Effect of Chemical Additives on the Functional Properties of Plain and 0.05% Yolk-Contaminated Spray-Dried Albumen[1]

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ABSTRACT

The effect of 0.1 and 0.2% additions of selected chemical additives on the functional performance of commercial spray-dried albumen and commercial spray-dried albumen with yolk added was investigated, using angel cakes as a test product. Sodium lauryl sulfate and triethyl citrate did not affect the functionality of commercial spray-dried albumen, but their addition significantly improved the performance of the 0.05% yolk-contaminated albumen in angel cake production. Of the two, sodium lauryl sulfate was more effective in producing angel cakes from yolk-contaminated albumen which were similar in quality to the plain albumen control cake. The addition of sodium oleate proved detrimental to both egg-white systems.

A minute quantity of yolk can greatly decrease the functional performance of albumen. In an early study, St. John and Flor (1) stated that a single drop of yolk in 30 g. of albumen would reduce the quantity of foam to one-third the original volume. In 1959, Harrel (2) reported 0.15% yolk contamination of albumen inhibited foaming. In frozen albumen as little as 0.01% yolk is harmful, while 0.1% causes angel cake failures (3,4).

Moreover, Cunningham and Cotterill (5) found that foam stability was decreased in direct proportion to the amount of yolk present. Whipping time of albumen was increased by yolk in concentrations as low as 0.001%, while angel cake volume was decreased by all concentrations of yolk above 0.001%. The researchers also reported that a 0.01% yolk contamination decreased foam volume.

Smith (3) studied the lipid composition of diffused yolk in relation to its effect on decreased performance of albumen. He found that diffused yolk lipids were primarily glycerides and contained substantially less phospholipids and cholesterol than is normally found in whole yolk, and further stated that these glyceride components were detrimental whereas the other yolk lipids had little or no effect on albumen performance. The diffused yolk was two to three times more harmful: a diffused yolk contamination of 0.03 to 0.04% (liquid basis) would have the same adverse effect as whole yolk contamination of 0.09 to 0.12%.

Cunningham and Cotterill (5) attributed the reduced foaming ability of yolk-contaminated albumen to lipid-protein interaction. The decreased foam stability and reduced amount of ovomucin insolubilized in the foam led the researchers to postulate that a lipid-ovomucin complex had been formed.

The adverse effects of yolk contamination are magnified in spray-dried albumen. Using albumen which was contaminated with yolk before drying, Cotterill et al. (6) found that the detrimental effects of yolk on albumen were enhanced by about ten times in the spray-drying process. Bergquist (7) suggested that adding certain chemical additives to albumen might preserve and enhance the foaming ability,

[1]Michigan Agricultural Experimental Station Journal Article No. 4478.

which is otherwise impaired during the spray-drying process. He recommended addition of such additives in 0.1 and 0.2% concentrations (based on the weight of the egg white solids).

Cotterill et al. (4) reported that an 0.03% concentration of the anionic additive Sarkosyl NL (sodium lauroyl sarcosinate) improved angel cake volume made from yolk-contaminated albumen to such an extent that the volumes exceeded those of cakes made from yolk-free albumen. The same concentration of a cationic surface-active compound, Arquad 12 (dodecyl trimethyl ammonium chloride), increased angel cake volume of yolk-contaminated albumen so that it approximately equalled those of the control. They found that the ester triethyl citrate improved angel cake volume of yolk-contaminated albumen, but that these cakes never equalled the volume of the yolk-free albumen cake. In contrast, the nonionic surfactant Tween 80 (polyoxyethylene sorbitan monooleate) further impaired the quality of yolk-contaminated albumen.

Cotterill et al. (4) further reported that the anionic additive was most effective in causing yolk lipids to remain in the foam and that the ester slightly decreased the amount of lipids in foam drainage, whereas the cationic surface-active compound was not effective. The yolk addition had little effect on the surface tension of the albumen. Thus, they concluded that the role of chemical additives in improving the functional performance of yolk-contaminated albumen cannot be explained on the basis of surface-active effects alone, but that the ionic character apparently had some effect in altering the performance of yolk-contaminated egg white. Harrel (2) maintained that the function of whipping aids was only to improve quality albumen, not to upgrade yolk-contaminated albumen. This study was initiated to determine the effect of three chemical additives on the functional performance of commercial spray-dried albumen and commercial spray-dried albumen with yolk added.

MATERIALS AND METHODS

Processing of Albumen

Fresh shell eggs were machine broken and separated, following USDA requirements, and strained through stainless-steel strainers (0.024 in. perforations) to remove all shell fragments and membranes. The albumen was made homogeneous in churns equipped with stainless-steel agitators and then desugared with *Aerobacter aerogenes* fermentation at 29°C. A 12-nozzle Roger's spray dryer, under an atomizing pressure of about 2,000 lb., was used to spray-dry the albumen. The intake temperature was 149° to 163°C. and exhaust temperature 66° to 71°C. After drying, the albumen was screened through an 80-mesh USBS screen and cooled to 29°C. before packaging in polyethylene bags.

Yolk Contamination

To achieve a detrimental level of yolk in the albumen, as evidenced by reduced quality of angel cakes during preliminary investigations, 0.05 g. spray-dried yolk was added to half of the 45.0 g. samples of spray-dried albumen. These variables were designated as commercially spray-dried albumen with yolk added; the other half of the variables was designated as commercial (plain) spray-dried albumen.

Data from the Bergquist and Wells (8) monomolecular film test conducted by the processor[2] showed the spray-dried albumen to have an initial yolk contamination of 0.022% (on a liquid basis). Therefore, since the addition of 0.05 g. yolk produced a contamination of 0.028% (on a liquid basis), the total yolk contamination of the reconstituted commercial spray-dried albumen with yolk added was 0.05% (on a liquid basis), whereas the reconstituted plain spray-dried albumen had an actual contamination of 0.022%.

Two anionic chemical additives (sodium lauryl sulfate and sodium oleate) and one ester (triethyl citrate) were added to the reconstituted plain and yolk-contaminated albumen in 0.1 and 0.2% concentrations based on weight of the egg white solids. A yolk-contaminated and a plain albumen containing no chemical additives served as controls. Thus, the fourteen variables consisted of the two concentrations of each of these three additives in the plain series and in the series with yolk added, and the two controls. Each of the fourteen variables was replicated five times.

Preparation and Baking

Angel cakes were prepared by Miyahara and Bergquist's (9) formula, designed specifically for use with spray-dried albumen. The formula was modified slightly by replacing the wheat starch with corn starch since it was readily available and produced cakes of similar quality (Table I).

A Hobart mixer, Model K-5, was set at speed 10 (280 r.p.m.) and used to whip the reconstituted albumen-sugar mixture for 2 min. to the meringue stage. The flour-sugar mixture was divided into four approximately equal portions; each portion was sifted over the meringue and folded in with a wire whip. Cake batter (650 g.) was tared into aluminum loaf pans, 16 X 3.25 X 4 in.

All cakes were baked for 33 min. at 177°C. in an ETCO forced-convection oven, Model 186, after which the cakes were inverted and cooled 1 to 1.5 hr. Volume was then determined and the cakes were removed from the pans, securely wrapped in

TABLE I. ANGEL CAKE FORMULA

Ingredients	g.	Percentage of Flour
Foam portion		
Egg white[a]	360.0	400.00
Granulated sugar	150.0	166.67
Salt	0.7	0.78
Cream of tartar	1.2	1.33
Fold-in portion		
Cake flour	90.0	100.00
Corn starch	45.0	50.00
Powdered sugar	59.4	66.00
Granulated sugar	150.0	166.67

[a]Reconstituted from 45.0 g. solids and 315 ml. distilled water.

[2]Seymour Foods, Topeka, Kansas.

Saran and sealed with masking tape to prevent any entrance of moisture. They were frozen and held at -23°C. for 3 to 4 weeks prior to sensory evaluations and remaining objective measurements. Cakes were sliced in the semi-frozen state with a Hobart slicer, Model 410, set at 60. Randomization of interior cake slices for subjective evaluation and objective measurements followed the procedures outlined by Funk et al. (10).

Sensory Evaluation

Slices designated for taste-panel evaluations were cut in half, individually wrapped with a plastic food wrap, and placed on coded white plates before being presented to an experienced six-member panel. The panel participated in three preliminary sessions in order for them to become completely familiar with the score sheet terminology and for the validity of their judgments to be ascertained. Two samples from one replication of each of three variables were served at each session. Quality characteristics of volume, appearance of the crust, inside color, texture, tenderness, moistness, and flavor were evaluated on a 7-point descriptive scale, with 7 depicting the most desirable score.

Objective Measurements

The specific gravity of the foam and batter; pH of the batter; cake volume; and tenderness, compressibility, and tensile strength, determined by the Allo-Kramer shear press, were measured using the procedures described by Franks et al. (11). The data were analyzed for variance and the Studentized range test (12) was used to sort out significant differences established by these analyses of variance. Simple correlation coefficients were calculated when appropriate.

RESULTS AND DISCUSSION

Sensory Evaluations

Variable means and significant Studentized range values for the sensory evaluations are summarized in Table II. No significant differences were found for any of the plain series of cakes except for those with 0.2% sodium oleate added. The control and other cakes were described as having a slightly cracked crust, good volume, white color, open texture but slightly irregular cell distribution, and a slightly sweet flavor, and as being very tender and moist but not sticky or gummy. The cake prepared with plain albumen with 0.2% sodium oleate was described as having poor volume, irregular texture with thick cell walls, and a slightly soapy or bitter aftertaste.

As would be expected, the volumes of the yolk-contaminated cakes were significantly lower than those of the plain albumen cakes. The addition of sodium lauryl sulfate to the yolk-contaminated albumen produced cakes with fair to good volume comparable to that of the plain albumen control. Triethyl citrate also improved these cake volumes; however, they were not comparable to the plain albumen cakes. The addition of sodium oleate to both types of albumen resulted in cakes of decreased volume.

Yolk contamination also produced cakes with a compact texture and thick cell walls, which were judged as tough. Addition of both levels of sodium lauryl sulfate improved the texture and tenderness so that judges evaluated these cakes as having

TABLE II. SENSORY EVALUATIONS[a] OF ANGEL CAKES PREPARED FROM PLAIN SPRAY-DRIED ALBUMEN AND ALBUMEN WITH 0.05% YOLK CONTAMINATION

Cake Variable	Additive conc.[b] %	Quality Characteristic						
		Crust	Volume	Color	Texture	Tenderness	Moistness	Flavor
Plain series								
Control	...	4.4	5.6	6.4	4.9	5.7	5.7	5.6
Sodium lauryl	0.1	4.7	5.4	6.0	4.6	5.3	5.6	5.4
sulfate	0.2	4.3	5.1	5.8	4.5	5.2	5.1	5.0
Triethyl	0.1	4.5	5.1	6.0	5.0	5.9	5.6	5.3
citrate	0.2	4.3	4.9	6.0	4.6	5.3	5.5	4.8
Sodium	0.1	4.8	4.7	6.0	3.9	4.7	4.7	4.7
oleate	0.2	4.2	2.5	5.3	2.5	3.9	3.7	3.9
0.05% Yolk-contaminated series								
Control	...	3.6	2.7	5.1	2.4	2.6	3.2	3.5
Sodium lauryl	0.1	4.2	5.8	6.1	4.7	5.7	5.2	4.9
sulfate	0.2	4.2	5.7	5.9	4.8	5.6	5.1	5.0
Triethyl	0.1	4.0	3.8	5.4	3.2	3.9	3.8	3.7
citrate	0.2	4.2	4.6	5.8	3.9	4.5	4.1	4.3
Sodium	0.1	3.5	1.7	4.8	1.8	2.0	2.9	3.0
oleate	0.2	3.9	1.6	5.3	1.7	2.3	2.3	3.5
Significant Studentized range values[c]								
1% level		1.1	0.9	0.7	0.9	1.1	1.1	1.2
5% level		0.8	0.7	0.6	0.7	0.8	0.8	0.9

[a]Average of five replications of evaluations by six taste panelists, 7 = highest score.

[b]Based on weight of albumen solids.

[c]Values by which two consecutive means must differ to be significantly different (12).

an open texture but slightly irregular cell distribution and as being very tender. Addition of both levels of triethyl citrate resulted in yolk-contaminated cakes with slightly improved texture and tenderness: the texture described as slightly compact with slightly thick cell walls and the tenderness as moderately tender. Sodium oleate additions to the yolk-contaminated systems resulted in cakes with compact texture and thick cell walls which were evaluated as tough and somewhat rubbery.

The lower moisture scores for the yolk-contaminated series were due to a slightly sticky or gummy characteristic, whereas the lowered flavor scores in this series resulted from descriptions of soapy, bitter, or metallic aftertastes; but the judges did not consistently use only one description for any one variable. The higher flavor scores for the yolk-contaminated cakes prepared with both levels of sodium lauryl sulfate probably reflected an over-all improvement in general acceptability, since this additive would not be expected to improve flavor *per se*.

Objective Measurements

The results of all objective tests (Table III) indicated that with the exception of sodium oleate, addition of a chemical additive did not significantly change or improve the functional properties of the commercial (plain) spray-dried albumen.

TABLE III. OBJECTIVE MEASUREMENTS[a] OF ANGEL CAKES PREPARED WITH PLAIN SPRAY-DRIED ALBUMEN AND WITH ALBUMEN WITH 0.05% YOLK CONTAMINATION

Cake Variable	Additive Conc.[b] %	Batter pH	Foam Specific Gravity	Batter Specific Gravity	Cake Volume ml.	Shear Press Measurements: Compressibility Force lb.	Compressibility Area cm.^{2}	Tenderness Force lb./g.	Tenderness Area cm.^{2}	Tensile Strength lb./cm.^{2}
Plain series										
Control	...	5.8	0.18	0.34	3369	0.82	0.68	2.40	1.59	0.029
Sodium lauryl	0.1	5.7	0.18	0.33	3321	1.05	0.91	2.13	1.63	0.026
sulfate	0.2	5.8	0.17	0.32	3304	0.98	0.85	2.15	1.64	0.027
Triethyl	0.1	5.8	0.16	0.33	3292	0.90	0.74	2.15	1.71	0.026
citrate	0.2	5.8	0.16	0.33	3309	0.97	0.79	2.36	1.85	0.025
Sodium	0.1	5.7	0.29	0.44	3111	1.03	0.86	2.31	1.58	0.035
oleate	0.2	5.8	0.41	0.54	2725	2.79	2.27	1.93	1.72	0.044
0.05% Yolk-contaminated series										
Control	...	5.8	0.48	0.60	2311	2.66	2.28	2.81	2.32	0.055
Sodium lauryl	0.1	5.8	0.20	0.36	3346	0.89	0.81	2.34	1.58	0.028
sulfate	0.2	5.8	0.21	0.36	3292	0.91	0.82	2.14	1.48	0.030
Triethyl	0.1	5.8	0.40	0.53	2683	1.25	1.50	2.25	1.71	0.049
citrate	0.2	5.8	0.33	0.48	2874	1.75	1.07	2.39	1.79	0.040
Sodium	0.1	5.8	0.52	0.65	2184	2.96	2.55	2.91	2.54	0.057
oleate	0.2	5.8	0.55	0.69	1935	3.24	2.77	3.23	2.73	0.066
Significant Studentized range values[c]										
1% level			0.03	0.03	266	0.51	0.45	0.58	0.63	0.012
5% level			0.03	0.02	199	0.66	0.59	0.78	0.47	0.008

[a]Average of five replications.

[b]Based on weight of albumen solids.

[c]Values by which two consecutive means must differ to be significantly different (12).

Addition of 0.1% sodium oleate significantly increased the specific gravities and decreased the cake volumes of this egg-white system, whereas the 0.2% addition proved significantly detrimental to the albumen according to all the objective measurements except those for tenderness and pH of the batter.

A yolk contamination of 0.05% of the spray-dried albumen significantly decreased its foaming ability as evidenced by tests for specific gravity of foam and batter, cake compressibility, tensile strength, and volume. The addition of chemical additives to this egg-white system produced more pronounced effects than in the plan albumen system. Addition of sodium lauryl sulfate and triethyl citrate significantly improved the functional properties of the 0.05% yolk-contaminated albumen in angel cake production. Sodium lauryl sulfate, the more beneficial of the two additives, yielded a 0.05% yolk-contaminated albumen that functioned the same as the plain albumen control in angel cake production ($p \leq 0.01$). Improvements to the 0.05% yolk-contaminated albumen by both concentrations of triethyl citrate were evident in decreased specific gravities and increased cake volumes, compressibility, and tenderness (based on area-under-the-curve values). A 0.2% concentration of triethyl citrate also produced cakes with significantly (**) lower tensile strength readings.

The addition of sodium oleate further impaired the quality of the 0.05% yolk-contaminated egg-white system. In comparison to the 0.05% yolk-contaminated control, both concentrations of this additive significantly increased specific gravities and decreased the compressibility of the angel cakes. A 0.2% concentration of sodium oleate also significantly decreased the tenderness of the cakes as based on the tensile strength readings.

Correlation of Subjective Evaluation with Objective Measurements

As shown in Table IV, objective measurements of compressibility, tenderness, and tensile strength correlated negatively with subjective evaluations of tenderness and texture. Compressibility correlated with the subjective evaluation of moistness. Both objective and subjective measurements of volume also correlated.

DISCUSSION

Yolk contamination has been previously reported to reduce foam specific gravity of frozen albumen (5). The effectiveness of sodium lauryl sulfate and triethyl citrate in improving the functionality of yolk-contaminated albumen supports the findings of Cotterill et al. (4) but contradicts those of Harrel (2).

TABLE IV. SIGNIFICANT CORRELATION COEFFICIENTS BETWEEN SENSORY EVALUATIONS AND SHEAR PRESS MEASUREMENTS OF ANGEL CAKES

Factor	r
Texture/compressibility (lb. force)	−0.89***
Texture/compressibility (area)	−0.89***
Texture/tensile strength (lb. force/cm.^{2})	−0.82***
Tenderness/compressibility (lb. force)	−0.85***
Tenderness/compressibility (area)	−0.85***
Tenderness/tenderness (lb. force/g.)	−0.57***
Tenderness/tenderness (area)	−0.69***
Moistness/compressibility (area)	−0.81***

Cotterill et al. (4) reported that anionic-type additives such as sodium lauryl sulfate were more effective than ester-types such as triethyl citrate. This is supported by the data in the current study. However, Cotterill's group reported sodium lauryl sulfate to improve the volume of cakes prepared with yolk-free frozen albumen and the current study did not find this to be true. It must be pointed out, nevertheless, that in the current study, albumen with a 0.022% yolk contaminated (liquid basis) was first spray-dried and then the sodium lauryl sulfate added to the powder. Thus differences in procedures could account for differences in results.

Gardner (13) offered a possible explanation for the deleterious effect of sodium oleate to both egg-white systems. He found that sodium oleate, unlike most whipping aids, increased the whipping time of the albumen. Since the whipping time of all albumen variables was the same in the present study, those with sodium oleate could have been simply underbeaten. This was evidenced by increased specific gravities of foam and batter for both the plain and yolk-contaminated series of cakes.

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[Received May 27, 1970. Accepted November 23, 1970]