NOTE

Evaluation of Alternative Fat and Sweetener Systems in Cupcakes

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ABSTRACT

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A commercial fat substitute, N-Flate, 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 (shortening and sugar, shortening and AFP, N-Flate and sugar, and N-Flate and AFP) were prepared. The batter from the two variations prepared with N-Flate had a significantly higher pH and specific gravity than the two variations prepared with shortening. A lower standing height, a firmer texture, a higher moisture content, and a darker crumb color were observed in the two variations prepared with N-Flate. 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 standing height, a firmer texture, a higher moisture content, and a lighter crust color were also observed in the two variations prepared with AFP. Interaction effects were significant for specific gravity, standing height, crust color, and tenderness. Sensory evaluation results showed that the two variations prepared with N-Flate were less tender and had less cell uniformity than those prepared with shortening. Variations prepared with AFP were less moist, had a more bitter crust and crumb, and showed greater cell uniformity than those prepared with sugar. No interaction effects were observed for any of the sensory attributes. To increase the standing height and improve the texture of cupcakes prepared with N-Flate or AFP, the relative proportions of the ingredients and the procedure may need to be altered to suit each variation. The use of flavoring agents and the elimination of aspartame from the sweetener system may help to mask or reduce the bitter aftertaste. Reduced-fat and reduced-calorie baked products offer an alternative for consumers who must restrict calorie intake.

The health-conscious public demands high-quality and low-calorie products that are low in fat and sugar. However, altering amounts of ingredients to reduce caloric content may compromise texture, mouthfeel, flavor, and appearance. Cake is a product that is high in calories, fat, and sugar. Therefore, a reduced-calorie alternative is needed in the marketplace.

In cakes, fat is usually used in the form of shortening, which incorporates air during mixing and helps to leaven the product (Matz 1960). In addition, shortening tenderizes the crumb and enhances mouthfeel. When shortening is completely removed from a cake formulation, volume decreases, the crumb becomes less tender, and the cell structure becomes uneven (Matz 1960). Kamel and Washnuik (1983) showed that shortening-free cakes made with 50% less egg and 20% less sugar are possible if higher-than-recommended levels of emulsifiers are used. N-Flate (National Starch and Chemical Corp., Bridgewater, NJ) is an emulsified blend of mono- and diglycerides and polyglycerol monoesters with pregelatinized waxy maize starch and guar gum in a skim milk powder base. Smith (1984) found that N-Flate, when used alone with no added oil or shortening, can successfully replace shortening in cakes.

High-intensity sweeteners are used in small quantities as a replacement for sucrose, thus reducing ingredient volume. The functional properties of sucrose, however, are not replaced when high-intensity sweeteners are used as a substitute. Polydextrose, a bulking agent, may be used to compensate for the loss in volume (Freeman 1982). Since polydextrose is only partially metabolized, caloric utilization is only 1 cal/g. Furthermore, polydextrose increases the onset and peak gelatinization temperatures of starch to values similar to those for sucrose (Kim et al 1986). Neville and Setser (1986) evaluated various levels of polydextrose for use in cakes. They found that 62.5% polydextrose, when used with constant amounts of N-Flate and a mixture of aspartame and saccharin, produced optimum products. Higher amounts of polydextrose produced gummy products. With increasing levels of polydextrose, bitterness also increased.

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Aspartame is generally not recommended for use in systems that require prolonged heating because it breaks down into diketopiperazine when exposed to heat (Horwitz and Bauer-Nehrling 1983). Although diketopiperazine is not harmful, it does not have the sweetness of aspartame. Nevertheless, aspartame has been used to sweeten layer cakes (Hess and Setser 1983). Hess and Setser (1983) also found that low levels of fructose enhanced sweetness and tenderness of cakes sweetened with aspartame.

The objective of this study was to evaluate the potential of N-Flate and a sweetener system of 1.5% aspartame, 35.5% fructose, and 63% polydextrose (AFP) as substitutes for shortening and sugar, respectively. Four cupcake variations were prepared to compare the effects of replacing shortening with N-Flate and sugar with AFP. The four variations consisted of shortening and sugar, shortening and AFP, N-Flate and sugar, and N-Flate and AFP. Compared to the shortening-sugar variation, the shortening-AFP variation, the N-Flate-sugar variation, and the N-Flate-AFP variation have 33, 47, and 76% fewer calories, respectively.

MATERIALS AND METHODS

Materials

The ingredients and amounts used for the four cupcake variations are shown in Table I. Non-fat dry milk was omitted from the two variations containing N-Flate because the blend contains a skim milk powder base. The amount of water used for the shortening-sugar variation was reduced to 100 g because preliminary testing showed that 120 g of water produced very thin batters.

Mixing and Baking Procedures

The dry ingredients, with the exception of sugar or AFP, were weighed and sifted together. The shortening and sugar or AFP were creamed for 1 min on speed 2 of a Hobart Kitchen Aid electric mixer with a paddle attachment (model K5SS, Troy, OH) connected to a Universal timer (Dimco Gray Corp., Dayton, OH). The dry ingredients, eggs, and half the water were added and mixed 1.5 min. The remaining half of the water was added and mixed an additional 1.5 min. After scraping down the bowl, the batter was mixed an additional 1 min on speed 6. For the variations containing N-Flate, the sugar or AFP was sifted with the other

dry ingredients.

For each cupcake variation, six 35-g portions of batter were weighed and placed in paper baking cups in an aluminum muffin pan. The cupcakes were baked in a 191°C (375°F) oven for 18 min.

Objective Measurements

The pH of the batter was measured with a pH meter (model 5, Corning Scientific Instruments, Medford, MA) to determine whether the batters were within the 6.5–7.5 range for cakes. Specific gravity of the batter was calculated by dividing the weight of 59 ml (1/4 cup) of batter by the weight of 59 ml of water. The standing height was measured, in the center of the cupcake, with a vernier caliper. Crust and crumb color were measured with a spectrocolorimeter (Hunter Lab Lab-Scan, Reston, VA). Cake crumb firmness was determined with a texture analyzer (model TA 1000, Stevens-LFRA, Texture Technology Corp., Scarsdale, NY). A TA 10 probe, penetrating the sample (a 2.5-cm cube) at a rate of 2 mm/sec, was used. Readings were recorded as the amount of gram-force required to compress the sample 6 mm. Moisture content was determined with a moisture tester (model SAS-692, C. W. Brabender Instruments, Hackensack, NJ). Samples containing both crust and crumb portions were used for moisture determinations. All objective measurements were performed in triplicate.

Sensory Evaluation

Sensory evaluation was performed by eight trained panelists who were graduate students in the Department of Human Nutrition and Foods at Virginia Polytechnic Institute and State University. The panel was made up of two males and six females between the ages of 22 and 30. The panelists became familiar with sensory evaluation procedures, the scorecard, and definitions of the attributes to be evaluated during three 45-min training sessions. Training also included triangle tests conducted with cake samples of a formula similar to that used in the study. The panelists were presented samples of increasing difficulty in discrimination of moistness and sweetness. The training was considered sufficient when all panelists evaluated the samples consistently with deviation of no more than 2 cm on unstructured line scales.

The scorecards were unstructured line scales with anchor words 2 cm from the ends of the scale to assess moistness, tenderness, sweetness, crust and crumb bitterness, and cell uniformity. The definitions of the terms were determined by consensus of the panelists during training. At each of the six sensory sessions, panelists evaluated all cupcake variations. Due to time constraints and panelist availability, the cupcakes were evaluated 24 hr after they were baked. They were covered in plastic wrap and stored at room temperature. Randomly coded samples were presented to the panelists on white plates. For each variation, each panelist received a fourth of a cupcake. All four variations were presented at one time in random order at each session. Water was provided for rinsing between samples.

Statistical Analysis

Statistical analysis consisted of a 2 × 2 factorial block design. The two main effects tested were fat or emulsifier effect and sweetener effect. The least square means were calculated for each measurement to compare the effects of shortening versus N-Flate and the effects of sugar versus AFP. The interaction effect of fat or emulsifier and sweetener was also tested. The analysis was performed for both objective and sensory data using SAS (SAS 1986). Least significant differences were used for mean comparison tests.

RESULTS AND DISCUSSION

Objective Results

The type of fat or emulsifier made a significant difference ($P < 0.01$) to the mean pH balance of the batter (Table II). 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 II). Although both fat-emulsifier type and sweetener type affected the pH of the batter, the pH of all four batters was within the optimum levels of 6.5–7.5 (Ash and Colmey 1973).

Batters prepared with N-Flate had a significantly ($P < 0.01$) higher specific gravity than those prepared with shortening (Table II). 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. Because N-Flate comes in a powdered form, it was not creamed with sugar or AFP but was sifted with the remaining dry ingredients. The type of sweetener also had a significant ($P < 0.01$) effect on the specific gravity of the batter (Table II). The batters containing AFP incorporated less air than the batters containing sugar.

Cupcakes prepared with N-Flate had a significantly ($P < 0.01$) lower standing height than those prepared with shortening (Table II). This finding is consistent with the higher specific gravity of the batters prepared with N-Flate. The N-Flate-sugar variation had a higher standing height than the shortening-sugar variation. 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 or less air incorporated would have a lower volume or standing height. One possible

TABLE I
Formulation for Four Cupcake Variations

Ingredients[a]	Shortening and Sugar (g)	Shortening and AFP[b] (g)	N-Flate[c] and Sugar (g)	N-Flate[c] and AFP (g)
Cake flour	150	150	150	150
Nonfat dry milk	15	15	...	...
Baking powder	8.5	8.5	8.5	8.5
Salt	2.5	2.5	2.5	2.5
Shortening	81	81	...	...
N-Flate	...	...	28.8	28.8
Sugar	180	...	180	...
Aspartame	...	1.8	...	1.8
Fructose	...	45	...	45
Polydextrose	...	80	...	80
Eggs	90	90	90	90
Water (deionized, distilled)	100	120	120	120

[a]Ingredients included Swans Down flour (W. B. Reiley & Co., New Orleans), Carnation dry milk (Los Angeles), Hearth Club baking powder (Rumford Co., Terre Haute, IN), Crisco shortening (Procter & Gamble, Cincinnati), and fructose from Estee (Parsippany, NJ). Salt, sugar, and eggs were purchased from a local supermarket.
[b]AFP = sweetening system containing 1.5% aspartame (G.D. Searle & Co., Deerfield, IL), 35.5% fructose, and 63% polydextrose (Pfizer, Inc., Groton, CT).
[c]N-Flate is a commerical emulsifier used as a fat substitute.

TABLE II
Least Square Means of Objective Measurements for the Type of Fat or Emulsifier and Sweetener

Measurement	Fat or Emulsifier[a] Shortening	Fat or Emulsifier[a] N-Flate[b]	Sweetener[a] Sugar	Sweetener[a] AFP[c]
pH	6.89 a	6.67 b	6.74 c	6.82 d
Specific gravity	0.88 a	0.94 b	0.86 c	0.96 d
Standing height	3.77 a	3.65 b	3.88 c	3.54 d
Crust ΔE value	76.6 a	77.0 a	76.0 c	77.6 d
Crumb ΔE value	87.3 a	82.4 b	84.8 c	85.0 c
Deformation value (tenderness)	181 a	215 b	130 c	266 d
Moisture content	26.6 a	31.1 b	27.3 c	30.4 d

[a]Least square means followed by different letters in the same row are significantly different ($P < 0.05$).
[b]N-Flate is a commercial emulsifier used as a fat substitute.
[c]AFP = aspartame, fructose, and polydextrose.

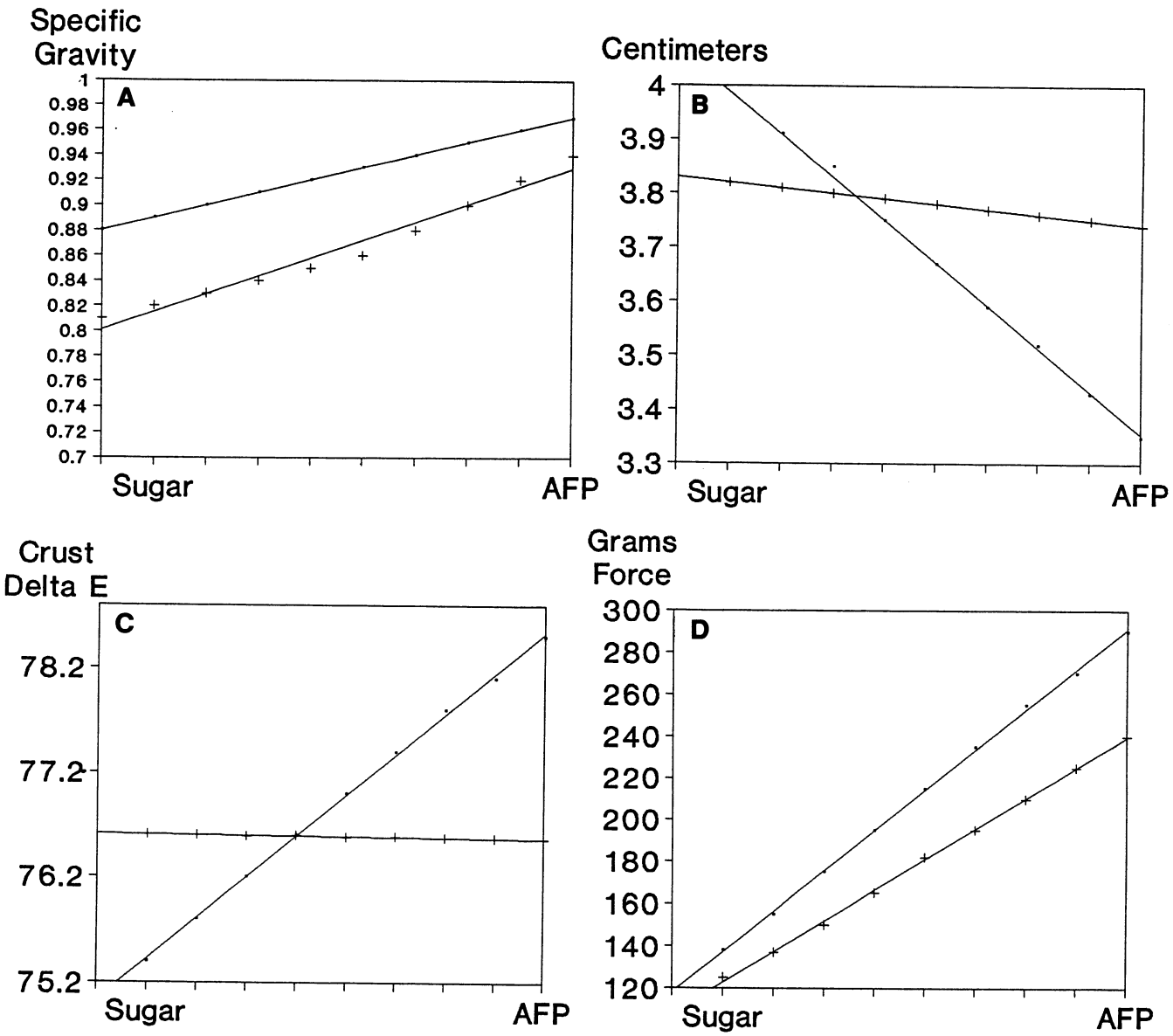

Fig. 1. Mean specific gravity values (**A**), mean index to volume values (**B**), mean crust E values (**C**), and mean deformation values (**D**) of four cupcake variations prepared with shortening (+) or N-Flate (·) and sugar or aspartame, fructose, and polydextrose combined (AFP).

TABLE III
Least Square Means[a] of Sensory Evaluation Results for the Type of Fat or Emulsifier and Sweetener

Measurement	Fat or Emulsifier[b]		Sweetener[b]	
	Shortening	N-Flate[c]	Sugar	AFP[d]
Moistness	4.56 a	5.15 a	5.31 c	4.39 d
Tenderness	6.49 a	4.87 b	5.66 c	5.71 c
Sweetness	6.04 a	5.54 a	5.71 c	5.88 c
Crust bitterness	5.34 a	5.27 a	3.58 c	7.04 d
Crumb bitterness	4.78 a	4.96 a	3.23 c	6.51 d
Cell uniformity	6.26 a	4.77 b	4.49 c	6.53 d

[a]Least square means range from 0 to 10.5. Zero indicates a dry, tough, bland, unbitter, and nonuniform cell formation, whereas 10.5 indicates a wet, tender, sweet, bitter, and uniform cell formation.
[b]Least square means followed by different letters in the same row are significantly different ($P < 0.05$).
[c]N-Flate is a commercial emulsifier used as a fat substitute.
[d]AFP = aspartame, fructose, and polydextrose.

explanation is that shortening incorporates a greater amount of air but does not maintain the air on baking. N-Flate, on the other hand, did not incorporate as much air but maintained more air bubbles. Visual observation revealed that the batter prepared with N-Flate and sugar 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 maintaining 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 standing height (Table II). Cupcakes prepared with AFP had a lower standing height than those prepared with sugar. This finding is supported by the fact that the specific gravity of the batters containing AFP was higher than that of the batters containing sugar.

The fat-emulsifier effect was highly significant ($P < 0.01$) for the color of the crumb but not for the crust color (Table II). 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 crumb color. Cupcakes prepared with AFP had a lighter crust than those prepared with sugar. The presence of fructose in AFP contributed to caramelization and Maillard browning. However, with the small amount of fructose used, excessive browning was not a problem.

The fat-emulsifier type and sweetener type both had a significant ($P < 0.01$) effect on the tenderness of the cupcakes. Variations with N-Flate and variations with AFP produced less tender cupcakes than those with shortening and sugar, respectively (Table II).

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 those prepared with shortening (Table II). The sweetener effect was also highly significant ($P < 0.01$). Variations prepared with AFP had a higher moisture content than variations prepared with sugar (Table II). The hygroscopic nature of fructose and polydextrose may account for the greater moisture content. Significant fat-emulsifier and sweetener interaction effects were observed for specific gravity, standing height, crust color, and tenderness (Figs. 1-4).

Sensory Results

No significant difference was found 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 III). Variations prepared with AFP were judged to be significantly ($P < 0.05$) less moist than those prepared with sugar (Table III). This, however, was not supported by the objective data. The mouthfeel effect of a less tender crumb may have led the panelists to perceive, on the average, a drier crumb.

Variations prepared with N-Flate were judged to be significantly ($P < 0.01$) less tender than those prepared with shortening (Table III). This was supported by the results of the texture analyzer. The sweetener type did not affect the sensory scores for tenderness (Table III). This contradicted the results of the texture analyzer. The difference may be attributed to the fact that the cupcakes were evaluated by the panelists 24 hr after baking.

There were no significant effects of fat-emulsifier type and sweetener type on the sensory scores for sweetness (Table III). However, the mean sensory scores of the four cupcake variations suggested that N-Flate may have masked the sweet taste of sugar. The masking effect of N-Flate was not evident in cupcakes containing AFP.

The effects of fat-emulsifier type and sweetener type on crust and crumb bitterness are shown in Table III. The effect of fat-emulsifier type was not significant. A highly significant ($P < 0.01$) effect of sweetener type on bitterness of both the crust and crumb was observed. The crust and crumb of the AFP variations were judged to be more bitter than those of the sugar variations. The bitterness may have been attributed to five factors: 1) the breakdown of aspartame as it is exposed to heat, 2) the bitterness of polydextrose when used in large amounts, 3) the breakdown of polydextrose as it is exposed to heat, 4) the products of caramelization and/or Maillard browning, and 5) the interaction of the ingredients. It is unlikely that the products of the browning reactions were the major cause of the bitter aftertaste since no excessive browning occurred.

The panelists judged that the cell uniformity of cupcakes was significantly ($P < 0.01$) affected by the type of fat or emulsifier and the type of sweetener (Table III). 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.

No interaction effects were observed for any of the sensory attributes.

CONCLUSIONS

The effects of replacing fat with N-Flate and sugar with AFP in cupcakes were studied with the use of both objective measurements and sensory evaluation. The major finding was that N-Flate and the sweetener system of aspartame, fructose, and polydextrose may be used together or separately to replace fat and sugar, respectively, in cupcakes.

Sensory results indicated that cupcakes prepared with AFP had a bitter aftertaste, although the sensory panel judged them to be as sweet as those prepared with sugar. A lower standing height and firmer texture were also noted in variations prepared with AFP than in those prepared with sugar. A lower standing height and firmer texture were also observed in variations prepared with N-Flate than in those prepared with shortening.

To maximize the volume or standing height and to improve the texture of cupcakes prepared with N-Flate or AFP, altering the procedures and the relative proportions of the ingredients to suit each variation may be necessary. In addition, 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 aspartame from the sweetener system since it appears to be one of the major causes of the bitter aftertaste. Efforts are also needed in the development of formulations for other baked products. Finally, to facilitate acceptance of these products, 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.

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