SOME CHARACTERISTICS OF YOLK SOLIDS AFFECTING THEIR PERFORMANCE IN CAKE DOUGHNUTS[1]

I. Effects of Yolk Type, Level, and Contamination with White

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ABSTRACT

Performance of egg-yolk solids was evaluated in a commercial cake doughnut mix. Yolk solids up to 4.5% of the dry mix were added as fresh liquid or spray-dried yolk. With both types of yolk, batter fluidity, rise time, fat absorption, specific volume, general appearance, and eating quality increased or improved with increasing yolk solids up to the 3% level. With the exception of its influence on batter fluidity, liquid yolk was without significant difference from spray-dried yolk in its effect on performance and quality. At any given yolk level, however, liquid yolk consistently yielded more-fluid batters than did dried yolk. Accordingly, for any desired batter consistency, less water is required when the liquid yolk is used. Limited studies on eating quality and staling rate indicated no significant advantage for liquid over dried yolk. The small amounts of egg-white solids normally present in commercial yolk caused slight decreases in fat absorption. Larger amounts of white caused marked decreases and also quality losses. These decreases were determined to be specific effects of the added white rather than merely a dilution of the yolk solids.

A principal use of egg-yolk solids, which are at present prepared by spray drying, is in cake doughnut mix. The usual specifications for procurement of these solids (moisture, fat, pH, reducing sugar, bacteria count, color, and granulation) are not sufficient to protect against variable performance attributable to the yolk ingredient. This paper represents the first part of an investigation into the causes of this variability.

It is recognized that commercial preparation of liquid yolk and its conversion to the dried product may induce varying degrees of change from pure liquid yolk. Commercial liquid yolk may contain variable amounts of adhering liquid egg white (usually 15 to 18%). Variable heat alteration may occur at certain processing steps in the preparation of spray-dried yolk, e.g., in preheating the liquid, during drying, or in storage after drying. Paul and co-workers (2,3) have reported that conventional heat-pasteurization of liquid yolk prior to drying was without effect on performance of the final powder in cake

[1]Manuscript received January 24, 1962. Presented at the 46th annual meeting, Dallas, Texas, April 1961. Contribution from the Western Regional Research Laboratory, one of the Laboratories of the Western Utilization Research and Development Division, Agricultural Research Service, U.S. Department of of Agriculture, Albany 10, California.

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doughnuts, but that high-temperature storage of standard (not deglucosed) yolk solids adversely affected their performance.

This paper describes studies on the effects of the following factors on cake doughnut performance: (a) level of yolk in mix, (b) liquid vs. dried yolk, and (c) variation in amount of adhering white. A second paper (1) describes results of studies on causes of variability in commercial dried yolk preparations.

Materials and Methods

Egg-yolk performance in cake doughnuts was appraised on a Lincoln Donut Machine using a mix formulated without yolk solids for these studies by a commercial mix manufacturer. The yolk was blended in as needed. The composition of the eggless mix was as follows:

	Proportion of Flour Weight
	%
Flour, cracker	100.0
Sugar, cane	39.2
Sugar, corn	2.74
Fat, soya oil	5.48
Milk, dry skim	5.48
Acid, pyro	1.81
Soda	1.26
Salt	1.60

Bulk quantities of mix were divided into 5-lb. batches and stored at −10°F. in airtight metal cans. Cans of mix were placed at room temperature the day before they were needed.

The liquid-yolk raw materials were prepared from unprocessed shell eggs obtained from local ranchers and held at 55°F. for not more than 3 weeks after the day of lay. Unless otherwise indicated, the laboratory-prepared liquid yolks, as normally separated without special precautions, contained approximately 8% by weight of adhering liquid white, corresponding to approximately 2% white solids in the dried product. (The 15 to 18% adhering white generally present in commercially prepared yolk yields approximately 5% white solids in the dried product.) Yolk powders were prepared in a Bowen Laboratory Spray Dryer. The liquid yolk was preheated to 125°F. and held at that temperature for less than a minute before it was atomized. The dryer was operated at an inlet temperature of 250°F. and an outlet temperature of about 140°F. Only the cyclone collector powders were used, and these were continuously and rapidly cooled to 85°F. They were packed in small cans in nitrogen and held at 34°F. until needed.

For studies comparing liquid and dried yolks, fresh liquid and spray-dried samples were drawn from a common lot of blended yolk to avoid any variation in amounts of adhering white or unknown factors. For studies on effects of graded levels of adhering white, a common lot of white-free blended yolk was prepared by rolling the intact yolks on absorbent paper towels to remove the white. Then, known levels of egg white were blended into the white-free yolk before spray drying.

Batter Preparation. The total weight of dry mix, including added yolk solids, used per run was 2,270 g., sufficient for 8 dozen doughnuts. All references to yolk levels denote the percentage of total egg solids in the dry ingredients, added either as dried or liquid yolk. When added in the dried form, the yolk solids were blended with the dry mix for 15 minutes at speed 1 on a Hobart A-200 mixer, using a paddle and a 12-qt. bowl. The blended dry ingredients were added to the water, mixed 30 seconds at speed 1, and then mixed 90 seconds at speed 2. The water-to-mix ratio was constant for a given study but varied slightly between the different batches of mix used. For the studies comparing liquid and dried yolks, the water added was 37.9% (±0.2%) of the eggless dry mix. For the adhering white studies, the water was 36.6% (±0.1%). The water temperature was adjusted to give a final batter temperature between 74° and 76°F.

When fresh liquid yolks were used, they were added after the eggless mix had been blended with the water for 30 seconds at speed 1. The water added was corrected for that in the liquid yolk so the total batter composition including water content was comparable. In the case of the spray-dried yolk, the first slow-speed mixing step was considered a reconstitution period.

The batter was allowed to stand 5 minutes before it was transferred to the hopper of the Lincoln machine. Air pressure was adjusted initially to produce 28-g. doughnuts and increased throughout the run to maintain this weight. In all runs, the pressure had to be increased 0.4 to 0.6 lb. during a run. For convenience in making comparisons, only the initial pressure requirement is reported.

Free fatty acid content of the frying fat was measured by dissolving 28.2 g. fat in 50 ml. benzene:isopropyl alcohol (1:1 v/v) and titrating to the phenolphthalein end point with 0.1*N* potassium hydroxide in isopropyl alcohol. Enough fresh fat was added at the beginning of each run to keep the free fatty acid level near 0.4%. The fat temperature was maintained between 380° and 395°F.

Evaluation Criteria. Characteristics studied included fluidity and rise time of the batter, height/diameter ratio, volume, fat absorption, appearance, eating quality, and staling rate of the finished doughnuts.

Batter fluidity was measured during each run by collecting three batter samples from every fifteen as they were extruded from the cutting mechanism and before they dropped into the hot fat. The weight of each sample was divided by the air pressure at the time of sampling for calculating g. of batter extruded per lb. of pressure. The average fluidity of 18 samples is reported for each run.

Rise time was measured from the time the batter dropped from the cutter into the fat to the time it rose to the surface. This interval was recorded and totaled on several sets of four batter samples and the average expressed as seconds per four doughnuts. It reflects the elastic qualities of the batter on heating.

Weight, linear, and volume measurements were made on lots of eight doughnuts from the third, fourth, and fifth dozens, after they had cooled for 45 minutes. The doughnuts were lined up on a meter stick for measurement of total outside diameter; they were stacked for measurement of total height. The ratio of height to diameter gives an indication of relative plumpness.

The volume of each lot of eight weighed doughnuts was measured by rapeseed displacement and the specific volume calculated.

For fat determinations, six doughnuts from each run were frozen 2 hours after baking and ground while frozen with added dry ice in a precooled hand meat grinder. Handling in this manner served to avoid extrusion of fat. After the ground samples were warmed to room temperature in a loosely covered container to permit CO_2 to escape, they were dried in a Stokes vacuum oven at relatively low temperatures, to obtain an estimate of moisture content. Duplicate 5-g. aliquots of the dried doughnut powders were extracted with 50 ml. of Skellysolve B: methanol (9:1 v/v), washed with three 25-ml. portions of the solvent, and filtered through Whatman No. 4 filter paper. The combined extracts were evaporated to near dryness on the steam bath and the solvent traces removed in a forced-air oven at 105°C. To calculate the fat absorbed, the fat residue was corrected for the fat contributed by the eggs and mix. The fat absorbed is reported on the fresh (i.e., wet) basis as a percentage of the total doughnut weight. The oz. of fat absorbed per doz. can be obtained by multiplying the percentage figure by 12 oz.—the average weight of each dozen.

Appearance factors evaluated included color, shape, center star formation, crust and crumb characteristics.

The initial eating quality and relative staling rates of doughnuts prepared with fresh liquid and spray-dried yolks were compared at the 3% level of yolk solids. Two hours after frying they were put into cardboard doughnut boxes and stored under ambient conditions (70° to 75°F., 20 to 40% r.h.) for 3 hours, 1, 2, 3, and 5 days. At each storage period, compressibility tests were made with both the Baker Compressimeter and Bloom Gelometer, using cores ½ in. thick cut with a No. 12 cork borer. Four such cores were cut from each of six doughnuts and two of these from each doughnut were measured on each instrument. Values reported represent the average stress for 12 samples at 4-mm. compression. Organoleptic comparisons of the doughnuts made with fresh and dried yolks were made at 0, 1, 2, and 3 days. Six trained judges ranked pairs of samples for staleness. Two replications were made at 0 days and four at 1, 2, and 3 days.

Results and Discussion

Effect of Yolk Level. The level of yolk used affected both batter and doughnut characteristics in the mix tested (Table I). As the

TABLE I

EFFECT OF YOLK-SOLIDS LEVEL ON BATTER AND DOUGHNUT CHARACTERISTICS

Yolk Solids		Batter Properties		Initial Air Pressure	Doughnut Properties		
		Rise Time	Fluidity		Specific Volume	Height/ Diameter	Fat Absorption (Fresh Basis)
% of dry mix		*sec/4*	*g/lb*	*psig*	*ml/g*		*%*
0		29.8	7.9	3.3	2.12	0.37	6.7
0.5	Dried	22.4	8.1	3.1	2.55	0.39	7.5
0.5	Liquid	22.4	8.5	2.9	2.53	0.39	7.0
1.5	Dried	14.4	8.4	2.8	3.01	0.40	12.9
1.5	Liquid	15.7	9.4	2.6	2.92	0.40	11.8
3.0	Dried	13.2	9.3	2.5	3.09	0.41	17.3
3.0	Liquid	13.3	11.4	2.1	3.08	0.40	15.8
4.5	Dried	13.0	10.7	2.1	3.16	0.40	16.1
4.5	Liquid	13.0	14.3	1.5	3.30	0.39	17.2

concentration of yolk solids increased, the pressure required to obtain 28-g. doughnuts decreased, owing to two separate influences of the yolk on the batter: 1) increasing the yolk solids concentration increased the fluidity of the batter (or the amount extruded at a given pressure), and 2) fat absorption also increased with increments of yolk solids up to 3% of the dry mix. These increases in fluidity and fat absorption both acted to decrease the operating pressure required for a 28-g. doughnut. Rise time of the batter decreased and specific volume of the finished doughnuts increased with increasing yolk concentration, the effects leveling off at the 3% level of yolk solids. The height/diameter ratio was greatest at the 3% level of yolk solids, denoting that doughnuts were more well-rounded or more plump. Considering all factors, including appearance (shape, center hole, and crust characteristics), use of over 3% yolk solids in the particular mix tested resulted in no further improvement in initial quality as evaluated by the criteria used.

Liquid vs. *Dried Yolk.* Fresh liquid yolk affected rise time, volume, height/diameter ratio, and fat absorption in a manner similar to that of the dried yolk. However, liquid yolk consistently yielded more-fluid batters at any given egg level (Table I), which, in the absence of a consistent difference in fat absorption, resulted in a lower air-pressure requirement for doughnuts of similar weight. With liquid yolk, the general shape and center star formation were best when 1.5% yolk was used. At the higher levels of liquid yolk the lack of good star formation could probably be attributed to the very fluid batters. Reducing the water content in these batters corrected the shape and star characteristics with no other improvements.

In addition to comparisons by the objective criteria described, liquid and dried yolk were also compared for their influence on initial eating quality and rate of staling. These comparisons were made at the 3% yolk level with adjustment made for the water contained in the liquid yolk so the batters had identical water contents. Taste panel and compressibility tests (Table II) indicated no important differences attributable to type of yolk. Although the doughnuts prepared from fresh liquid yolk were consistently rated slightly less stale than those made with spray-dried yolk, the difference was

TABLE II

COMPARISON OF KEEPING QUALITY OF DOUGHNUTS MADE WITH FRESH LIQUID AND SPRAY-DRIED YOLK

Storage Time	Yolk Solids [a]	Stress at 4 mm. Compression		Panel Rank [b]	Doughnut Moisture
		Baker	Bloom		
days		*g*	*g*		%
0	Fresh	97	106	1.3	19.4
	Spray-dried	87	98	1.7	19.4
1	Fresh	173	216	1.2)**	...
	Spray-dried	168	216	1.8)	...
2	Fresh	194	285	1.2)**	...
	Spray-dried	215	270	1.8)	...
3	Fresh	236	316	1.4	...
	Spray-dried	242	329	1.6	...
5	Fresh	315	424 [c]	..	15.4
	Spray-dried	363	474 [c]	..	16.6

[a] 3% of dry mix.
[b] 1 = least stale.
[c] Some values off scale of instruments.

significant only at 1 and 2 days of storage and was not borne out by the compressimeter and gelometer tests. In another study on similar doughnut treatments using triangle taste tests, no significant differences were found. Moisture loss, a contributor to staling, was slightly greater after 5 days for the doughnuts prepared from fresh liquid yolk. Thus the use of liquid yolk would appear to offer no significant advantages over dried yolk in production of cake doughnuts.

Effects of Adhering Egg White. It is evident from the data in Table I that both fat-absorption and volume increases, two important criteria in cake doughnut evaluation, have leveled off when 3% yolk solids were present. Accordingly, it was considered that effects of adhering white could be studied better at a lower yolk level (1.5%) where the mix would be more responsive to performance variations induced by the added egg ingredient. Table III illustrates the effect

TABLE III
INFLUENCE OF ADHERING WHITE ON YOLK-SOLIDS PERFORMANCE IN CAKE DOUGHNUTS

Adhering White in "Yolk"[a]		Egg Solids in Doughnut Mix		Batter Properties		Initial Air Pressure	Doughnut Properties	
Liquid	Dried Solids	Yolk	White	Rise Time	Fluidity		Spec. Vol.	Fat Absorption (Wet Basis)
%	%	%	%	*sec/4*	*g/lb*	*psig*	*ml/g*	%
..	..	1.5	..	15.8	9.4	2.5	2.89	13.6
18[b]	5[b]	1.42	.08	16.3	9.2	2.6	2.78	12.6
30	10	1.36	.14	17.2	9.6	2.5	2.82	12.2
50	20	1.20	.30	18.6	9.3	2.7	2.88	9.3

[a] Liquid white blended with liquid yolk (white-free) before drying (column 1). For convenience percentage of white in resulting powders is also given (column 2).
[b] Usual level in commercial yolk.

of graded levels of adhering white when the total egg-solids content is held constant at 1.5% of the dry mix. Tests were conducted at the usual level of adhering white present in commercially dried yolk (5%) and at higher levels of white (up to 20% of the solids) in order to provide an indication of what might be expected if whole-egg solids were substituted for yolk solids in cake doughnut manufacture.

The principal effects of substituting white solids for some of the yolk solids (Table III) appear to be a reduction in fat absorption and a slight increase in rise time. Since the batter fluidity was not significantly affected, the slightly higher initial air-pressure requirement indicated at the 50% adhering white level was probably due to the decreased fat absorption. At this level the decrease in fat absorption was very substantial and represented a serious quality defect, which was also obvious in the tougher and generally poorer eating quality of the doughnuts. It is evident that replacing the yolk with commercially prepared whole egg, which contains approximately 60% white on a liquid basis, would further magnify these deficiencies.

At the level of adhering white usually encountered in commercial yolk products, the decrease in fat absorption was approximately 1%. In several similar studies, fat-absorption decreases between 1 and 1.5% have been observed. It is the view of the authors that the usual amounts of adhering white encountered commercially are not of vital importance, and gross variations in white content are, of course, avoided by the fat-content requirement used in procurement specifications.

It was of interest to determine whether egg white, in the amounts encountered in yolk solids, influenced fat absorption by simple dilution or by a damaging (or interfering) effect. It is apparent (Table IV) that at either the 1.5 or the 3.0% level of yolk solids, simple reduction in yolk solids by 5% (to 1.42 and 2.84% respectively) had little or no effect on fat absorption. However, inclusion of white solids as 5% of the total egg present resulted in a decrease in fat absorption of 1.0 and 1.7% respectively. Higher levels of white contamination (approximately 20% of the total egg solids) resulted in a marked decrease in fat absorption beyond the substantial decrease due to the lowering of the yolk content from 1.5 to 1.2%. Rise time increased with the decrease in yolk content.

TABLE IV
COMPARISON OF DAMAGING AND DILUENT EFFECTS OF EGG WHITE

Adhering White in "Yolk" [a]		Egg Solids in Doughnut Mix		Rise Time	Fat Absorption (Fresh Basis)
Liquid	Dried Solids	Yolk	White		
%	%	%	%	sec/4	%
A. Usual level of adhering white in commercial "yolk"					
0	0	1.50	. .	15.8	13.6
0	0	1.42	. .	16.4	13.7
18	5	1.42	.08	16.3	12.6
0	0	3.00	. .	12.3	19.6
0	0	2.84	. .	13.2	19.4
18	5	2.84	.16	12.7	17.9
B. Higher level of adhering white					
0	0	1.5	. .	15.8	13.6
0	0	1.2	. .	19.8	11.7
50	20	1.2	.30	18.6	9.3

[a] Compare: footnote a, Table III.

In another study, using a rich commercial mix designed to have high fat absorption and containing 3% commercial yolk solids, addition of white solids in an amount equal to 20% of the resulting total egg solids content also caused a marked decrease in fat absorption from 20.7 to 14.3%.

White solids can apparently be substituted for yolk as far as batter fluidity and doughnut volume are concerned. Their inability to induce adequate fat absorption may be due, in part, to the lower temperature at which egg white initially coagulates.

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