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Sensory and Physical Properties of Cakes with Bovine Plasma Products Substituted for Egg[1]

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ABSTRACT

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The sensory and physical properties of cakes in which egg products were replaced with bovine plasma products were studied. Dried egg whites were replaced by dried plasma in high-ratio, white layer cakes at five different levels (0, 25, 50, 75, and 100%). Egg whites could be replaced by dried plasma without reducing cake volume. Cake symmetry was altered by substituting plasma for 75 or 100% of the egg. Substitution altered the colors of both crust and crumb. Cakes with plasma replacing 25% of the egg had decreased L and Θ values compared with those of the control cakes. Cakes with plasma replacing egg were softer, more moist and gummy, and slightly sweeter than the controls. A blend of hydrolyzed plasma and beef stock could replace 50% of the egg in devil's food cake without affecting symmetry or shrinkage and with only a slight decrease in volume. Consumer panels indicated that cakes made with plasma products were as well liked as the control cakes.

Low-cost egg and milk protein substitutes are desired by the baking industry because egg and milk products are relatively expensive ingredients. Egg and milk substitutes, however, must possess functional properties appropriate for the products in which they are used. Spray-dried bovine plasma has functional properties similar to those of egg whites and is believed to have the potential to replace egg whites in cakes (Brooks and Ratcliff 1959, Johnson et al 1979, Khan et al 1979). In recent years, high-quality, food-grade, spray-dried plasma protein concentrates have been produced, and they are currently marketed as food protein ingredients at a cost only about one-third that of spray-dried egg whites. A previous study (Lee et al 1991) showed that nearly equivalent cake quality was achieved by replacing 1.0 part of egg white protein with 1.1 part of plasma protein. Few significant differences in

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cake baking performance were noted among fresh, frozen, and spray-dried products for either plasma or egg whites. Moreover, the replacement of egg whites with a spray-dried blend of 90% enzymatically hydrolyzed plasma and 10% beef stock gave cakes better volume but darker crusts than did native plasma. Very little information, however, has been published about sensory properties of cakes made with plasma as an egg substitute. Khan et al (1979) reported that angel food cakes made with 25% of the egg white replaced by a plasma protein isolate had acceptable flavor, color, and mouth feel.

The goal of this study was to evaluate sensory and physical properties of cakes prepared with plasma. Specific objectives were 1) to evaluate sensory and physical characteristics of high-ratio, white layer cakes with various levels of dried egg whites replaced with dried native plasma; 2) to assess the feasibility of using a dried, hydrolyzed plasma and beef stock blend to replace whole eggs and egg white in devil's food cake; and 3) to conduct consumer tests with plasma and control cakes for degree of liking and for preference.

MATERIALS AND METHODS

Cake Preparation

High-ratio, white layer cakes. Spray-dried native plasma and a spray-dried blend of 90% enzymatically hydrolyzed plasma and 10% beef stock were obtained from the American Meat Protein Corp., Ames, IA. Spray-dried egg whites (type p-20) were obtained from Henningsen Foods, Inc., Omaha, NE. Betrkake emulsified shortening (the emulsifiers were mono- and diglycerides) was obtained from Durkee Industrial Foods Corp., Cleveland, OH. Softasilk cake flour, a cake flour for institutional food service use, was obtained from the Iowa State University Food Service Center and produced by General Mills, Inc., Minneapolis, MN. Breadlac nonfat dry milk solids were obtained from Galloway West Co., Fond du Lac, WI.

Protein contents of egg and plasma products were determined by the macro-Kjeldahl procedure described in AACC method 46-13 (AACC 1983). Moisture was determined by oven drying at 130°C for 2 hr (method 44-31, AACC 1983). The protein and moisture contents of the egg white and plasma products are shown in Table I.

Cakes were prepared by using the modified AACC method 10-90 (AACC 1983) described by Lee et al (1991), except that 89 g of water was added in the first mixing stage and cakes were baked for 26 min. Cakes were prepared with dried plasma replacing 0, 25, 50, 75, and 100% of dried egg white. Dried plasma was added to give 1.1 g of plasma protein for every gram of egg protein replaced. The amount of water added in the first mixing stage was adjusted to compensate for the different moisture contents of the plasma and egg whites.

Precisely 425 g of batter was scaled into each of two 8-in.-diameter cake pans and baked at 190°C (375°F) for 26 min in a rotary electric oven. Baking trials were replicated six times on different days. Each treatment (level of substitution) was prepared each day to control for day-to-day variation. Cakes were cooled for 60 min, stored in plastic bags overnight, and evaluated the next day.

Devil's food cakes. The ingredients for preparing devil's food cakes, a whole-egg cake formula, were similar to those for high-ratio, white layer cakes with the following exceptions: Dutch processed cocoa was obtained from Baker's Chocolate and Coconut, Industrial Business Operation, Dover, DE; lecithin 40 was obtained from Beatreme Food Ingredients, Inc., Beloit, WI; xanthan gum (Keltrol TF) was obtained from Kelco Division, Merck & Co., Chicago, IL; and dried whole eggs were obtained from Henningsen Foods.

The formula for devil's food cake (J. Ponte, Jr., *personal communication*) is shown in Table II. Cakes were prepared by using the spray-dried, 90/10 blend of enzymatically hydrolyzed plasma and beef stock to replace 0, 50, and 100% of the dried egg. The amount of plasma product needed to replace the protein in dried whole egg was calculated on the basis of values in Ockerman (1991). Shortening and lecithin were added to the formulas for the modified cakes to compensate for the loss of fat and lecithin when whole egg was reduced or eliminated. Replacement calculations were based on published values for fat and lecithin in egg yolk (Ockerman 1991).

Cakes were made by mixing the dry ingredients first. Shortening and emulsifiers were then added and mixed in a KitchenAid Hobart mixer, model K5SS, at speed no. 1 for 1 min. At the first stage, 101 g of distilled water was added and mixed at speed no. 1 for 6 min. At the second and third stages, 30 g of distilled water was added and mixed at speed no. 1 for 1 and 4 min, respectively. After mixing, 425 g of batter was scaled into each of two 8-in.-diameter cake pans and baked at 182°C (360°F) for 27 min in a rotary electric oven. Baking trials were replicated three times. Cakes were cooled for 60 min, stored in plastic bags overnight, and evaluated the next day.

Cake Quality—Physical Evaluation

Cake batter specific gravity was determined by weighing a known volume of batter in a standardized cup. Cake volume was measured by rapeseed displacement. The layer cake measuring template was used as described in AACC method 10-91 (AACC 1983) to determine shrinkage value and symmetry index.

Colors of the cake crust and crumb were measured by using a Hunterlab Labscan Spectro colorimeter, L-5-5100 color difference meter (Hunter Associates Laboratory, Reston, VA), to obtain *L, a,* and *b* values. Hue angle, Θ ($\tan^{-1} b/a$), was calculated to define the actual color for the cakes. Procedures for measuring cake crust and crumb colors were described in detail by Lee et al (1991).

A modified instrumental texture profile analysis was performed on the white cakes prepared with various levels of plasma substituted for egg white. Test conditions were as described by Lee et al (1991). Cubes (20 mm) cut from the center portion of each cake were compressed twice to 20% of their original height (80% compression) using an Instron universal testing machine (model 1122, Instron Inc., Canton, MA). Ten cubes from each cake were tested. Crosshead and chart speeds were 200 and 500 mm/min,

TABLE I
Protein and Moisture Contents of Egg and Plasma Products

Product	Moisture (%)	Protein[a] (%)
Spray-dried plasma	4.19	70.19
Spray-dried enzyme-hydrolyzed plasma and beef stock	5.10	70.08
Dried egg white	6.28	73.50

[a] A conversion factor of 6.25 was used to convert grams of N to grams of protein.

TABLE II
Formulations for Devil's Food Cakes Prepared with Various Replacement Levels of Hydrolyzed Plasma and Beef Stock Blend for Egg

	Egg Replacement Level		
Ingredient[a]	0%	50%	100%
Cake flour	100.0	100.0	100.0
Sugar	140.0	140.0	140.0
Shortening	45.0	45.5	46.0
Cocoa (Dutch processed)	20.0	20.0	20.0
Nonfat dry milk	10.0	10.0	10.0
Salt	3.75	3.75	3.75
Sodium bicarbonate	0.63	0.63	0.63
Baking powder	5.00	5.00	5.00
Dried whole eggs	11.25	5.63	...
Dried egg whites	2.40	1.20	...
Dried plasma and beef stock blend	...	6.39	12.78
Lecithin	...	0.21	0.42
Xanthan gum	0.20	0.20	0.20
Water	161	161	161

[a] All values are in grams.

respectively. The following textural parameters were derived from the force distance curves, on the basis of definitions provided by Bourne (1978). Hardness was the peak force in the first compression, cohesiveness was the ratio of the areas under the curve in the first and second downstrokes, springiness was the width of the base of the downstroke portion of the second compression curve, gumminess was the product of hardness × cohesiveness, and chewiness was the product of gumminess × springiness.

Statistics were performed by using the Statistical Analysis System (SAS Institute Inc., Cary, NC). Data from physical tests were subjected to analysis of variance, and means were compared by using Fisher's least significant difference method.

Cake Quality—Sensory Evaluation

Laboratory panel testing. White cakes were evaluated by a 13-member panel recruited from faculty, staff, and students in the Food Science and Human Nutrition Department at Iowa State University. Panelists used a 150-mm line with anchors 12.5 mm from each end to rate the intensity of sensory attributes. Attributes evaluated were firmness (defined as force to bite through the sample with the incisors), toughness (defined as the resistance to breakdown during the first few chews with the molars), moistness (defined as the moistness of the mass after chewing to mix with saliva), gumminess (defined as the degree to which the mass held together during chewing), and sweetness (defined as the taste stimulated by sucrose).

Panelists were selected on the basis of their interest and availability. Six training sessions were conducted over a period of three weeks in which the panelists were trained to evaluate key attributes of cakes. Commercially available samples were presented and references were prepared by altering the ingredients and the method of preparation to produce variations that were likely to be seen in the tested samples.

Immediately before sensory tests, cakes were cut into 20-mm cubes. Cake samples were served on white plastic plates labeled with three-digit codes from a random number table. Cake samples with plasma substituted for 0, 50, and 100% of the egg were presented to each panelist in each session. The order of presentation was balanced. Samples were served to panelists in partitioned booths, which were illuminated with red fluorescent lights. Panelists were asked to swallow samples and to rinse their mouths with water between samples.

Six replications were conducted over a period of three weeks. Sensory data were subjected to analysis of variance, and when between-treatment F ratios were significant, the least significant difference test was used to test means. Statistics were performed by using the Statistix system (NH Analytical Software, Roseville, MN).

Consumer tests. The participants in consumer tests were students and staff members at Iowa State University. In each test, the participants were presented with coded samples from two cakes and asked to check the category on a hedonic scale that indicated how much they liked the samples (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely). Participants were also asked to indicate which of the samples they preferred. The test area was illuminated by white fluorescent lights.

Samples from control white layer cakes and cakes with plasma substituted for 100% of the egg white were evaluated by 57 judges. In a subsequent test with 68 participants, samples from control cakes and cakes containing hydrolyzed plasma and beef stock substituted for 100% of the egg were presented. In the third con-

TABLE III
Mean Values for Physical Characteristics of Cakes Containing Various Levels of Plasma[a]

Percentage of Egg Replaced by Plasma	Specific Gravity (g/cm³)	Volume (cm³)	Symmetry Index (mm)	Shrinkage (mm)
White layer cakes				
0	0.589 a	989 a	12.3 a	18.8 a
25	0.585 a	983 a	12.7 a	16.7 b
50	0.580 a	983 a	10.2 ab	17.0 b
75	0.563 ab	988 a	8.7 b	16.8 b
100	0.548 b	993 a	7.7 b	17.5 ab
Devil's food cakes				
0	1.003 a	1,075 a	29.2 a	22.1 a
50	0.998 a	995 b	28.1 a	19.2 a
100	0.998 a	890 c	11.2 b	25.2 b

[a] For a cake type, values within a column with different letters are significantly different ($P < 0.05$).

TABLE IV
Mean Values for Crust and Crumb Colors of High-Ratio White Layer Cakes Prepared with Various Levels of Plasma Replacing Egg Whites[a]

	Percentage of Egg Replaced by Plasma				
Color Value	0	25	50	75	100
Crust color					
L	42.63 a	39.06 b	38.36 bc	36.21 cd	34.99 d
Θ	60.23 a	57.07 b	56.44 bc	54.66 cd	53.82 d
Crumb color					
L	72.81 a	72.22 b	71.39 c	70.49 d	70.19 d
Θ	98.75 a	97.99 b	96.91 c	95.80 d	95.48 d

[a] Values within a row with different letters are significantly different ($P < 0.05$).

TABLE V
Instrumental Texture and Sensory Measures of High-Ratio White Layer Cakes Prepared by Replacing Egg Whites with Various Levels of Plasma[a]

	Percentage of Egg Replaced by Plasma				
Measure	0	25	50	75	100
Instrumental					
Hardness, kg	5.59 a	5.13 b	5.07 bc	4.71 cd	4.48 d
Springiness, mm	25.5 a	20.1 b	17.3 bc	17.0 c	14.9 c
Cohesiveness	0.38 a	0.39 a	0.37 a	0.38 a	0.39 a
Gumminess, kg	2.12 a	1.99 ab	1.88 bc	1.77 c	1.77 c
Chewiness, kg·mm	54.4 a	40.2 b	32.6 c	30.4 c	26.6 c
Sensory[b]					
Firmness on first bite	59.5 a	...	47.9 b	...	43.8 c
Toughness during chewing	57.0 a	...	47.3 b	...	44.1 b
Moistness of chewed mass	54.3 a	...	67.1 b	...	71. 5 c
Gumminess of chewed mass	55.9 a	...	65.9 b	...	71.8 c
Sweetness	71.7 b	...	77.2 a	...	80.1 a

[a] Values within a row with different letters are significantly different ($P < 0.05$).

[b] Sensory values were obtained by using a 150-mm line scale with 0 = very soft, very tender, very dry, not gummy, and no sweetness and 150 = very firm, very tough, very moist, very gummy, and very sweet.

TABLE VI
Results of Consumer Tests on Control Cakes and Cakes with Egg Replaced by Plasma

Test	Products Tested	Mean Hedonic Score[a]	Number of Judges Preferring Sample
1	Control white layer cake	6.8 a	25
	White layer cake with 100% of egg replaced by plasma	7.4 b	32
2	Control white layer cake	6.8 a	26
	White layer cake with 100% of egg replaced by plasma and beef stock blend	6.9 a	42
3	Control devil's food cake	7.0 a	30
	Devil's food cake with 50% of egg replaced by plasma and beef stock blend	7.1 a	40

[a] Within a test, mean values with different letters are significantly different ($P < 0.05$). Hedonic scores were obtained by using a scale with 1 = dislike extremely and 9 = like extremely.

sumer test, 70 participants evaluated control devil's food cakes and devil's food cakes prepared with hydrolyzed plasma and beef stock replacing 50% of the egg.

The studentized t test was used to analyze the data from the hedonic tests, and a table for a two-tailed paired comparison test for difference (Meilgaard et al 1987) was used to establish the minimum number of agreeing responses needed for significance at $P < 0.05$.

RESULTS AND DISCUSSION

Cake batter specific gravity, cake volume, symmetry, and shrinkage values are shown in Table III. For high-ratio, white layer cakes, the specific gravity of the batter was decreased when 100% of the egg was replaced by plasma, but it was not greatly affected at 0, 25, or 50% substitution levels. Volume was not affected by egg replacement. Cake symmetry was decreased at the two highest levels of substitution. Cakes with 25, 50, and 75% of the egg replaced with plasma had lower shrinkage values than did the control. Shrinkage in controls and cakes with a 100% replacement of egg by plasma was not significantly different.

For devil's food cakes, batter specific gravity was not affected by substitution of plasma for egg. Volume was, however, reduced in the cakes with 50% of the egg replaced with plasma, and the cakes at the 100% substitution level had less volume than those at the 50% level. Symmetry and shrinkage values of cakes made with 0 and 50% substitution differed from those of cakes with 100% of the egg replaced by plasma.

Color measures of white layer cakes are shown in Table IV. Crust and crumb were significantly darker and tanner than those of the control when 25% or more of the egg was replaced by plasma.

Table V shows the results of the instrumental texture tests. Hardness and springiness decreased when 25% or more of the egg was replaced with plasma. Cohesivenes was not affected by the substitutions. Gumminess decreased significantly when 50% or more of the egg was replaced by plasma, and the chewiness was decreased when 25% of the egg was replaced by plasma. Since the cohesiveness values were the same for all cakes, the calculated values (gumminess and chewiness) reflect changes in hardness and/or springiness.

The trained panel found that the cakes with 50% of the egg replaced by plasma were less firm on the first bite and broke down more readily on subsequent chewing than the control (Table V). The cakes with plasma replacing 50% of the egg were moister, more gummy, and sweeter than controls. Compared with the results for samples at the 50% level of substitution, replacing 100% of the egg further reduced firmness on the first bite and increased moistness and gumminess.

Mean hedonic scores given to cakes are presented in Table VI. White layer cakes made with 100% plasma were liked significantly ($P < 0.005$) more than the control white cakes. Hedonic scores for control white cakes and cakes prepared with the plasma and beef stock blend did not differ significantly, and hedonic scores for the two types of devil's food cakes were not significantly different. Although a greater number of the participants chose the cakes prepared with plasma over the control in the paired preference tests, the number of judges agreeing on a preferred sample was not great enough to achieve statistical significance at $P < 0.05$ (Table VI).

CONCLUSIONS

High-ratio white layer cakes made with plasma substituted for 100% of the egg differed slightly but significantly from controls in symmetry, shrinkage, color, and textural characteristics. Consumers, however, liked the white cakes prepared with plasma or hydrolyzed plasma and beef stock as well as the control samples. Devil's food cake made with plasma replacing 50% of the egg had volume, symmetry, and shrinkage measures the same as or only slightly different from the controls. Consumers liked the devil's food cakes with 50% plasma as well as the control cakes. Plasma protein products are a cost-effective egg substitute that can be used in layer cakes without adverse effects on sensory qualities.

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