19	150	187	169	174	183	161	167	180	167	191	195	184
20	152	190	168	178	187	165	169	183	167	195	198	187
21	153	193	168	183	191	168	172	185	168	196	200	189

[1] Measurements 1, 2, and 3 were taken 2.54 cm (1 in.) from the center of the cake, in the center of the cake, and 3.81 cm ($1\frac{1}{2}$ in.) from the center of the cake, respectively.

Table A-12. (cont.)

Time (min)	1 g APM			2 g APM			37 g Fructose			50 g Fructose		
	Measurement			Measurement			Measurement			Measurement		
	1	2	3	1	2	3	1	2	3	1	2	3
22	155	195	167	187	194	170	174	187	169	198	201	190
23	159	198	167	190	197	173	175	190	170	201	205	193
24	161	200	167	193	200	177	178	192	172	204	207	197
25	165	202	168	196	202	180	181	193	174	206	210	200
26	167	205	169	199	205	184	183	197	177	210	213	203
27	171	208	172	202	207	187	186	199	180	212	215	206
28	174	211	175	204	209	191	189	201	183	214	218	209
29	177	214	178	206	210	195	193	204	187	216	220	212
30	180	216	181	208	214	199	195	207	190	218	221	215

Table A-13. Mean values[1] when differences were not significant for sensory evaluation of cake flavor.

Panel Type Cake Characteristic	Chocolate	Lemon	Orange	Spice
Diabetic				
Tenderness[2]	3.57	3.69	3.83	3.81
Moistness[2]	2.53	3.19	3.03	2.99
Sweetness[2]	2.56	2.23	2.27	2.28
Crumb bitterness[3]	4.11	4.18	4.26	4.19
Crust bitterness[3]	3.84	3.84	4.10	4.00
Overall eating quality[2]	2.35	2.22	2.36	2.31
Non-diabetic				
Tenderness[2]	3.49	3.68	3.73	3.75
Moistness[2]	2.41	3.11	3.11	2.99
Sweetness[2]	2.59	2.46	2.36	2.29
Crumb bitterness[3]	3.89	4.13	4.14	4.23
Crust bitterness[3]	3.50	3.69	3.87	3.92
Overall eating quality[2]	2.68	2.72	2.67	2.72

[1]Three replications, eight treatments, total of 24 observations.

[2]Five point scale with 5.0, highest to 1.0, lowest.

[3]Five point scale with 5.0, lowest to 1.0, highest.

Table A-14. Mean values[1] when differences were not significant for sensory evaluation of treatments of cakes.

Oven Type[2]	Type and Level of Sweetener	Type of Panel[3]	Cell Uniformity[4]	Tenderness[4]	Sweetness[4]	Crust Bitterness[5]	Crumb Bitterness[5]	Overall Eating Quality[4]
C	1 g APM	D	3.09	3.82	2.08	3.82	4.09	2.23
C	1 g APM	N	3.20	3.77	2.07	3.43	3.90	2.48
M	1 g APM	D	3.25	3.46	2.27	3.94	4.08	2.07
M	1 g APM	N	3.23	3.11	2.23	3.67	3.88	2.39
C	2 g APM	D	3.11	3.75	2.18	3.70	3.95	2.25
C	2 g APM	N	3.17	3.73	2.48	3.23	3.73	2.58
M	2 g APM	D	3.26	3.47	2.49	3.93	4.04	2.11
M	2 g APM	N	3.29	3.24	2.44	3.54	3.85	2.37
C	37 g Fructose	D	3.23	3.93	2.22	3.86	4.30	2.53
C	37 g Fructose	N	3.21	4.00	2.39	3.91	4.36	2.99
M	37 g Fructose	D	3.27	3.68	2.34	4.33	4.38	2.31
M	37 g Fructose	N	3.51	3.54	2.43	4.23	4.28	2.75
C	50 g Fructose	D	3.42	4.02	2.47	3.72	4.28	2.66
C	50 g Fructose	N	3.42	4.11	2.67	3.89	4.44	3.23
M	50 g Fructose	D	3.36	3.67	2.60	4.26	4.34	2.35
M	50 g Fructose	N	3.64	3.80	2.69	4.07	4.36	2.79

[1]Three replications, four cake flavors, total of 12 observations.

[2]C--conventional oven and M--microwave oven.

[3]D--diabetic panel and N--non-diabetic panel.

[4]Five point rating scale with 5.0, highest to 1.0, lowest.

[5]Five point rating scale with 5.0, lowest to 1.0, highest.

Table A-15. Mean values[1] for interactions among type of treatment, cake flavor, and panel type for sensory characteristics.

Cake Flavor	Oven Type[2]	Panel Type[3]	Treatment[4]	Cell Uniformity[5]	Moistness[5]	Tenderness[5]	Sweetness[5]	Crust Bitterness[6]	Crumb Bitterness[6]	Overall Eating Quality[5]
Chocolate	C	D	1	2.65	2.87	3.42	2.23	3.85	4.02	2.34
Chocolate	C	N	1	2.63	2.47	3.14	2.17	3.47	3.85	2.74
Lemon	C	D	1	3.14	3.50	3.79	2.11	3.55	4.09	2.08
Lemon	C	N	1	3.19	3.63	3.79	2.11	3.55	4.07	2.42
Orange	C	D	1	3.72	3.27	4.02	2.09	4.02	4.33	2.43
Orange	C	N	1	3.62	3.72	3.92	1.88	3.45	3.87	2.54
Spice	C	D	1	2.83	3.47	4.04	1.90	3.86	3.93	2.06
Spice	C	N	1	3.36	3.60	4.23	2.12	3.25	3.81	2.22
Chocolate	M	D	2	3.13	2.13	3.47	2.47	4.04	4.10	2.28
Chocolate	M	N	2	3.12	2.14	3.40	2.53	3.48	4.02	2.71
Lemon	M	D	2	3.35	2.93	3.48	2.22	3.60	3.98	1.88
Lemon	M	N	2	3.53	2.72	3.09	2.32	3.61	3.61	2.28
Orange	M	D	2	3.36	2.83	3.50	2.31	4.11	4.07	2.24
Orange	M	N	2	3.17	2.40	3.22	1.98	3.58	3.60	2.08

[1]Three observations.

[2]C--conventional oven and M--microwave oven.

[3]D--diabetic panel and N--non-diabetic panel.

[4]Treatment 1 and 2--1 g of APM, Treatment 3 and 4--2 g APM, Treatment 5 and 6--37 g fructose and Treatment 7 and 8--50 g fructose.

[5]Five point rating scale with 5.0, highest to 1.0, lowest.

[6]Five point rating scale with 1.0, highest to 5.0, lowest.

Table A-15. (cont.)

Cake Flavor	Oven Type	Panel Type	Treat-ment	Cell Uni-formity	Moist-ness	Tender-ness	Sweet-ness	Crust Bitter-ness	Crumb Bitter-ness	Overall Eating Quality
Spice	M	D	2	3.14	2.29	3.40	2.10	4.03	4.17	1.86
Spice	M	N	2	3.12	2.66	2.72	2.11	4.03	4.29	2.47
Chocolate	C	D	3	2.81	2.86	3.30	2.22	3.36	3.81	2.08
Chocolate	C	N	3	2.72	2.65	3.20	2.43	3.23	3.57	2.24
Lemon	C	D	3	3.24	3.14	3.70	1.90	3.83	3.88	2.07
Lemon	C	N	3	3.86	3.43	3.58	2.64	2.99	3.71	2.75
Orange	C	D	3	3.35	3.39	4.03	2.36	4.03	4.04	2.53
Orange	C	N	3	3.04	3.61	3.97	2.46	3.48	3.95	2.49
Spice	C	D	3	3.03	3.34	3.95	2.26	3.59	4.09	2.33
Spice	C	N	3	3.06	3.44	4.18	2.37	3.21	3.68	2.84
Chocolate	M	D	4	2.77	2.38	3.53	2.96	4.01	4.12	2.28
Chocolate	M	N	4	3.06	2.10	3.44	2.61	3.19	3.75	2.44
Lemon	M	D	4	3.58	2.95	3.48	2.27	3.71	3.94	1.89
Lemon	M	N	4	3.56	2.65	3.26	2.29	3.41	3.94	2.29
Orange	M	D	4	3.16	2.64	3.28	2.27	3.92	3.92	1.85
Orange	M	N	4	3.00	2.54	2.88	2.54	3.58	3.62	2.22
Spice	M	D	4	3.52	2.69	3.60	2.47	4.06	4.16	2.41
Spice	M	N	4	3.55	2.52	3.41	2.31	3.99	4.08	2.53
Chocolate	C	D	5	2.72	2.68	3.74	2.34	3.63	4.32	2.60
Chocolate	C	N	5	2.92	3.05	3.53	2.66	3.58	4.06	3.00
Lemon	C	D	5	3.45	3.77	4.07	2.22	4.05	4.37	2.59
Lemon	C	N	5	3.31	3.84	4.08	2.32	3.78	4.25	2.84
Orange	C	D	5	3.43	3.08	4.05	2.09	3.82	4.37	2.43
Orange	C	N	5	3.27	3.66	4.29	2.31	4.17	4.57	3.00
Spice	C	D	5	3.31	3.11	3.88	2.24	3.94	4.16	2.48
Spice	C	N	5	3.34	3.34	4.10	2.26	4.12	4.54	3.12
Chocolate	M	D	6	2.80	2.20	3.59	2.56	4.07	4.22	2.38
Chocolate	M	N	6	3.09	1.96	3.53	2.59	3.74	3.94	2.69

Table A-15. (cont.)

Cake Flavor	Oven Type	Panel Type	Treat-ment	Cell Uni-formity	Moist-ness	Tender-ness	Sweet-ness	Crust Bitter-ness	Crumb Bitter-ness	Overall Eating Quality
Lemon	M	D	6	3.30	2.96	3.51	2.25	4.34	4.42	2.17
Lemon	M	N	6	3.67	2.51	3.70	2.45	4.32	4.24	2.69
Orange	M	D	6	3.45	2.66	3.72	2.21	4.42	4.40	2.15
Orange	M	N	6	3.77	2.52	3.44	2.33	4.30	4.47	2.75
Spice	M	D	6	3.54	2.82	3.90	2.33	4.48	4.47	2.57
Spice	M	N	6	3.52	2.19	3.49	2.37	4.55	4.47	2.86
Chocolate	C	D	7	2.91	3.08	3.80	2.74	3.60	4.09	2.73
Chocolate	C	N	7	3.56	2.71	3.63	2.77	3.52	3.91	3.00
Lemon	C	D	7	3.62	3.64	3.89	2.38	3.33	4.19	2.54
Lemon	C	N	7	3.67	3.59	4.07	2.85	3.85	4.69	3.50
Orange	C	D	7	3.69	3.57	4.28	2.42	4.08	4.47	2.91
Orange	C	N	7	3.05	3.87	4.46	2.69	4.30	4.63	3.36
Spice	C	D	7	3.46	3.43	4.13	2.36	3.87	4.35	2.45
Spice	C	N	7	3.42	3.68	4.27	2.37	3.90	4.54	3.08
Chocolate	M	D	8	3.19	2.07	3.71	2.93	4.19	4.19	2.14
Chocolate	M	N	8	3.49	2.17	4.06	2.99	3.82	4.02	2.65
Lemon	M	D	8	3.41	2.66	3.61	2.52	4.31	4.57	2.54
Lemon	M	N	8	4.12	2.56	3.87	2.69	4.05	4.53	2.98
Orange	M	D	8	3.38	2.80	3.76	2.37	4.39	4.46	2.36
Orange	M	N	8	3.47	2.60	3.68	2.67	4.07	4.41	2.80
Spice	M	D	8	3.47	2.72	3.61	2.58	4.16	4.15	2.37
Spice	M	N	8	3.49	2.50	3.62	2.41	4.35	4.47	2.63

ALTERNATIVE SWEETENING SYSTEMS IN LAYER CAKES USING ASPARTAME AND FRUCTOSE

by

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ABSTRACT

Quality of shortened cakes prepared with aspartame was studied to determine the effect of cake flavor, cooking in a microwave or conventional oven and additional aspartame or fructose for sweetening. Sodium stearoyl-2-lactylate (SSL), was added to improve texture, xanthan gum (XG), was added to enhance sweetness, and double acting baking powder was added to increase cake volume. A randomized complete block design, blocked for cake flavor, was used. Cakes using two levels of additional aspartame and two levels of fructose were prepared in the microwave and conventional oven for each cake flavor. The four flavors included: chocolate, lemon, orange and spice.

Products were evaluated the following day at mid-morning and mid-afternoon sessions by panels of diabetics and non-diabetics. Panelists were trained to evaluate the cakes for textural and flavor qualities including: cell uniformity, moistness, tenderness, sweetness, bitter crust, bitter crumb, and overall eating quality. The Instron Universal Testing Machine (IUTM) was used to evaluate the texture of the cakes.

Chocolate flavored cakes were evaluated sweetest and most bitter of the four flavors studied by sensory analysis. Additional fructose and aspartame enhanced the sweetness of the cakes; however, the use of the higher levels of aspartame was not as effective as the addition of small amounts of fructose to cakes made with aspartame. Fructose further improved the textural qualities of cakes. IUTM measurements indicated chocolate cakes had the greatest crumb strength.

Cakes cooked in the microwave oven were evaluated sweeter than conventionally baked cakes but tenderness and moistness was rated lower for the microwave cooked cakes. Diabetic and non-diabetic panelists did not

differ in their evaluation of the textural characteristics. However, non-diabetics perceived sweetness and crust bitterness as more intense than did the diabetic panelists.