Angel Cakes Using Frozen, Foam-Spray-Dried, Freeze-Dried, and Spray-Dried Albumen[1]

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ABSTRACT

The performance and quality-characteristics of frozen, foam-spray-dried, freeze-dried, and spray-dried egg albumen in angel cakes were investigated. Whipping times for the frozen and reconstituted albumen were established to obtain foams of the same specific gravity. Standardized procedures were used for mixing, baking, and evaluating all cakes. Rates of temperature rise as measured at two depths within each cake were not affected by the type of processing. Cakes with foam-spray-dried albumen had the largest volume; cakes with spray-dried albumen had the smallest volume. Shear press measurements of tenderness expressed as area-under-the-curve, compressibility, and tensile strength showed no significant differences attributable to processing. Cakes with foam-spray- and freeze-dried albumen were tougher than cakes with frozen albumen, according to shear press measurements of tenderness expressed as maximum force. Freeze-dried albumen produced cakes which scored lowest in the quality characteristics of texture defined as thickness of cell walls, tenderness, and moistness. The flavor of cakes with frozen albumen was superior to the flavor of cakes with the three types of processed albumen. However, all cakes received good to very good scores for the quality characteristics evaluated.

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New or improved methods of processing, such as foam-spray-drying and freeze-drying or spray-drying, offer the potential of high-quality dehydrated egg albumen for use by homemakers, volume feeding operations, and industry. Limited research on the performance of albumen processed by all of these methods has been reported in the literature. Zabik et al. (1) studied the functional properties and palatability of frozen, freeze-, foam-spray-, and spray-dried yolks and albumen in chiffon cakes. Anderson[3] investigated the performance of yolk-contaminated spray-dried albumen in angel cake. Rolfes et al. (2) studied the performance of freeze-dried albumen in angel cakes, and Cuccui[4] investigated the use of spray-dried albumen.

This study was undertaken to assess the functional properties and quality characteristics of foam-spray-, freeze-, and spray-dried albumen in angel cakes. Cakes prepared from frozen albumen were used as a control for determining the effect of processing on the functional properties.

MATERIALS AND METHODS

Processing of the Albumen

Liquid albumen was procured from a commercial processor in a sufficient amount so that eggs from a common lot could be processed by the four methods. The albumen was obtained by machine-breaking fresh-receipt shell eggs, varying in age from 1 to 2 weeks in grades A to C, and separating under USDA supervision. After production, the liquid products were strained through stainless-steel strainers with 0.024-in. perforations to remove shell fragments and membranes and then churned to ensure homogeneity. The liquid albumen was desugared with an *Achrobacter aerogenes* type of fermentation carried out at 29°C. After fermentation, the albumen was frozen in 30-lb. metal containers and held at −30°C. until further processing and/or shipment. Approximately one-fourth of the original frozen material was allocated for the frozen variable; the remaining was either foam-spray-, freeze-, or spray-dried.

The portion of the albumen to be used for spray-drying was thawed, blended, and spray-dried using a pilot plant spray-dryer under an atomizing pressure of about 2,000 lb.[5] Intake temperature was 149° to 163°C. and exhaust temperature was 66° to 71°C. After drying, the albumen was screened through an 80-mesh USBS screen and cooled to 20.6°C.

The frozen eggs for freeze- and foam-spray-drying were shipped in dry ice to the appropriate processor[6]. For freeze-drying, the albumen was thawed under running water for 24 hr. and transferred to trays containing a 3/4-in. depth of albumen. The albumen was refrozen at −32°C. in a Stokes Freeze Dryer, Laboratory Model $2003F_2$. The freeze-dryer operated for 24 hr. at approximately 200 μ Hg. pressure with a platen temperature of 45°C. The freeze-dried albumen was passed through a Fitzmill Comminuting Machine, Model D, and sieved prior to packaging.

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[3]Carolyn Anderson. Effect of chemical additives on the functional properties of commercial and 0.05% yolk-contaminated spray-dried albumen. Thesis, Michigan State University, East Lansing, 1968.

[4]P. A. Cuccui. Performance and economic comparisons of egg products. Conference on Eggs and Baking. American Institute of Baking, Chicago, Illinois, May 25-26, 1965.

[5]J. Gorman, Personal communication. Seymour Foods Inc., P. O. Box 116, Topeka, Kansas.

[6]L. E. Dawson. Personal communication. Department of Food Science, Michigan State University, East Lansing, Michigan.

For foam-spray-drying the albumen was partially thawed under running water and then heated to 54°C. prior to processing. Foam-spray-drying was carried out using a modification of the procedure described by Blakely and Stine (3). A cocurrent horizontal inverted tear-drop dryer equipped with two No. 56 nozzles and No. 17 spinners was used with an atomization pressure of 850 p.s.i. Nitrogen was injected into the albumen at 950 p.s.i. prior to atomization. Inlet air temperature was maintained at 107°C., outlet temperature at 79°C. The solids were cooled to room temperature and screened prior to packaging.

The dried albumen was pasteurized by holding at 54°C. for 7 days. All dried eggs were similarly packaged[7]. The pouches consisted of polyethylene terephthalate (0.005-in. thickness), foil aluminum (0.001-in. thickness), and polyethylene (0.002-in. thickness). The packaging process involved drawing 27 in. of vacuum, purging the albumen twice with nitrogen, and sealing on the third vacuum. All albumen was held at −23°C. upon receipt at the foods research laboratory. Just prior to experimentation, the 30-lb. container of frozen albumen was defrosted under running water until slushy, mixed, and refrozen in package sizes appropriate for one replication.

All other ingredients were also purchased in common lots. Flour and sugars were preweighed into appropriate amounts before storage at room temperature; salt, cream of tartar, and almond extract were weighed or measured as needed. Six replications were prepared for each variable.

Preparation and Baking

The angel cake formula contained 500.0 g. granulated sugar, 118.8 g. confectioner's sugar, 270.0 g. cake flour, 6.0 g. salt, 2.5 g. cream of tartar, and 3 ml. almond extract, along with the amounts of albumen and distilled water shown in Table I. The amounts of dried albumen were based on the solids in the frozen eggs and corrected for variance in powder moisture among processes. Moisture content was determined by official methods of the AOAC (4). The moisture content of the frozen albumen was 89.00%; that of dehydrated samples was 3.85% for foam-spray-, 3.63% for freeze-, and 3.74% for spray-dried albumen.

Dried albumen was allowed to warm to room temperature, then placed in a 5-qt. bowl of a Kitchen-Aid mixer, Model K-5. Using speed 1 (56 r.p.m.), 250 ml. of distilled water at 25°C. was blended into the powder with the paddle attachment for 30 sec. The bowl was scraped, the remaining water was added, and blending was continued for an additional 60 sec. The reconstituted albumen was routinely strained to ensure that complete reconstitution had taken place.

TABLE I. ALBUMEN AND DISTILLED WATER USED FOR ANGEL CAKES

Type of Albumen	Albumen g.	Distilled Water ml.
Frozen	960.0	...
Freeze-dried	118.1	842
Foam-spray-dried	118.3	842
Spray-dried	118.5	842

[7] G. G. Jianas. Personal communication. Jianas Brothers, 2533 Southwest Boulevard, Kansas City, Missouri.

Salt was added to the defrosted albumen (25°C.) or reconstituted albumen contained in a 12-qt. bowl of a Hobart mixer, Model 200-A. Using the whip attachment, the albumen and salt were blended for 35 sec. at speed 1 (48 r.p.m.). The cream of tartar was added and the mixture was whipped for 60 sec. at speed 2 (96 r.p.m.). The granulated sugar was added gradually over a 60-sec. interval, during which the mixer was operating at speed 2. After addition of the almond extract by pipet, whipping was continued at speed 2 for 9, 10, 13, and 30 min. with frozen, freeze-, foam-spray-, and spray-dried albumens, respectively. Whipping times were established in preliminary studies to obtain similar specific gravities of 0.18 for the foams of albumen processed by the different methods.

Three approximately equal portions of flour-confectioner's sugar mixture, which had been presifted three times, were folded into the foam by hand. The folding was continued until all traces of dry flour disappeared.

Using 660 g. per pan, the cake batter was poured into two aluminum pans (15½ by 4 by 4 in.), and cut through with a metal spatula to reduce large air bubbles. All cakes were baked at 177°C. for 33 min. in an ETCO forced-air oven Model 186-A, equipped with a Versatronik controller. Time-temperature relationships were continuously recorded during baking as described by Elgidaily et al. (5).

Immediately after baking, the potentiometer leads were carefully removed. The cakes were inverted and cooled in the pans for 1 hr. before volume determinations were made. After the cakes were removed from the pan, they were placed on cardboard bases, wrapped in plastic food wrap and frozen at −23°C. for later evaluation. After 2 weeks of storage, cakes were sliced in the semifrozen state with a Hobart slicer, Model 410, set at 60. The interior slices from the two cakes baked for one replication were randomized by the method described by Funk et al. (6), hence two samples from the two cakes comprising one replication were evaluated by each judge and triplicate determinations were made of each shear press measurement.

Sensory Evaluation

Samples, 5.25 cm. in diameter, cut from the center of designated slices, individually wrapped in plastic food wrap, and placed on coded white plates, were presented to an eight-member taste panel. The panel, made up of experienced panelists, participated in three preliminary sessions, during which time the score sheet terminology was explained and the validity of their judgments ascertained. Two samples from one replication of each of three variables were served at each session under 15-watt fluorescent lighting. A seven-point numerical scale with 7-excellent, 6-very good, 5-good, 4-medium, 3-fair, 2-poor, and 1-very poor, designated to correspond to appropriate descriptive terminology, was used to evaluate each cake sample independently. Quality characteristics of 1) texture, defined as distribution and size of cells and as cell wall thickness, 2) tenderness, 3) moistness, and 4) flavor were evaluated. Thus, an excellent cake was described as having thin-walled cells of medium to large size in a slightly irregular pattern; extremely tender; moist, but not sticky or gummy; and having a bland, over-all flavor characterized by a slight sweetness and very slight overtones of egg. At the opposite end of the scale, a very poor cake had very compact or collapsed, thick-walled cells, was very tough; was extremely moist or dry, and had a strong, disagreeable flavor.

Objective Measurements

The specific gravity of foam and batter as well as cake volume was determined as outlined by Brown and Zabik (7). The pH of the batter was determined with a Beckman Zeromatic pH meter.

Tenderness, compressibility, and tensile strength were measured with an Allo-Kramer shear press, Model SP-12, equipped with an E2EZ electronic recorder by the methods outlined by Funk et al. (6). A 100-lb. proving ring and 25 lb. of pressure were used for all determinations, and ranges of 100 lb., 5 lb., and 1 lb. were used for tenderness, compressibility, and tensile strength, respectively. Tenderness was expressed as maximum force and area-under-the-curve indices (6), whereas compressibility and tensile strength were expressed only as maximum force. Maximum force values were calculated as:

$$\frac{\text{Maximum graph reading (\%)} \times \text{Range (\%)} \times \text{Ring}}{\text{Sample weight}}$$

For area-under-the-curve values, the curves graphed by the electronic recorder were carefully cut out and then weighed on a Mettler balance, type H15. A conversion factor of 174.2 was used to calculate area in sq. cm. under each curve (6).

RESULTS AND DISCUSSION

Time-Temperature Relationships

Time-temperature relationships, as measured 2.5 and 5.0 cm. from the bottom of the baking pans, were each averaged at 5-min. intervals for all cakes prepared with each of the four types of processed albumen. Very similar rates of temperature rise for each depth were noted for all cakes. Temperatures recorded 2.5 cm. from the bottom rose at a more rapid rate than those recorded 5.0 cm. from the bottom during the first 20 min. of baking. During the next 7 min. approximately the same rates of temperature rise were recorded at the two positions. Temperatures recorded throughout the final 6 min. of baking were 100° and 99°C. for positions 2.5 and 5.0 cm. from the bottom of the pans, respectively. Elgidaily et al. (5) suggested that the maximum temperature reached was dependent on the oven temperature used for baking. In their study, the maximum temperature of the cakes rose as the baking temperature rose, and no leveling of cake temperatures during the latter part of the baking period was noted.

Objective Measurements

Treatment means, standard deviations, and significant differences for objective measurements of angel cakes are presented in Table II. Analyses of process means revealed no significant differences in the specific gravities of foams or batters. Because whipping times were adjusted to yield foams of similar specific gravity, no significant differences would be expected. Preliminary investigations had shown reduced whipping speeds, and hence, longer whipping times were necessary to produce stable foams which would support the weight of the added ingredients. The data indicate that this was accomplished. Using the same types of processed albumen, Zabik et al. (1) reported foam-spray-dried albumen had poorer foaming ability than the other types of processed albumens. However, in their study all albumen was whipped at the same speed and for the same length of time. Also, the

TABLE II. TREATMENT MEANS[a], STANDARD DEVIATIONS, AND SIGNIFICANT DIFFERENCES FOR OBJECTIVE MEASUREMENTS OF ANGEL CAKES

Measurement	Treatment Means				Significant Differences[b]	
	Froz	FD	FSD	SD	at 1%	Additional at 5%
Specific gravity of foam	0.18 ±0.01	0.18 ±0.01	0.18 ±0.01	0.18 ±0.01	None	None
Specific gravity of batter	0.24 ±0.01	0.26 ±0.01	0.24 ±0.01	0.25 ±0.01	None	None
Volume (ml)	3,780 ±107	3,756 ±171	3,927 ±117	3,665 ±0.77	FSD Froz FD SD	Froz FD > SD
Tenderness (lb. force/g.)	2.93 ±0.25	3.18 ±0.04	3.26 ±0.10	3.11 ±0.17	FSD FD SD Froz	FD > Froz
(area under-curve, $cm.^2$)	1.31 ±0.21	1.44 ±0.18	1.38 ±0.23	1.41 ±0.20	None	None
Compressibility (lb. force/g.)	0.61 ±0.04	0.80 ±0.03	0.66 ±0.06	0.82 ±0.08	SD FD > FSD Froz	None
Tensile strength (lb. force/$cm.^2$)	.038 ±0.004	0.041 ±0.005	0.039 ±0.002	0.045 ±0.004	None	None

[a]Froz denotes frozen albumen, FD denotes freeze-dried albumen, FSD denotes foam-spray-dried albumen, SD denotes spray-dried albumen.

[b]Processes underscored by same line are not significantly different (9).

TABLE III. TREATMENT MEANS[a], STANDARD DEVIATIONS, AND SIGNIFICANT DIFFERENCES OF SENSORY EVALUATIONS[b] OF ANGEL CAKES

Characteristic	Treatment Mean				Significant Differences[c]	
	Froz	FD	FSD	SD	At 1%	Additional at 5%
Texture distribution and cell size	4.0 ±0.4	4.6 ±0.3	4.9 ±0.4	5.1 ±0.2	None	None
Thickness of cell wall	5.8 ±0.2	5.4 ±0.3	6.0 ±0.5	5.9 ±0.3	FSD SD Froz FD	None
Tenderness	6.2 ±0.2	5.1 ±0.2	5.6 ±0.3	5.6 ±0.2	Froz FSD SD FD	None
Moistness	5.9 ±0.3	5.3 ±0.1	5.8 ±0.4	5.9 ±0.3	Froz SD FSD FD	FSD > FD
Flavor	6.0 ±0.2	5.7 ±0.2	5.7 ±0.3	5.7 ±0.2	None	Froz FSD SD FD

[a]Froz denotes frozen albumen, FD denotes freeze-dried albumen, FSD denotes foam-spray-dried albumen, SD denotes spray-dried albumen.

[b]Evaluations based on a 7-point numerical scale.

[c]Processes underscored by the same line are not significantly different (9).

processing procedures for foam-spray-dried and freeze-dried albumen used in their investigation differed slightly from procedures used in this study.

Comparison of albumen type means showed cakes with foam-spray-dried albumen had greater volume than cakes with frozen and freeze-dried albumen; cakes with spray-dried albumen had the lowest. These results are in agreement with data reported by Rolfes et al. (2) and Bergquist (8). However,Cuccui(see footnote 4) reported that frozen and dried albumen produced similar foam and batter specific gravities and cake volume when beating time was varied among the differently processed albumens.

No significant differences were shown in comparing albumen type means for tenderness values expressed as area-under-the-curve, and compressibility or tensile strength values expressed as maximum force. Ranked in order of decreasing tenderness values expressed as maximum force were cakes with frozen, spray-, freeze-, and foam-spray-dried albumens.

Sensory Evaluation

Treatment means, standard deviations, and significant differences for subjective evaluation are reported in Table III. Moderately irregular distribution of cells, open texture, and large cell size were judged as being characteristic of cakes prepared with the four types of processed eggs. Cell walls of cakes prepared with freeze-dried albumen were judged to be thicker than those of cakes prepared with frozen, foam-spray-dried, and spray-dried albumen. In addition, tenderness and moistness of cakes with freeze-dried albumen were scored lower than the same quality characteristics of cakes with frozen, foam-spray-dried, and spray-dried albumens. The cakes with frozen albumen were scored higher for tenderness and flavor than cakes prepared with dried albumens. Cakes with all types of dried albumen scored the same for flavor. All cakes were scored as medium to very good for all quality characteristics evaluated.

Relation of Objective Measurements and/or Sensory Evaluations

Significant correlation coefficients are summarized in Table IV. The correlation coefficient between the specific gravities of the foam and the batter indicated a stable foam which was not altered by the addition of the flour, sugar, and other ingredients. However, the correlation coefficient between the specific gravity of the batters and the cake volumes was not significant. Cake volumes correlated negatively with compressibility, indicating that cakes with increased volume required less force to compress the delicate cake structure.

Objective measurements of tenderness expressed as maximum force and compressibility were negatively correlated with tenderness scores and thus more force was required to shear or compress cakes which scored low in tenderness. These results agree with the report of Funk et al. (6), who established the validity of the shear press for measuring tenderness of angel cakes. Measurements of tensile strength correlated with the specific gravity of the cake batter, indicating that cakes with low specific gravity required less force to pull them apart than did cakes with high specific gravity.

Texture scores, defined as distribution and size of cells, correlated with texture scores, defined as thickness of cell walls, indicating that as the size of the cells increased, thin cell walls resulted. The correlation coefficients between moistness scores and the texture evaluations indicate that cakes with thick cell walls and small

TABLE IV. SIGNIFICANT CORRELATION COEFFICIENTS BETWEEN OBJECTIVE MEASUREMENTS AND/OR SENSORY EVALUATIONS

Relation	Correlation Coefficient
Foam specific gravity/batter specific gravity	0.616**
Volume/compressibility	−0.592**
Tenderness, lb. force/tenderness scores	−0.515**
Compressibility/tenderness scores	−0.719**
Tensile strength/batter specific gravity	0.501**
Texture scores, cell size/texture scores, cell walls	0.528**
Texture scores, cell size/moistness scores	0.429**
Texture scores, cell walls/moistness scores	0.611**
Moistness scores/tenderness scores	0.677**
Moistness scores/flavor scores	0.441*

cells were scored as having more moisture than cakes with thin cell walls and large cells. This would be expected, since judges were given samples of equal size, and compact samples would have an increased concentration of the components of the cake. The correlation coefficient between moistness and tenderness scores showed that cakes which were tender were slightly moist. Moisture and flavor scores showed a relation between these quality characteristics, indicating that judges associated a good to very good flavor with cakes which were slightly moist. All cakes were scored as being moderately sweet and bland in flavor.

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