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제과제빵 모델 시스템으로서 저열량케익에 미치는 주재료 성분중 함유된 단백질 및 전처리된 유화제의 영향

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Effects of Protein Contained in Major Ingredients with Treated Emulsifiers on Chemically Leavened Reduced-Calorie Cake as Baked Product Model Systems

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Abstract

The effects of five hydrated emulsifiers with or without specified proteins (flour, egg) and /or polydextrose on the reduced-calorie cake as baked product model systems were compared. The small molecule amphiphiles (SMA) used were monoglycerides (MG), sorbitan monostearate (SMS), polysorbate (PS) 60, sucrose ester (SE) F70, and SE F160. All flour batters with each emulsifier and supplements had similar low foam drainages (0.00~1.63 m*l*) indicating those systems were fairly stable in the presence of flour protein. The cake batter using starach instead of flour without egg and polydextrose and with some emulsifiers had relatively large amount of drainages (4.20~5.87 m*l*). When the egg and polydextrose were added to the blank cake batters using starch, foam drainages tended to show relatively low scores (0.13~1.48 m*l*) indicating the cake batter dispersion system is stabilized. Starch cakes made with SE F70 without egg or polydextrose(blank) unexpectedly had high volume index of 199.

Key words: emulsifiers, reduced calorie baked products

I. Introduction

Cake dispersions are complicated, multiphase systems consisting of dissolved sugars, salts, colloidally dispersed proteins, coarsely dispersed starch, and emulsified oils and fats. Under various conditions and stages, the batter system can be considered as a foam, an oil-in-water or a water-in-oil emulsion. Cake batter is heat-set to form a sponge-like gel with starch gelatinization and protein coagulation during the baking[1]. Egg protein is a macromolecular surface active agent that is believed to play a primary role in forming a large, stable foam structure, which is related to the rheological properties of the batter and to cake volume and structure. Howard *et al.*[2] noted that soluble foamable protein was essential to retain air incorporated into the cake batter, especially in the first aeration stage. Emulsifiers such as small molecule amphiphiles (SMA) are believed to influence the system indirectly and to interact at the interfaces of air and water making the system stable[3]. The SMA in a cake batter system aids in formation of a large number of small gas cells during mixing. Thus, only relatively small amounts of the air is lost before heat setting even when bubbles are enlarged by chemical leavening, water vapor generation, and normal gas diffusion. This aids fat distribution, and increases cake volume[4-7]. Pre-study[8] suggested that a fine dispersion of small amount of SMA and water before mixing with other ingredients improved the cake model sturcture by aiding the formation of numerous air cells in cake batter, which increased the final volume and improved the crumb of the finished cakes.

This study examined the effects of five hydrated SMA with or without specified proteins (flour, egg) and/or polydextrose on reduced-calorie cake in an attempt of developing a structural matrix of the reduced-calorie cake model systems.

II. Materials and Methods

1. Sample Preparation

Cakes were made using a formula developed by Kim[9] as shown in Table 1. The experimental treatment combinations are given in Table 2. The forty treatments were compared to predict the functions of major ingredients by deleting the egg, or polydextrose, and/or egg and polydextrose in the system. Starch cakes were made using corn starch replacing the cake flour portion in basic cake formulation. Flour and blank combinations in the Table 2 represents the cakes prepared with the basic formula (Table 1) without egg and polydextrose. The flour and egg combinations in Table 2 represents the cakes made without polydextrose in the formula. The flour and polydextrose combinations omitted eggs in the system. The flour and egg and polydextrose combinations were prepared with the whole ingredients of Table 1. The first step was to blend dry ingredients one min at speed 2 (Kitchenaid, Model K5SS, U.S.A) using wire whip. Remaining ingredients were added and mixed at speed 2 for 30 sec.. They were scraped and mixed at speed 10 for 2 min. twice. The 300 g of prepared batter was poured into lightly greased 6-inch pan discarding the rest of batters. They were baked at 177°C for 35 minutes. Baked cakes were cooled approximately 1 hr on a wire rack. The cake was cut in half using an electric knife for the volume index and other related readings.

Table 1. Basic formulation for reduced-calorie cake model system

Ingredient	% of Total System (dry weight basis)	Amount (g)
Flour	100.0	120.0
Small molecule amphiphiles	1.5	1.8
Water	104.0	124.8
Whole egg	58.6	70.3
Polydextrose	63.0	75.6
Baking powder	9.8	11.8

The SMA used at 1.5% level (flour weight basis) in this system were sorbitan monostearate (SMS) (Patco, Kansas City, U.S.A), distilled monoglycerides (MG) (Patco), polysorbate (PS) 60 (Patco), sucrose ester (SE) F70 and F160 (Dai-Ichi Kogyo Seiyaku Co., Japan). The treated SMA were made as follows: 1) Each SMA was added to water in 250 m*l* beaker. 2) The beaker containing thermometer to monitor mixture temperature was placed in a hot water bath (Thermomix, 1480, B. Braun, Germany) with temperature set at 65°C. 3) The mixture was stirred until well dispersed (about 1 hr). 4) The dispersion was cooled to ambient temperature (22+4°C). Preliminary studies indicated SMS and MG were dispersed at high pH, thus, the pH of water was adjusted to pH 10 for SMS and MG dispersions.

2. Experimental Methods

(1) Specific gravity

Specific gravity (SG) cups were filled with water of the same temperature as the sample and weighed using a digital balance. The weight of water was obtained by the following: (the weight of the filled

Table 2. Treatment combinations for the effects of flour protein, egg protein, and polydextrose with treated SMA[a] on reduced-calorie cake systems

Type of SMA[a]	Flour				Starch			
	Blank	Egg	PD[a]	Egg+PD[a]	Blank	Egg	PD[a]	Egg+PD[a]
SMS[a]	1	2	4	4	5	6	7	8
MG[a]	9	10	11	12	13	14	15	16
PS 60[a]	17	18	19	20	21	22	23	24
SE[a] F70	25	26	27	28	29	30	31	32
SE[a] F160	33	34	35	36	37	38	39	40

[a]Abbreviations: SMA, small molecule amphiphiles; SMS, sorbitan monostearate; MG, monoglycerides; PS, polysorbate; SE, sucrose ester; PD, polydextrose.

cup)-(the weight of the empty cup). The density of water was assumed 1.00 g/cc. Therefore, the volume of the cup was (the weight of water)/1.00. Then, the dry cup was filled uniformly with samples. The excess of the sample was removed with a spatula, and the outer surface of the cup was cleaned. After weighing the filled cup, the SG was calculated according to the following equation:

$$SG = \frac{\text{(the weight of sample–filled cup)} - \text{(the weight of empty cup)}}{\text{(the weight of water–filled cup)} - \text{(the weight of empty cup)}}$$

(2) Foam drainage

The foam drainage was measured by comparing the volume of liquid drained after 1 hr at room temperature. The apparatus employed was a funnel with a filter paper (Carl Schleicher & Schuell Co., Shark skin). The 58.0 m*l* of the foam was transferred to the funnel with a spatula. The foam was directly drained to the 10 m*l* graduate cylinder and the volume of the liquid drained was read directly from the cylinder.

(3) pH

The pH measurements were taken in auto-lock mode of the pH meter (American Scientific, American TM pH/ISE) while stirring the solution with stir bar. Final value was read when the value was stopped after the flash with ± 0.05 pH accuracy.

(4) Indicies of cake volume, uniformity and symmetry

The AACC method (Template method 10-91)[10] was modified to determine indices of cake volume, uniformity and symmetry of 6-inch layer cake models. Cake was cut vertically through center and placed with cut surface down on template. It was centered and aligned with baseline of template. Since the cake was 6 inch long, which was shorter than standard 8 inch, both ends of the cake were assigned to A' and E'. Diameter (A' to E') was read to nearest 0.1 cm. The B' and D' points were assigned in the middle of A'C and CE' respectively and calculated indices as follows (Fig. 1):

Volume index = B' + C + D'

Symmetry index = 2C - B' - D'

Uniformity index = B' - D'

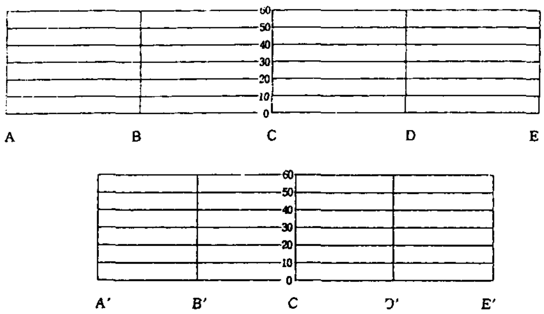

Fig. 1. The AACC plastic cake measuring template chart: 8 inch Standard (upper) and 6 inch modified (below) template (Template method 10-91).

3. Analysis of Data

Three replications of the experiment were conducted. The order of preparation of treatments was randomized for each replication. Data were tested using analysis of variance (ANOVA) procedures of the Statistical Analysis System[11]. For physical measurements, means were compared and differences were separated using Duncan's multiple range tests.

III. Results and Discussion

The F-values and probabilities from the ANOVA of the six physical measurement result showed significant differences in specific gravity ($p < 0.0006$), foam drainage ($p < 0.0001$), volume index ($p < 0.0015$), and symmetry index ($p < 0.0010$). Means of some attributes had relatively large variances. The unstable batters that occurred if some ingredients were omitted, perhaps as a result of weak bubble films, resulted in the breakdown or collapse of cake structures for some replications of a treatment.

Mean values of the cake batter specific gravity measurements are presented in Table 3. Batters made using flour had the same or significantly higher specific gravities than batters using starch with the same SMA made without egg or polydextrose indicating the same or more air incorporation to the system. Batters made with starch plus egg and polydextrose had relatively low specific gravities (0.40~0.46). Batters using starch plus SMS and egg, SMS and polydextrose, MG and egg, SE F70 without egg and polydextrose, SE F70 and polydextrose, and the flour batters made with SMS and polydextrose, and

Table 3. Specific gravity[a] of cake batter for the effect of flour protein, egg protein, and polydextrose with treated SMA[b]

Type of SMA[b]	Flour				Starch			
	Blank	Egg	PD[b]	Egg+PD[b]	Blank	Egg	PD[b]	Egg+PD[b]
SMS[b]	0.78 ijklmn	0.69 klmnop	0.57 opqrst	0.52 qrst	0.88 defghij	0.52 pqrst	0.51 qrst	0.40 t
MG[b]	0.79 hijklm	0.87 efghij	0.86 efghij	0.72 jklmno	0.83 fghijkl	0.40 st	1.05 abcd	0.46 rst
PS60[b]	1.15 ab	1.12 abc	1.17 ab	0.78 ijklmn	0.83 fghijkl	0.71 jklmno	0.86 efghijk	0.42 t
SE F70[b]	0.96 cdefgh	0.97 cdefg	0.79 hijklm	0.66 lmnopq	0.56 opqrst	0.71 jklmno	0.49 rst	0.41 t
SE F160[b]	1.03 abcde	0.90 defghi	1.02 abcde	0.60 mnopqr	1.00 bcdef	0.61 nopqrs	0.79 hijk	0.40 t

[a]Three replications/mean; means with same letter are not significantly different. ($P < 0.05$); Duncan's multiple range test.
[b]Abbreviations: SMA, small molecule amphiphiles; PD, polydextrose; SMS, sorbitan monostearate; MG, distilled monoglycerides; PS 60, polysorbate 60; SE F70, sucrose ester F70; SE F160, sucrose ester F160.

Table 4. Foam drainage[a] of cake batter for the effect of flour protein, egg protein, and polydextrose with treated SMA[b]

Type of SMA[b]	Flour				Starch			
	Blank	Egg	PD[b]	Egg+PD[b]	Blank	Egg	PD[b]	Egg+PD[b]
SMS[b]	0.00 e	0.00 e	0.00 e	0.03 e	2.50 cd	0.80 de	0.30 de	0.13 de
MG[b]	0.37 de	1.00 de	0.33 de	0.50 de	5.50 b	0.93 de	4.20 bc	1.40 de
PS 60[b]	0.23 de	0.65 de	0.65 de	0.10 e	4.75 b	9.03 a	1.70 de	1.33 de
SE F70[b]	0.00 e	1.60 de	0.00 e	0.03 e	0.53 de	1.60 de	0.00 e	0.40 de
SE F160[b]	0.00 e	1.63 de	0.17 de	0.33 de	5.87 b	5.82 b	2.23 cde	0.93 de

[a]Three replications/mean; means with same letter are not significantly different. ($p < 0.05$); Dunca's multiple range test.
[b]Abbreviations: SMA, small molecule amphiphiles; PD, polydextrose; SMS, sorbitan monostearate; MG, distilled monoglycerides; PS 60, polysorbate 60; SE F70.

SMS and egg and polydextrose were not significantly different from the batters with all SMA systems using starch plus egg and polydextrose (0.46~0.57). Addition of egg to the batters using flour and blank combinations did not change specific gravities with any type of SMA. However, the specific gravities decreased significantly if egg was added to batters using starch and blank combinations indicating air was less incorporated to the batter system compared with the flour counter part. Addition of polydextrose to flour batters resulted in the same or lower specific gravities with all SMA. The addition of both egg and polydextrose to the system resulted in lower specific gravities in both flour and starch batters. As is known, lower specific gravity indicates fewer air incorporation to cake batter system resulting smaller volume of finished products.

The measurements of foam drainage from each cake batter are given in Table 4. Flour batters with all treatments had similar low foam drainages (0.00~1.63 ml) indicating the batters with the all types of treatments were fairly stable in the presence of flour protein. Starch batters with PS 60 and egg had the largest drainage (9.03 ml). Starch batter without egg and polydextrose and with MG, PS 60, SE F160, starch batter made with polydextrose and MG, and starch batter made with SE F160 and egg had relatively large amount of drainages (4.20~5.87 ml). If both egg and polydextrose were added to starch batters with all types of SMA, the batters became stable and exhibited low foam drainages (0.13~1.48 ml).

Cake volume indices for the effect of flour protein, egg protein, and polydextrose with treated SMA are given in Table 5. Starch cakes made with SE F70 without egg or polydextrose and flour cakes made with SMS without egg and polydextrose had high volume indices of 199 and 174, respectively. Addition of egg or polydextrose to the batter system resulted in cakes with similar or lower volumes except for the starch cake made with PS 60 and polydextrose, which had higher volumes than the starch cake without either or without egg. Addition of both egg and polydextrose to the batter system resulted in cakes with similar or higher volumes except for the starch cakes made with SMS, or SE F70, which had lower volumes than the corresponding starch cake made without egg or polydextrose. Starch batters made with egg and polydextrose, which had high air incorporations (low specific gravities; 0.40~0.46), did not necessarily result in high-volumed cakes indicating that the foam preformed was not very stable. In most cases, flour protein apparently contributed to foam stability.

Cake symmetry indices are presented in Table 6. Starch cakes made with PS 60 and polydextrose, and flour cakes made using SMS without egg and polydextrose were evenly rounded, thus showed the highest symmetry values of all cakes with values of 22.0 and 17.0, respectively. Addition of egg and polydextrose did not affect the symmetrical contour of flour or starch cakes compared to the corresponding cakes made without egg or polydextrose except for the flour cakes made with SMS. It was less symmetrical and more concave if egg and polydextrose were present than without those ingredients.

Cakes without egg and polydextrose were generally described as white, cakes with egg were yellow, and cakes with polydextrose were brown. When the cake had more than two layers, generally the upper part was drier, crumblier, and chalkier with some cake-like structure, and bottom part was stickier and firmer without any obvious cell structure as is characteristics of an art gum eraser.

Table 5. Volume index[a] of reduced-calorie model cakes[b] for the effect of flour protein, egg protein, and polydextrose with treated SMA[c]

Type of SMA[c]	Flour				Starch			
	Blank	Egg	PD[c]	Egg+PD[c]	Blank	Egg	PD[c]	Egg+PD[c]
SMS[c]	174 ab	145 bcdef	125 efghijkl	158 bcde	124 fghijkl	58 qr	49 r	69 pqr
MG[c]	150 bcdef	147 bcdef	143 bcdefgh	154 bcdef	55 qr	52 r	80 nopqr	107 jklmno
PS60[c]	127 defghijkl	134 cdefghijk	114 ghijklm	128 defghijkl	77 opqr	85 mnopq	110 ijklmn	100 lmnop
SE F70[c]	155 bcdef	135 cedfghijk	147 bcdef	156 bcdef	199 a	105 klmno	165 bc	159 bcd
SE F160[c]	138 cdefghij	135 cdefghi	140 cdefghijk	164 bc	99 lmnop	111 hijklm	76 opqr	138 cdefghij

[a]AACC template method 10-91.
[b]Three replications/mean; means with same letter are not significantly different. ($P < 0.05$); Duncan's multiple range test.
[c]Abbreviations: SMA, small molecule amphiphiles; PD, polydextrose; SMS, sorbitan monostearate; MG, distilled monoglycerides; PS 60, polysorbate 60; SE F70, sucrose ester F70; SE F160, sucrose ester F160.

Table 6. Symmetry index[a] of reduced-calorie cakes[b] for the effect of flour protein, egg protein, and polydextrose with treated SMA[c]

Type of SMA[c]	Flour				Starch			
	Blank	Egg	PD[c]	Egg+PD[c]	Blank	Egg	PD[c]	Egg+PD[c]
SMS[c]	17.0 ab	6.0 cdefghi	2.7 defghijk	6.0 cdefghi	1.0 defghijk	-1.3 hijk	2.7 defghijk	-5.3 kl
MG[c]	3.0 defghijk	7.0 cdefgh	1.7 defghijk	6.3 cdefghi	0.7 efghijk	-0.7 ghijk	1.3 defghijk	-3.0 jkl
PS[c] 60	6.3 cdefghi	9.0 cde	1.7 defghijk	1.7 defghijk	2.0 defghijk	3.0 defghijk	22.0 a	-2.0 ijkl
SE[c] F70	12.3 bc	8.3 cde	6.0 cdefghi	8.0 cdef	8.0 cdef	-3.0 jkl	0.7 efghijk	-9.7 l
SE[c] F160	9.3 cd	5.0 cdefghij	6.0 cdefghi	6.7 cdefgh	-0.3 fghijk	7.7 cdefg	1.7 defghijk	-4.0 kl

[a]AACC template method 10-91.
[b]Three replications/mean; means with same letter are not significantly different. ($P < 0.05$); Duncan's multiple range test.
[c]Abbreviations: SMA, small molecule amphiphiles; PD, polydextrose; SMS, sorbitan monostearate; MG, distilled monoglycerides; PS60, polysorbate 60; SE F70, sucrose ester F70; SE F160, sucrose ester F160.

In conclusion, some SMA influenced the volume or crumb texture similarly to major ingredients such as polydextrose and proteins. Synergistic effects of egg protein and polydextrose were observed on structural characteristics. Starch cake made with SE F70 without egg or polydextrose and flour cake made with SMS but neither egg nor polydextrose had high volumes and a characterictic cake crumb structure in this study. Some researchers reported successful baking performances of gluten-free layer cakes previously[2,12,13]. Donelson[13] reported total crumb scores of white layer cakes without gluten or starch fractions resulted in lower crumb scores than normal cakes, but gluten-free cakes had similar cake volumes to the normal cakes, while starch-free cakes had significantly lower volumes than the normal cakes. When egg or polydextrose was added to the reduced-calorie cake model system, cake volume tended to decrease but crumb structure was improved in the present study. This agreed with the findings of Neville and Setser[14], in which increased polydextrose level in the reduced-calorie cake systems inversely affected specific volume, symmetry, and shrinkage. Protein was related to texture improvement, such as increased cell uniformity and decreased crumbliness, but, at least, egg protein did not seem to be crucial for foam formation or batter stability in the reduced-calorie cake model system.

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