FUNCTIONAL PERFORMANCE AND SELECTED CHEMICAL AND PHYSICAL PROPERTIES OF FROZEN EGG YOLK CONTAINING VARIOUS ADDITIVES

by 4589

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THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

INTRODUCTION

Freezing of liquid egg is a commercially important method for preserving egg quality. In 1966, 96,109,000 pounds of liquid egg yolk were frozen for later use in food products. This amounted to 27.0% of the total frozen egg production and 15.5% of the total liquid egg production in the United States during that year (U.S.D.A., 1967).

The use of frozen egg yolk is complicated by a phenomenon referred to as gelation. Freezing and defrosting egg yolk causes it to form a thick, viscous mass, rather than retaining the fluidity of fresh yolk. The mechanism responsible for gelation is not known.

Commercial egg processors currently add up to 10% salt or sugar to egg yolk prior to freezing to reduce gelation. Although this is effective in reducing the viscosity of the frozen-defrosted yolks, it does not completely inhibit gelation and may affect the functional performance of the yolks in the products for which they are used.

Little information was found in the literature on the chemical changes which accompany gelation of egg yolk. The mode of action of the additives which inhibit gelation is largely a matter of speculation.

The objective of this study was to investigate the effects of selected additives on some chemical and physical characteristics and the functional performance of frozen egg yolk. Comparisons with fresh egg yolk were also made.

REVIEW OF LITERATURE

The performance of frozen yolk in food products, especially in emulsions and sponge-type cakes, has been studied by a few investigators. In evaluating the functional performance of frozen egg yolk, however, most investigators have considered viscosity of primary importance because high viscosity causes difficulty in handling and mixing the yolk with other ingredients. A few studies of chemical properties of frozen yolk have been done in an effort to elucidate the gelation mechanism.

Functional performance of frozen egg yolk

Most studies of the functional performance of frozen egg yolk have concentrated on baked goods and emulsions, the main commercial uses of frozen yolk.

Sponge cakes. Jaax and Travnicek (1968) studied the functional performance of frozen yolk in egg yolk sponge cakes. They found that frozen yolk with fructose or salt as an additive produced batter of lower specific gravity than yolk without additive, fructose being slightly more effective than salt in producing a light batter. Cakes made with frozen salted yolks were larger in volume than cakes made with fructose-treated yolks, and both were larger than cakes made with frozen yolks containing no additive. Compressibility was highest with salted yolks, and decreasingly less with fructose-treated yolks and yolks containing no additive, in that order. Under the conditions of that investigation, variations in scores for shape, texture, grain, and crumb color were not significant. Because of the level of salt used (6.5% by weight), cakes made with salted yolks had an unacceptably salty flavor. Gardner color difference meter values indicated that yolk containing an additive was darker and oranger than untreated yolk, but this was not reflected in the sponge cake panel color scores. Pasteurizing the yolk did not affect the functional properties investigated.

Jordan et al. (1952b) prepared whole egg sponge cakes from yolks and whites frozen separately, and found that the volume of cakes made with frozen yolks containing salt (2.5% or 5%), sugar (5% or 10%), or sirup (8.4% or 16.8%) did not differ significantly from the volume of cakes made from fresh shell eggs. Also, little difference in average tensile strength was found. However, cakes made from untreated frozen yolks were undesirable because of low volume, small yellow particles in the crumb, and low scores for moistness, tenderness, and flavor. Five percent salted yolks gave an undesirably salty flavor to the cakes, but sugared yolks and yolks containing sirup produced cakes which had higher flavor scores than cakes prepared with fresh shell eggs.

Zabik and Brown (1969) tested the foaming ability of frozen-defrosted yolk containing corn sirup solids, and found that the extreme viscosity resisted incorporation of air. However, a later study (Zabik et al., 1969) showed that yolk sponge cakes made with frozen yolks containing corn sirup solids had above average texture scores, and good to very good moistness, flavor and tenderness scores.

Emulsions. Miller and Winter (1951) made mayonnaise with unfrozen and frozen yolks containing no additive. Penetrometer readings indicated that frozen yolks produced stiffer mayonnaise than unfrozen yolks. Preferences for flavor varied widely among the six judges.

Zabik (1969) studied the emulsifying properties of frozen yolk containing corn sirup solids, using a simple oil-in-water system, and found that emulsifying properties were greater at the normal pH than when adjusted to pH 6.2 or 5.6. According to Jaax and Travnicek (1968), the emulsifying ability of frozen yolk was increased by salt, but decreased by fructose. Jordan (1962) also found that 3.3 - 5.0% salt added to yolk increased the stability of a simple emulsion. Correlation coefficients between emulsion separation and pH indicated that as the pH of yolk increased, separation of simple emulsions also increased (Zabik, 1969; Jaax and Travnicek, 1968).

Other products. Jordan *et al.* (1952a) stated that baked custards made from frozen untreated yolk were extremely soft, with a thick crust containing hard yellow lumps. This may have been due to the fact that the highly viscous yolks did not combine well with the milk and sugar. Custards made with yolks from fresh shell eggs were firmer than custards made with frozen yolk containing salt, sugar, or sirup, as indicated by penetrometer readings. Judges preferred the flavor of custards made with fresh shell eggs to any of the frozen egg products.

Lopez *et al.* (1954) reported that the texture of frozen-defrosted yolk fried in Crisco was rubbery and paler in color than fried unfrozen yolk.

Effect of freezing and additives on physical and chemical properties of yolk

Freezing and thawing of liquid egg yolk causes it to become highly viscous, a phenomenon known as gelation. Very little is known about the chemical changes that accompany gelation of egg yolk. Many additives have been used to inhibit gelation, with varying degrees of success. Changes accompanying gelation, and the effects of additives which reduce it, are usually described in terms of viscosity changes.

Physical properties. The average freezing point of egg yolk is -0.65°C, but gelation and the corresponding increase in viscosity does not occur unless yolk is frozen to -6°C or below (Moran, 1925). The magnitude of the viscosity increase in frozen-defrosted yolk as compared with unfrozen yolk is dependent on several factors, including freezing rate, thawing rate, and additives in the yolk.

Rapid freezing of untreated egg yolk by immersion in liquid nitrogen, alcohol-carbon dioxide, or acetone-carbon dioxide resulted in a less viscous product than slower freezing in still air freezers (Jaax and Travnicek, 1968; Marion and Stadelman, 1958a; Lopez *et al.*, 1954). This effect was lessened with fructose-treated yolk, and was not apparent with salted yolk (Jaax and Travnicek, 1968). Rapid thawing also reduced gelation (Lopez et al., 1954; Moran, 1925). Moran (1925) reported that yolk frozen rapidly and thawed in mercury at 30°C regained normal fluidity. It seems likely that the gelation reaction can occur during either freezing or thawing (Lopez et al., 1954).

Many investigators (Jaax and Travnicek, 1968; Powrie et al., 1963; Meyer and Woodburn, 1965; Marion and Stadelman, 1958b; Jordan and Whitlock, 1955) have reported that addition of salt at levels of 1% to 10% increased the viscosity of unfrozen yolk, but decreased the viscosity of frozen-defrosted yolk. Addition of 4.76% to 37.6% sucrose reduced the viscosity of frozen-defrosted egg yolk (Marion and Stadelman, 1958b; Jordan et al., 1952b; Moran, 1925). Other sugars such as fructose (Jaax and Travnicek, 1968; Meyer and Woodburn, 1965; Urbain and Miller, 1930), arabinose and galactose (Lopez et al., 1954), glucose (Urbain and Miller, 1930), and corn sirup or corn sirup solids (Jordan et al., 1952b; Zabik and Figa, 1968) have also been used to retard gelation.

Enzymes which are effective in reducing the viscosity of frozen egg yolk include papain, trypsin, Rhozyme (Lopez et al., 1955), and crotoxin from rattlesnake venom (Feeney et al., 1954), but all have other effects which make them unsuitable for use in commercial egg products. Trisodium citrate, ethylene glycol, propylene glycol, sorbitol, and glycerol (Lopez et al., 1954), and hexane (Marion and Stadelman, 1958a) are other compounds which have been found to reduce the degree of gelation, but are not used commercially.

Substances which seem to have little or no effect on gelation of frozen egg yolk include compounds containing sulfhydryl groups (Meyer and Woodburn, 1965), commercial emulsifiers, the sugars cellobiose, maltose, and lactose, ethyl ether and ethyl alcohol (Lopez et al., 1954), and ribonuclease (Marion and Stadelman, 1958a). Pasteurization of egg yolk does not produce significant viscosity changes (Jaax and Travnicek, 1968).

As a result of gelation, frozen egg yolk decreased in volume and had a different coefficient of expansion than unfrozen yolk (Moran, 1925).

Chemical properties. Most investigators agree that the chemical changes in frozen egg yolk involve the structural rearrangement and aggregation of lipoproteins. According to Evans and Bandemer (1961), egg lipoprotein consists of 22.0% lipovitellin, a high-density lipoprotein consisting of 78.7% protein and 21.3% lipid, and 78% lipovitellenin, a low-density lipoprotein consisting of 18.0% protein and 82.0% lipid. Martin et al. (1963) determined the percentage of lipid in lipovitellin and the low-density fraction of yolk plasma as 22 - 26% and 89%, respectively, and Saari et al. (1964a) reported that low-density lipoprotein was 86 - 89% lipid. Most of the lipovitellin is found in the yolk granules, which are 70% α- and β-lipovitellin

(Burley and Cook, 1961), and most of the lipovitellenin, or low-density lipoprotein, is in the yolk plasma which remains after the granules are removed by centrifugation (Saari _et al_., 1964a; Martin _et al_., 1963).

Crude preparations of lipovitellin and lipovitellenin exhibited a large increase in viscosity after freezing and thawing, indicating that both probably contribute to the viscosity increase in frozen-defrosted egg yolk (Davey, 1968). Paper electrophoresis of samples from the same preparations failed to detect any change in mobility of the frozen lipovitellin, but lipovitellenin was altered in such a manner that a majority of its proteins became non-mobile after freezing. The decrease in electrophoretic mobility of lipovitellenin after freezing and thawing also has been demonstrated by Powrie _et al_. (1963) and Meyer and Woodburn (1965). Of the various additives tested, Meyer and Woodburn (1965) found that salted yolks produced an electrophoretogram most nearly like that of the unfrozen control. Fructose was slightly less effective than salt in promoting migration of the lipovitellenin.

The effect of freezing on the electrophoretic mobility of lipovitellenin seems to be similar to the effect of ether extraction, as ether extraction of lipovitellenin changed its properties so that it gave a peak at the same point as lipovitellin (Evans and Bandemer, 1957). Possibly some lipid is actually removed from the lipoprotein structure during freezing.

That idea is supported by Chang *et al.* (1969), who reported that although the granular structure of yolk was maintained during freezing, electron micrographs gave evidence of free lipid masses throughout the samples.

Solubility studies of lipoproteins suggest that although the low-density lipoproteins are normally micellar in nature (Martin *et al.*, 1963), the soluble lipoproteins of frozen yolk plasma form turbid solutions and probably exist as small aggregates rather than being micellarly dispersed (Saari *et al.*, 1964b).

Freezing and thawing also destroys the solubility of lipovitellin (Lea and Hawke, 1952), but the transparency of suspensions of lipovitellin containing 10% salt, sucrose, maltose, raffinose, or arabinose was not affected by freezing (Powrie *et al.*, 1963).

There is conflicting evidence for the relationship of protein structure breakdown and change in viscosity. Powrie *et al.* (1963) found that urea, a protein denaturing agent, increased the viscosity of egg yolk. However, proteolytic enzymes have been found to decrease the viscosity of frozen-defrosted yolk (Lopez *et al.*, 1955). Most of the lipid in lipovitellin is held within the protein network in such a way that it is not extracted by ether (Evans *et al.*, 1968). Treatment with sodium deoxycholate or sodium dodecyl sulfate increases the amount of lipid extracted by ether, presumably by disrupting hydrophobic bonding and "loosening" the protein network (Evans *et al.*, 1968). Freezing and thawing also increases the amount of lipid extractable from lipovitellin by ether (Lea and Hawke, 1952), suggesting that interruption of hydrophobic bonds during freezing may be important in the gelation reaction.

EXPERIMENTAL METHODS

Eggs were obtained from the Kansas State University Poultry Farm on the day of lay. Eggs were from the same flock of hens, fed the same ration throughout the study.

Yolks were separated from the whites, and the adhering white removed by rolling gently on paper towels, washing with distilled water, and drying on absorbent tissue. The vitelline membrane was punctured and the yolk contents allowed to drain. A 45-sec mixing period using a portable electric mixer on low speed was used to insure homogeneity of the mass.

The yolk mass was then weighed into portions for treatment with additives. Salt (2.5% and 5.0% by weight), sugar (2.5% and 5.0%), a combination of salt and sugar (2.5% of each), and sodium deoxycholate (0.5%) were the additives used. One portion was not treated with an additive. A 2-min mixing period with a portable electric mixer on low speed was used to insure dispersion of the additive.

For frozen yolks, one hundred gram samples were weighed into small glass jars and placed on the coils in an upright freezer at -10°C. All frozen samples were used after a period of 4 - 12 days. Fresh samples were refrigerated and used within

36 hours of lay. Before use, frozen samples were thawed for 30 min in a water bath at 37°C, then allowed to come to room temperature. Fresh samples were also used at room temperature.

Functional performance

Evaluations of functional performance were made on eight treatments, designated as follows:

T1	Fresh yolk, no additive
T2	Frozen yolk, no additive
T3	Frozen yolk, 2.5% salt added
T4	Frozen yolk, 5.0% salt added
T5	Frozen yolk, 2.5% salt and 2.5% sugar added
T6	Frozen yolk, 2.5% sugar added
T7	Frozen yolk, 5.0% sugar added
T8	Frozen yolk, 0.5% sodium deoxycholate added

A balanced incomplete block design with 14 blocks, 7 replications of the 8 treatments and 4 treatments per block, was used (Cochran and Cox, 1957). The order of the replications and of the treatments within each block was assigned at random using a table of random numbers. An outline of the design is presented in the Appendix (Table 6). Statistical analysis was performed as outlined by Cochran and Cox (1957) for this design.

Sponge cake and mayonnaise were chosen as products to test functional performance. In addition, simple emulsions were made as a further test of emulsifying ability.

Sponge cake. Sponge cakes were made according to the formula of Jaax and Travnicek (1968), except that the amount of salt was increased to 1.5 g, and 1.6 ml vanilla extract was added as a flavoring agent. Also, the amounts of salt and sugar in the formula were adjusted to account for that present as an additive to the yolk. Preliminary experiments indicated that 1.5 g salt did not give an objectionable salty flavor to the cake. By using this level of salt, it was possible to adjust the sponge cake formula so that the proportion of ingredients was the same in all the cakes, regardless of the additive used in the frozen-defrosted yolk, with two exceptions -- those made with yolk containing 5.0% salt, which contained twice as much salt, and those made with yolk containing 0.5% deoxycholate.

Specific gravity of the sponge cake batter was determined by the method presented by Griswold (1957). A laboratory panel consisting of six members evaluated the cakes for brownness of crust, shape, volume, size of cells, uniformity of cell size, crumb color, crust appearance, moistness, tenderness, flavor, and flavor desirability. A descriptive scale with a range of 1 - 7 was used for all characteristics except crust appearance and flavor. Panelists described those two characteristics by checking the appropriate adjectives from a list which was developed by the panel in preliminary experiments. The score cards are presented in Figs. 1 and 2. Standing height was measured at five points on the center slice (each side, the center, and half way between the center and each side) and the

Directions: Evaluate the selected characteristics of the sponge cakes under the skylight, rating each characteristic according to the key which follows that characteristic.

BROWNNESS OF CRUST

#1______
#2______
#3______
#4______

Dark brown			Medium golden brown			Pale brown
7	6	5	4	3	2	1

SHAPE

#1______
#2______
#3______
#4______

Peaked		Rounded		Flat		Fallen
7	6	5	4	3	2	1

VOLUME

#1______
#2______
#3______
#4______

Large			Medium			Small
7	6	5	4	3	2	1

GRAIN: SIZE OF CELLS

#1______
#2______
#3______
#4______

Very large	Moderately large	Large	Medium	Small	Very small	Compact
7	6	5	4	3	2	1

GRAIN: UNIFORMITY OF CELL SIZE

#1______
#2______
#3______
#4______

Very uniform		Slight variation		Moderate variation		Extreme variation
7	6	5	4	3	2	1

CRUMB COLOR

#1______
#2______
#3______
#4______

Dark yellow		Medium yellow		Light yellow		Very pale yellow
7	6	5	4	3	2	1

CRUST APPEARANCE: (For each sample, place a check mark in the appropriate columns.)

		Cracked	Smooth	Pebbly	Spotty	Moist
Sample	#1					
	#2					
	#3					
	#4					

Comments:

Figure 1. Score card for visual characteristics of egg yolk sponge cakes.

Directions: Evaluate the selected characteristics of the sponge cake samples, by rating each characteristic according to the key which follows that characteristic.

MOISTNESS

#1____		Very	Moderately		Slightly	Moderately	
#2____	Soggy	moist	moist	Moist	dry	dry	Dry
#3____							
#4____	7	6	5	4	3	2	1

TENDERNESS

#1____	Extremely	Moderately	Slightly	Neither tender	Slightly	Moderately	Very tough
#2____	tender	tender	tender	nor tough	tough	tough	(rubbery)
#3____							
#4____	7	6	5	4	3	2	1

FLAVOR DESIRABILITY

#1____	Very	Moderately	Slightly		Slightly	Moderately	Very
#2____	desirable	desirable	desirable	Neutral	undesirable	undesirable	undesirable
#3____							
#4____	7	6	5	4	3	2	1

FLAVOR DESCRIPTION: (For each sample, place a check mark in the appropriate columns.)

	Delicate	Eggy	Bland	Salty	Sour	Bitter
Sample #1						
#2						
#3						
#4						

Comments:

Figure 2. Score card for eating quality of sponge cakes.

average height was used as an index to volume. Compressibility was determined on the center one-inch slice using the Universal Precision Penetrometer with a 100-g weight and depressing the lever for 5 sec.

Mayonnaise. The basic recipe for mayonnaise was as follows:

2.0	g	sugar
1.5	g	salt
0.2	g	dry mustard
16.0	g	egg yolk
15	ml	cider vinegar
110	g	Wesson oil

All ingredients were at room temperature. The sugar, salt, mustard, and egg yolk were mixed in a small glass bowl for 30 sec, using a Sunbeam Mixmaster mixer at speed 1. Half of the vinegar was added all at once and mixed for 1 min at speed 4. Sixty ml oil was added at a constant rate from a separatory funnel, while beating continuously at speed 4. The addition of the 60 ml took 4.5 - 5.0 min. The remaining 7.5 ml vinegar was then added all at once and blended for 1 min at speed 1. After scraping the bowl, the remaining oil was added at a constant rate from a separatory funnel, beating continuously at speed 4. This addition took 2.8 - 3.0 min. The mayonnaise was stored at room temperature in 8-oz jelly glasses.

The basic recipe was adjusted to account for the salt and sugar added to the frozen yolk, so that the proportion of ingredients was the same in all samples.

A laboratory panel consisting of four members evaluated samples of mayonnaise for consistency and presence of off-flavor. The score card is shown in Fig. 3. Stability of the mayonnaise

Directions:

1. Note the behavior of each sample on the plate, when cut, and when spread on a cracker. Rate the samples for consistency according to the key which follows.

2. Taste the samples. Do you detect an off-flavor in any of them? If so, which one(s)? Please describe the off-flavor, if any.

Key: Consistency

1 Thin -- almost runny; too thin to spread
2 Slightly thick -- spreadable, but does not retain shape on plate
3 Moderately thick -- spreads easily; may flow slightly
4 Very thick, but not stiff -- spreads easily, but does not flow
5 Slightly stiff -- slight resistance to spreading
6 Moderately stiff -- moderate resistance to spreading
7 Very stiff -- difficult to spread

	Consistency	Off-flavor(✓)	Description
Sample #1			
#2			
#3			
#4			

Comments:

Figure 3. Score card for mayonnaise.

was evaluated by observing the presence or absence of oil separation after 2, 4, and 6 wks of storage at room temperature, and each mayonnaise was assigned an oil separation score as follows:

0 No separation after 6 wks of storage
1 No separation after 4 wks, but visible separation after 6 wks of storage
2 No separation after 2 wks, but visible separation after 4 wks of storage
3 Visible separation after 2 wks of storage

Simple emulsions. Simple emulsions were prepared according to the method of Jaax and Travnicek (1968) using Wesson oil instead of corn oil. Amount of water separation was recorded at half-hour intervals up to four hours. A correlation coefficient was calculated to determine the relationship between water separation in simple emulsions and oil separation in mayonnaise.

Physical and chemical properties

Determinations of selected chemical and physical properties of egg yolk were made on 14 treatments, including both the fresh and frozen product prepared with each of the additives and proportions given on p. 10. A factorial arrangement of treatments with 4 replications of each treatment combination was used. The data were subjected to analysis of variance and LSD's were computed if F values were significant. Viscosity and pH determinations were made on whole yolk samples. In addition, yolk samples from each treatment were separated into density fractions by centrifugation, and the relative amounts of neutral lipid and phospholipid in each fraction were determined by thin layer chromatography.

Viscosity. Viscosity measurements were made using a Fisher Improved MacMichael viscosimeter, model 90, and a Brookfield Synchro-Lectric viscometer, model RVT, with a Helipath stand. Viscosity readings were converted to centipoises using the appropriate correction factors, and a correlation coefficient was calculated to determine the agreement between the two instruments. Hot-plate rotation speed, wire sizes, and depth of plunger for the Fisher-MacMichael viscosimeter and spindle sizes and rotation speeds for the Brookfield viscometer were determined by preliminary experiments, and this information is presented in the Appendix (Table 7). All viscosity measurements were made at room temperature.

pH. The pH of the yolk samples was recorded from the expanded scale of a Fisher Accumet pH meter, model 310. All pH measurements were made at room temperature.

Centrifugation. Ten gram samples of egg yolk and 20 g distilled water were weighed into 50 ml polyethylene centrifuge tubes. The yolk was dispersed by shaking, then centrifuged for 30 min at 10,000 rpm (12,100 x g) in a RCB-2 high-speed refrigerated (+2^{o}C) centrifuge, using the SS-34 rotor. The supernatant plasma was then decanted, leaving the packed granules in the bottom of the tube. The surface of the granules was washed with 2 ml distilled water. The two fractions were then weighed and the weights recorded.

Extraction and analysis of lipid. Total lipids were extracted from the granules and supernatant plasma by the method of Folch _et_ _al_. (1957). Samples of the two fractions (1.25 g granules and a volume of supernatant to correspond to 1.25 g undiluted plasma) were extracted with 20 ml chloroform-methanol (2:1 volume), by homogenizing for 1 min at low speed in a small Waring blender. The homogenate was filtered into volumetric flasks, diluted to 25 ml, and poured into separatory funnels where the two phases were allowed to separate. The lipid extract was washed with an appropriate amount of water, then removed and stored in a glass vial at -20°C. Samples were analyzed within a week after extraction.

Relative amounts of neutral lipid and phospholipid in the lipid extracts were determined by thin layer chromatography on silica gel impregnated glass fiber strips (Gelman ITLC type SG). A 20 µl sample of the lipid extract was spotted on the strip. After drying in the dessicator for 5 - 10 min, the strip was allowed to equilibrate in the chromatography chamber for 10 min, then developed in acetone to a height of 10 cm. Two spots were obtained -- a predominantly neutral lipid spot near the solvent front (R_F=.96) and a phospholipid spot which remained at the origin. Phospholipid was detected in the spot at the origin by the method of Dittmer and Lester (1964). The lipid spots were visualized by staining overnight (16 hr) in an Oil Red O solution (Cunningham, 1963), then rinsing for 5 min in distilled water. The dye was eluted from the spots with 3 ml chloroform-methanol (2:1) and the optical density was measured at λ=490 with a Beckman DU, using a slit width of 0.71.

RESULTS AND DISCUSSION

Results of studies of functional performance of frozen egg yolks and selected chemical and physical properties of frozen egg yolks are presented and discussed below.

Functional performance

Visual characteristics of sponge cakes. Adjusted mean scores for visual characteristics of sponge cakes are presented in Table 1. Except for brownness of crust, all factors studied exhibited significant differences between treatments.

Deoxycholate yolks and sugared yolks tended to produce more rounded cakes than salted yolks, and cakes made with fresh yolks had the flattest shape of all. However, all cakes had mean scores for shape which fell in the range of "slightly rounded" on the descriptive scale.

Fresh yolks produced cakes with greater volume than any of the frozen yolk products, although not significantly greater than frozen yolks to which either 5% sugar or 5% salt had been added. This finding concurs with Jordan et al. (1952b). Among the frozen yolk products, those containing 5% additive yielded higher volumes than those containing 2.5% additive. The trend indicated that salt is slightly more effective than sugar in increasing volume, but this was not statistically significant. Frozen yolks containing no additive produced cakes of lower volume than the sugared or salted yolks. Similar results were reported by Jaax and Travnicek (1968). Yolks containing

Table 1. Adjusted mean[1] scores for visual characteristics of egg yolk sponge cakes.

	Treatments									
Characteristics	fresh	no add.	2.5% salt	5% salt	sugar & salt	2.5% sugar	5% sugar	deoxycholate	F value[2]	LSD[3]
Scores[4]										
Brownness of crust	5.0	4.6	5.1	5.1	5.1	4.7	4.7	4.7	1.54 NS	---
Shape	4.1	4.3	4.2	4.2	4.4	4.5	4.9	4.8	3.48 ***	0.2
Volume	5.4	4.3	4.9	5.3	5.1	4.7	5.2	3.4	9.74 ***	0.3
Grain: cell size	3.9	3.9	4.0	4.0	4.5	4.1	4.2	3.5	3.78 ***	0.2
Grain: uniformity	4.7	4.6	3.8	4.3	4.3	4.3	4.4	4.7	2.12 *	0.3
Crumb color	5.0	3.4	3.6	3.5	3.6	3.6	3.6	3.3	11.53 ***	0.2
No. checking characteristic										
Crust:										
Cracked	0.7	4.2	4.9	2.1	3.2	3.7	3.0	4.5	3.53 ***	1.1
Smooth	0.6	2.9	1.1	3.1	3.5	3.9	2.4	0.8	-1.16 NS	---
Pebbly	2.0	2.7	1.7	2.3	1.8	1.9	1.2	2.5	1.10 NS	---
Spotty	0.0	0.3	0.4	0.1	0.3	0.1	0.0	0.6	1.40 NS	---
Moist	0.4	0.7	0.9	1.0	0.8	0.7	0.6	0.6	3.62 ***	0.2

[1] Mean of 7 replications

[2] Levels of significance: ***, $P < 0.001$
*, $P < 0.05$
NS, not significant

[3] LSD = least significant difference, $P < 0.05$

[4] Scoring range 1 - 7

sodium deoxycholate produced the lowest volume cakes of any of the products tested.

Adjusted mean scores for size of cells were all clustered around "medium" on the descriptive scale. The cakes with the largest (although not large) cells were made with yolks containing a combination of 2.5% sugar and 2.5% salt. Yolks containing sodium deoxycholate produced the cakes with the smallest cells. Of the remaining six treatments, the trend was cell size of cakes made with sugared yolks > salted yolks > no additive.

Variation in cell size was slight to moderate for all the cakes tested. Cakes made with fresh yolk tended to have the most uniform grain; and cakes made with salted yolks, the least.

A deeper yellow color was observed when sponge cakes were made with fresh yolks than with any of the frozen yolk products. Yolks containing sodium deoxycholate produced cakes which were significantly paler than all of the other cakes except those made with untreated frozen yolk.

Cakes made with fresh yolk seldom had cracked crusts, while the crusts of cakes made with the frozen yolk products cracked quite frequently. In general, higher levels of additives reduced the frequency of cracking.

The number of panelists checking "smooth", "pebbly", and "spotty" in describing the appearance of the crust did not differ significantly among the eight treatments.

Crusts of cakes made with frozen yolks containing salt as an additive tended to be described more often as having a "moist" appearance. Crusts of cakes made with fresh yolks tended to be described least often as appearing moist.

Eating quality of sponge cakes. Scores for eating quality of sponge cakes are presented in Table 2.

There were significant differences in moistness among the eight treatments, although all the adjusted mean scores were in the range of "slightly moist" on the descriptive scale and the differences were small. Cakes made with yolks containing no additive, either fresh or frozen, tended to be more moist than cakes made with yolks containing any of the additives tested. Salted yolks tended to produce moister cakes than sugared yolks. 2.5% levels of salt and sugar tended to produce moister cakes than 5% levels of salt and sugar, respectively. Cakes made with sodium deoxycholate yolks tended to be least moist of the eight treatments.

The highest tenderness score was given to cake made with fresh yolks, followed by the frozen yolks containing salt. Yolks containing 5% sugar and yolks containing sodium deoxycholate, in that order, produced the least tender cakes. All of the tenderness scores, however, fell in the range of "slightly tender."

Scores for flavor desirability exhibited no obvious trend regarding the various additives, except that yolks containing 5% salt resulted in the least desirable flavor (too salty), and the flavor of cake made with yolks containing sodium deoxycholate was less desirable than the remaining six treatments (slight bitterness).

Table 2. Adjusted mean[1] scores for eating quality of egg yolk sponge cakes.

Characteristics	Treatments: fresh	no add.	2.5% salt	5% salt	sugar & salt	2.5% sugar	5% sugar	deoxycholate	F value[2]	LSD[3]
Scores[4]										
Moistness	4.4	4.3	4.1	4.0	4.1	4.0	3.9	3.8	1.83 *	0.2
Tenderness	5.4	4.8	5.1	5.0	5.0	4.8	4.5	4.2	4.73 ***	0.2
Flavor desirability	4.7	5.0	5.2	3.7	5.0	4.8	5.1	4.5	9.62 ***	0.2
No. checking characteristic										
Flavor:										
Delicate	2.8	3.1	3.6	1.4	3.7	2.9	3.8	2.0	3.45 ***	0.6
Eggy	1.6	0.3	0.8	0.3	0.3	0.8	0.0	1.2	4.10 ***	0.4
Bland	0.7	0.6	0.1	0.0	1.3	1.3	0.9	1.0	3.29 ***	0.4
Salty	0.6	0.5	1.3	4.3	1.0	1.7	0.3	0.9	14.70 ***	0.5
Sour	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.00 NS	---
Bitter	0.7	0.8	0.2	1.0	0.1	0.4	0.3	1.5	3.17 ***	0.4

[1] Mean of 7 replications
[2] Levels of significance: ***, $P < 0.001$
*, $P < 0.05$
NS, not significant

[3] LSD = least significant difference, $P < 0.05$
[4] Scoring range 1 - 7

Analysis of the flavor descriptions shows that sponge cake made with fresh yolks was described most often as "delicate." It was also described as "eggy" significantly more times than any other treatment. Frozen yolks containing no additive produced cakes which were most often described as "delicate." Cakes made from yolks containing salt as an additive tended to taste saltier, even though the amount of salt in all treatments was the same, except for cake made with frozen yolks containing 5% salt. Cakes made from yolks containing 2.5% sugar also received a high number of salty responses. Cakes made from frozen yolks containing sugar tended to rank higher than other treatments in the number of "bland" responses. Cake made from sodium deoxycholate yolks also received a relatively high number of "bland" responses, as well as the second highest adjusted mean score for "eggy" responses. As expected, cake made from sodium deoxycholate yolks was significantly more "bitter" than any of the other treatments. However, according to the flavor desirability scores, this bitterness was not objectionable enough at the 0.5% level to be completely unacceptable. Sour was not a significant factor in the flavor of egg yolk sponge cakes. Flavor desirability scores seemed to parallel "delicate" scores more closely than any other flavor factor.

Objective measurements on sponge cakes. Values for standing height, compressibility, and specific gravity are presented in Table 3.

Table 3. Adjusted means[1] for objective measurements on egg yolk sponge cakes.

	Treatments									
Characteristics	fresh	no add.	2.5% salt	5% salt	sugar & salt	2.5% sugar	5% sugar	deoxycholate	F value[2]	LSD[3]
Standing height (cm)	5.68	5.29	5.48	5.71	5.68	5.54	5.63	4.92	18.96 ***	0.09
Compressibility (mm)	12.75	8.53	10.87	12.64	11.57	9.64	9.94	5.20	48.08 ***	0.51
Specific gravity	.36	.45	.39	.39	.39	.43	.39	.49	77.06 ***	0.01

[1] Mean of 7 replications
[2] Level of significance: ***, $P < 0.001$
[3] LSD = least significant difference, $P < 0.05$

Standing height measurements indicated no significant differences in volume between cakes made with fresh yolks and cakes made with frozen yolks containing 5% salt, sugar, or a combination of salt and sugar. Cakes made with frozen yolks containing 2.5% sugar or salt were intermediate in volume, followed by cakes made with frozen yolks containing no additive. Sodium deoxycholate yolks produced the lowest volume cakes of all. With the exception of fresh yolks and sodium deoxycholate yolks, which are at opposite ends of the array, standing height seemed to be directly proportional to the level of additive, regardless of whether the additive was salt or sugar. Although there are some minor differences in the ordered arrays, standing height measurements and panel volume scores are generally in agreement.

Compressibility values indicated that only cakes made with frozen yolks containing 5% salt were as soft as cakes made with fresh yolks. Cakes made with frozen yolks containing salt as an additive were all significantly softer than those made with sugared yolks. In agreement with Jaax and Travnicek (1968), cakes made with frozen yolks containing no additive were less compressible than cakes made with either sugared or salted yolks. Sodium deoxycholate yolks produced the least compressible cakes of all eight treatments. Five percent salted or sugared yolks tended to produce softer cakes than 2.5% salted or sugared yolks, respectively. There are several differences between the ordered arrays of compressibility values and panel tenderness scores, although the trend for salted yolks to produce softer, or more tender, cakes than sugared yolks can be observed with both measurements.

Cake batter made with sodium deoxycholate yolks had the highest specific gravity, followed by batter made with untreated frozen yolks, then yolks containing 2.5% sugar. There were no significant differences in specific gravity among batters made with 5% sugared yolks or any of the frozen yolk products containing salt. Fresh yolks produced the lightest batter of all the treatments.

Mayonnaise. Adjusted mean scores for mayonnaise characteristics are presented in Table 4. Fresh yolks produced mayonnaise which was significantly thinner, or less stiff, than any of the frozen yolk products. This finding is in agreement with Miller and Winter (1951). Among the frozen yolk products, sugared yolks tended to produce stiffer mayonnaise than salted yolks.

Mayonnaise made with 2.5% sugared yolks received the highest score for off-flavor. The off-flavor was usually described as "oxidative rancidity." No explanation can be given by the author for this result. Sodium deoxycholate yolks produced mayonnaise with the second highest off-flavor score. This off-flavor was described as "chemical acidity" or "acid, but not vinegary" or occasionally "bitter." The remaining treatments exhibited no well-defined trend in off-flavor scores. Except for mayonnaise made with sodium deoxycholate yolks, the off-flavors detected were described as "oxidative rancidity." Under the conditions of

Table 4. Adjusted mean[1] scores for oil separation, consistency, and off-flavor of mayonnaise.

	Treatments									
Characteristics	fresh	no add.	2.5% salt	5% salt	sugar & salt	2.5% sugar	5% sugar	deoxycholate	F value[2]	LSD[3]
Oil separation	2.4	1.4	0.4	1.4	2.1	1.1	1.0	1.4	3.14 ***	0.5
Consistency	2.3	5.5	4.9	4.4	5.0	5.1	5.6	4.5	41.55 ***	0.2
Off-flavor	0.7	0.7	0.8	1.2	0.5	1.8	0.8	1.1	2.85 ***	0.3

[1] Mean of 7 replications
[2] Level of significance, ***, $P < 0.001$
[3] LSD = least significant difference, $P < 0.05$

this experiment, it seems unlikely that any of the samples were actually rancid, and no explanation can be given for this result.

Fresh yolks and frozen yolks containing a combination of sugar and salt produced the least stable mayonnaises. Both exhibited oil separation after only 2 - 4 wks of storage. The remaining mayonnaises, except for mayonnaise made with 2.5% salted yolks, separated after 4 - 6 wks of storage, on the average. Frozen yolks containing 2.5% salt produced a mayonnaise which was still stable after 6 wks of storage.

Simple emulsions. Water separation from the simple emulsions is presented in Fig. 4. The least stable emulsion was obtained with fresh yolk, which exhibited the highest separation at every interval tested. The emulsion prepared with yolks containing 5% salt had the least drainage. Jaax and Travnicek (1968) and Jordan (1962) also found that salt increased emulsion stability. However, yolks containing 2.5% salt or a combination of sugar and salt did not give the same stability as yolks containing 5% salt. Since the stability of simple emulsions has been used to indicate the emulsifying ability of yolk in food products, it was of interest to determine the relation between water separation from simple emulsions containing an excess of water and oil separation from mayonnaise, which contains an excess of oil. Under the conditions of the experiment, the two measurements of emulsion stability were highly related (correlation coefficient, r=.87 - .92 ***, depending on time interval of separation from simple emulsions).

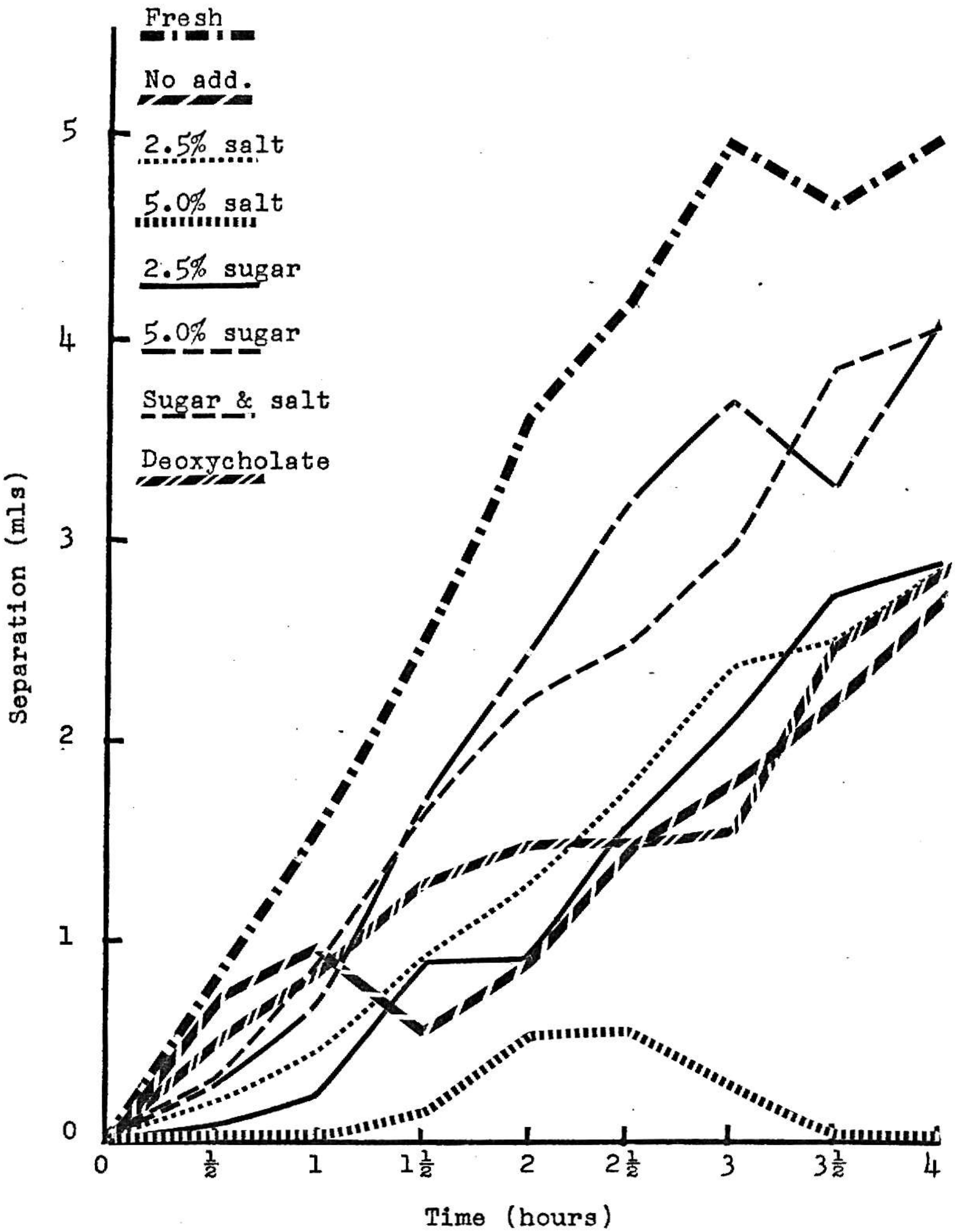

Figure 4. Water separation from simple emulsions.

Selected physical and chemical properties

Viscosity. The mean values for viscosity measurements are presented in Table 5. Viscosity measurements made using the Brookfield viscometer and Helipath stand and the Fisher MacMichael viscosimeter were related positively (correlation coefficient, r = 0.86***). The effects of the various additives, freezing, and additive-freezing interaction were all highly significant, regardless of the instrument used. Freezing and defrosting resulted in a large increase in viscosity for all treatments. Addition of salt to fresh yolk resulted in a large increase in viscosity, whereas addition of sugar resulted in a slight decrease. A combination of 2.5% sugar and 2.5% salt added to fresh yolk resulted in an increase in viscosity, but the increase was considerably less than with the addition of 2.5% salt. After freezing and defrosting, yolk containing the combination of sugar and salt had a lower viscosity than any of the other frozen and thawed products tested. Salt was more effective than sugar in reducing viscosity of frozen yolks, and 5% salt or sugar was more effective in reducing viscosity than 2.5% salt or sugar, respectively.

pH. The mean pH values for fresh and frozen-defrosted yolk are presented in Table 5. In general, freezing resulted in a slight increase in the pH of yolk. Although this effect was not large, it was consistent enough to be statistically significant at the 5% level. The addition of sodium deoxycholate to yolk resulted in an average pH increase of .24 units over

Table 5. Mean values[1] for viscosity, pH, and density fractions[2] of fresh and frozen-defrosted egg yolk.

Treatments		Viscosity Brookfield (cps)	Viscosity Fisher-MacMichaels (cps)	pH	Granules (g)	Supernatant (g)
No additive	Fresh	1,825	1,369	6.00	3.1	27.5
	Frozen	842,600	184,724	6.02	5.9	22.6
2.5% salt	Fresh	14,675	14,967	5.92	3.4	27.2
	Frozen	42,200	71,436	5.91	2.9	26.9
5% salt	Fresh	21,800	23,532	5.81	0.8	29.6
	Frozen	34,250	58,278	5.87	1.1	29.6
2.5% sugar	Fresh	1,450	1,192	6.06	3.0	27.5
	Frozen	112,350	119,911	6.06	5.2	22.9
5% sugar	Fresh	1,400	1,170	6.01	2.9	27.5
	Frozen	46,825	64,989	6.08	4.2	25.2
Sugar & salt	Fresh	9,000	8,698	5.90	3.2	27.3
	Frozen	24,500	35,143	5.92	2.6	27.3
Deoxycholate	Fresh	2,850	1,920	6.24	3.1	27.4
	Frozen	587,800	177,483	6.32	8.8	19.2
LSD[3]		1,622	1,616	0.08	0.6	0.7
F values[4]						
Additive effect (A)		16.99***	48.37***	55.00***	97.30***	127.33***
Freezing effect (F)		60.04***	979.68***	5.03 *	187.25***	458.57***
A x F interaction		17.80***	67.49***	0.83 NS	51.82***	77.29***
Replications		1.75 NS	2.08 NS	3.13 *	2.71 NS	7.84***

[1] Mean of 4 replications

[2] Granules and supernatant obtained by centrifugation at 12,100 x g for 30 min

[3] Least significant difference, $P < 0.05$

[4] Levels of significance: ***, $P < 0.001$; *, $P < 0.05$; NS, not significant

fresh yolk containing no additive. This difference was even larger after freezing and thawing. Addition of salt to yolks lowered the pH significantly (0.08 - 0.19 units).

Centrifugation. After centrifugation at 12,100 x g for 30 min, yolk separated into granules packed in the bottom of the tube and supernatant plasma, containing both the livetin and low density fractions described by Davey (1968). The weight in grams of these fractions for the various treatments is shown in Table 5. Since addition of 5% salt causes disruption of most of the granules (Chang et al., 1969), very little sedimenting material was obtained with that treatment. Otherwise, there were no significant differences in the amounts of granular material obtained from fresh yolks. After freezing and thawing, yolks containing salt had less granular material than before freezing, possibly because concentration of salts during freezing caused further disruption of the granules. Sugared yolks, deoxycholate yolks, and yolks containing no additive yielded a greater amount of sedimenting material after freezing and the supernatant was turbid, indicating aggregation of the lipoproteins (Saari et al., 1964b). This effect was especially pronounced with deoxycholate yolks.

Chromatographic analysis. Results of the chromatographic analysis are presented in Table 8 in the Appendix. Separation of the lipid extract into predominantly neutral lipid and phospholipid fractions by TLC did not result in any significant differences between treatments. As expected, the lower density supernatant fraction contained more lipid material than the granules, indicated by higher optical densities for both spots. The highly significant difference among replications is difficult to explain. It seems unlikely that it represented variation in the chromatography technique, because all of the lipid extracts were stored for up to one week, then analyzed at random on the same day. Whether it represented the day to day variation in the eggs used, or some change which may have occurred during storage is unknown.

SUMMARY

In general, cake made with fresh yolks was better than cake made with any of the frozen yolk products, and received the highest score among all eight treatments for volume, grain uniformity, moistness, tenderness, compressibility, yellow color, and "eggy" flavor. Batter made from fresh yolks had the lowest specific gravity, and the crust cracked during baking fewer times than with any other treatment. However, water separation in simple emulsions and oil separation in mayonnaise was higher when fresh yolks were used than with any of the frozen yolk products.

Frozen salted yolks were less viscous than frozen sugared yolks, and yielded cakes which were more moist, more tender, and more compressible than cakes made with sugared yolks. The flavor of cake made with 5% salted yolks was too salty, but cake made with 2.5% salted yolks had the highest flavor desirability score of all treatments. Cakes made with sugared yolks tended to be more bland in flavor than cakes made with salted yolks. In addition, salted yolks tended to give more emulsion stability than sugared yolks.

Use of a combination of 2.5% sugar and 2.5% salt for frozen egg yolks for sponge cake seemed to offer certain advantages, indicated by higher moistness and tenderness scores and greater compressibility than with sugared yolks, a volume not significantly different than fresh yolks (as indicated by standing height), and a high score for flavor desirability. The lowest viscosity of any of the frozen yolk products was obtained with that treatment. However, mayonnaise made with frozen yolk containing both sugar and salt was significantly less stable than with any of the other frozen yolk products.

Frozen yolk containing no additive yielded cakes which were lower in volume, less tender, less compressible, and paler in color than any other treatment except deoxycholate yolks. Deoxycholate yolks and untreated yolks also produced batters of high specific gravity. The high viscosity of those yolks was undoubtably a factor in producing less desirable cakes. The large amounts of sedimenting material and turbid plasma obtained by centrifugal separation indicated that freezing resulted in a greater amount of damage to untreated yolks or deoxycholate yolks than to sugared and/or salted yolks.

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APPENDIX

LIST OF ABBREVIATIONS:

Fsh	Fresh yolk
Fro	Frozen yolk
No add	No additive
2.5 salt	2.5% salt added
5 salt	5% salt added
S and S	2.5% sugar and 2.5% salt added
2.5 sug	2.5% sugar added
5 sugar	5% sugar added
deoxy	0.5% sodium deoxycholate added

Table 6. Outline for balanced incomplete block design for evaluating functional performance of frozen egg yolk.

Rep.	Block	Treatments			
1	1	deoxy	S and S	5 sugar	2.5 salt
	2	2.5 sug	no add	fresh	5 salt
2	3	2,5 salt	fresh	S and S	no add
	4	deoxy	5 sugar	5 salt	2.5 sug
3	5	2.5 salt	5 salt	deoxy	no add
	6	S and S	2.5 sug	fresh	5 sugar
4	7	fresh	5 sugar	5 salt	2.5 salt
	8	2.5 sug	deoxy	S and S	no add
5	9	2.5 salt	2.5 sug	no add	5 sugar
	10	fresh	5 salt	deoxy	S and S
6	11	5 salt	2.5 sug	2.5 salt	S and S
	12	no add	fresh	5 sugar	deoxy
7	13	2.5 salt	deoxy	fresh	2.5 sug
	14	5 salt	no add	5 sugar	S and S

Table 7. Specifications for measuring viscosity of fresh and frozen-defrosted yolks.

Treatment	Replication 1	2	3	4
	Brookfield viscometer[1]			
All fresh yolks	T-D/20	T-D/20	T-D/20	T-D/20
Frozen yolks:				
No additive	T-D/2.5	T-D/2.5	T-D/1.0	T-D/2.5
2.5% salt	T-D/20	T-D/20	T-D/20	T-D/20
5% salt	T-D/20	T-D/20	T-D/20	T-D/20
Sugar and salt	T-D/20	T-D/20	T-D/20	T-D/20
2.5% sugar	T-D/20	T-D/20	T-D/10	T-D/20
5% sugar	T-D/20	T-D/20	T-D/20	T-D/20
Deoxycholate	T-D/2.5	T-D/2.5	T-D/2.5	T-D/5
	Fisher-MacMichaels viscosimeter[2]			
All fresh yolks	3/10/30	3/10/30	3/10/30	3/10/30
All frozen yolks	3/10/26	3/10/26	3/10/26	3/10/26

[1]Specifications: spindle/rotation speed (rpm)
[2]Specifications: plunger depth/rotation speed (rpm)/wire gauge

Table 8. Optical densities[1] of eluted neutral lipid (NL) and phospholipid (PL) spots separated by thin layer chromatography.

Treatments		Density fraction[2]			
		Granules		Supernatant	
		PL	NL	PL	NL
No additive	Fresh	.143	.232	.241	.347
	Frozen	.125	.251	.207	.330
2.5% salt	Fresh	.132	.237	.201	.321
	Frozen	.128	.231	.198	.300
5% salt	Fresh	---	---	.200	.349
	Frozen	---	---	.198	.376
2.5% sugar	Fresh	.125	.223	.221	.388
	Frozen	.125	.234	.209	.362
5% sugar	Fresh	.137	.210	.182	.383
	Frozen	.136	.220	.168	.338
Sugar & salt	Fresh	.133	.216	.197	.399
	Frozen	.131	.205	.193	.348
Deoxycholate	Fresh	.130	.239	.218	.420
	Frozen	.129	.253	.194	.335
F values[3]					
Additive effect (A)		0.42 NS	2.25 NS	1.71 NS	1.01 NS
Freezing effect (F)		0.68 NS	0.60 NS	2.21 NS	2.86 NS
A x F interaction		0.28 NS	0.40 NS	0.26 NS	0.50 NS
Replications		1.62 NS	11.56***	28.19***	18.07***

[1]Mean of 4 replications
[2]Granules and supernatant obtained by centrifugation at 12,100 x g for 30 min
[3]Levels of significance: ***, $P < 0.001$; NS, not significant

Table 9. Average scores[1] for brownness of crust of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	4.7	5.0	5.3	5.4	5.2	5.0	4.7	5.0
No add.	5.0	5.0	4.0	4.6	5.0	4.0	4.5	4.6
2.5 salt	5.5	5.2	4.2	4.2	5.5	5.0	6.2	5.1
5 salt	5.8	5.3	4.2	4.8	5.5	4.7	4.5	5.1
S and S	5.7	5.3	5.0	5.2	5.2	4.3	5.5	5.1
2.5 sug	4.5	4.3	4.5	4.8	5.5	4.5	5.2	4.7
5 sugar	5.0	4.3	4.7	4.0	5.7	4.7	4.7	4.7
deoxy	6.7	4.2	3.8	4.0	4.8	4.8	4.6	4.7

[1]Average of 6 panel members
Scoring range: 1 (pale brown) - 7 (dark brown)

Table 10. Average scores[1] for shape of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	4.2	4.8	3.8	3.4	3.5	3.8	4.6	4.1
No add.	5.2	4.2	5.0	4.0	4.0	3.8	4.5	4.3
2.5 salt	4.4	4.2	4.0	4.2	3.8	4.0	4.2	4.2
5 salt	4.3	4.8	4.0	3.6	4.0	4.0	4.0	4.2
S and S	4.6	4.2	4.7	3.5	4.2	5.8	4.0	4.4
2.5 sug	4.2	4.7	4.8	4.8	4.2	4.2	4.3	4.5
5 sugar	4.6	5.3	4.5	5.8	4.3	5.8	5.0	4.9
deoxy	5.0	4.3	5.0	4.6	5.0	4.7	4.8	4.8

[1]Average of 6 panel members
Scoring range: 1 (fallen) - 7 (peaked)

Table 11. Average scores[1] for volume of egg yolk sponge cakes.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	5.2	5.5	5.5	4.8	5.7	5.0	5.8	5.4
No add.	5.2	4.0	4.3	3.9	4.0	4.0	4.7	4.3
2.5 salt	4.2	5.3	5.6	4.2	5.2	4.9	4.8	4.9
5 salt	5.0	5.3	5.8	4.4	6.0	6.0	5.2	5.3
S and S	6.0	5.7	4.2	5.2	5.2	4.5	4.7	5.1
2.5 sug	4.8	5.0	4.5	4.4	5.0	4.8	4.8	4.7
5 sugar	5.6	5.7	5.0	4.4	5.7	4.2	5.5	5.2
deoxy	1.8	4.2	4.6	3.8	3.3	3.8	2.5	3.4

[1]Average of 6 panel members
Scoring range: 1 (small) - 7 (large)

Table 12. Average scores[1] for size of cells of egg yolk sponge cakes.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	4.0	4.0	3.8	3.8	4.3	4.0	3.4	3.9
No add.	3.8	3.4	4.4	3.4	4.2	3.8	4.2	3.9
2.5 salt	4.2	3.6	5.0	3.6	4.3	3.8	3.8	4.0
5 salt	4.2	3.9	4.6	3.8	3.7	4.0	3.7	4.0
S and S	4.2	4.2	4.7	4.6	3.8	5.8	4.2	4.5
2.5 sug	4.3	3.8	4.8	4.4	4.0	3.7	3.8	4.1
5 sugar	4.4	3.9	4.3	4.0	3.8	5.0	4.2	4.2
deoxy	3.4	3.3	3.6	4.2	3.3	3.8	3.0	3.5

[1] Average of 6 panel members
Scoring range: 1 (compact) - 7 (very large)

Table 13. Average scores[1] for grain uniformity of egg yolk sponge cakes.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	4.8	4.6	5.2	4.0	4.2	4.2	4.5	4.7
No add.	4.5	3.4	4.4	5.8	4.5	4.8	5.2	4.6
2.5 salt	3.6	4.8	2.8	4.8	4.3	4.2	4.5	3.8
5 salt	4.8	4.8	3.8	4.0	4.5	3.2	5.3	4.3
S and S	5.2	4.0	4.2	4.6	5.5	4.2	3.5	4.3
2.5 sug	4.0	4.3	4.6	4.2	4.0	4.2	4.2	4.3
5 sugar	3.2	4.3	3.5	3.8	5.2	4.7	4.5	4.4
deoxy	5.0	4.2	5.6	2.8	4.8	4.5	5.3	4.7

[1]Average of 6 panel members
Scoring range: 1 (extreme variation) - 7 (very uniform)

Table 14. Average scores[1] for crumb color of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	3.5	6.2	5.8	3.4	5.3	5.2	5.5	5.0
No add.	3.5	3.3	3.4	3.0	3.7	3.7	3.5	3.4
2.5 salt	3.6	3.3	3.8	3.4	3.7	3.7	3.5	3.6
5 salt	3.5	3.8	3.8	3.4	3.2	3.7	3.5	3.5
S and S	3.8	4.0	3.5	3.6	3.2	3.7	3.5	3.6
2.5 sug	3.5	3.8	3.5	3.4	3.7	3.7	3.5	3.6
5 sugar	3.6	4.0	3.3	3.4	3.8	3.7	3.5	3.6
deoxy	3.0	3.7	3.4	3.2	3.0	3.3	3.3	3.3

[1]Average of 6 panel members
Scoring range: 1 (very pale yellow) - 7 (dark yellow)

Table 15. Number of panel members[1] checking "cracked" in describing crust appearance of egg yolk sponge cakes.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	1	0	0	0	0	0	0	0.7
No add.	5	6	5	1	4	5	6	4.2
2.5 salt	5	6	3	4	6	6	5	4.9
5 salt	4	0	5	1	0	4	0	2.1
S and S	0	6	6	0	6	0	6	3.2
2.5 sug	5	5	0	5	0	4	6	3.7
5 sugar	6	6	6	1	5	0	0	3.0
deoxy	5	6	4	1	6	6	6	4.5

[1]Panel consisting of 6 members

Table 16. Number of panel members[1] checking "smooth" in describing crust appearance of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	5	5	3	5	6	4	5	0.6
No add.	1	0	1	4	0	0	2	2.9
2.5 salt	1	0	2	1	0	1	2	1.1
5 salt	3	6	1	5	3	3	5	3.1
S and S	4	0	1	5	0	5	0	3.5
2.5 sug	1	0	5	0	5	3	0	3.9
5 sugar	0	0	0	5	1	6	6	2.4
deoxy	1	0	1	4	0	0	2	0.8

[1]Panel consisting of 6 members

Table 17. Number of panel members[1] checking "pebbly" in describing crust appearance of egg yolk sponge cakes.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	2	1	5	1	1	4	1	2.0
No add.	0	3	3	2	3	5	3	2.7
2.5 salt	0	3	1	2	2	2	1	1.7
5 salt	0	1	3	1	5	1	4	2.3
S and S	1	3	2	1	4	1	2	1.8
2.5 sug	0	1	2	2	1	2	4	1.9
5 sugar	2	1	2	1	1	1	1	1.2
deoxy	3	2	3	3	2	4	1	2.5

[1]Panel consisting of 6 members

Table 18. Number of panel members[1] checking "spotty" in describing crust appearance of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	0	0	0	0	0	0	0	0.0
No add.	0	0	1	0	1	0	0	0.3
2.5 salt	0	1	0	0	2	0	0	0.4
5 salt	0	0	0	0	0	0	1	0.1
S and S	0	1	0	0	0	1	0	0.3
2.5 sug	0	0	0	0	0	1	0	0.1
5 sugar	0	0	0	0	0	0	0	0.0
deoxy	1	1	1	0	1	0	0	0.6

[1]Panel consisting of 6 members

Table 19. Number of panel members[1] checking "moist" in describing crust appearance of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	1	0	1	0	1	0	2	0.4
No add.	0	0	0	1	1	1	0	0.7
2.5 salt	0	1	2	1	1	1	0	0.9
5 salt	1	1	2	0	1	1	2	1.0
S and S	0	3	1	1	0	1	2	0.8
2.5 sug	1	2	0	0	0	0	1	0.7
5 sugar	3	0	1	1	0	1	0	0.6
deoxy	0	1	0	0	0	0	0	0.6

[1]Panel consisting of 6 members

Table 20. Average scores[1] for moistness of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	4.3	3.8	4.0	4.6	4.7	4.3	4.8	4.4
No add.	3.7	3.8	4.5	3.6	4.8	5.0	4.7	4.3
2.5 salt	3.6	3.8	4.6	4.2	4.5	4.2	4.0	4.1
5 salt	3.3	3.8	3.7	3.8	4.2	4.3	4.7	4.0
S and S	4.2	4.3	3.8	4.0	4.2	3.3	4.8	4.1
2.5 sug	3.7	3.7	4.0	4.4	3.8	4.0	4.0	4.0
5 sugar	4.6	4.0	3.5	3.2	4.3	3.3	4.5	3.9
deoxy	4.2	3.5	3.8	4.2	3.2	3.5	4.0	3.8

[1]Average of 6 panel members
Scoring range: 1 (dry) - 7 (soggy)

Table 21. Average scores[1] for tenderness of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	5.5	5.0	4.8	5.2	5.5	5.0	5.3	5.4
No add.	3.9	4.3	5.0	4.6	5.5	5.3	5.2	4.8
2.5 salt	4.8	4.8	5.8	5.0	5.3	5.5	4.8	5.1
5 salt	4.6	4.7	5.0	4.6	5.0	5.7	5.8	5.0
S and S	5.6	4.8	5.0	5.6	4.6	4.2	5.5	5.0
2.5 sug	5.0	4.8	4.8	4.8	4.8	5.3	4.3	4.8
5 sugar	4.6	5.1	4.2	3.6	5.2	4.0	5.3	4.5
deoxy	4.6	5.0	4.2	3.8	3.8	3.8	4.2	4.2

[1]Average of 6 panel members
Scoring range: 1 (least tender) - 7 (most tender)

Table 22. Average scores[1] for flavor desirability of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	5.3	4.2	5.0	4.8	5.0	4.3	4.5	4.7
No add.	5.0	5.0	4.8	4.4	5.2	5.5	5.2	5.0
2.5 salt	5.0	4.8	5.6	5.4	5.3	5.2	5.2	5.2
5 salt	3.7	4.2	3.6	3.6	3.7	3.5	3.8	3.7
S and S	5.4	5.5	4.5	5.0	4.8	4.3	5.3	5.0
2.5 sug	4.5	4.4	5.2	5.2	4.7	5.0	4.7	4.8
5 sugar	5.8	5.2	4.8	4.4	5.3	4.5	5.5	5.1
deoxy	5.0	5.0	4.2	5.0	3.8	4.5	4.3	4.5

[1]Average of 6 panel members
Scoring range: 1 (least desirable) - 7 (most desirable)

Table 23. Number of panel members[1] checking "delicate" in describing flavor of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	5	1	4	2	3	2	2	2.8
No add.	4	3	1	2	6	2	4	3.1
2.5 salt	2	2	3	4	4	5	5	3.6
5 salt	1	3	0	1	1	2	2	1.4
S and S	5	3	3	4	4	2	5	3.7
2.5 sug	2	2	2	4	4	4	3	2.9
5 sugar	5	5	2	3	3	4	5	3.8
deoxy	1	2	1	4	1	3	2	2.0

[1]Panel consisting of 6 members

Table 24. Number of panel members[1] checking "eggy" in describing flavor of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	0	3	2	0	3	2	2	1.6
No add.	1	0	0	0	0	0	0	0.3
2.5 salt	1	1	2	1	0	1	0	0.8
5 salt	2	0	0	0	0	0	0	0.3
S and S	0	1	0	0	0	1	0	0.3
2.5 sug	2	0	0	1	0	0	0	0.8
5 sugar	0	0	0	0	2	0	0	0.0
deoxy	2	4	0	1	0	0	2	1.2

[1]Panel consisting of 6 members

Table 25. Number of panel members[1] checking "bland" in describing flavor of egg yolk sponge cakes.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	1	0	0	1	1	1	1	0.7
No add.	0	1	0	2	0	0	1	0.6
2.5 salt	0	1	0	0	0	0	0	0.1
5 salt	0	0	0	0	0	0	0	0.0
S and S	1	1	0	1	2	3	1	1.3
2.5 sug	2	2	2	1	0	1	1	1.3
5 sugar	1	1	1	1	1	0	1	0.9
deoxy	2	0	2	0	2	0	1	1.0

[1]Panel consisting of 6 members

Table 26. Number of panel members[1] checking "salty" in describing flavor of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	1	2	0	1	0	2	0	0.6
No add.	1	1	0	0	0	3	0	0.5
2.5 salt	2	3	1	0	2	0	2	1.3
5 salt	5	3	4	4	5	3	6	4.3
S and S	0	2	3	0	0	2	0	1.0
2.5 sug	2	2	1	1	3	1	2	1.7
5 sugar	0	0	1	1	0	0	0	0.3
deoxy	0	1	0	1	1	2	1	0.9

[1]Panel consisting of 6 members

Table 27. Number of panel members[1] checking "sour" in describing flavor of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	0	0	0	0	0	0	0	0.0
No add.	0	0	0	0	0	0	0	0.0
2.5 salt	0	0	0	0	0	0	0	0.0
5 salt	0	0	0	1	0	0	0	0.1
S and S	0	0	0	0	0	0	0	0.0
2.5 sug	0	0	0	0	0	0	0	0.0
5 sugar	0	0	0	0	0	0	0	0.0
deoxy	0	0	0	0	0	0	0	0.0

[1]Panel consisting of 6 members

Table 28. Number of panel members[1] checking "bitter" in describing flavor of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	0	1	1	1	1	0	1	0.7
No add.	0	1	3	1	0	0	1	0.8
2.5 salt	0	0	0	1	0	0	0	0.2
5 salt	0	3	1	1	0	2	0	1.0
S and S	0	0	0	1	0	0	0	0.1
2.5 sug	0	1	1	0	0	0	1	0.4
5 sugar	0	0	0	0	0	2	0	0.3
deoxy	0	1	3	1	2	2	1	1.5

[1]Panel consisting of 6 members

Table 29. Standing height (cm) of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	5.62	5.76	5.78	5.50	5.70	5.80	5.64	5.68
No add.	5.68	5.30	5.28	5.20	5.46	5.04	5.06	5.29
2.5 salt	5.50	5.36	5.40	5.02	5.78	5.54	5.72	5.48
5 salt	5.70	5.70	5.66	5.50	6.00	5.76	5.68	5.71
S and S	5.64	5.86	5.56	5.54	6.00	5.50	5.66	5.68
2.5 sug	5.60	5.56	5.42	5.36	5.60	5.62	5.66	5.54
5 sugar	5.46	5.72	5.72	5.80	5.36	5.62	5.74	5.63
deoxy	4.78	4.94	4.68	4.96	5.12	4.96	5.02	4.92

Table 30. Compressibility (mm) of egg yolk sponge cakes.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	12.22	14.25	13.15	13.11	13.37	12.15	10.86	12.75
No add.	7.93	8.98	9.23	8.37	10.42	9.09	7.61	8.53
2.5 salt	8.39	10.72	12.73	10.89	11.88	12.01	9.30	10.87
5 salt	11.80	12.12	12.91	12.58	13.37	11.81	14.16	12.64
S and S	9.18	13.12	11.14	14.07	11.43	9.48	12.70	11.57
2.5 sug	8.72	9.72	9.35	9.37	10.59	10.28	9.15	9.64
5 sugar	8.39	8.70	11.46	10.66	11.12	8.62	10.45	9.94
deoxy	3.50	5.05	5.61	5.19	5.13	5.73	4.81	5.20

Table 31. Specific gravity of egg yolk sponge cake batters.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	.37	.35	.36	.38	.35	.36	.39	.36
No add.	.45	.46	.45	.46	.40	.45	.46	.45
2.5 salt	.39	.39	.40	.39	.39	.39	.39	.39
5 salt	.39	.37	.39	.39	.37	.40	.39	.39
S and S	.37	.39	.40	.38	.39	.40	.40	.39
2.5 sug	.41	.41	.43	.44	.43	.42	.42	.43
5 sugar	.40	.41	.39	.35	.41	.41	.40	.39
deoxy	.49	.49	.50	.50	.49	.48	.50	.49

Table 32. Oil separation scores[1] for mayonnaise.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	1	3	3	3	3	3	0	2.4
No add.	0	3	0	1	0	2	2	1.4
2.5 salt	0	0	3	0	0	1	0	0.4
5 salt	1	1	1	2	1	2	2	1.4
S and S	0	1	3	3	2	2	2	2.1
2.5 sug	0	0	0	2	3	2	2	1.1
5 sugar	0	0	2	0	1	2	2	1.0
deoxy	0	3	1	0	2	2	3	1.4

[1]Scores:
0 No separation after 6 wks of storage
1 No separation after 4 wks, but visible separation after 6 wks of storage
2 No separation after 2 wks, but visible separation after 4 wks of storage
3 Visible separation after 2 wks of storage

Table 33. Average scores[1] for consistency of mayonnaise.

Treatment	Replication 1	2	3	4	5	6	7	Adj. mean
Fresh	2.5	2.5	2.3	2.3	2.0	2.5	2.3	2.3
No add.	5.8	5.4	5.7	5.7	5.7	6.0	5.3	5.5
2.5 salt	4.3	5.0	5.0	5.0	5.0	5.5	4.8	4.9
5 salt	4.8	3.8	5.3	3.7	5.0	4.3	4.3	4.4
S and S	4.8	5.5	3.3	5.0	5.8	5.0	5.5	5.0
2.5 sug	5.3	4.5	4.7	5.0	5.0	5.0	5.8	5.1
5 sugar	5.3	5.3	5.3	4.7	6.0	6.3	5.5	5.6
deoxy	3.8	4.8	4.7	4.4	5.0	4.8	4.8	4.5

[1]Average of 4 panel members
Scoring range: 1 (least stiff) - 7 (most stiff)

Table 34. Number of panel members[1] checking "off-flavor" in describing mayonnaise.

Treatment	Replication							Adj. mean
	1	2	3	4	5	6	7	
Fresh	0	1	1	2	0	0	1	0.7
No add.	1	1	0	0	0	1	0	0.7
2.5 salt	0	2	0	0	1	0	2	0.8
5 salt	1	2	1	1	0	2	3	1.2
S and S	0	0	1	0	0	1	1	0.5
2.5 sug	2	2	0	3	1	2	2	1.8
5 sugar	1	0	1	0	1	2	1	0.8
deoxy	2	1	2	1	1	1	1	1.1

[1]Panel consisting of 4 members

Table 35. Viscosity (cps) of fresh and frozen egg yolk, determined using Brookfield viscometer with Helipath stand.

Treatment		Replication 1	2	3	4	Average
No add.	Fsh	2,500	1,800	1,700	1,300	1,825
	Fro	697,600	561,600	1,428,000	683,200	842,600
2.5 salt	Fsh	17,600	15,500	13,800	11,800	14,675
	Fro	42,500	42,200	46,700	37,400	42,200
5 salt	Fsh	24,600	22,900	21,600	18,100	21,800
	Fro	36,000	37,800	34,900	28,300	34,250
S and S	Fsh	9,700	9,500	9,000	7,800	9,000
	Fro	22,500	27,600	29,100	18,800	24,500
2.5 sug	Fsh	1,800	1,300	1,400	1,300	1,450
	Fro	92,000	95,900	182,200	79,300	112,350
5 sugar	Fsh	1,700	1,300	1,400	1,200	1,400
	Fro	43,700	51,600	55,000	37,000	46,825
deoxy	Fsh	2,300	2,100	4,800	2,200	2,850
	Fro	701,600	600,000	709,600	340,000	587,800

Table 36. Viscosity (cps) of fresh and frozen egg yolk, determined using Fisher-MacMichael viscosimeter.

Treatment		Replication 1	2	3	4	Average
No add.	Fsh	1,413	1,501	1,413	1,148	1,369
	Fro	228,167	157,527	176,600	176,600	184,724
2.5 salt	Fsh	19,691	15,982	12,715	11,479	14,967
	Fro	63,576	79,823	81,236	60,750	71,346
5 salt	Fsh	26,225	31,258	22,252	14,393	23,532
	Fro	55,099	63,576	68,521	45,916	58,278
S and S	Fsh	9,801	9,713	8,653	6,623	8,698
	Fro	28,962	40,265	41,678	29,669	35,143
2.5 sug	Fsh	1,236	1,060	1,325	1,148	1,192
	Fro	108,786	145,518	117,262	108,079	119,911
5 sugar	Fsh	1,325	971	1,236	1,148	1,170
	Fro	57,925	81,236	64,282	56,512	64,989
deoxy	Fsh	1,942	1,501	1,854	2,384	1,920
	Fro	166,004	197,792	180,132	166,004	177,483

Table 37. pH of fresh and frozen-defrosted egg yolk.

Treatment		Replication				Average
		1	2	3	4	
No add.	Fsh	6.02	6.01	5.97	6.01	6.00
	Fro	6.10	5.99	5.95	6.05	6.02
2.5 salt	Fsh	5.91	6.00	5.81	5.95	5.92
	Fro	5.95	5.80	5.97	5.90	5.91
5 salt	Fsh	5.81	5.87	5.70	5.87	5.81
	Fro	5.91	5.80	5.91	5.84	5.87
S and S	Fsh	5.88	5.92	5.88	5.92	5.90
	Fro	5.94	5.90	5.92	5.92	5.92
2.5 sug	Fsh	6.09	6.10	5.95	6.10	6.06
	Fro	6.06	6.10	6.10	5.98	6.06
5 sugar	Fsh	6.03	6.01	5.93	6.07	6.01
	Fro	6.10	6.07	6.06	6.10	6.08
deoxy	Fsh	6.28	6.25	6.18	6.24	6.24
	Fro	6.43	6.30	6.30	6.23	6.32

Table 38. Granules (g) obtained by centrifugation[1] of 10 g fresh or frozen defrosted egg yolk.

Treatment		Replication				Average
		1	2	3	4	
No add.	Fsh	2.9	3.0	3.1	3.3	3.1
	Fro	4.7	6.0	6.2	6.6	5.9
2.5 salt	Fsh	3.3	3.3	3.5	3.4	3.4
	Fro	2.7	3.1	2.9	2.7	2.9
5 salt	Fsh	1.4	1.4	0.1	0.4	0.8
	Fro	1.2	1.4	0.9	1.0	1.1
S and S	Fsh	3.1	3.3	3.2	3.3	3.2
	Fro	2.5	2.8	2.8	2.2	2.6
2.5 sug	Fsh	2.9	3.0	2.9	3.1	3.0
	Fro	4.6	4.7	5.3	6.2	5.2
5 sugar	Fsh	2.8	2.9	2.8	2.9	2.9
	Fro	3.8	4.4	3.9	4.8	4.2
deoxy	Fsh	3.0	3.0	3.2	3.1	3.1
	Fro	7.6	8.7	8.8	9.9	8.8

[1] 12,100 x g for 30 min

Table 39. Supernatant plasma (g) obtained by centrifugation[1] of 10 g fresh or frozen-defrosted egg yolk diluted with 20 g distilled water.

Treatment		Replication 1	2	3	4	Average
No add.	Fsh	27.6	27.0	27.6	27.6	27.5
	Fro	22.1	22.8	23.3	22.3	22.6
2.5 salt	Fsh	26.8	27.0	27.1	27.9	27.2
	Fro	26.8	27.4	26.8	26.6	26.9
5 salt	Fsh	28.8	29.1	30.3	30.2	29.6
	Fro	29.5	29.3	29.7	29.9	29.6
S and S	Fsh	26.9	26.9	27.6	27.6	27.3
	Fro	27.2	27.2	27.2	27.6	27.3
2.5 sug	Fsh	26.8	26.9	28.5	27.7	27.5
	Fro	21.3	23.8	24.0	22.5	22.9
5 sugar	Fsh	26.7	27.1	27.9	28.2	27.5
	Fro	24.8	25.2	25.5	25.1	25.2
deoxy	Fsh	26.8	27.6	27.4	27.8	27.4
	Fro	19.1	18.2	20.3	19.2	19.2

[1]12,100 x g for 30 min

Table 40. Optical density of eluted neutral lipid spot separated by thin layer chromatography of lipid extract of granules from fresh or frozen egg yolk.

Treatment		Replication				Average
		1	2	3	4	
No add.	Fsh	.239	.234	.239	.214	.232
	Fro	.244	.254	.273	.233	.251
2.5 salt	Fsh.	.250	.267	.233	.197	.237
	Fro	.208	.240	.281	.193	.231
5 salt	Fsh	----	----	----	----	----
	Fro	----	----	----	----	----
S and S	Fsh	.261	.219	.213	.170	.216
	Fro	.229	.216	.206	.167	.205
2.5 sug	Fsh	.228	.247	.209	.209	.223
	Fro	.228	.313	.214	.181	.234
5 sugar	Fsh	.208	.303	.179	.151	.210
	Fro	.272	.229	.214	.164	.220
deoxy	Fsh	.266	.251	.237	.203	.239
	Fro	.269	.283	.220	.240	.253

Table 41. Optical density of eluted phospholipid spot separated by thin layer chromatography of lipid extract from granules from fresh or frozen egg yolk.

Treatment		Replication 1	2	3	4	Average
No add.	Fsh	.142	.130	.115	.185	.143
	Fro	.124	.136	.108	.133	.125
2.5 salt	Fsh	.119	.127	.115	.166	.132
	Fro	.120	.128	.118	.144	.128
5 salt	Fsh	----	----	----	----	----
	Fro	----	----	----	----	----
S and S	Fsh	.162	.128	.122	.120	.133
	Fro	.144	.127	.137	.114	.131
2.5 sug	Fsh	.128	.131	.124	.115	.125
	Fro	.118	.136	.139	.107	.125
5 sugar	Fsh	.133	.173	.122	.121	.137
	Fro	.159	.157	.115	.114	.136
deoxy	Fsh	.152	.121	.125	.122	.130
	Fro	.141	.129	.125	.122	.129

Table 42. Optical density of eluted neutral lipid spot separated by thin layer chromatography of lipid extract of supernatant plasma from fresh or frozen yolk.

Treatment		Replication 1	2	3	4	Average
No add.	Fsh	.308	.264	.312	.504	.347
	Fro	.215	.244	.299	.560	.330
2.5 salt	Fsh	.259	.263	.358	.402	.321
	Fro	.267	.249	.313	.371	.300
5 salt	Fsh	.255	.311	.415	.416	.349
	Fro	.267	.302	.625	.309	.376
S and S	Fsh	.384	.317	.436	.459	.399
	Fro	.311	.239	.441	.400	.348
2.5 sug	Fsh	.272	.346	.563	.372	.388
	Fro	.258	.340	.500	.351	.362
5 sugar	Fsh	.286	.412	.472	.360	.383
	Fro	.285	.295	.402	.370	.338
deoxy	Fsh	.302	.343	.519	.517	.420
	Fro	.250	.275	.460	.356	.335

Table 43. Optical density of eluted phospholipid spot separated by thin layer chromatography of lipid extract of supernatant plasma from fresh or frozen yolk.

Treatment		Replication 1	2	3	4	Average
No add.	Fsh	.164	.252	.260	.287	.241
	Fro	.149	.161	.249	.267	.207
2.5 salt	Fsh	.172	.157	.245	.229	.201
	Fro	.159	.159	.270	.202	.198
5 salt	Fsh	.154	.175	.306	.163	.200
	Fro	.199	.158	.277	.157	.198
S and S	Fsh	.205	.136	.276	.172	.197
	Fro	.176	.154	.269	.174	.193
2.5 sug	Fsh	.183	.185	.350	.166	.221
	Fro	.173	.188	.305	.170	.209
5 sugar	Fsh	.203	.156	.228	.142	.182
	Fro	.165	.143	.212	.150	.168
deoxy	Fsh	.186	.151	.324	.210	.218
	Fro	.185	.145	.229	.217	.194

FUNCTIONAL PERFORMANCE AND SELECTED CHEMICAL AND PHYSICAL PROPERTIES OF FROZEN EGG YOLK CONTAINING VARIOUS ADDITIVES

by

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Functional performance in emulsions and sponge cakes and selected physical and chemical properties of frozen egg yolk containing various additives were investigated. Additives used included salt (2.5% and 5%), sugar (2.5% and 5%), a combination of salt and sugar (2.5% of each), and sodium deoxycholate.

In general, cake made with fresh yolks was better than cake made with any of the frozen yolk products, and received the highest score among all eight treatments for volume, grain uniformity, moistness, tenderness, compressibility, yellow color, and "eggy" flavor. Batter made from fresh yolks had the lowest specific gravity, and the crust cracked during baking fewer times than with any other treatment. However, water separation in simple emulsions and oil separation in mayonnaise was higher when fresh yolks were used than with any of the frozen yolk products.

Frozen salted yolks were less viscous than frozen sugared yolks, and yielded cakes which were more moist, more tender, and more compressible than cakes made with sugared yolks. The flavor of cake made with 5% salted yolks was too salty, but cake made with 2.5% salted yolks had the highest flavor desirability score of all treatments. Cakes made with sugared yolks tended to be more bland in flavor than cakes made with salted yolks. In addition, salted yolks tended to give more emulsion stability than sugared yolks.

Use of a combination of 2.5% sugar and 2.5% salt in frozen egg yolks for sponge cake seemed to offer certain advantages, indicated by higher moistness and tenderness scores and greater compressibility than with sugared yolks, a volume not significantly different than fresh yolk (as indicated by standing height), and a high score for flavor desirability. The lowest viscosity of any of the frozen yolk products was obtained with this treatment. However, mayonnaise made with frozen yolk containing both sugar and salt was significantly less stable than with any of the other frozen yolk products.

Frozen yolk containing no additive yielded cakes which were lower in volume, less tender, less compressible, and paler in color than any other treatment except deoxycholate yolks. Deoxycholate yolks and untreated yolks also produced batters of high specific gravity. The high viscosity of those yolks was undoubtably a factor in producing less desirable cakes. Larger amounts of sedimenting material and turbid plasma obtained by centrifugal separation indicated that freezing resulted in a greater amount of damage to untreated yolks or deoxycholate yolks than to sugared and/or salted yolks, so impairment of functional performance of those products might be expected.