Optimizing Texture of Reduced-Calorie Yellow Layer Cakes[1]

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ABSTRACT

Response surface regression models were used to optimize textural attributes of a yellow layer cake with calories reduced approximately 45% from the level in standard cake formulations. Six bulking agents (sorbitol, a hydrogenated starch hydrolysate mixture, lactitol, isomalt, 18-dextrose-equivalent maltodextrin, and polydextrose) were used in combinations to totally or partially replace sucrose. Formulations containing a combination of polydextrose and the hydrogenated starch hydrolysate mixture and a combination of polydextrose and sucrose at two emulsifier levels were optimized. Textural attributes of reduced-calorie, shortening-free cakes were rated between those of a commercial pound cake and a yellow layer cake.

Interest in nutrition is driving consumer demands for less fat, sugar, and calories. The food industry is being challenged to redesign traditional foods for optimal nutritional value, while making them taste the same or better (Anonymous 1989, Carter 1989, Sills-Levy 1989).

One way to achieve a salubrious food product is to omit some of the calorie-laden ingredients. However, in most foods, the removal or reduction of ingredients causes readily detectable losses in appearance, texture, and mouthfeel. Sucrose is a principal ingredient in layer cakes, and its role extends beyond providing energy and sweetness. It acts as a tenderizer by retarding and restricting gluten formation, increasing the temperatures of egg protein denaturation and starch gelatinization, and contributing bulk and volume (Osman 1975, Bean et al 1978, Meyer 1978, Campbell et al 1979a, Charley 1982, Spies and Hoseney 1982). The reduction of sucrose levels in a cake system affects structural and sensory properties.

Bulking agents, which replace the nonsweet functional characteristics of sucrose, have been used as alternatives to sucrose in bakery products (Beereboom 1979). No bulking agent possesses all of sucrose's unique properties; thus a combination of bulking agents must be used. The objectives of this study were 1) to explore combinations and levels of various bulking agents to totally or partially replace sucrose in reduced-calorie layer cakes and 2) to compare textural characteristics of optimized formulations with those of two commercial products. The study's three stages were: 1) optimization, 2) validation, and 3) comparison of optimized reduced-calorie cakes with commercial products.

MATERIALS AND METHODS

Cake Preparation

The formulations used for the reduced-calorie, shortening-free, yellow layer cakes, and the suppliers from which they were obtained, are given in Table I. Fresh eggs were purchased weekly. All other ingredients were ordered from single lots before each study. The six bulking agents studied, as partial and complete substitutes for sucrose, were: 1) polydextrose K; 2) hydrogenated starch hydrolysate (Lycasin), a mixture of sorbitol, maltitol, and various oligosaccharides and polysaccharides with 55 dextrose equivalent (DE) before hydrogenation; 3) lactitol; 4) sorbitol; 5) isomalt, an equimolar mixture of α-D-glucopyranosyl-1→6-sorbitol and α-D-glucopyranosyl-1→1-mannitol (Palatinit); and 6) an 18-DE maltodextrin.

A single-bowl mixing procedure was used. Batters were mixed for 0.5 min at speed 2 and 4.0 min at speed 10 using a Kitchen-Aid mixer (model 5-C, Hobart, IN). Batter weight was 400 g for optimization and 500 g for validation and comparison studies.

Cakes were baked in 8-in. pans for 35 min at 177°C in a rotary hearth oven (National Manufacturing Co., Lincoln, NE).

The final phase of the study compared the textural differences of cakes made with optimized formulations (sucrose and

TABLE I
Cake Formulations

Phase and Ingredient	Percent (fwb)[a]
Optimization phase	
Constant ingredients	
Cake flour (Sno-Sheen, pH 4.8; Pillsbury Inc., Minneapolis, MN)	100.00
Baking powder (ADM Arkaday, Olathe, KS)	9.80
Salt (Carey Co., Mission, KS)	2.22
Xanthan gum (Kelco, Div. of Merck & Co. Inc., San Diego, CA)	0.25
Whey protein concentrate (Danmark, Aarhus, Denmark)	8.30
Sucrose esters (DK Ester F 160; Dai-Chi Kogyo Seihaku Co., Ltd., Tokyo, Japan)	1.50
Whole fresh egg (local market)	39.00
Variable ingredients	
Water (r/o)[b]	110, 120, 130
Polydextrose (type K; Pfizer Inc., New York, NY)	0–65
Hydrogenated starch hydrolysates (Lycasin; Roquette Corp., Gurnee, IL)	0–130
Lactitol (Purac Inc., Arlington Heights, IL)	0–130
Sucrose (C & H Inc., Concord, CA)	0–120
Sorbitol (Neosorb P60; Roquette Corp., Gurnee, IL)	0–130
Isomalt (Palatinit, grade F; SuGunsmittel GmbH, Germany)	0–130
Maltodextrin (Maltrin M180; Grain Processing Corp., Muscatine, IA)	0–130
Validation phase	
Additional ingredients held contant	
Water (r/o)	130.0
Polydextrose K	32.5
Variable ingredients	
Sucrose esters	2.0–2.5
Sucrose	0.0–60.0
Hydrogenated starch hydrolysates (Lycasin)	0.0–65.0
Acesulfame K (Sunette; Hoechst Celanese Corp., Somerville NJ)	0.0–0.25
Comparison phase	
Additional ingredients held constant	
Water (r/o)	130.0
Sucrose	60.0
Sucrose esters	2.0
Acesulfame K	0.25
Vanilla (McCormick, Hunt Valley, MD)	1.6
Variable ingredients	
Polydextrose K	0.0–32.5
Polydextrose (type F, Litesse; Pfizer, Inc., New York, NY)	0.0–32.5

[a] Flour-weight basis.
[b] Reverse-osmosis distilled.

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polydextrose type K and sucrose and polydextrose type F [Litesse]) from the validation phase; a commercial yellow layer cake (from a Duncan Hines yellow layer cake mix, Procter and Gamble, Cincinnati, OH); and a commercial pound cake (Sara Lee frozen pound cake, Deerfield, IL). The cake mix was prepared according to the manufacturer's instructions. Polydextrose F was exchanged for polydextrose K in one treatment to determine whether the mouth-drying effects, which were associated with polydextrose K in earlier phases of the study, could be reduced. Vanilla and a high-potency sweetener, acesulfame K (Sunette), were added to the texturally optimized formulations to approximate the flavor of commercial products.

All cakes for the validation and optimization phases were mixed and baked approximately 8 ± ½ hr before evaluation. Cakes for the comparison phase were baked approximately 6 ± ½ hr before evaluation.

Physical Measurements of Batters and Cakes

Batter measurements included specific gravity, pH, and viscosity. All measurements were triplicated, and means were recorded. Specific gravity was determined gravimetrically by dividing the weight of the batter by the weight of an equal volume of water (Campbell et al 1979b). Twenty-five grams of batter were mixed with 50 ml of reverse-osmosis, distilled water in a 100-ml glass beaker. Batter viscosity was measured using an RV-8 viscometer (Viscometers U.K. Ltd., London, England) with a no. 7 spindle at 7 rpm. Indices for volume, symmetry, uniformity, and shrinkage of the cakes were determined using a plastic template according to AACC Method 10-91 (AACC 1983).

Sensory Studies

Sample preparation. Cake samples were prepared 1–2 hr before sensory evaluation. For determining crust profiles, whole cakes were halved along the diameter. One cake half was placed on a coded white plastic plate and covered with an aluminum foil tent. The other cake half was used for evaluation of the crumb attributes. The crust was removed, and interior crumb was sliced in ¾- × ¾- × ½-in. samples.

Reference samples. Reference samples and textural attributes are listed for the optimization and validation phases in Table II and for the comparison phase in Table III.

Panel training and procedures. Four graduate students served as panelists for the first two developmental stages of the study. Five professional panelists from the Kansas State University Sensory Analysis Center were employed for the final comparison study. All panelists had training in sensory evaluation and previous experience in the evaluation of reduced-calorie cakes. Panel sizes were small; however, Chambers et al (1981) reported that a trained, experienced, three-member sensory panel could be used instead of a typical seven- or eight-member panel without decreasing panel accuracy.

In the optimization and validation stages, panelists were oriented to the product in nine 1½-hr training sessions. During orientation, panelists established references, determined anchor points on the score card, and clarified terminology. Evaluations were divided to include quantitative and consensus descriptive analyses.

The following attributes were evaluated quantitatively: manual springiness, crumb firmness, crumbliness, cell uniformity, and cell size. The intensity of each attribute was recorded on a 6-in. unstructured line scale with anchor points. The definitions of textural terms were those used in previous studies (Bramesco and Setser 1990), and reference pictures for the visual textural attributes, cell uniformity and size, were provided at each session.

Cake samples were presented simultaneously and evaluated in random order among panelists. Panelists' performance was

TABLE II
Texture References for Optimization and Validation Phases

Attribute	Definition of High Level	Reference Low	Reference Middle	Reference High
Cohesiveness of mass	Cohesive	Saltine cracker[a]		White bread[b]
Crumbliness	Very crumbly	White bread[b]	Muffins[c]	Cornbread[d]
Crumb firmness	Firm	White bread[b]	Muffin[c]	Pound cake[e]
Manual springiness	Very springy			White bread[b]
Moistness to lips	Very moist	Saltine cracker[a]	Pound cake[e]	Cornbread[d]
Mouth drying	Very mouth drying	Brownie[f]		Saltine cracker[a]

[a]Nabisco unsalted tops saltine crackers, New Hanover, NJ.
[b]Wonder bread, Continental Baking Co., St. Louis, MO.
[c]Betty Crocker blueberry muffin mix (prepared without blueberries), General Mills Inc., Minneapolis, MN.
[d]Martha Gooch complete cornbread muffin mix, Gooch Foods, Inc., Lincoln, NE.
[e]Sara Lee frozen pound cake, Deerfield, IL.
[f]Duncan Hines original fudge brownie mix, Procter and Gamble, Cincinnati, OH.

TABLE III
Texture References for Comparison Phase

Attribute	Definition of High Level	References Low	References Middle	References High
Adhesiveness of mass	Very adhesive	Waffle[a]	Pumpernickel bread[b]	White bread[c]
Cohesiveness of mass (8 chews)	Very cohesive	Waffle[a]		White bread[c]
Crumbliness	Very crumbly	White bread[c]		Cornbread[d]
Dryness of mouth (after 8 chews)	Very dry	Waffle[a]	Pumpernickel bread[b]	Saltine cracker[e]
Firmness	Very firm	Brownie[f]		Pumpernickel bread[b]
Manual springiness	Very springy	Brownie[f]		White bread[c]
Mouth etching (at swallowing after 5 sec)	High degree of etching			Alum[g]

[a]Aunt Jemima original frozen waffles, The Quaker Oat Co., Chicago, IL.
[b]Pepperidge Farm pumpernickel bread, Norwalk, CT.
[c]Wonder bread, Continental Baking Co., St. Louis, MO.
[d]Martha Gooch complete cornbread muffin mix, Gooch Foods Inc., Lincoln, NE.
[e]Nabisco unsalted tops saltine crackers, New Hanover, NJ.
[f]Duncan Hines original fudge brownie mix, Procter and Gamble, Cincinnati, OH.
[g]0.50% alum ($AlKS_2O_8$ dodecahydrate) solution.

checked for consistency by evaluation of a warm-up sample before each session.

Consensus descriptive analysis was used to describe some crumb and crust characteristics. Crumb properties of moistness to lips, mouth drying, adhesiveness, and cohesiveness of mass were described because panelists noted differences related to individual oral cavity characteristics that made quantitative agreement difficult for those attributes. Crumb sweetness, bitterness, and aftertaste also were described by consensus. Crust characteristics included browning, color ring formation, crust stickiness, undercrust stickiness, crust color, and air pocket formation.

For the final comparison study, the professional panelists had four 1-hr orientation sessions at which they reviewed terminology and established anchor points on the 6-in. unstructured line scale. Adhesiveness of mass and mouth etching, attributes not defined or evaluated in earlier studies, were included in the comparison phase of this study. Adhesiveness of mass was the degree to which the sample adhered to mouth surfaces during mastication; mouth etching was the degree of roughness, or etching, on the surface of the mouth, including the teeth, palate and gums.

Experimental Design and Statistical Analysis

The optimization phase used response surface methodology (RSM) to derive optimal formulations for sucrose replacement in the reduced-calorie layer cake system. Combinations and levels of bulking agents were determined by a randomized mixture design. High and low levels for bulking agents and water were determined in preliminary work before starting the RSM study (Table I). The bulking agents were used at 0–100% (flour weight basis, fwb) of preestablished high levels. The experimental design included 60 combinations with varied levels of water and bulking agents. Twelve of those cakes were replicated as check points, giving a total of 72 cakes.

Data were analyzed using the Statistical Analysis System (SAS Institute 1982). The best-fitting models were determined by stepwise regression procedures and used as predictors of the treatment factors and to estimate properties of independent variables (Table IV). A 0.25 level of significance was selected for a variable to remain in the model. If a variable was significant in either a quadratic or a cross-product term, it was kept in the model at the linear level also. Ranges of selected sensory attributes and cake volume were used as predictors for the optimal levels and combinations of bulking agents and water. The ranges, based on the six-point sensory scale, were set to define a formula that would produce a cake with high cell uniformity (>3.0 on the 6.0 scale) and manual springiness (>3.0), small cell size (<2.0), and moderate crumb firmness (1.5–4.5) and crumbliness (1.5–4.5). The volume index was set at >100.

A randomized design with three replications was used in the validation phase, and a randomized complete block design with four replications was used for the comparison phase. Data were analyzed using analysis of variance on the SAS program (SAS Institute 1982). Least significant differences at $P = 0.05$ were used to compare sample means.

RESULTS AND DISCUSSION

Optimization Phase

Significant effects from the regression analysis for sensory and physical responses are summarized in Table V. These values reflect linear, quadratic, and cross-product trends for sensory attributes and physical measurements. The significant F values provided guidelines for further model building. The R^2 coefficient values from the best-fitting models were high for springiness (0.94), crumbliness (0.90), firmness (0.82), and cell size (0.86). These indicated good fit of the models, which was supported by the lack-of-fit test. The R^2 values for volume (0.51) and cell uniformity (0.53) were lower, suggesting that the models did not adequately predict those characteristics. Mean values for these attributes were within a small range, so this is reasonable.

Panelist variability and other factors not investigated in this study also might explain the lower R^2 values. Additional factors could influence cake volume or cell uniformity. For example, our continuing research has demonstrated that cake volume can be increased by increasing mixing times and by heat-treating sucrose esters with a portion of the water and mixing the emulsifier with the dry ingredients before adding the remaining liquid.

Significant linear, quadratic, and cross-product effects of bulking agents and water on sensory and physical attributes are given in Table VI. The various ingredients and combinations produced significant effects on cake attributes. No one ingredient or combination of ingredients produced significant effects for all attributes. Polydextrose appeared in many interactions and consequently was considered essential in optimized formulations.

Consensus descriptions. Descriptions of cakes indicated crust air pockets (a raised space between crumb and crust producing a "puffed" appearance) with 100% levels of sorbitol, hydrogenated starch hydrolysates, lactitol, isomalt, or sucrose. No air pockets were evident when maltodextrin or polydextrose was used. The puffed characteristic could have been related to the viscosity of the batters. Cake batters containing polydextrose and/or maltodextrin were approximately twice as viscous as other batters. Viscosity of a batter controls the rate at which air bubbles rise to the surface (Shepherd and Yoell 1976). During baking, the degree of bulk flow of the batter from convection currents at any given time depends on its batter viscosity, with low batter

TABLE IV
Models[a] for Selected Attributes Used in Response Surface Optimization Phase

Cell uniformity =	20.8886 + 0.00760828·x1 − 0.01649682·x3 + 0.67047598·x4 − 0.0983247·x5 − 0.01584358·x7 + 0.02555874·x8 − 0.01139551·x4 − 0.00301835·x5·x5 − 0.000301835·x1·x7 + 0.00237084·x3·x7 − 0.00803704·x4·x5 + 0.0043501·x5·x8
Cell size =	− 20079.73 + 154.964·x1 + 155.052·x2 + 155.079·x3 + 310.651·x4 + 154.515·x5 + 155.088·x6 + 167.959·x7 − 0.25224988·x8 + 0.00224828·x5·x5 − 0.0038697·x2·x4 + 0.01002565·x3·x4 + 0.00629787·x4·x5 − 0.00497727·x4·x6 − 0.00768454·x4·x8
Manual springiness =	8829.64 − 67.5148·x1 − 67.07525·x2 − 67.5117·x3 − 134.995·x4 − 67.7250·x5 − 67.5223·x6 − 73.1300·x7 + 0.02802897·x8 − 0.00132884·x5·x5 + 0.00279068·x1·x5 − 0.00450544·x2·x5 − 0.00385160·x2·x8 − 0.00288502·x3·x5 − 0.00480841·x5·x6 − 0.00137685·x6·x7
Crumb firmness =	−28.8586 − 0.04021796·x1 + 0.02239955·x3 + 0.11697209·x4 + 0.22191136·x5 + 0.42234739·x6 + 0.02105305·x7 + 0.43093547·x8 + 0.00085192·x1·x1 + 0.00182643·x5·x5 + 0.00022579·x7·x7 − 0.00194643·x3·x6 − 0.00162768·x3·x7 − 0.00510773·x5·x8 − 0.00400386·x6·x8
Crumbliness =	− 3819.43 + 30.2058·x1 + 29.8675·x2 + 29.9362·x3 + 59.9913·x4 + 29.1359·x5 + 29.90192·x6 + 32.1696·x7 − 0.29252282·x8 + 0.00146213·x5·x5 + 0.00108540·x7·x7 − 0.00296652·x1·x8 + 0.00158790·x2·x6 + 0.0023082·x3·x6 + 0.00475667·x4·x6 + 0.00275279·x5·x7 + 0.00290379·x5·x8
Cake volume =	−7066.67 + 56.3855·x1 + 56.1188·x2 + 56.07452·x3 + 112.228·x4 + 55.0849·x5 + 54.6449·x6 + 60.9176·x7 − 0.975768·x8 − 0.003019·x1·x1 + 0.004434·x2·x6 − 0.005185·x2·x7 + 0.005498·x3·x6 + 0.007092·x4·x6 + 0.009220·x5·x8 + 0.012740·x6·x8

[a]Codes for ingredients: x1 = hydrogenated starch hydrolysates, x2 = sorbital, x3 = lactitol, x4 = polydextrose K, x5 = maltodextrin (dextrose equivalent 18), x6 = isomalt, x7 = sucrose, and x8 = water (reverse-osmosis, distilled).

viscosity resulting in more convection flow. The crust sets before the interior center of the cake, and the numerous air bubbles that have risen to the surface of the cake with a low-viscosity batter could be prevented from escaping by the set crust. Thus, air pockets could form between the set crust structure and the unset cake interior.

Polydextrose K at the 100% level caused long and severe mouth drying, whereas the 100% level of sorbitol elicited moderate mouth drying. A mixture of the polydextrose with maltodextrin, sorbitol, or isomalt resulted in severe but less prolonged mouth drying. Sorbitol combined with maltodextrin, isomalt, or polydextrose also produced high levels of mouth drying. Cakes containing polydextrose, especially if it had been used alone for sucrose replacement, had a bitter to salty aftertaste. Kamel and Rasper (1988) also reported that cakes containing polydextrose and sucrose (50:50) had a mild, but easily detectable, bitter aftertaste.

Replacement with 18-DE maltodextrin alone produced a fragile cake with a thick top crust. The delicate crumb structure could reflect the maltodextrin's effects on protein denaturation and/or starch gelatinization. Slade and Levine (1987) reported that sucrose increased gelatinization temperature more than 10-DE maltodextrin. However, effects of an 18-DE maltodextrin are not known. Low-DE corn syrups used for complete replacement of sucrose cause fragile structure; this might also be true in this instance.

The RSM optimization phase resulted in five formulations that were within the previously defined acceptable ranges using 0, 50, or 100% (fwb) of the highest bulking agent level and water levels of 110, 120, or 130% (fwb). The five formulations were 32.5% polydextrose plus 65% sorbitol or hydrogenated starch hydrolysates, each with 120 or 130% water, and 32.5% polydextrose with 60% sucrose and 100% water. Bench-top testing was done to assure that the predicted formulas met the defined criteria. The 130% water level met all the criteria for all cakes. The sorbitol plus polydextrose combination gave noticeable mouth drying and aftertaste and was eliminated from the validation study. The mouth drying and aftertaste of those cakes concurred with the descriptions given by panelists of similar cakes in the optimization phase of the study. Cakes containing polydextrose with the hydrogenated starch hydrolysates were less sweet than those containing the polydextrose with sucrose. Each of the formulations produced a cake with approximately 45% fewer calories than cakes prepared from a standard yellow layer cake mix (Pennington and Church 1989). The reduced-calorie, shortening-free cakes yielded approximately 1.9 kcal/g.

Validation Phase

Mean values for all except one of the sensory attributes designated as predictors in the optimization phase were within the optimum ranges (Table VII). The values for crumbliness were slightly higher than the defined optimum. No significant interactions were indicated between bulking agents and emulsifier levels for any sensory attribute or physical measurement. The cakes in this phase of the study behaved contrary to the usual expectation that low batter specific gravity yields a high volume. No significant difference of cake volume indices was found between high (2.5%) and low (2.0%) levels of emulsifiers, although low levels had higher specific gravity values ($P = 0.05$). The cakes containing the sucrose-polydextrose combinations had significantly higher mean volumes and higher batter specific gravity values than cakes with polydextrose plus hydrogenated starch hydrolysate. No significant difference was found for other physical measurements (pH, viscosity, cake symmetry, cake uniformity, or shrinkage) or for appearance evaluations of cell uniformity or cell size. Firmness or crumbliness did not differ significantly among bulking agents. The low level of emulsifier produced cakes with significantly higher springiness and firmness than the high level of emulsifier, and the high level of emulsifier produced significantly higher crumbliness than the low level. No advantage was found for the higher emulsifier level.

Consensus descriptions. All cakes had similar descriptive profiles. Bitterness and mouth drying were noted in all cakes. The bitterness and astringency were thought to be related to the presence of polydextrose. The formulation containing hydrogenated starch hydrolysate plus polydextrose with 2.5% emulsifier produced long and delayed mouth drying.

Comparison Phase

All dependent variables had significant effects on cake attributes. Least square means are summarized in Table VIII. The

TABLE V
Significant *F*-Ratios from Response Surface Regression Analysis for Optimization of Reduced-Calorie Yellow Layer Cakes

Attribute	*F*-Ratio	Probability
Linear effect		
Viscosity	2.23	0.0567
Volume	2.68	0.0264
Cell uniformity	2.21	0.0589
Cell size	35.36	0.0001
Springiness	59.53	0.0001
Firmness	14.78	0.0001
Crumbliness	35.78	0.0001
Quadratic effect		
Specific gravity	2.38	0.0441
Cell uniformity	2.71	0.0248
Cross-product effect		
Springiness	3.42	0.0015
Cell size	3.01	0.0038

TABLE VI
Significant Effects[a] of Bulking Agents on Sensory and Physical Attributes

Effects	Cell Size	Cell Uniformity	Crumbliness	Firmness	Springiness	Volume
Linear[b]						
H	x				x	
L	x				x	
M	x				x	
I	x			x	x	
P	x	x		x	x	
S	x				x	
W	x		x			x
Quadratic						
H				x		x
M	x	x	x	x	x	
P		x				
S			x			
Cross product[b]						
P × S	x				x	
P × L	x					
P × M	x					
P × I	x		x			
M × H					x	
M × S					x	
M × L					x	
Su × L		x				
Su × H		x				
M × P		x				
M × W		x				
L × I			x	x		
L × Su				x		
M × I	x				x	
I × S			x			x
I × Su					x	
I × L						x
I × P						x
I × W				x		x
S × Su						x
M × Su			x			
M × W			x	x		x
W × H			x			
W × S					x	

[a] An x indicates that the effect was significant at the 0.15 level or lower.
[b] Codes for ingredients: H = hydrogenated starch hydrolysates (Lycasin), I = isomalt (Palatinit), S = sorbitol, L = lactitol, P = polydextrose K, W = water, M = maltodextrin (Maltrin 180), and Su = sucrose.

only significant difference between the cakes containing polydextrose K plus sucrose and those containing polydextrose F plus sucrose was for cell size. The polydextrose K-sucrose and polydextrose F-sucrose cakes were significantly different from commercial products for all attributes except springiness. The reduced-calorie cakes were rated between the commercial cakes for most attributes. Differences were small but significant, because the coefficients of variation from the highly trained panelists were small (3.9–14.7), except for firmness (46.8). A highly trained panel identifies differences that many consumers probably would not perceive, but the most perceptive consumer could notice some or all of the differences. Thus, both polydextrose K and polydextrose F cakes were rated significantly higher than both commercial cakes in cohesiveness of mass, adhesiveness of mass, mouth drying, and mouth etching.

Significant panelist-by-cake effects were examined, and all but one were related to slight differences in the section of the scoring instrument used. The one exception was a crossover interaction in the evaluation of manual springiness for the yellow layer cake from the commercial mix. The cause of this interaction was not determined definitively, but it could have resulted from slight variations in surface drying of samples, in spite of precautions taken. Because the crossover interaction was not found for any other cake treatments, inadequate panel training or confusion regarding the evaluation procedure for this attribute were not believed to be causes.

CONCLUSIONS

Successful textural optimization was achieved for the reduced-calorie, shortening-free cake system replacing sucrose with bulking agents. Final optimized cake formulations had an approximately 45% calorie reduction compared with a standard yellow layer cake. Reduced-calorie cakes were rated between a commercial pound cake and a yellow layer cake prepared from a commercial mix for most of the sensory textural attributes studied. However, cakes containing polydextrose had some bitter or astringent aftertaste and mouth drying. When polydextrose F was exchanged with polydextrose K in the reduced-calorie formula, no significant difference between the cakes was noted for any attribute except springiness. Both polydextrose F and polydextrose K cakes had small but significantly higher ratings for cohesiveness of mass, adhesiveness of mass, mouth drying, and mouth etching compared to either of the commercial products. Further work with flavorings is underway to mask mouth drying and mouth etching effects.

TABLE VII
Mean Scores for Sensory and Physical Attributes[a] for Validation Phase

	Bulking Agent			Emulsifier Levels		
Attribute	Sucrose + Polydextrose	Lycasin + Polydextrose	Significance[b] of Difference Between Agents	High[c]	Low[c]	Significance[b] of Difference Between Levels
Sensory[d]						
Cell uniformity	40.5	43.3	NS	43.2	40.5	NS
Cell size	29.8	26.5	NS	29.7	26.7	NS
Springiness	51.5	49.7	NS	48.7	52.4	*
Firmness	18.1	17.3	NS	14.8	20.6	*
Crumbliness	51.1	50.6	NS	52.6	49.1	*
Physical						
Specific gravity[e]	9.8	9.3	*	9.3	9.8	*
Volume index[f]	137.3	128.5	*	131.7	134.2	NS
Viscosity[g]	10,005.0	9,160.0	NS	10,216.7	8,948.3	NS
pH	6.9	6.9	NS	6.9	6.9	NS
Symmetry[f]	3.7	6.0	NS	3.3	6.3	NS
Cake uniformity	0.7	0.3	NS	0.3	0.7	NS
Shrinkage	159.9	163.4	NS	159.9	163.3	NS

[a]Means of three replications.
[b]* = Significant at $P = 0.05$, NS = not significant.
[c]High level = 2.5% (flour weight basis), low level = 2.0%.
[d]Intensity scale: 0 = none, 6 = high.
[e]Measured using method of Campbell et al (1979b).
[f]AACC Method 10-91 (AACC 1983).
[g]Spindle 7, 7 rpm, RV-8 viscometer.

TABLE VIII
Least Square Means[a] for Sensory Attributes[b] of Cakes Evaluated in the Comparison Phase

Attribute	CV[c]	Commercial Pound Cake[d]	Polydextrose Layer Cake	Improved Polydextrose[e] Layer Cake	Commercial Yellow Cake[f]
Cell uniformity	3.9	5.8 a	5.1 b	4.9 b	4.2 c
Cell size	17.8	0.3 d	1.6 c	2.1 b	3.1 a
Springiness	4.5	4.6 b	5.3 a	5.1 a	5.2 a
Firmness	46.8	2.5 a	1.4 b	1.1 b	0.2 c
Crumbliness	9.0	0.4 d	4.2 bc	4.2 bc	5.7 a
Cohesiveness of mass	9.6	1.9 c	4.9 a	4.9 a	3.5 b
Adhesiveness of mass	10.9	1.7 c	5.1 a	5.0 a	3.0 b
Mouth drying	15.5	2.0 b	3.2 a	3.2 a	0.9 c
Mouth etching	19.7	0.1 c	2.5 a	2.5 a	0.5 b

[a]Like letters within a row indicate no significant difference, $P = 0.05$.
[b]Scale: 0 = none, 6 = high intensity.
[c]Coefficient of variation.
[d]Sara Lee frozen, thawed.
[e]Litesse.
[f]Prepared from Duncan Hines mix.

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