COMPARATIVE STUDY OF EGG WHITE PROTEIN AND EGG ALTERNATIVES USED IN AN ANGEL FOOD CAKE SYSTEM

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ABSTRACT

Comparisons of the physical and sensory properties of several commercial egg alternatives in angel food cake formulation were studied. Fourteen samples were investigated for foaming properties at 10 and 20 min whipping time: collagen, Cryogel gelatin, Solugel collagen hydroysates, gelatin, whey protein concentrate, fish protein, whey protein isolate (95% WPI, 90%WPI), hydrolyzed whey protein isolate, pea protein, rice protein concentrate, soy protein, corn zein and casein. However, only eight samples showed potential and were moved forward for further evaluation. Only the WPI alternative was able to maintain a meringue during baking. All other foams collapsed during the baking process. The angel food cake formulated with WPI exhibited a significantly firmer crust and crumb compared with the egg white control. The L *value, height and volume of control cake were also significantly higher than the egg alternative. The control significantly outperformed the angel food cake formulated with the egg alternative in all sensory categories evaluated.*

PRACTICAL APPLICATIONS

The egg alternatives were used to replace egg as a functional ingredient in angel cake productions. These alternatives can deliver functionality at a lower cost and can be incorporated to produce a suitable angle cake, especially whey

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protein isolate (WPI). These results may help producers in formulating angle cake that rely on WPI as an egg alternative.

INTRODUCTION

Angel food cake is traditionally made by combining an egg white meringue with flour and sugar to form a batter that is baked to form a solid foam cake. Egg white is composed of a variety of proteins that range in chemical properties (molecular weight, pI, glycosylation, phosphorylation and sulfhydry/disulfide content) (Lin-Chan *et al.* 1989). Not all individual egg white proteins have the ability to function in making angel food cake. Ovalbumin (54% of total protein) and globulins (8% of total protein), when tested individually, are the only two that produce angel food cakes with volume equal or greater than egg white (Johnson and Zabik 1981a,b; Lin-Chan *et al.* 1989).

Commercial egg alternatives available for application in bakery products are marketed as considerable long-term cost savings. The partial replacement of egg white protein (EWP) with cheese whey protein concentrates (WPC) or whey protein isolate (WPI) in angel food cake formulations has been reported previously (Morr *et al.* 1973; Haggett 1976; Khan *et al.* 1979; Morr and Han 1993; Lawson 1994; Zhu and Damodaran 1994; Arozarena *et al.* 2001). The excellent foaming and heat-induced gelation properties of commercial WPI (Morr and Foegeding 1990; Philips *et al.* 1990; Morr 1992) and lipid and calcium content-reduced WPC prepared from pretreated and microfiltered whey (Karleskind *et al.* 1995a,b,c) suggested that they might be used to replace EWP in angel cake formulations. Arunepanlop *et al.* (1996) investigated the effect of replacing 25 and 50% of liquid egg white with WPI solution in angel food cakes. Patino *et al.* (2007) found that the foaming capacity increases by increasing the sunflower protein concentration and its hydrolysates in solution. Foams retain a higher amount of liquid, are denser and the bubbles are smaller when the protein concentration increases. The foam stability also increases with the amount of protein in solution. Therefore, these proteins might be used to replace EWP in angel cake formulations.

With the advent of new technologies, many new food ingredients are being advertised. However, there is very little literature that compares these ingredients with eggs in a scientific study. The hypothesis of this study is whether egg alternatives may replace egg as a functional ingredient in angel food cake system. The objective was to evaluate the physical and sensory properties of the angel food cake systems formulated with either egg or egg alternatives.

MATERIALS AND METHODS

The ingredients used in all angel food cake formulations included ionized salt (Kroger Co., Cincinnati, OH), pure cane sugar (C&H Sugar Co., Crockett, CA) and corn oil (Kroger Co).

The egg and egg alternatives evaluated in the angel food cake formula were either donated or purchased. They included: pasteurized liquid egg yolk purchased from Cutler Egg Products (Abbeville, AL), collagen (Great Lakes, Magnolia, AR), Cryogel gelatin (CG) and Solugel collagen hydroysates (SCH) (PB Gelatins, Carlsbad, NM), gelatin (Rousselat, Dubuque, Iowa), whey protein concentrate (WPC) and fish protein (FP) (Parmalat Ingredients, Ontario, Canada), 90% whey protein isolate (90% WPI), 95% whey protein isolate (95% WPI), hydrolyzed whey protein isolate (HWPI) (Davisco International, Eden Prairie, MN), pea protein (PP) (Parrheim Foods, Manitoba, Canada), rice protein concentrate (RPC) (A&B ingredients, Fairfield, NJ), soy protein (ADM, Decatur, IL), corn zein and casein (Sigma, St. Louis, MO).

Foaming Property Test

Fourteen samples were investigated for foaming properties at 10 and 20 min whipping time. Foam capacity and stability were measured using a modified method of Philips *et al.* (1990). Three replication and three subsamples per replications were performed on nine different treatments. Foam capacity and stability were measured after whipping/aerating a 150 mL of a 12% protein solution (w/v) for 10 or 20 min in a Kitchen Aid Mixer (Kitchen Aid, St. Joseph, MI) at approximately 100 W. The drainage was measured every 5 min for 30 min using a funnel and a graduated cylinder apparatus at room temperature. However, we included only the drainage results for 10, 20 and 30 min because they clearly demonstrated the most significant change.

Batter and Cake Preparation

Angel food cake was used as a system to compare and evaluate the functionality of the egg alternatives relative to the egg white protein. A commercial angel food cake formulation (Table 1) was modified for the study. The blended protein solutions were whipped 1 min at speed setting 8 with an Ultra Power Mixer Model KSM90AC (Kitchen Aid Portable Appliances) equipped with a wire whisk attachment.

A Reed reel oven (Reed Oven Co., Kansas City, MO) was preheated to 375°F (190.5C), during which time a pan of water was placed in the oven for conditioning. For the experimental angel food cakes being baked and evaluated, the pan of water was removed prior to checking the first test cake to ensure proper baking conditions.

TABLE 1.
A COMMERCIAL ANGLE FOOD CAKE FORMULATION

Ingredient	(g)	% (flour basis)
Flour	110.0	100
Sugar	314.0	285
Dried egg white/protein	40.0	36.4
Monocalcium phosphate, monohydrate	1.5	1.4
NaCl	3.0	2.7
Water	295	268.0

About 18 h before baking either the reconstitute egg white or egg alternative was mixed in requisite amount of water with in a Kitchenaid mixer (Model K5-A, Hobart Corp., Kitchenaid Div., Troy, OH) using a whip attachment on low for 5 min. The mixtures were covered and stored at 4C overnight. The following day, either the egg white or egg alternative solution was transferred to a to a Hobart A-100 12 quart mixer, and the remaining dry ingredients (sodium chloride, monocalcium phosphate and one-half of the sugar) were added and blended. The blending was done with the egg protein or egg alternative mixture at low speed for 1 min or until a homogeneous solution was obtained. Then, the mixture was blended on the highest mixer setting until the specific gravity of the mixture was between 0.14 to 0.13. The specific gravity was determined by the weight comparison method 10-14 (AACC 1983).

The cake flour was sifted, combined and mixed at low speed with the remaining sugar for at least 20 s. The flour–sugar mixture was folded by dipping the whip into the batter and was shacked off 10 times and then poured into aluminum pans. Aluminum pans were filled with 650 g batter and baked for 55 min at 375F (or until the surface of cake springs back when lightly touched). Then cakes were cooled in an inverted position on a wire rack for 40 min, and the cake volume was determined.

Cake Color

Crumb color was measured using a Hunter Miniscan portable colorimeter (HunterLab, Reston, VA). The colorimeter was calibrated using a light trap and white tile according to procedure set forth by the HunterLab owner's manual. Color was measured using natural light (C) at a 10° angle. Three measurements of each sample were taken and then averaged. The *L*, *a* and *b* values were all recorded. These angle cake color attributes can be defines as the following: (lightness [*L*], yellowness to blueness [*b*], and redness to greenness [*a*]). Procedures for color were adapted from Lee *et al.* (1991).

Cake Volume

Cakes volume was determined 1 day after baking by American Association of Cereal Chemists (AACC) Baking Quality Method 10-91 (AACC 2000). Two cakes were each sliced into two similar-sized halves. The index template was placed up against the cut edges of the cakes, and the height of designated positions B, C and D were recorded. These recorded heights were used to compute volume as instructed in AACC (2000) method 10-91. Volume is computed by B + C + D. Measurements were then averaged.

Texture Analysis

Cake firmness was determined with TA-XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) equipped with a 25-kg load cell. The angel food cake sections were compressed to 60% of the original height using a 20-mm cylindrical probe in the TPA mode (two-compression test) with a 15 s delay between compressions. Results were analyzed with the aid of a XTRAD computer program and presented as a force versus time graph with a 15-g force threshold setting. The (8 in.) angel food cake was longitudinally sliced to obtain two halves. The crust and crumb were evaluated for firmness. Individual halves were probed in five randomly selected locations around each half. This procedure was performed on three cakes per treatment. The firmness of each measurement was recorded. Cakes were tested within 24 h after baking. Measurements were taken by using the following setting: test mode: texture profile analysis (T.P.A.), pretest speed: 3 mm/s, test speed: 1.7 mm/s, posttest speed: 1.7 mm/s, distance: 6 mm, trigger: auto at 20 g, acquisition rate: 200 pps.

Sensory Analysis

Cakes were evaluated within 2 days after being baked using a complete block design to randomize the order of evaluation. After cooling and depanning, cakes were cut into 1.5-cm radial sections, placed in plastic freezer bags, sealed and stored at 23C until they were subjected to sensory analysis. Evaluations were performed by 100 untrained sensory panels that are at least 18 years old. Panelists were prescreened for potential food allergies and on the basis of being an angel food cake consumer. Panelists were provided with an instruction/score sheet with specific instructions for evaluating the samples. Angel food cake samples were offered to panelists on odorless plastic plates coded by three-digit random numbers at room temperature. Samples were served to panelists monadically. The order of serving was determined by random permutation. Questionnaires were provided with samples. Panelists were instructed to use unsalted crackers and distilled water to cleanse their palate before tasting the samples and any time during the test as needed. The panelists evaluated angel food cake on a 9-point hedonic scale to determine degree of liking of the cake (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely). The samples were rated for aroma, taste, texture and overall acceptability on the same scale.

Statistics Analysis

Three replications and three subsamples per replication were performed on nine different treatments. Treatments were compared for their physical and sensory characteristics following a one-way completely randomized design. The analysis of variance (ANOVA) and means comparison were conducted by the general linear model (Proc GLM) and ANOVA (Proc ANOVA) procedures with Statistical Analysis System software (version 8.2, SAS Institute, Inc., Cary, NC). Comparisons among treatments were analyzed by using Fisher's least significant difference, with a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Foaming Property

Commercial egg alternatives available for application in bakery products are marketed as considerable long-term cost savings. These egg alternatives are advertised to possess useful functional properties, including: browning, cohesiveness, foaming, gelling water binding and emulsifying attributes. There were many stages of screening for egg alternatives to be considered for use in angel food cakes. The initial screening was the ability of the egg alternative to form stable foam. The next screening consideration was the ability of the stable foam to be baked under processing conditions (temperature and time) that would be used in the production of angel food cake. Therefore, only the egg alternatives that passed the baked meringue test were used in the final experimental design. Only the egg alternatives that exhibit an acceptable foam property performance level as deemed by the evaluators were designated for use in the angel food cake model system study.

Fourteen egg alternatives and an egg white protein were evaluated and investigated for foaming properties. Only eight showed potential and were moved forward for further evaluation (Tables 2 and 3). The suppliers advertise their products for use as egg white protein alternatives. Figures 1 and 2 provide images of selected egg alternatives and their foam capacity and stability. Therefore, one may observe the range of foaming functionality that these selected egg alternatives possess. Tables 2 and 3 exhibited differences in foam capacity and stability as a function of mixing time. This experiment was conducted to determine if egg alternatives needed a different mixing time to

TABLE 2.
COMPARISON OF FOAM CAPACITY AND STABILITY BETWEEN EGG WHITE PROTEIN AND EGG ALTERNATIVES AFTER MIXING FOR 10 MIN

Treatment	Specific gravity	Time (min)		
		10	20	30
		Drainage (mL)		
Egg white	0.078 ± 0.014	0.905 ± 1.124	2.19 ± 0.580	3.285 ± 0.163
CG	0.299 ± 0.001	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Collagen	0.266 ± 0.050	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
95% WPI	0.088 ± 0.042	0.85 ± 1.203	2.465 ± 3.486	3.98 ± 4.310
WPC	0.155 ± 0.013	9.76 ± 1.500	14.09 ± 1.990	14.46 ± 1.470
90% WPI	0.117 ± 0.021	0.00 ± 0.00	0.065 ± 0.092	0.29 ± 4.10
Gelatin	0.096 ± 0.005	4.84 ± 0.339	7.69 ± 0.410	8.8 ± 0.566
HWPI	0.039 ± 0.005	0.00 ± 0.00	2.044 ± 0.427	3.389 ± 0.155

CG, Cryogel gelatin; WPI, whey protein isolate; WPC, whey protein concentrate; HWPI, hydrolyzed whey protein isolate.

TABLE 3.
FOAM CAPACITY AND STABILITY WHEN MIXED FOR 20 MIN

Treatment	Specific gravity	Time (min)		
		10	20	30
		Drainage (mL)		
Egg white	0.093 ± 0.004	2.334 ± 0.566	4.40 ± 0.188	5.40 ± 0.188
CG*	N/A	N/A	N/A	N/A
Collagen*	N/A	N/A	N/A	N/A
95% WPI	0.040 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	1.967 ± 0.041
WPC	0.114 ± 0.009	13.350 ± 0.494	15.506 ± 0.502	15.883 ± 0.469
90% WPI	0.055 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Gelatin	0.108 ± 0.005	4.867 ± 0.208	8.4 ± 0.608	9.767 ± 0.643
HWPI	0.312 ± 0.002	0.00 ± 0.00	0.378 ± 0.402	1.90 ± 0.506

* No foam formed; instead, a gel-like substance was formed.
CG, Cryogel gelatin; N/A, not applicable; WPI, whey protein isolate; WPC, whey protein concentrate; HWPI, hydrolyzed whey protein isolate.

enhance their foaming properties compared with egg white protein (Fig. 3). It was found that 95% WPI and gelatin foams exhibited similar foam density to egg whites (Table 2). CG, collagen, WPC and 90% WPI had a greater specific gravity. However, only CG, collagen and 90% WPI had longer foam stability compared with egg white foams. Ninety-five percent WPI and HWPI had relatively similar foam stability at 30 min drainage. WPC had both poor foam

A B C D E

FIG. 1. REPRESENTATIVE IMAGES COMPARING FOAMS PREPARED WITH EGG WHITE AND SELECTED FOAMING EGG ALTERNATIVES
(A) egg white, (B) casein, (C) whey protein isolate (WPI), (D) Parmalat whey protein concentrate (WPC), and (E) 90% WPI.

A **B** **C**

FIG. 2. REPRESENTATIVE IMAGES COMPARING FOAM STABILITY OF (A) PARMALAT WHEY PROTEIN CONCENTRATE (WPC), (B) EGG WHITE AND (C) WHEY PROTEIN ISOLATE (WPI)

density and stability. gelatin had similar foam density to egg white, but lesser drainage capacity. CG and collagen did not form foams; instead, they formed a gelatin-like substance. Ninety-five percent WPI and gelatin exhibited similar or better specific foam capacity than fresh egg white.

Many of the egg alternatives were able to produce a stable foam (Fig. 4), although the specific gravity did vary form one protein source to the next. Based on the foaming data, the whey protein sample (WPI, 90 and 95%) exhibited potential to make an acceptable angel food cake compared with the other egg alternatives evaluated.

Meringues

Preliminary data showed that not all egg alternatives that performed well in the foaming study could withstand the high temperatures (375F/30 min)

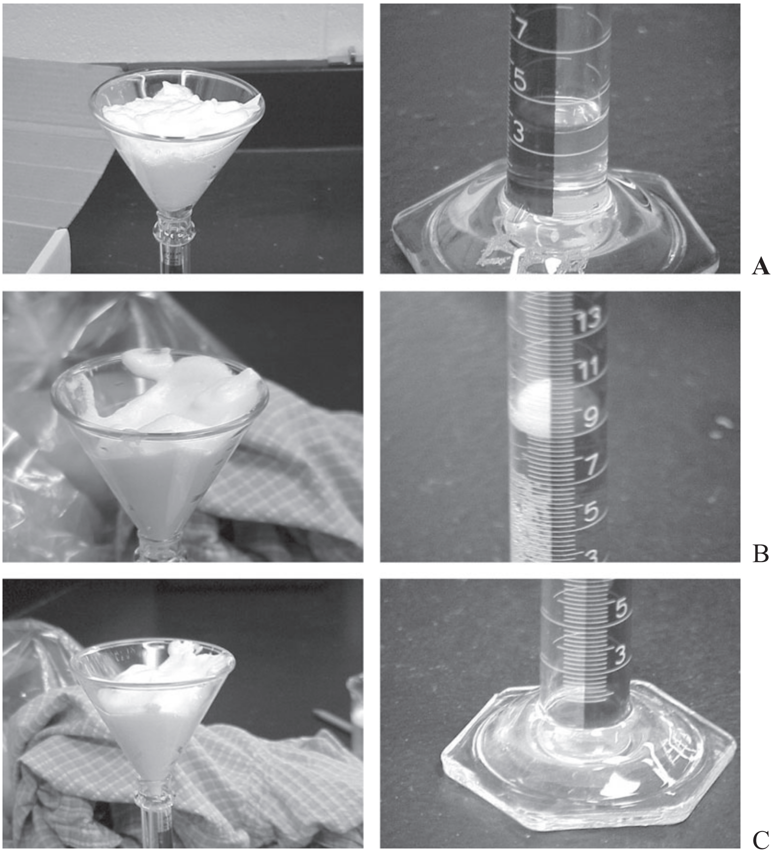


FIG. 3. REPRESENTATIVE COMPARISON OF FOAM CAPACITY AND FOAM STABILITY OF SELECTED EGG ALTERNATIVES
(A) egg white, (B) gelatin and (C) collagen.

required to bake an angel food cake. Prior to preparing all the foams for cake testing, a series of baked meringue were evaluated. Only the egg alternatives that successfully were able to deliver a baked meringue were considered for testing in the angel food cake experiments. Below are images that depicted the success of the egg alternatives in a baked meringue experiment (Fig. 5). Only the 95%WPI egg alternative was able to maintain a meringue during baking. All other foams collapsed during the baking process, and representative samples are depicted in Fig. 6. The angel food cake formulated with 95% WPI exhibited a significantly firmer crust and crumb compared with the egg white control (Fig. 7).

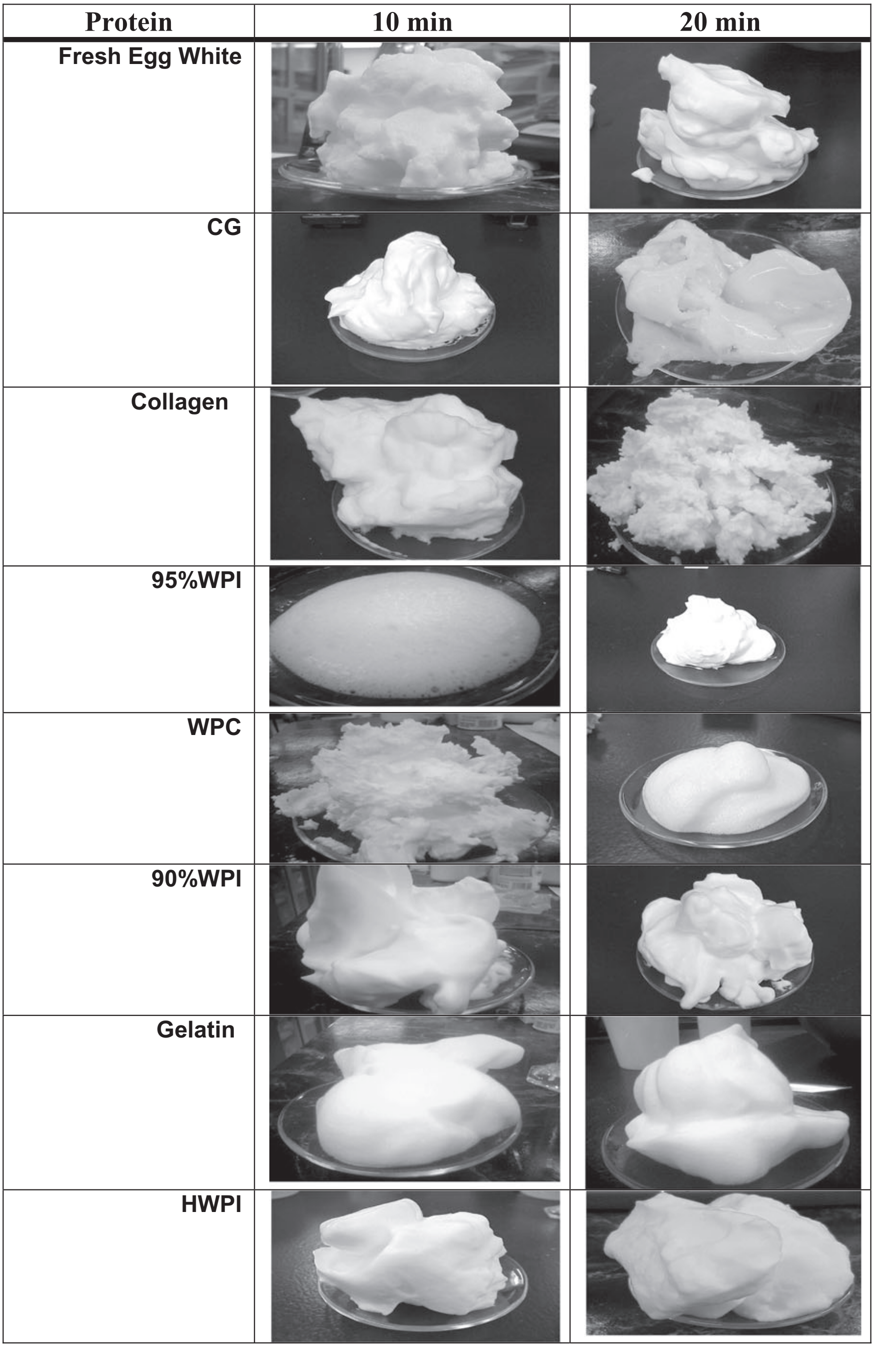


FIG. 4. DEPICTION OF EGG WHITE AND EGG ALTERNATIVE FOAMS AFTER 10 AND 20 MIN OF MIXING

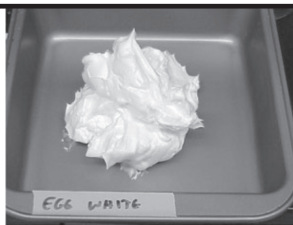
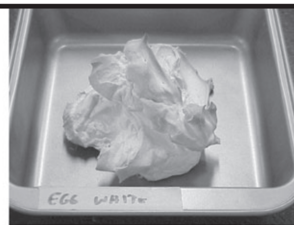
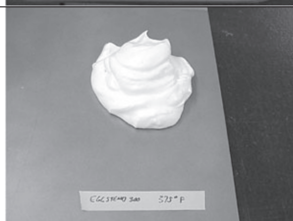
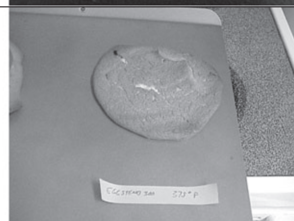
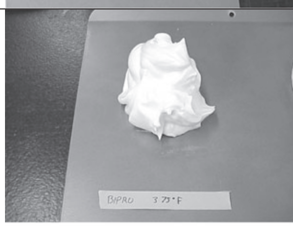
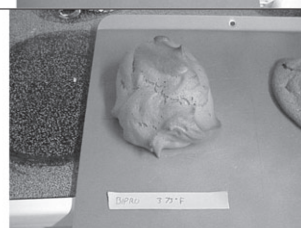
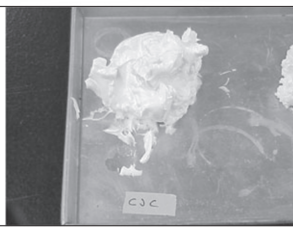
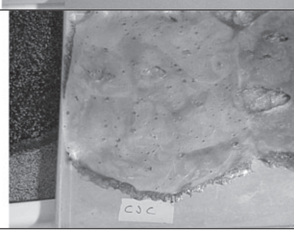
Protein	Before	After
Fresh Egg White		
WPC		
95%WPI		
Collagen		

FIG. 5. DEPICTION OF MERINGUES OF EGG WHITE AND EGG ALTERNATIVES BEFORE AND AFTER BAKING AT 375F FOR 30 MIN

L Values

The *L* value of the angel food cake formulated with egg white protein exhibited a significantly higher *L* value compared with the WPI (Table 4). The *a* and *b* values of angel food cake formulated with egg white protein had a lower value compared with 95%WPI.

Volume

Data showed that replacing eggs with a single ingredient did not produce volumes close to that of cakes with eggs (Table 4). The control cake's height

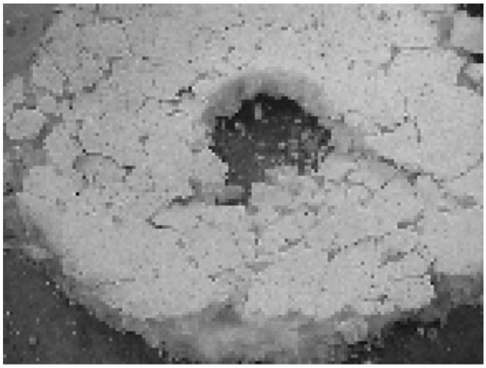
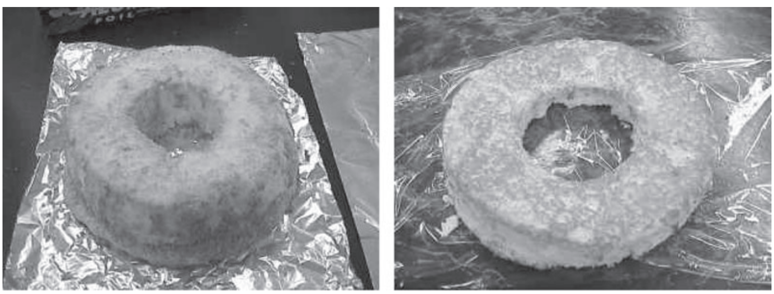


FIG. 6. REPRESENTATIVE IMAGE OF AN ANGEL FOOD CAKE FORMULATED WITH AN EGG PROTEIN ALTERNATIVE TREATMENT (COLLAGEN) THAT DID NOT MAKE THE SCREENING BECAUSE OF UNACCEPTABLE QUALITY



Egg protein **95%WPI**

FIG. 7. REPRESENTATIVE IMAGES OF ANGEL FOOD CAKES PREPARED WITH EGG WHITE PROTEIN AND WHEY PROTEIN ISOLATE (95% WPI)

TABLE 4.
COMPARISON OF SELECTED PHYSICAL ATTRIBUTES OF ANGEL FOOD CAKES FORMULATED WITH EGG WHITE PROTEIN OR WHEY PROTEIN ISOLATE

Treatments	Color			Height (cm)	Volume (cm^3)
	*L**	*a**	*b**		
Control	80.96 ± 5.95^A	2.40 ± 1.65^B	17.42 ± 2.19^B	8.55 ± 0.28^A	$3,193.23 \pm 131.55^A$
95% WPI	63.11 ± 2.83^B	14.04 ± 4.82	35.79 ± 7.04^A	4.53 ± 0.43^B	$1,411.45 \pm 212.55^B$

Average ± SD. Means followed by the same superscript letters in the same column are not significantly different ($P < 0.05$).
WPI, whey protein isolate.

TABLE 5.
COMPARISON OF ANGEL CAKE FIRMNESS OF ANGEL FOOD CAKE FORMULATED WITH EGG WHITE PROTEIN AND WHEY PROTEIN ISOLATE

Treatments	Crust firmness (g-force)	Crumb firmness (g-force)
Control (egg white)	35.83 ± 2.87^{B}	38.12 ± 3.43^{B}
95% WPI	217.49 ± 93.09^{A}	461.05 ± 172.96^{A}

Average ± SD. Means followed by the same superscript letters in the same column are not significantly different ($P < 0.05$).
WPI, whey protein isolate.

TABLE 6.
CONSUMER SENSORY OF ANGEL FOOD CAKE FORMULATED WITH EGG WHITE PROTEIN OR WHEY PROTEIN ISOLATE

Sensory attributes					
Treatments	Appearance	Texture/mouthfeel	Flavor/taste	Acceptability	Willing to purchase (%)
Control	7.14 ± 1.37^{A}	7.19 ± 1.60^{A}	6.99 ± 1.54^{A}	7.21 ± 1.35^{A}	80.2
95%WPI	5.85 ± 1.85^{B}	5.54 ± 2.00^{B}	5.91 ± 2.11^{B}	5.61 ± 1.95^{B}	42.3

Average ± SD following a hedonic scale of 1–9 (1: dislike extremely, 5: neither like nor dislike, 9: like extremely). Means followed by the same superscript letters in the same column are not significantly different ($P < 0.05$).
WPI, whey protein isolate.

and volume were also significantly higher than the egg protein alternative. Cake volumes were still significantly less than control cakes for 95% WPI alternative. These results were similar to those of Arunepanlop *et al.* (1996) and Pernell *et al.* (2002).

Texture

Texture was affected by replacing eggs with other ingredients. Hardness data showed that treatment containing 95% WPI had significantly higher values than control (Table 5). At 95% WPI replacement, crust and crumb firmness were 217.49, 461.05 (g-force) for treatment, respectively, whereas 35.83 and 38.12 (g-force) for control.

Consumer Panel

The control significantly outperformed the angel food cake formulated with the egg alternative in all sensory categories evaluated (Table 6). The sensory data supported the physical data.

Consumers found that the cake formula control was significantly more favorable than the 95% WPI cake in appearance, texture, flavor and overall acceptability (Table 6). It is expected that 95% WPI was exposed to different processing conditions and pretreatments that may affect its functions as an egg alternative. Consumers stated that they would be more willing to buy the control formulation than the WPI alternative. Only 42.3% of consumer stated they would be willing to purchase the cake formulated with WPI alternative.

CONCLUSION

Many of the egg alternatives were able to produce a stable foam. Although the specific gravity did vary from one protein source to the other. Based on the foaming data, the whey protein sample exhibited potential to produce an acceptable angel food cake compared with the other egg alternatives evaluated. The egg protein alternative did not perform as well as the control in the physical attributes evaluation. The angel food cake formulated with the egg alternative exhibited a firmer crust, lower volume and darker color compared with the control.

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