EVALUATION OF ALTERNATIVE FAT AND SWEETENER SYSTEMS IN CUPCAKES

by

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(ABSTRACT)

N-Flate^{TM} and a sweetening system of 1.5% aspartame, 35.5% fructose, and 63% polydextrose (AFP) were evaluated for their potential as fat and sugar substitutes, respectively. Four cupcake variations were prepared to compare the effects of replacing shortening with N-Flate^{TM}, and sugar with AFP. The four variations were shortening/sugar, shortening/AFP, N-Flate^{TM}/sugar, and N-Flate^{TM}/AFP. The evaluation involved objective measurements of the batter and the baked cupcakes, and sensory evaluation of the cupcakes.

Results of the objective measurements showed that the batter from the two variations prepared with N-Flate^{TM} had a significantly higher pH and specific gravity than the two variations prepared with shortening. A lower cake volume, a firmer texture, a higher moisture content, and a darker crumb color were also observed in the two variations prepared with N-Flate^{TM}.

The batter from the two variations prepared with AFP also had a higher pH and specific gravity than the two variations prepared with sugar. A lower cake volume, a firmer texture, a higher moisture content, and a lighter crust color were also observed in the two variations prepared with AFP.

Among the objective measurements, interaction effects were significant for specific gravity, volume, crust color and tenderness.

Sensory evaluation results showed that the two variations prepared with N-Flate™ were less tender and have poorer cell uniformity than those prepared with shortening. Variations prepared with AFP were found to be less moist, have a more bitter crust and crumb, and better cell uniformity than those prepared with sugar. No interaction effects were observed for any of the sensory attributes.

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INTRODUCTION

The health conscious public demands high quality, low calorie products that are low in fat and sugar. However, altering ingredient amounts to reduce the caloric content may compromise texture, mouthfeel, flavor and appearance.

The elimination of fat in cakes can be made possible by substituting with N-Flate^{TM}, an emulsifier blend of pregelatinized waxy maize starch and guar gum in a skim milk powder base (Smith, 1984). N-Flate^{TM} has been shown to produce good quality shortening-free cakes (Smith, 1984).

High intensity sweeteners are used in small quantities as a replacement for sucrose, thus reducing ingredient volume (Neville and Setser, 1986). A combination of aspartame and fructose as a replacement for sucrose was found to produce higher quality cakes than aspartame alone (Hess and Setser, 1983). The functional properties of sugar, however, are not replaced when other high intensity sweeteners are used as a substitute. Polydextrose, a bulking agent, may be used to compensate for the loss in volume. It has also been reported to function much like sugar but it is not sweet and contains only one calorie per gram (Freeman, 1982).

The objective of this study was to evaluate the potential of N-Flate^{TM} and a sweentener system of 1.5% aspartame, 35.5% fructose, and 63% polydextrose (AFP) as substitutes for fat and sugar, respectively. Four cupcake variations were prepared to compare the effects of replacing shortening with N-Flate^{TM} and sugar with AFP. The four variations were: shortening/sugar, shortening/AFP, N-Flate^{TM}/sugar, and N-Flate^{TM}/AFP. Compared to the caloric content of the shortening/sugar variation, the shortening/AFP variation, N-Flate^{TM}/sugar variation, and N-Flate^{TM}/AFP variation have 33%, 47% and 76% less calories respectively.

REVIEW OF LITERATURE

Functions of Cake Ingredients

Flour

Flour is considered to be a structure builder or toughener by Lawson (1970). When hydrated, combined with other ingredients, and heated, the gluten protein serves as the basic structural element (Matz, 1972). Soft wheat flours are usually used for cakes because they have a lower protein content which produces a softer and crumblier texture (Matz, 1972). Starch, which becomes embedded in the gluten matrix, provides structural reinforcement.

Sugar

Besides providing sweetness, sugars have a tenderizing effect on the crumb (Matz, 1972). The tenderizing effect is exerted because sugar competes with gluten for water during mixing (Campbell, 1972). Campbell (1972) stated that due to the ability of sugar to increase the coagulation temperature of proteins and the gelatinization temperature of starch, the tenderness and elasticity of the crumb is further enhanced. In addition, sugars have a tendency to retain moisture which help to retard staling.

According to Matz (1972), sugars promote browning of the crust. Sucrose, unlike glucose and fructose, is a nonreducing sugar, and does not contribute to Maillard browning of the crust (Campbell, 1972). Maillard browning involves the reaction between the carbonyl group of the sugar and the amine group of amino acids or proteins.

Shortening

Shortening, being insoluble in water, can be spread through a flour mixture to interfere with the cohesiveness of the structure resulting in a more tender crumb. (Campbell, 1972). Shortening also entraps air during mixing; the air bubbles contribute to the leavening as well as to the control of grain size by serving as foci for gas evolution (Matz, 1972). Campbell (1972) reported that the softness of the crumb is increased and the rate of firming is decreased with increasing levels of shortening.

Eggs

Whole eggs are made up of 74% water, 13-14% protein, and 10-11% fat (Lawson, 1970). The water is classified as a moistener, the protein as a structure builder, and the fat, which is rich in lecithin, as a tenderizer and emulsifier (Lawson, 1970). The egg protein helps the gluten proteins form the cell walls of the crumb structure because the gluten alone will not provide all of the structural strength. In addition, fat found in the yolk permits the entrapment of air in the batter during mixing (Matz, 1972). The yolk also provides color and flavor (Campbell,1972).

Milk

Campbell (1972) stated that milk and other liquids serve to dissolve sugar and other solutes, hydrate proteins, and partially gelatinize starch. Milk contains a reducing sugar, lactose, which participates in the browning reaction and accentuates the crust color (Matz, 1972). Whole milk was reported to have a tenderizing effect, while skim milk has a toughening effect on the crumb. Matz (1972) attributed this to the presence or absence of milkfat.

Leavening

Sources of leavening in cakes include carbon dioxide from added chemical leavening agent(s), water vapor, and air incorporated during mixing and expanded by the heat of the oven during baking (Matz, 1972). Baking powder, a mixture of acid salts and sodium bicarbonate, is commonly used in cakes (Matz, 1972). The pH of the batter may be controlled by the amount of baking powder used (Campbell, 1972). An excess of baking powder causes the finished product to be crumbly, have open and irregular grains, darker crumb and crust, and a soapy taste (Campbell, 1972). Alternatively, Campbell (1972) reported that a low pH will result in a cake with low volume, compact crumb, and an acidic taste. Ash et al. (1973) observed that cakes with a good balance of ingredients were in the pH range of 6.5 to 7.5.

General Rules for Formulating Cakes

Equal weights of flour and sugar were once common in cakes. However, formulas with higher concentration of sugar have become more popular because of the moist, tender, and fine-grained crumb (Paul, 1972). Lawson (1970) reported that 120-140 parts sugar to 100 parts flour is most acceptable for cakes. Matz (1972) recommended the following guidelines for cake formulation:

1) The amount of sugar should be between 110% to 160% of the weight of the flour.
2) The amount of eggs should equal or exceed the shortening.
3) The total weight of the liquid, including the water in the eggs and milk, should exceed the amount of sugar by 25% to 35%.
4) Shortening should fall in the range of 30% to 70% of the weight of the flour.
5) Sodium bicarbonate should be between 1.2% to 2% of the weight of the flour.

6) Salt should be between 3% to 4% of the weight of the flour.

Fat Replacement with N-Flate™

As described in the previous section, shortening has a tenderizing effect on the crumb and provides volume and mouthfeel. When shortening is completely removed from a cake formulation, volume decreases, the crumb becomes less tender, and the cell structure becomes uneven (Matz, 1972). Kamel and Washnuik (1983) showed that shortening-free cakes may be produced by using higher amounts of emulsifiers. In addition, reductions of eggs by 50% and sugar by 20% are possible when a large amount of emulsifier is used (Kamel and Washnuik, 1983).

N-Flate™ was described by Smith (1984) as an emulsifier blend with pregelatinized waxy maize starch and guar gum in a skim milk powder base. The emulsifier component of N-Flate™ consists of mono- and diglycerides and polyglycerol monoesters (Waring, 1988). These emulsifiers are commonly used in systems containing both water and fat. They reduce the surface tension and allow the water and fat to be mixed readily. This creates a larger number of small fat cells that allow incorporation of more air. The pregelatinized waxy maize starch is used because of its moisture retention properties. It also increases batter viscosity which in turn aids in the retention of air cells. Guar gum helps to increase batter viscosity while the skim milk powder base acts as a carrier for other ingredients. When comparing cakes using N-Flate^{TM} alone as a fat substitute and cakes using N-Flate^{TM} with oil or shortening, Smith (1984) found that cakes made from N-Flate^{TM} alone were more tender, had a greater volume and a more uniform cell structure. The cakes were also found to be more freeze-thaw stable and had greater water tolerance than their high fat counterparts.

Use of Polydextrose as a Bulking Agent

Polydextrose, a bulking agent, allows the creation of reduced-calorie foods by replacing fats and sugars (Freeman, 1982). The functional properties of polydextrose are similar to that of sucrose, but polydextrose itself is not sweet. Since polydextrose is only partially metabolized, the caloric utilization is only one calorie per gram. Sugar and fat, on the other hand, contain four calories and nine calories per gram, respectively.

In a study conducted by Kim et al. (1986), polydextrose altered the thermal setting properties of starch and/or gluten. Using differential scanning calorimetry, Kim et al. (1986) showed that polydextrose increased the onset and peak gelatinization temperatures of starch to values similar to those for sucrose. Furthermore, polydextrose can act as a humectant to prevent or retard undesireable changes in the moisture content of food (Liebrand et al., 1985). Liebrand et al. (1985) observed that baked products containing polydextrose can gain or lose water during prolonged periods, thereby extending their shelf life.

Neville and Setser (1986) found that 62.5% polydextrose when used with N-Flate^{TM} and a mixture of aspartame and saccharin produced optimum cakes. Higher amounts of polydextrose produced gummy products. With increasing levels of polydextrose, bitterness also increased. Cell uniformity, however, was not affected by the varying levels of polydextrose.

Use of Aspartame and Fructose as a Sweetener System

Aspartame is a nutritive sweetener that has 200 times the sweetening power of sucrose (Horwitz and Bauer-Nehrling, 1983). Chemically, it is a dipeptide made up of phenylalanine and aspartic acid, with a methyl group esterified to the carboxyl group of the phenylalanine. When subjected to temperature and pH extremes, aspartame decomposes to diketopiperazine. Carbonated beverages stored for eight weeks at 20°C (68°C) had 84 to 89 percent of the original aspartame remaining, with 3 to 4 percent degrading to diketopiperazine. Over the same storage period with an elevated storage temperature of 30°C (86°F), 62 percent of aspartame remained with 12 percent being converted to diketopiperazine. Although diketopiperazine is not harmful, it does not have the sweetness of aspartame. As a result, aspartame is generally not recommended for use in systems that require prolonged heating.

Fructose has been reported to be the sweetest, most soluble and hygroscopic of all the natural sugars (Matz, 1972). Since it is a reducing sugar, it readily undergoes Maillard browning and caramelization. Fructose has also been suggested for diabetics. Unlike other sugars, fructose does not cause sudden peaks in blood sugar and insulin levels (Osberger and Olinger, 1985).

In a study conducted by Hess and Setser (1983), aspartame was used alone or used with two different levels of fructose to replace sugar in cakes. They found that cakes prepared with aspartame and the higher level of fructose were more tender, had a greater volume and a less bitter crust and crumb than those prepared with aspartame alone.

MATERIALS AND METHODS

Experimental Design and Pilot Study

The experimental design for evaluating cupcakes prepared with two types of fat/emulsifier and two types of sweeteners is shown in Table 1. The cupcake variations were prepared using shortening or N-Flate^{TM} as a source of fat, and sugar or a sweetener system made up of 1.5% aspartame, 35.5% fructose, and 63% polydextrose (AFP). The four cupcake variations were shortening/sugar, shortening/AFP, N-Flate^{TM}/sugar, and N-Flate^{TM}/AFP. Six replications of each of the four variations were made.

A pilot study was conducted during the summer of 1989 to establish the formulations. The formulations and procedures for mixing and baking are shown in Appendix A for each variation.

Non-fat dry milk (NFDM) was omitted from the two variations containing N-Flate^{TM} because N-Flate^{TM} already comes in a skim milk powder base. The amount of water used for the shortening/sugar variation had to be reduced to 100 gm. because when 120 gm. of water was used, the batter became too thin.

The schedule for the baking, objective measurements, and sensory evaluation is shown in Appendix B.

TABLE 1

Experimental Design for Evaluating the Effects of Fat and Sweetener Replacements in Cupcakes

	Sweetener	
Fat/Emulsifier	Sugar	AFP[1]
Shortening	Shortening/Sugar	Shortening/AFP
N-Flate™	N-Flate™/Sugar	N-Flate™/AFP

[1] AFP = Aspartame, Fructose, and Polydextrose

Procurement and Storage of Ingredients

Two 2-pound containers of N-Flate™ were obtained from National Starch and Chemical Corp. (Bridgewater, New Jersey).

One 50-gram container of aspartame was obtained from G.D. Searle & Co. (Deerfield, Illinois).

Four 100-gram containers of polydextrose were obtained from Pfizer Inc. (Groton, Connecticut).

Other cake ingredients were purchased from a local grocery store in Blacksburg, Virginia.

All ingredients, except the eggs were stored at ambient temperature in a laboratory out of direct light. The eggs were stored in the refrigerator compartment of a Frigidaire refrigerator (Model FP C1-170T, Dayton, Ohio).

The dry ingredients were purchased three weeks prior to the study while the eggs were purchased two days prior to the study.

Objective Measures of Batter

The number of replications performed each day for the objective measures made on the batters is included in Appendix C.

All objective measures made on the batters were made immediately after batter preparation.

pH of the batter was determined using a Corning Scientific Instrument pH meter (Model 5, Scientific Instruments, Medford, Massachusetts).

Specific gravity of the batter was determined using the following equation:

$$\text{Specific Gravity} = \frac{X - Y}{Z - Y}$$

where X = weight of 1/4 cup dry measure filled with batter

Y = weight of empty 1/4 cup dry measure

Z = weight of 1/4 cup dry measure filled with water

Objective Measures of Cupcakes

The number of replications performed each day for the objective measures made on the cupcakes is included in Appendix C.

All objective measures made on the cupcakes except the evaluation of the crust and crumb color were conducted approximately three hours after baking. The crust and crumb color were evaluated one week after the last sensory evaluation session. The cupcakes were kept frozen until needed.

Index to volume was determined by measuring the standing height in the center of a cupcake with a vernier caliper.

Moisture content was determined by a Brabender moisture tester (model SAS-692, C.W. Brabender Instruments, Hackensack, New Jersey). Samples containing both the crust and crumb were dried in metal pans for 1.5 hours at 110°C.

Index to tenderness was determined by a Stevens-LFRA Texture Analyzer (Model TA 1000, Texture Technology Corp., Scarsdale, New York). The following specifications were used for all measurements:

(i) The probe used was a TA 10

(ii) The depth of penetration was 6 mm.

(iii) The penetration speed of the probe was 2mm/sec.

The crust portion was sliced off as shown in Appendix D and the remaining portion was used for evaluation. A higher deformation value indicates a firmer crumb than one with a lower deformation value.

Crust and crumb color were measured by a Hunter Lab Lab-Scan spectrocolorimeter (Reston, Virginia). The crust and crumb portions were placed separately over the aperture that supplied the light source. The L, A, B, and ΔE values were recorded. A higher ΔE value indicates that it is lighter in color than one with a lower ΔE value.

Sensory Evaluation

Sensory evaluation was performed by eight trained judges who are graduate students of the Department of Human Nutrition and Foods, Virginia Polytechnic Institute and State University. Panelists selected were not taking any medication which could interfere with taste acuity, were not sensitive to aspartame, and were available for all training and testing sessions.

During the training session, the panelists were familiarized with sensory evaluation procedures, the scorecard, and the definitions of the attributes to be evaluated. The panelists were instructed to refrain from eating, drinking, smoking or chewing gum for 30 minutes before each sensory session.

The sensory evaluation sessions were conducted in a laboratory with individual booths of neutral background and fluorescent lights.

A sample of the scorecard is included in Appendix E.

Statistical Analysis

Statistical analysis consisted of a 2 X 2 factorial block design. The two main effects tested were fat/emulsifier effect and sweetener effect. The least square means were calculated for each measurement in order to compare the effects of shortening versus N-Flate^{TM}, and the effects of sugar versus AFP. For example, the least square mean of batter pH for shortening, is the average of the pH readings for the shortening/sugar variation and the shortening/AFP variation. Similarly, the least square mean of batter pH for N-Flate^{TM} is the average pH readings for the N-Flate^{TM}/sugar variation and the N-Flate^{TM}/AFP variation. The fat/emulsifier and sweetener interaction effect was also tested. The analysis was performed for both objective and sensory data. Sources of variations including day effect and person effect were not tested for significance.

RESULTS AND DISCUSSION

The purpose of this study was to evaluate the potential of a fat substitute and a sweetener system for use in baked products. The fat substitute, N-Flate^{TM}, and, the sweetener system consisting of 1.5% aspartame, 35.5% fructose, and 63% polydextrose (AFP), was used as a substitute for sugar. Four cupcake variations were prepared to compare the effects of replacing shortening with N-Flate^{TM} and sugar with AFP. The four variations were: shortening/sugar, shortening/AFP, N-Flate^{TM}/sugar, and N-Flate^{TM}/AFP. Although this study was made on the effects of the type of fat/emulsifier and the effects of the type of sweetener on the characteristics of cupcakes only, the findings may be applicable to most baked products.

Objective Results

The least square means of the objective measures for fat/emulsifier types and sweetener types are shown in Tables 2 and 3. The mean values of the objective measures for the four cupcake variations are shown in Figures 1 through 7.

pH

The type of fat/emulsifier had a significant effect ($p < 0.01$) on the pH of the batter (Table 2). The two batters prepared with N-Flate™ had a lower pH than the batters prepared with shortening. The type of sweetener also affected the pH of the batter. Batters prepared with AFP had a significantly ($p < 0.05$) higher pH than those prepared with sugar (Table 3). Although both fat/emulsifier type and sweetener type both affected the pH of the batter, the pH of all four batters were within the optimum levels of 6.5 - 7.5 (Ash et al., 1973). There was no interaction effect between fat/emulsifier and sweetener on the pH of the cupcake batter. Therefore, the differences in pH were attributed to fat/emulsifier or sweetener alone (Fig. 1).

Specific Gravity

The batters prepared with N-Flate™ had a significantly ($p < 0.01$) higher specific gravity than the batters prepared with shortening (Table 2). The preparation of the batters for variations containing shortening involved an additional step in which the shortening was creamed with either sugar or AFP. This additional step may be responsible for the increased amount of air incorporated. Since N-Flate™ comes in a powder form, it was not creamed with sugar or AFP. Instead, the N-Flate™ was sifted with the remaining dry

TABLE 2

Least Square Means of Objective Measurements for the Type of Fat/Emulsifier

	Fat/Emulsifier	
	Shortening	N-Flate™
pH	6.89a[1]	6.67b
Specific Gravity	0.88a	0.94b
Index to Volume	3.77a	3.65b
Crust ΔE Value	76.6a	77.0a
Crumb ΔE Value	87.3a	82.4b
Deformation Value (Tenderness)	181a	215b
Moisture Content	26.6a	31.1b

[1] Least square means followed by different letters in the same row are significantly different.

TABLE 3

Least Square Means of Objective Measurements for the Type of Sweetener

	Sweetener	
	Sugar	AFP[1]
pH	6.74a[2]	6.82b
Specific Gravity	0.86a	0.96b
Index to Volume	3.88a	3.54b
Crust ΔE Value	76.0a	77.6b
Crumb ΔE Value	84.8a	85.0a
Deformation Value (Tenderness)	130a	266b
Moisture Content	27.3a	30.4b

[1] AFP = Aspartame, Fructose, and Polydextrose

[2] Least square means followed by different letters in the same row are significantly different

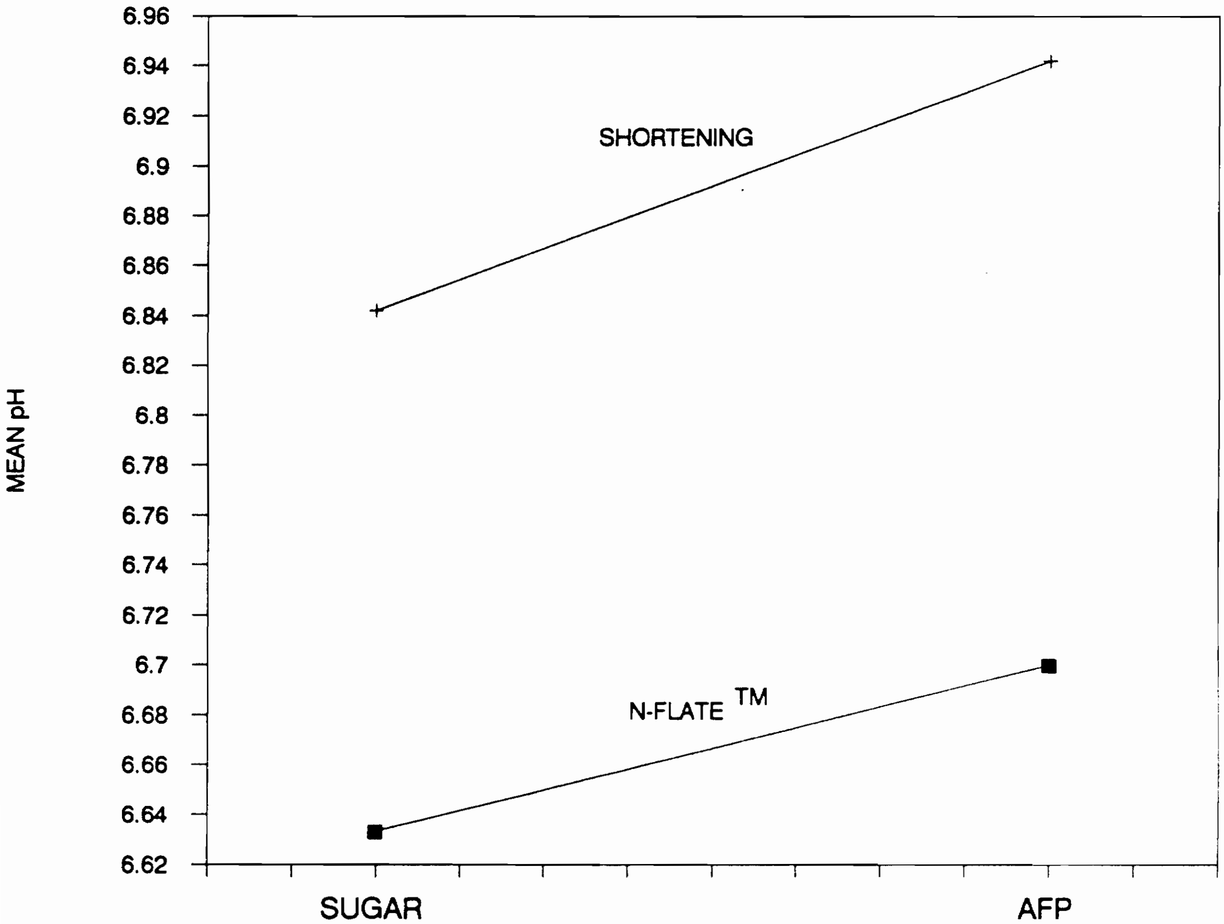

Figure 1: Mean[1] pH values of four cupcake batter variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 12 replications

[2] AFP = Aspartame, Fructose and Polydextrose

ingredients as detailed in Appendix A. The type of sweetener also had a significant ($p < 0.01$) effect on the specific gravity of the batter (Table 3). The batters containing AFP incorporated less air than the batters containing sugar. A significant ($p < 0.01$) interaction of fat/emulsifier and sweetener was observed (Fig. 2). Although the parallel lines in Figure 2 may indicate no fat/emulsifier and sweetener interaction, the statistical analysis showed that an interaction exists.

Index to Volume

Cupcakes prepared with N-Flate™ had a significantly ($p < 0.01$) lower index to volume than shortening (Table 2). This finding is consistent with the higher specific gravity of batters prepared with N-Flate™. The N-Flate™/sugar variation had a higher volume than the shortening/sugar variation (Fig. 3). This was unexpected since the N-Flate™/sugar variation had a higher specific gravity than the shortening/sugar variation, and generally a batter of high specific gravity would have a lower volume. One possible explanation is that shortening is able to incorporate a greater amount of air but is not able to maintain it. N-Flate™, on the other hand, did not incorporate as much air but maintained more air bubbles. Visual observation of the batters showed that the batter of

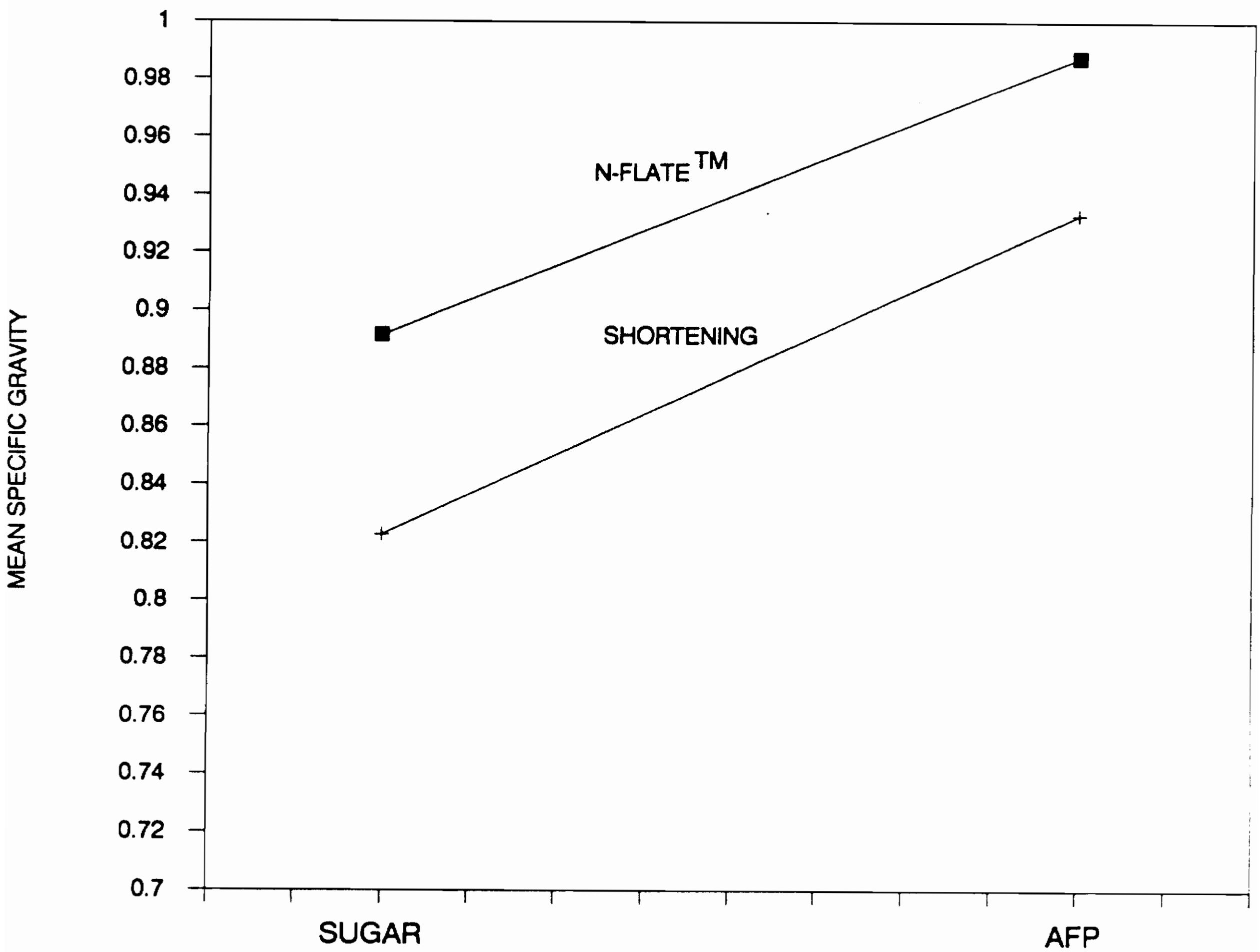

Figure 2: Mean[1] specific gravity values of four cupcake batter variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 12 replications

[2] AFP = Aspartame, Fructose and Polydextrose

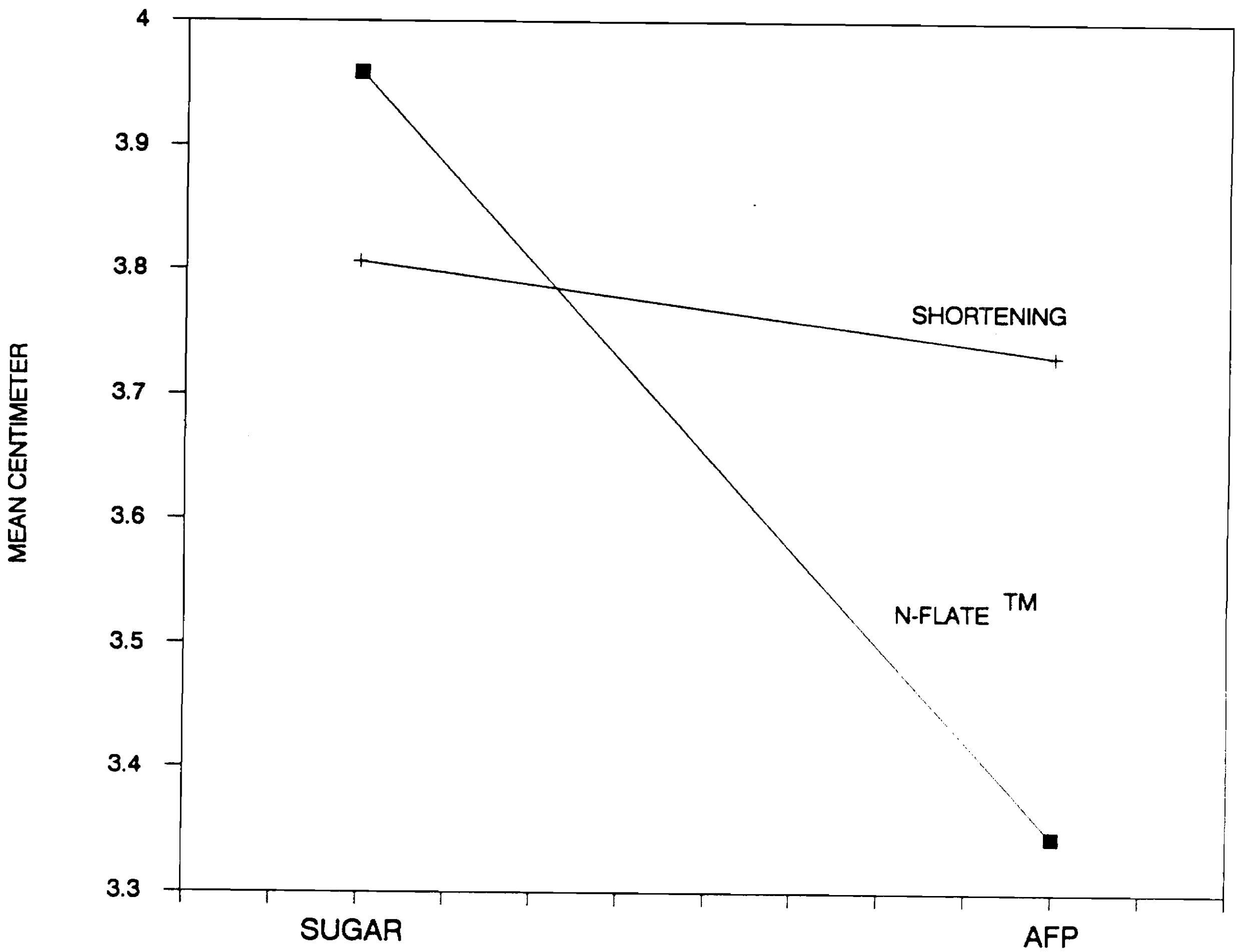

Figure 3: Mean[1] index to volume values in centimeters of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 36 replications

[2] AFP = Aspartame, Fructose and Polydextrose

the N-Flate™/sugar variation was more viscous than that of the shortening/sugar variation. The higher viscosity of the batter made with N-Flate™ and sugar may have contributed to its ability to maintain the air bubbles by forming stronger and more cohesive films around them. The type of sweetener also had a significant ($p < 0.01$) effect on volume (Table 3). Cupcakes prepared with AFP had a lower volume than those prepared with sugar. This finding is supported by the fact that the specific gravity of the batters containing AFP is higher than that of the batters containing sugar. A significant ($p < 0.01$) fat/emulsifier and sweetener interaction effect on index to volume was found (Fig. 3).

Crust and Crumb Color

The effects of fat/emulsifier type and sweetener type on crust and crumb color are shown in Tables 2 and 3. The fat/emulsifier effect was highly significant ($p < 0.01$) for the crumb, but not for the crust. The beige color of N-Flate™ may have contributed to the darker crumb color. Sweetener type, on the other hand, had a significant ($p < 0.01$) effect on the color of the crust, but not on the color of the crumb. Cupcakes prepared with AFP had a lighter crust than those prepared with sugar. When sugar is used, the browning of the crust primarily results from caramelization. The presence of fructose in AFP contributed to caramelization and Maillard browning. However, since only a small amount of fructose was used, the crusts were light in color. A significant ($p < 0.01$) fat/emulsifier and sweetener interaction effect was found for the crust color but not for the crumb color (Figs. 4 and 5).

Tenderness

The fat/emulsifier type and sweetener type both had significant ($p < 0.01$) effects on the tenderness of the cupcakes. Variations prepared with N-Flate™ and variations prepared with AFP produced less tender cupcakes than those prepared with shortening and sugar respectively (Tables 2 and 3). There was also a significant ($p < 0.01$) fat/emulsifier and sweetener interaction effect on tenderness (Fig. 6).

Moisture Content

The fat/emulsifier type had a highly significant ($p < 0.01$) effect on moisture. Variations prepared with N-Flate™ had a significantly ($p < 0.01$) higher moisture content than variations prepared with shortening (Table 2). Sweetener effect was also highly significant ($p < 0.01$). Variations prepared with AFP had a higher moisture content than variations prepared with sugar (Table 3). The hygroscopic nature of fructose and polydextrose may account

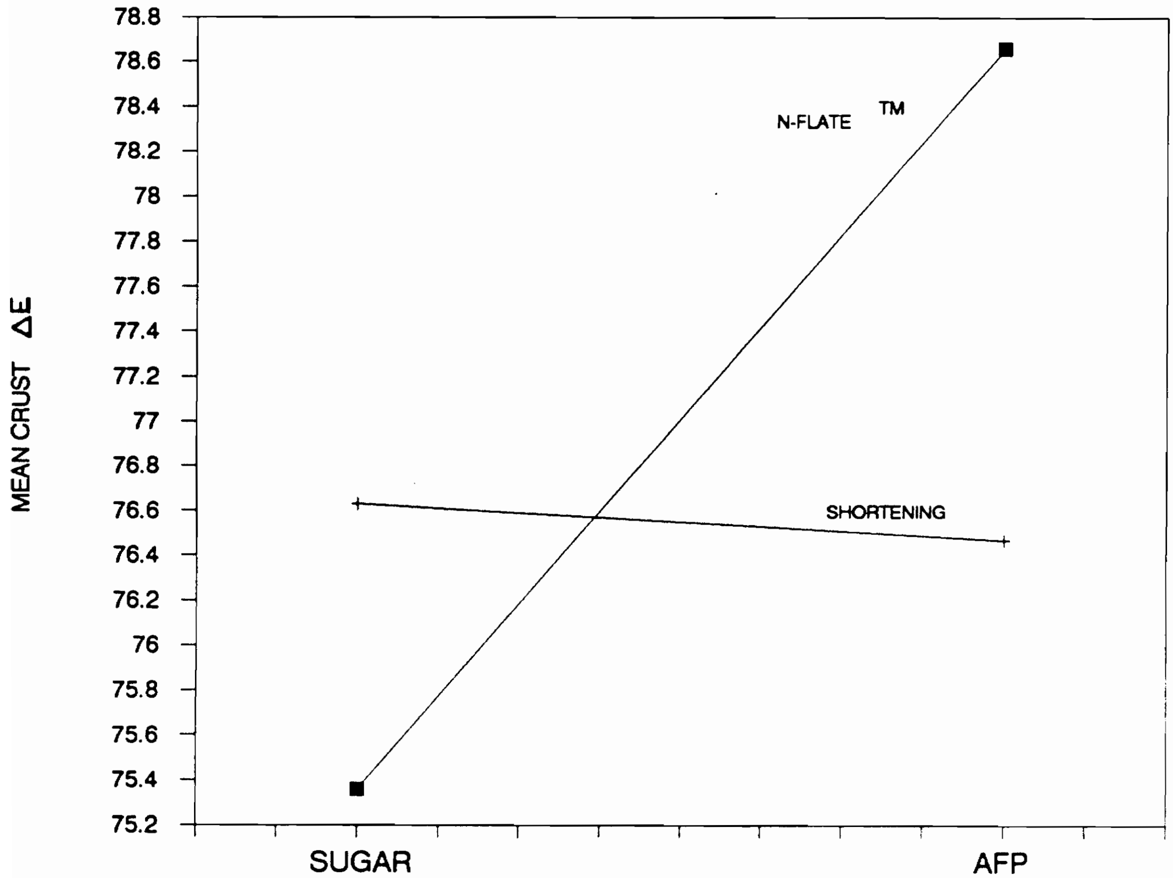

Figure 4: Mean[1] crust ΔE values of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 12 replications

[2] AFP = Aspartame, Fructose and Polydextrose

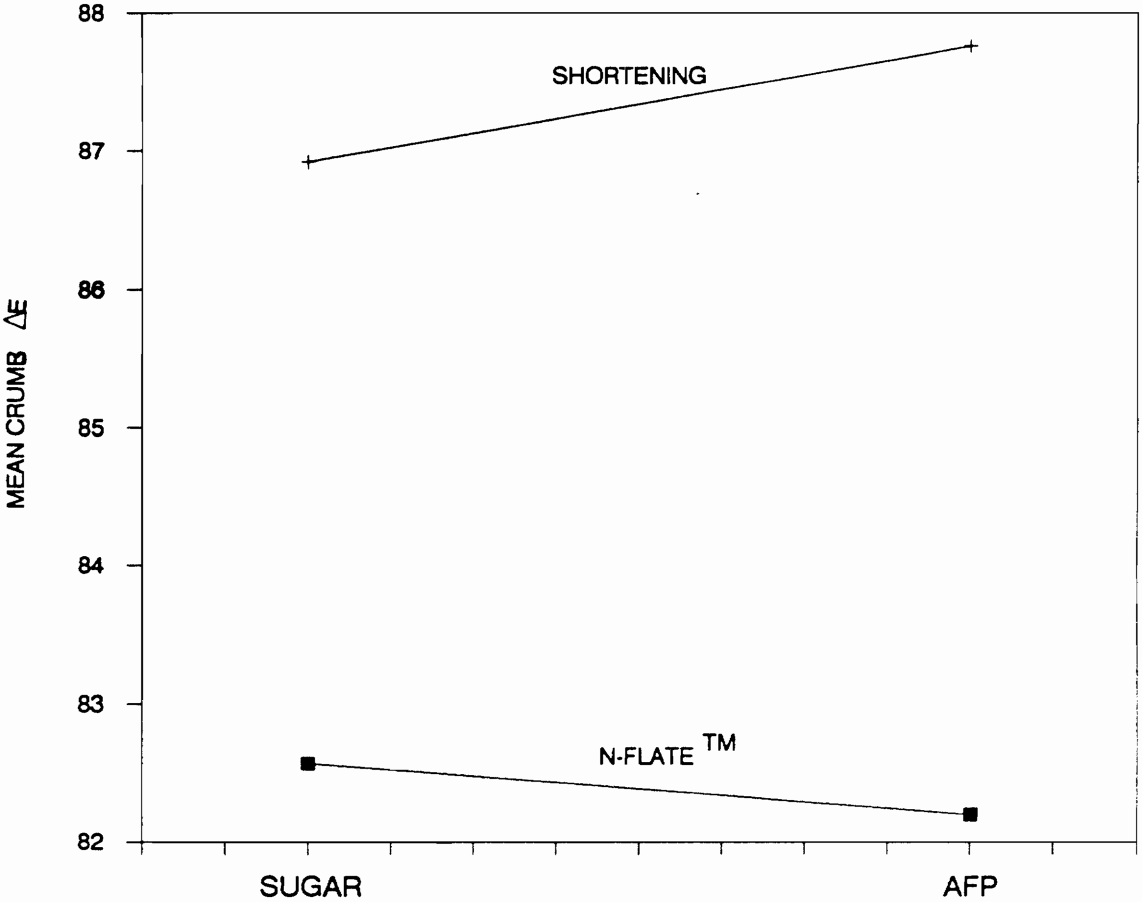

Figure 5: Mean[1] crumb ΔE values of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 12 replications

[2] AFP = Aspartame, Fructose and Polydextrose

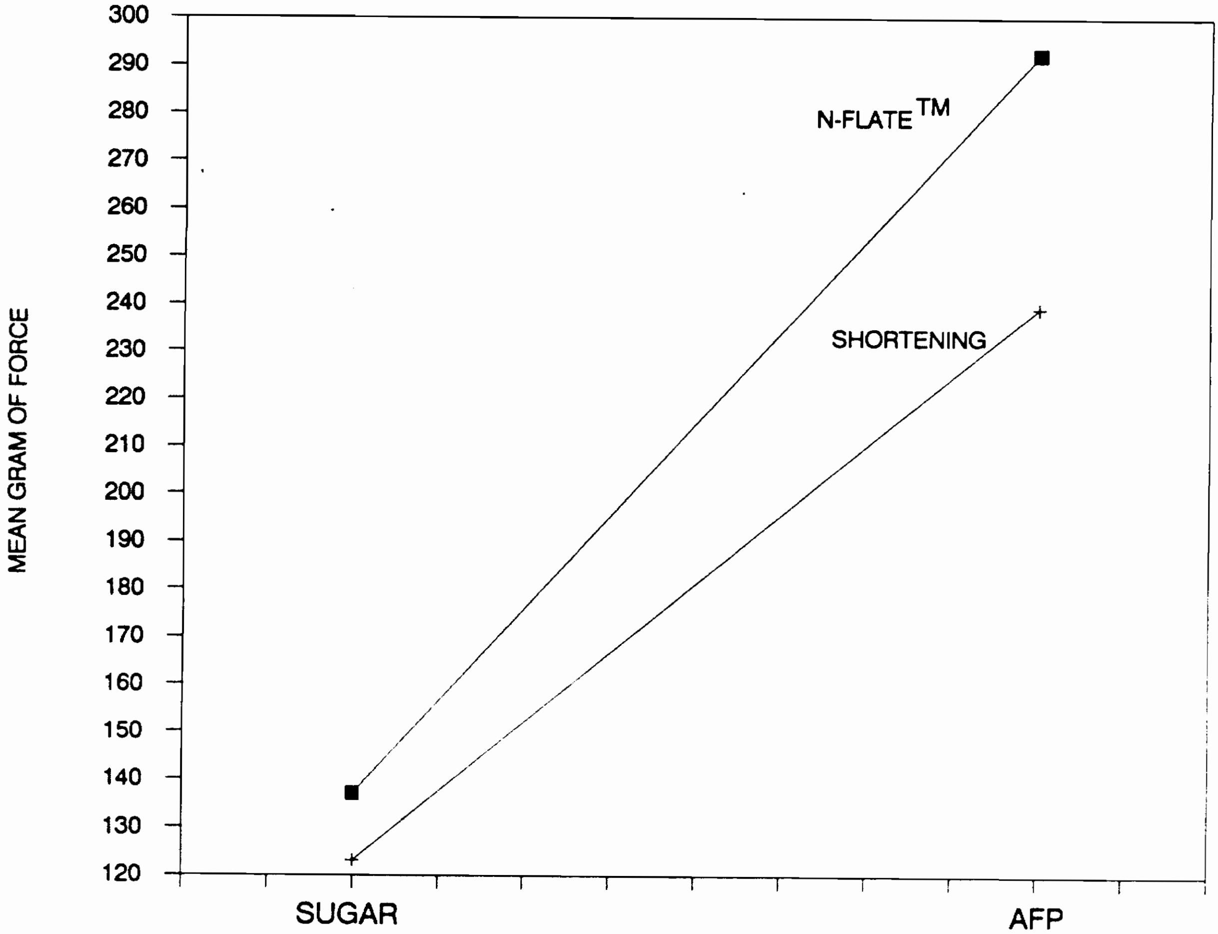

Figure 6: Mean[1] deformation values of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 18 replications

[2] AFP = Aspartame, Fructose and Polydextrose

for the greater moisture content. A significant ($p < 0.05$) fat/emulsifier and sweetener interaction effect was observed (Fig. 7).

Sensory Scores

The least square means of the sensory scores for the six attributes evaluated by trained sensory panelists are shown in Tables 4 and 5). Figures 8 through 13 illustrate the mean sensory scores of the six attributes for the four cupcake variations. No significant fat/emulsifier and sweetener interaction effects were observed in any of the six attributes evaluated.

Moistness

There was no significant difference in sensory scores for moistness between variations prepared with N-Flate™ and those prepared with shortening, although variations prepared with N-Flate™ had a higher mean sensory score for moistness (Table 4). Variations prepared with AFP were found to be significantly ($p < 0.05$) less moist than variations prepared with sugar (Table 5). This, however, was not supported by the objective data. For variations prepared with AFP, the objective data showed a significantly higher moisture content but also a significantly less tender crumb. The

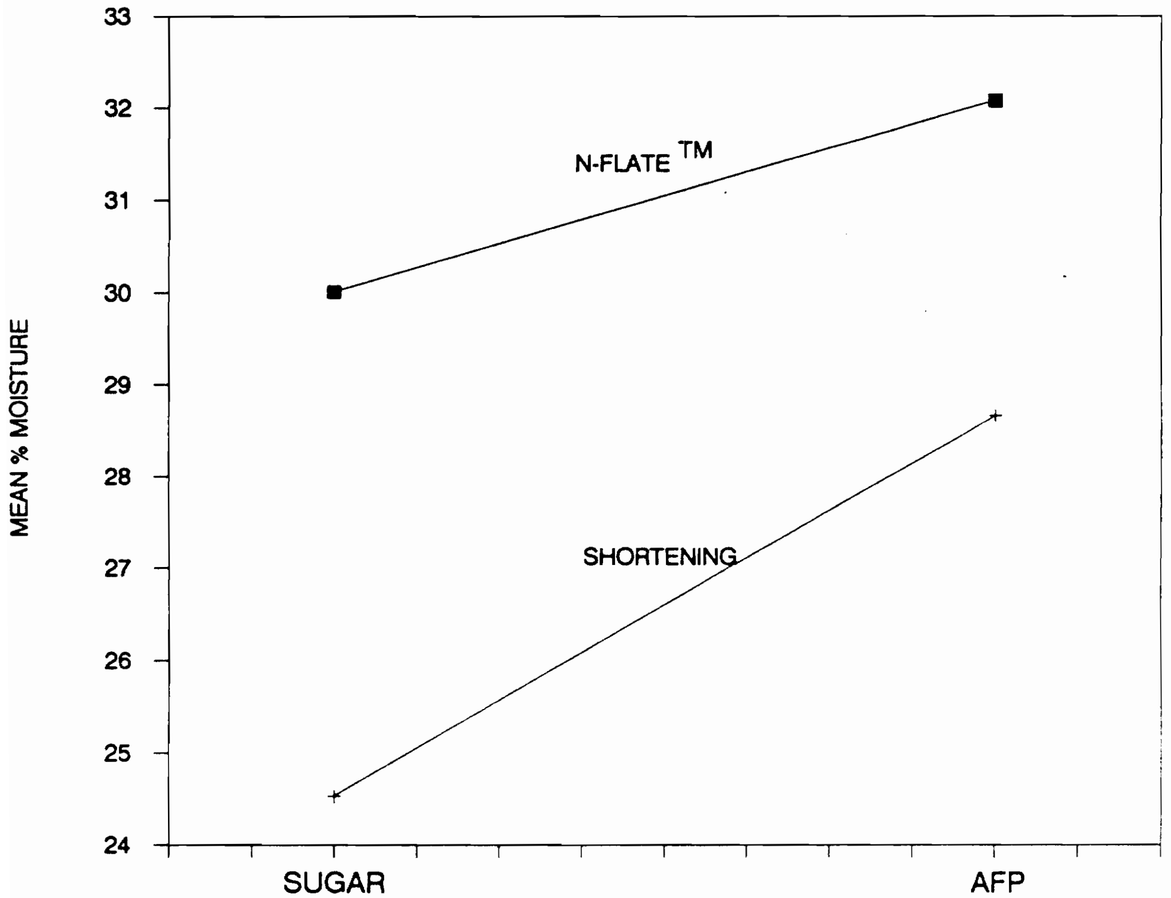

Figure 7: Mean[1] moisture content values of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 12 replications

[2] AFP = Aspartame, Fructose and Polydextrose

TABLE 4

Least Square Means[1] of Sensory Evaluation Results for the Type of Fat/Emulsifier

	Fat/Emulsifier	
	Shortening	N-Flate™
Moistness	4.56a[2]	5.15a
Tenderness	6.49a	4.87b
Sweetness	6.04a	5.54a
Crust Bitterness	5.34a	5.27a
Crumb Bitterness	4.78a	4.96a
Cell Uniformity	6.26a	4.77b

[1] Least square means range from 0 to 10.5. 0 indicates a dry, tough, bland, not bitter and non-uniform cell formation whereas, 10.5 indicates a wet, tender, sweet, bitter and uniform cell formation.

[2] Least square means followed by different letters in the same row are significantly different.

TABLE 5

Least Square Means[1] of Sensory Evaluation Results for the Type of Sweetener

	Sweetener	
	Sugar	AFP[2]
Moistness	5.31a[3]	4.39b
Tenderness	5.66a	5.71a
Sweetness	5.71a	5.88a
Crust Bitterness	3.58a	7.04b
Crumb Bitterness	3.23a	6.51b
Cell Uniformity	4.49a	6.53b

[1] Least square means range from 0 to 10.5. 0 indicates a dry, tough, bland, not bitter and non-uniform cell formation whereas, 10.5 indicates a wet, tender sweet, bitter and uniform cell formation.

[2] AFP = Aspartame, Fructose, and Polydextrose

[3] Least square means followed by different letters in the same row are significantly different.

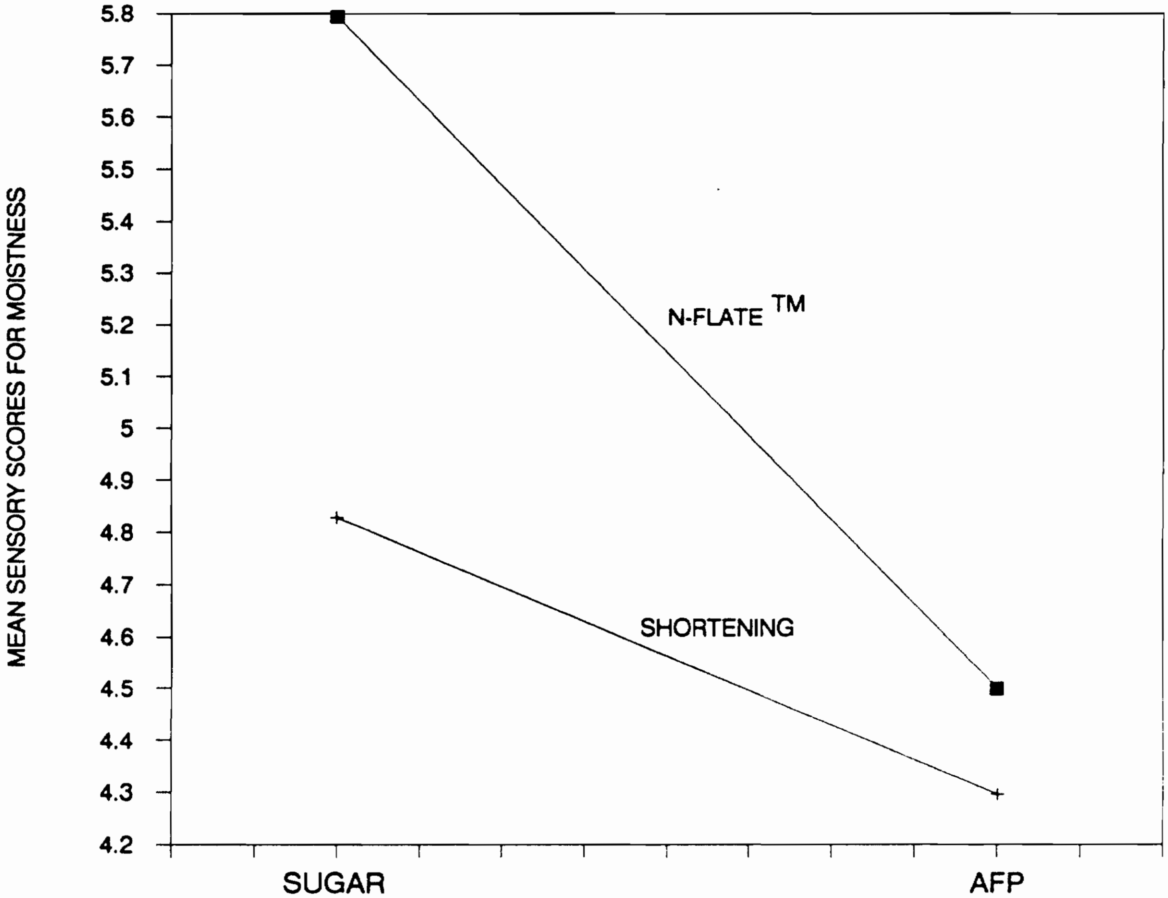

Figure 8: Mean[1] sensory scores for moistness of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 8 replications

[2] AFP = Aspartame, Fructose and Polydextrose

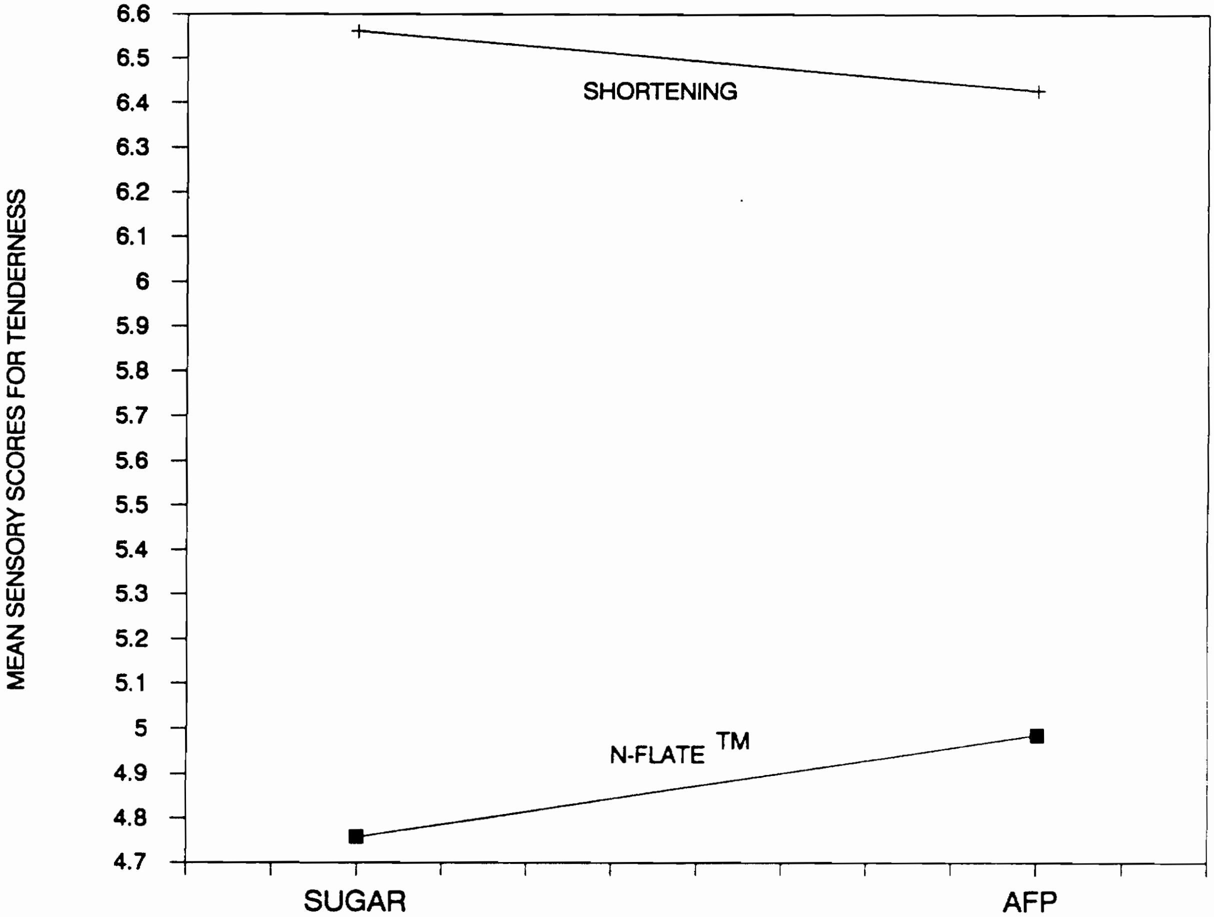

Figure 9: Mean[1] sensory scores for tenderness of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 8 replications

[2] AFP = Aspartame, Fructose and Polydextrose

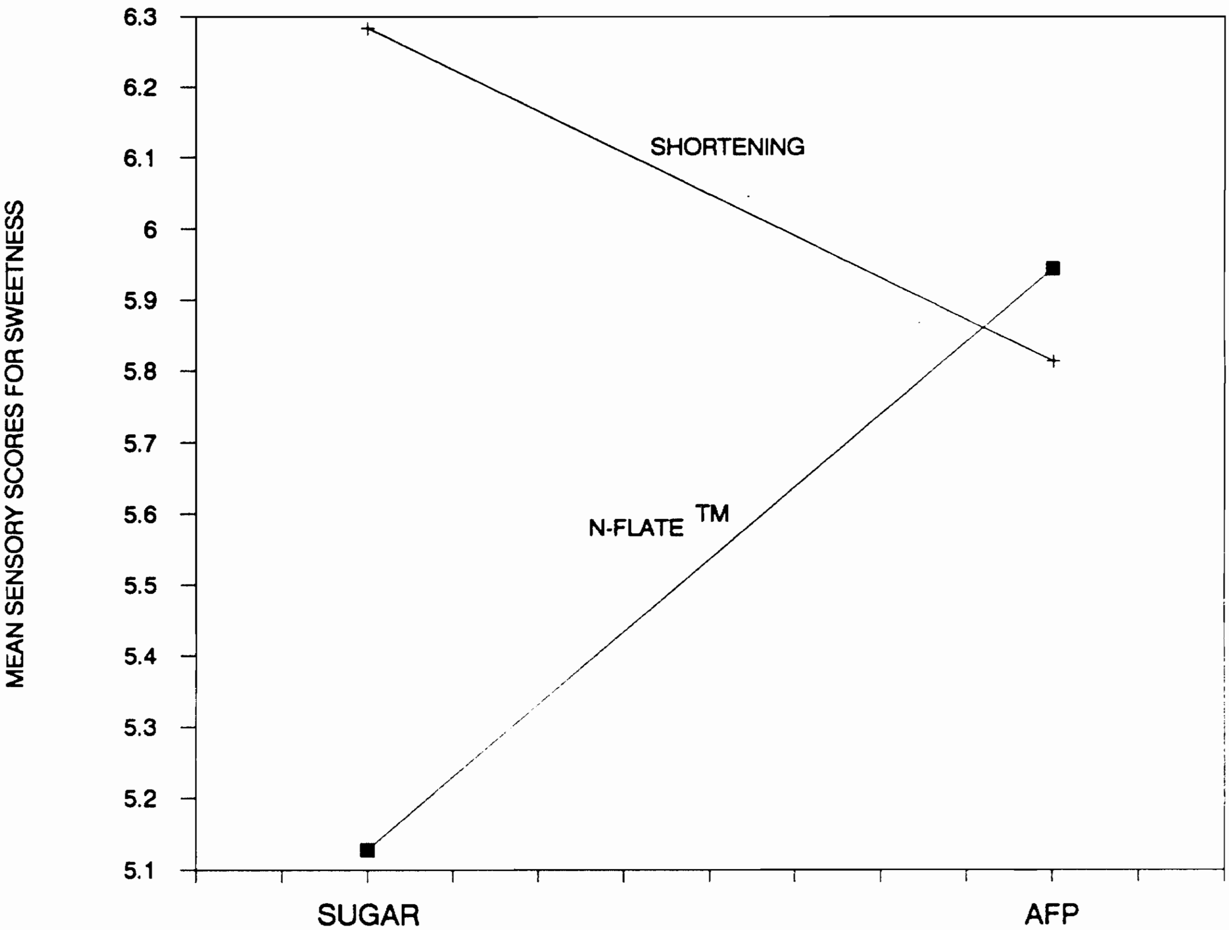

Figure 10: Mean[1] sensory scores for sweetness of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 8 replications

[2] AFP = Aspartame, Fructose and Polydextrose

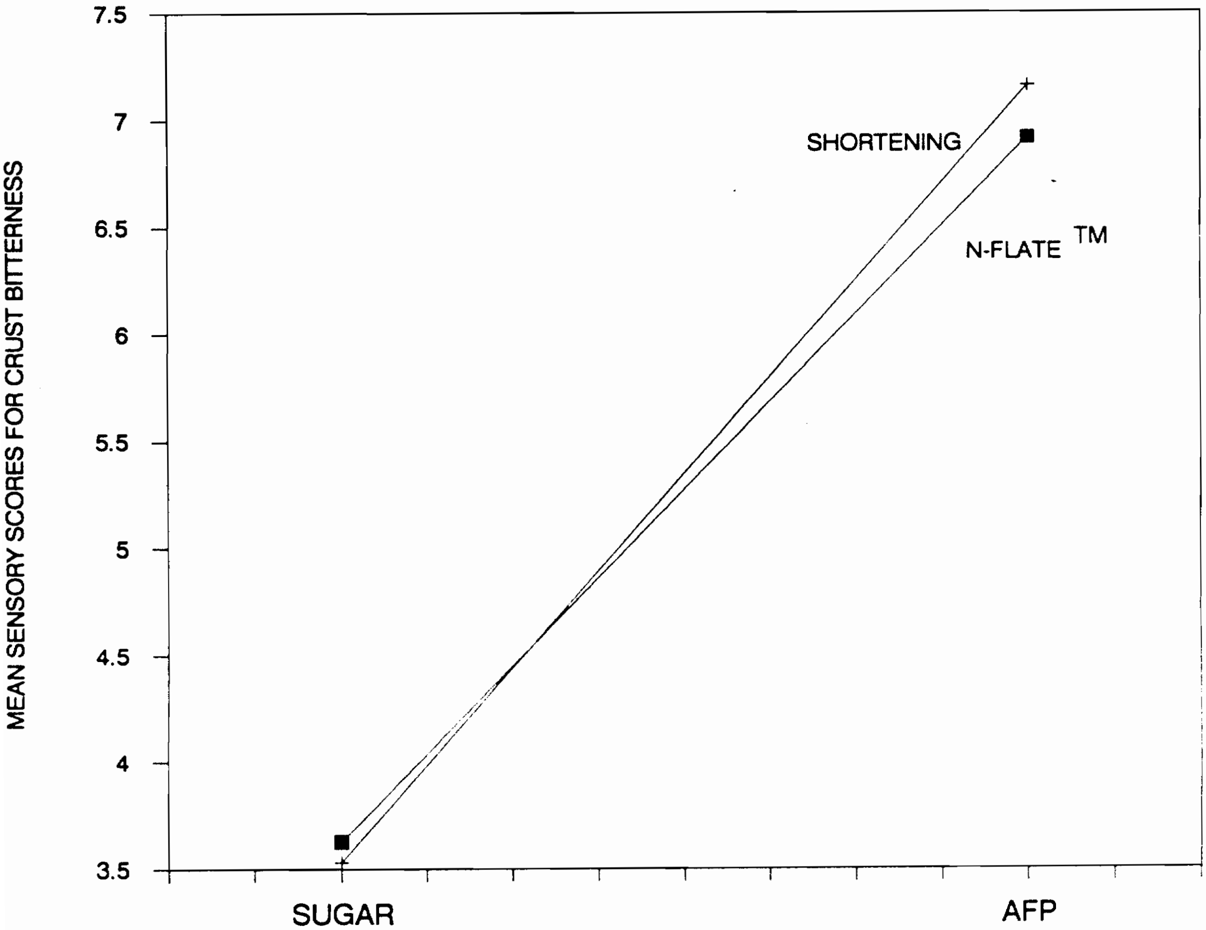

Figure 11: Mean[1] sensory scores for crust bitterness of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 8 replications

[2] AFP = Aspartame, Fructose and Polydextrose

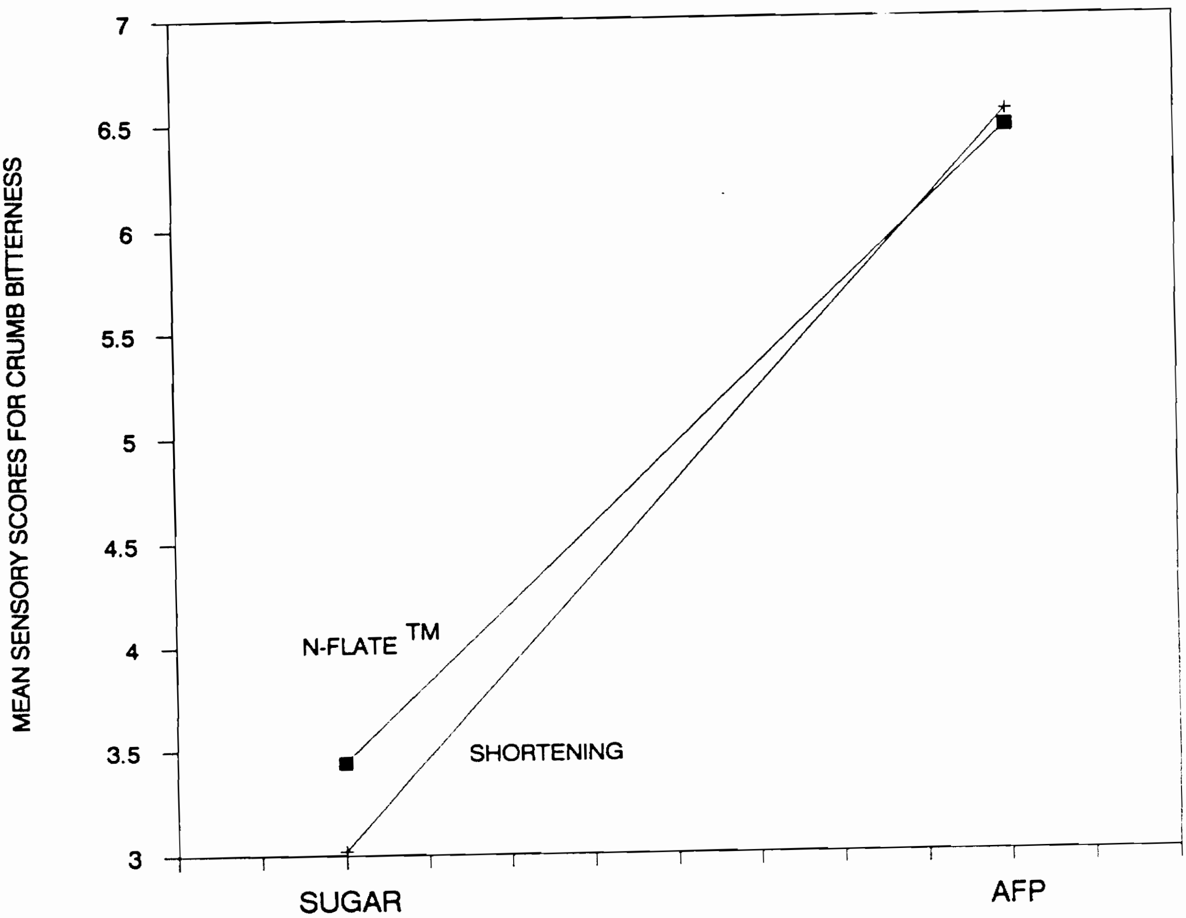

Figure 12: **Mean[1] sensory scores for crumb bitterness of four** cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 8 replications

[2] **AFP = Aspartame, Fructose and Polydextrose**

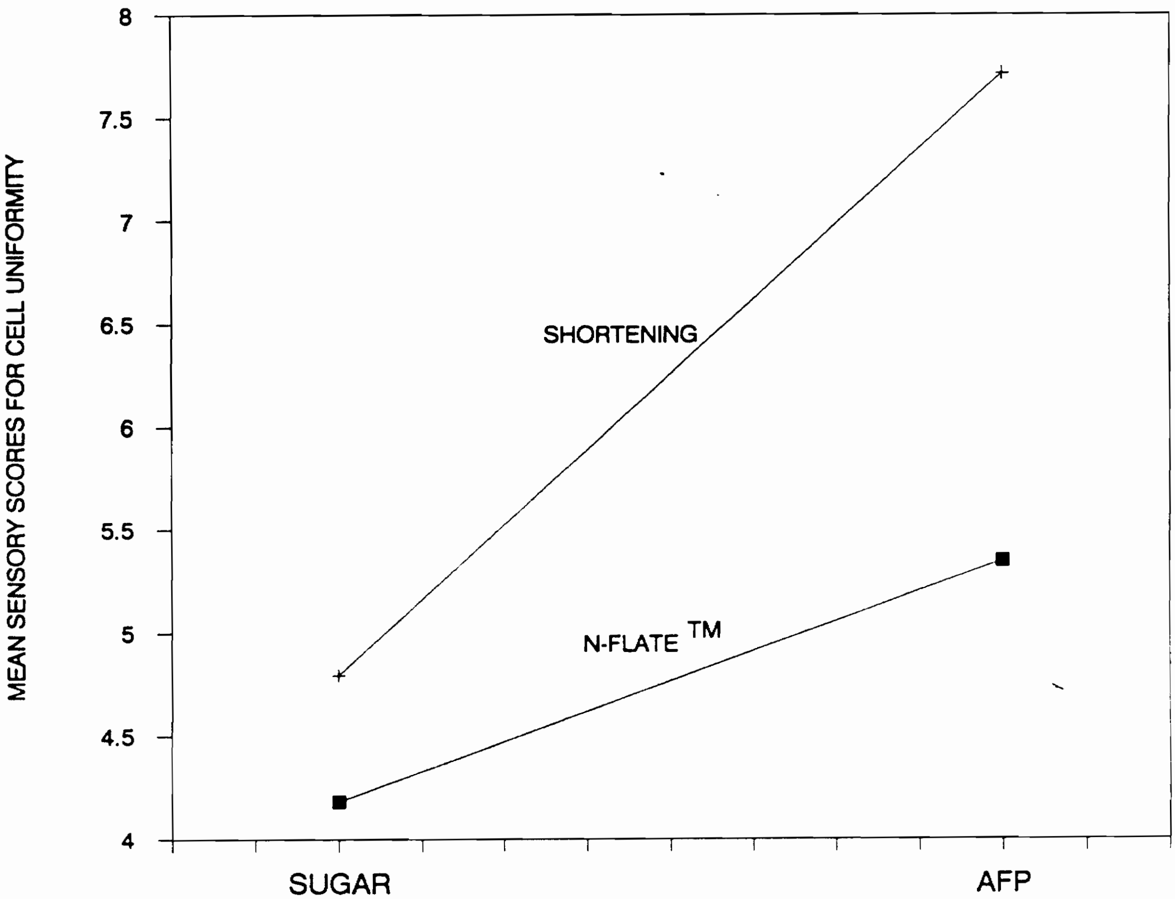

Figure 13: Mean[1] sensory scores for cell uniformity of four cupcake variations prepared with shortening or N-Flate™ and sugar or AFP[2]

[1] Mean value from 8 replications

[2] AFP = Aspartame, Fructose and Polydextrose

mouthfeel effect of a less tender crumb may have led the panelist to perceive on the average, a drier crumb.

Tenderness

Variations prepared with N-Flate^{TM} were judged to be significantly ($p < 0.01$) less tender than those prepared with shortening (Table 4). This was supported by the results of the Stevens-LFRA Texture Analyzer. However, the sweetener type did not affect the sensory score for tenderness (Table 5). This contradicted the results of the Stevens-LFRA Texture Analyzer. The difference may be attributed to the fact that the cupcakes were evaluated for tenderness objectively the day they were made, but the panelists evaluated the cupcakes the next day. This may suggest that the cupcakes made with sugar became stale faster, and became less tender.

Sweetness

There were no significant effects of fat/emulsifier and sweetener on the sensory scores for sweetness (Table 4 and 5). The sugar and AFP variations had similar average sensory scores (Fig. 10). N-Flate^{TM} decreased the sweetness as shown by the overall mean of the sugar variations. The difference in sensory scores between the two sugar variations indicate that N-Flate^{TM} may have masked the sweet taste of sugar. The masking effect of N-Flate™ was not evident when used with AFP.

Crust and Crumb Bitterness

The effects of fat/emulsifier type and sweetener type on crust and crumb bitterness are shown in Tables 4 and 5. The effect of fat/emulsifier type was not significant. A highly significant ($p < 0.01$) sweetener type effect on both the crust and crumb was observed. The crust and crumb of the AFP variations were judged to be more bitter than the sugar variations. The bitterness may have been attributed to five factors: (i) the breakdown of aspartame as it is exposed to heat, (ii) the bitterness of polydextrose when used in large amounts, (iii) the breakdown of polydextrose as it is exposed to heat, (iv) the products of caramelization and/or Maillard browning, and (v) the interaction of the ingredients. It is unlikely that the products of the browning reactions were the major cause of the bitter aftertaste since there was no excessive browning.

Cell Uniformity

The panelists judged that the cell uniformity of cupcakes is significantly ($p < 0.01$) affected by the type of fat/emulsifier and the type of sweetener (Tables 4 and 5). Variations prepared with shortening and those prepared with

AFP were judged to have a more uniform cell structure. The fine granular nature of AFP may have aided in the formation of a more uniform cell structure.

Circular Graph

Figure 14 illustrates graphically the mean sensory scores of the four cupcake variations. The following observations were made:

1) On the moistness scale, the N-Flate^{TM}/sugar variation was the moistest of the four variations. The other three variations received similar moistness scores.

2) The two shortening variations were judged to have similar tenderness scores. The two N-Flate^{TM} variations were also judged to have similar tenderness scores. However, the shortening variations were more tender than the N-Flate^{TM} variations.

3) The N-Flate^{TM}/sugar variation was found to be the least sweet of the four variations. The other three variations were similar in sweetness.

4) For both the crust and crumb, variations prepared with AFP were twice as bitter as those prepared with sugar.

5) On the cell uniformity scale, the shortening/AFP variation had the most uniform cell structure of the four variations.

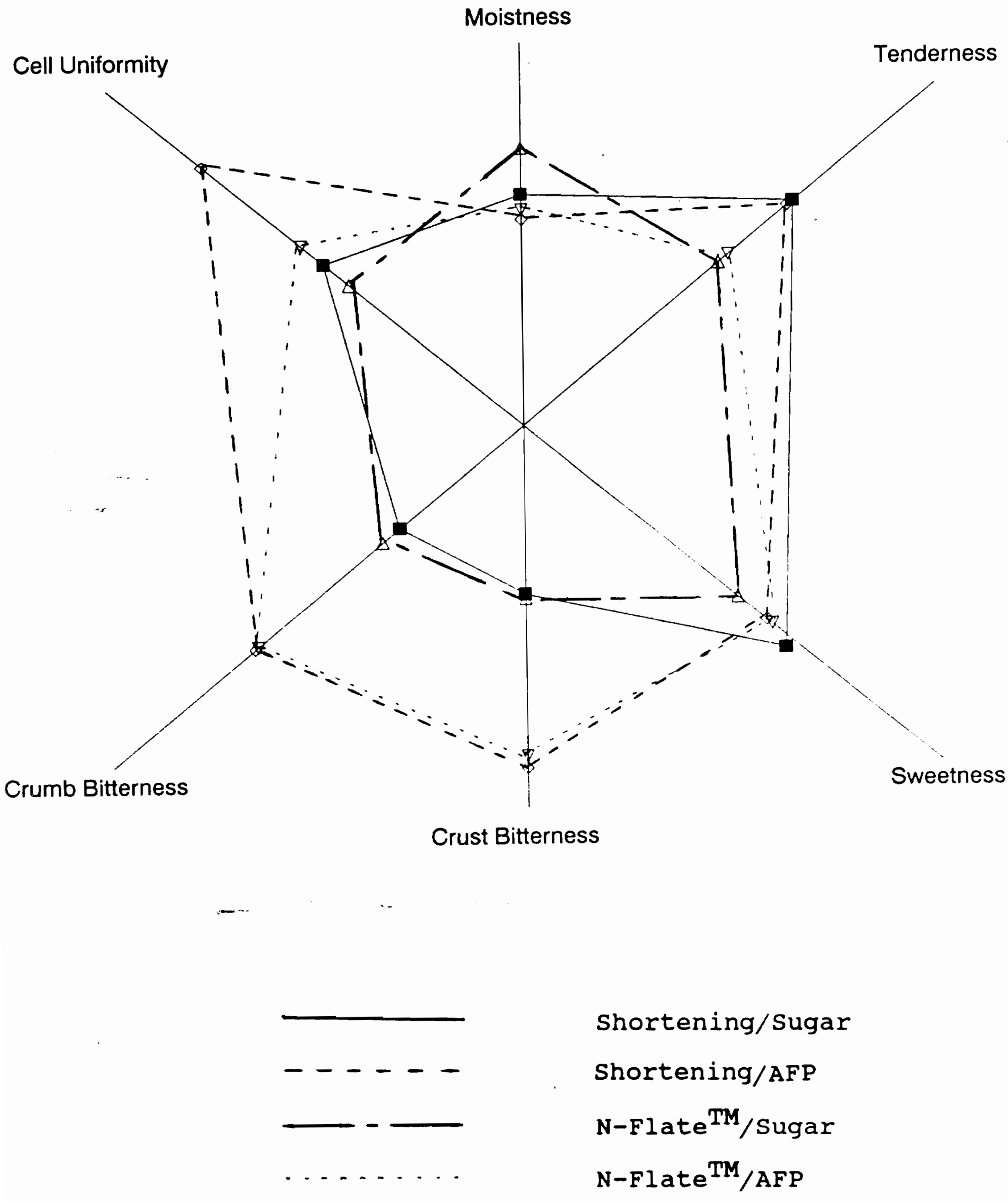

Figure 14: Circular graph for sensory evaluation results

CONCLUSION

The effects of replacing fat with N-Flate™, and sugar with AFP, in cupcakes were studied using both objective measurements and sensory evaluation. The major finding is that N-Flate™ and the sweetener system of aspartame, fructose and polydextrose may be used together or separately to replace fat and sugar in cupcakes, respectively. This, however, does not preclude their use in other baked products.

The studies showed that cupcakes prepared with AFP had a bitter aftertaste. Although the sensory panel judged the samples prepared with AFP to be as sweet as those prepared with sugar, they were also judged to be significantly more bitter. A lower volume and firmer texture were also noted in variations prepared with AFP compared with those prepared with sugar. A lower volume and firmer texture were also observed in variations prepared with N-Flate™ than those prepared with shortening.

In order to maximize volume and improve the texture of cupcakes prepared with N-Flate™ or AFP, it may be necessary to alter the relative proportions of the ingredients and the procedures to suit each variation. In addition, the use of leavening agents that better suit the system and the use of egg white foam to increase volume may also help improve the texture.

Further research in this area should include masking the bitter aftertaste associated with the use of aspartame and polydextrose. It may be worthwhile to study the effectiveness of various natural and artificial flavoring agents. It may also be possible to eliminate the use of aspartame from the sweetener system since aspartame appears to be one of the major causes of the bitter aftertaste. Efforts are also needed in the development of formulations for use in other baked products. Finally, consumers should be made aware that reduced fat and reduced calorie baked products do not have the same characteristics as their high fat and high calorie counterparts, which may help improve the acceptance of these products

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Appendix A

Cake Formulations, Mixing and Baking Procedures

Cake Formulations, Mixing and Baking Procedures

Ingredients	Shortening/ Sugar (gm)	Shortening/ AFP (gm)	N-Flate™/ Sugar (gm)	N-Flate™/ AFP (gm)
Cake Flour (Swans Down)	150	150	150	150
NFDM (Carnation)	15	15	-	-
Baking Powder (Hearth Club)	8.5	8.5	8.5	8.5
Salt (Kroger)	2.5	2.5	2.5	2.5
Shortening (Crisco)	81	81	-	-
N-Flate™	-	-	28.8	28.8
Sugar (Kroger)	180	-	180	-
Aspartame	-	1.8	-	1.8
Fructose (Estee)	-	45	-	45
Polydextrose	-	80	-	80
Eggs (Kroger)	90	90	90	90
Water (Deionized, Distilled)	100	120	120	120

Mixing Method for Variations Containing Shortening

The procedure for mixing the ingredients for cakes containing shortening is as follows:

1) Sift together flour, NFDM, baking powder and salt.
2) Cream shortening with sugar or AFP for 1 minute at speed 2.
3) Add flour mixture to creamed shortening mixture followed by the eggs and half of the water.
4) Mix for 1.5 minutes at speed 1.
5) Scrape bowl with rubber spatula and add the rest of the water.
6) Mix for 1.5 minutes at speed 1.
7) Scrape bowl again and mix for 1 minute at speed 6.

All ingredients were mixed in a Hobart Kitchen Aid electric mixer (model K5SS, listed 775A) connected to a Universal timer.

Method for Variations Containing N-Flate^{TM}

The procedure for mixing the ingredients for cakes containing N-Flate^{TM} is as follows:

1) Sift together flour, N-Flate^{TM}, baking powder salt and sugar or AFP.
2) Add eggs and half of the water to the mixture above.
3) Mix for 1.5 minutes at speed 1.
4) Scrape bowl with rubber spatula and add the rest of the water.
5) Mix for 1.5 minutes at speed 1.
6) Scrape bowl again and mix for 1 minute at speed 6.

All ingredients were mixed in a Hobart Kitchen Aid electric mixer (model K5SS, listed 775A) connected to a Universal timer.

Baking Procedures

All cupcake variations were baked according to the following procedure:

1) Weigh out six-35 gm. portions of batter.
2) Place each portion in a 2.5 inch paper baking cup.
3) Place batter filled paper baking cups into an aluminium muffin pan.
4) Bake at 375°F (191°C) for 18 minutes.

Appendix B

Baking, Objective Measurements and Sensory Evaluation Schedule

Week	Sun.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.
1	B/O	S	B/O	S	B/O	S	-
2	B/O	S	B/O	S	B/O	S	-
3	-	-	-	-	-	C	-

B = All four variations were baked.

O = All objective measurements of the batters and the cupcakes except for the crust and crumb color measurements

S = Sensory evaluation session was held. All four cupcake variations were evaluated

C = Crust and crumb color measurements were made

Appendix C

Subsamples for Objective Measurements

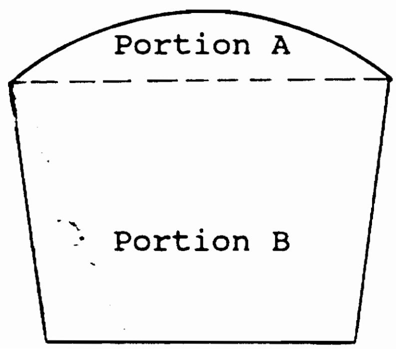
All four cupcake variations were prepared each day for six days. The table below shows the number of replications of objective measurements made each day for each variation.

Objective Measurement	Number of replications per day for each variation
pH	2
Specific gravity	2
Index to volume	6
Crust color	2
Crumb color	2
Tenderness	3
Moisture content	2

Appendix D

Method Used to Prepare Samples for Crust and Crumb Color Analysis, and for Tenderness Measurements

The top of the cupcake was sliced off with a serrated knife. The top or crust portion (Portion A) was used for crust color analysis. The bottom or crumb portion (Portion B) was used for (i) crumb color analysis and (ii) tenderness measurements.



Appendix E

Sample Sensory Scorecard

Sensory Scorecard

Name ________________

Date ________________

Please place a vertical slash through the line at the point that best describes the sample, and note its corresponding code.

1. Moistness

Dry ____ Wet

2. Tenderness

Tough ____ Tender

3. Sweetness

Bland ____ Sweet

4. Crust Bitterness

Not Bitter ____ Bitter

5. Crumb Bitterness

Not Bitter ____ Bitter

6. Cell Uniformity

Not Uniform ____ Uniform

VITA

Lisa Pong was born on April 24, 1966 in Hong Kong. In 1976 she immigrated to the United States with her family. She attended Cornell University where she received a Bachelor of Science in Experimental and Consumer Food Studies in 1988. She is currently working on a Master of Science degree at Virginia Polytechnic Institute and State University in the Department of Human Nutrition and Foods. Upon completion of her degree she plans to pursue a career in the food industry.