Problems Encountered in the Commercial Utilization of Frying Fats[1]

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THE problems encountered in the use of fats for frying cake and yeast raised doughnuts are related to one or more of the following elements of evaluation:

1. Flavor.
2. Stability of the frying fat during the frying cycle (9).
3. Stability of the fried product.
4. Fat absorption.
5. Effect of fat upon the doughnut coating (coating sugar or glaze).
6. Effect upon symmetry, specific volume, and other physical characteristics of the fried product.
7. "Gum" or polymer formation in the fat (9).

These elements must be considered not only at the start of any frying cycle, but rather as part of a dynamic system, due to the changing composition of the fat.

Some of the changes that have been reported are:

1. Decrease in iodine value (1, 2, 4, 10, 8, 5).
2. Increase in refractive index (1, 2, 4, 11, 10).
3. Increase in free fatty acids (1, 2, 4, 6, 11, 8, 12, 5).
4. Increase in acetyl value (2).
5. Drop in smoke point, correlated with the increase in free fatty acids (3, 6, 9).

The effect of surface area exposed, time, and temperatures on smoke point has been described by Blunt and Feeney (3). A smoke point of 185°C. is reported as the minimum requirement.

6. Lowering of melt point (4, 10).
7. Appearance of foaming during frying (11, 10).

Robinson, Black, and Mitchell (11), in a study of foaming tendencies, report a range of 10 to 21 hours for appearance of strong foam when heating a number of hydrogenated and unhydrogenated oils in open air at 375°F.

Addition of highly polymerized cotton oil at the 25% level caused immediate foaming. Addition of magnesium stearate extended foam time from 20 to 55 hours.

8. Flavor deterioration, increase in peroxide values (8).
9. Increase in fat absorption (12).

Some factors leading to change in fat absorption have been investigated by Arenson and Heyl, who report that this is not a function of degree of saturation or of free fatty acids below 0.6% (7). Fisher (12) reports correlation between free fatty acids and fat absorption in the 0.031-0.40 range.

Carlin and Lantz (9) report that the advantages reported for certain types of fats for deep fat frying are exaggerated, with three hydrogenated and two compound shortenings exhibiting substantially equal fat absorptions after 4 to 14 days of commercial frying in spite of wide variance at the start of the frying cycle.

Because of the economic significance of fat absorption this question is of primary interest to doughnut bakers. Commercial free fatty acids in kettle fats vary from 0.3% FFA to 1.0% FFA, with no difference in fat absorptions when hydrogenated lard is used as a frying fat. It is to be expected that the reaction products produced on heating and oxidizing a fat are quite different from the hydrolytic products formed during frying. It is also known that variation in frying practice results in different time relationships between heating time and frying time.

To examine the relative effect of oxidized fat on doughnut characteristics and fat absorption, it was decided to study fats deteriorated by open air heating as compared with fats used for frying.

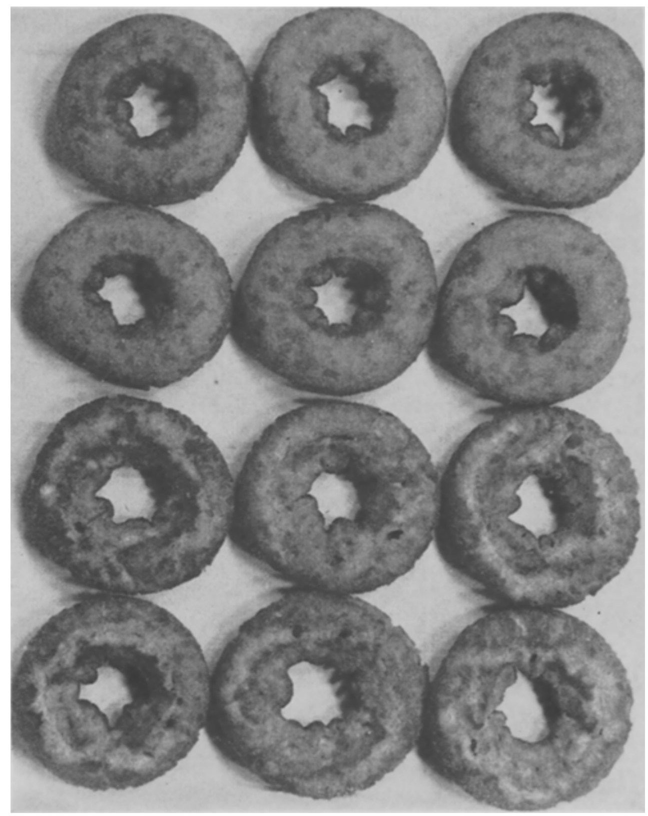

FIG. 1.

Experimental

A hydrogenated commercial soybean shortening was heated at approximately 375°F. until the free fatty acids reached 1.33%. The same starting material was used for frying doughnuts in a Lincoln automatic doughnut machine, with normal fat replacement until the free fatty acids reached 0.74% (control fat). Sixteen dozen doughnuts were fried in each fat sample; fat absorption was determined by recording the weight of fat in the machine before and after frying.

Mixtures of the heated fat and fresh fat, with fat absorptions and iodine values, were prepared to varying fatty acid levels, as shown in Table I.

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TABLE I

Comparison of Fat Absorptions, Percent FFA, I_v of Unused Fat, Heated Fat, and Fat Used for Frying

Sample No.	% FFA	Fat Absorption	Iodine Value
1[a]	0.14	2.06	65.2
2	0.40	2.37	58
3	0.73	2.75	52
4[a]	1.01	2.75	49
5	1.33	2.81	47
Fat prepared by frying	0.74	2.00	61.5
Original fat	0.12	1.50	68.0

[a] Samples 1 to 4 prepared by blending sample 5 with fresh fat.

Results

Figure I shows the results of frying in the undiluted, heated fat, with excessive cracking and spotting of the doughnuts. Such a product would be totally unsalable. Fat absorption is 40% higher than control fat.

Figure II illustrates the doughnut frying process itself with excessive foaming.

Figure III illustrates the same effect after much dilution with fresh fat, corresponding to sample 2 in Table I—still approximately 18% over control in fat absorption.

Figure IV illustrates the control doughnut fried in fat which had reached 0.74% FFA through normal, continuous frying.

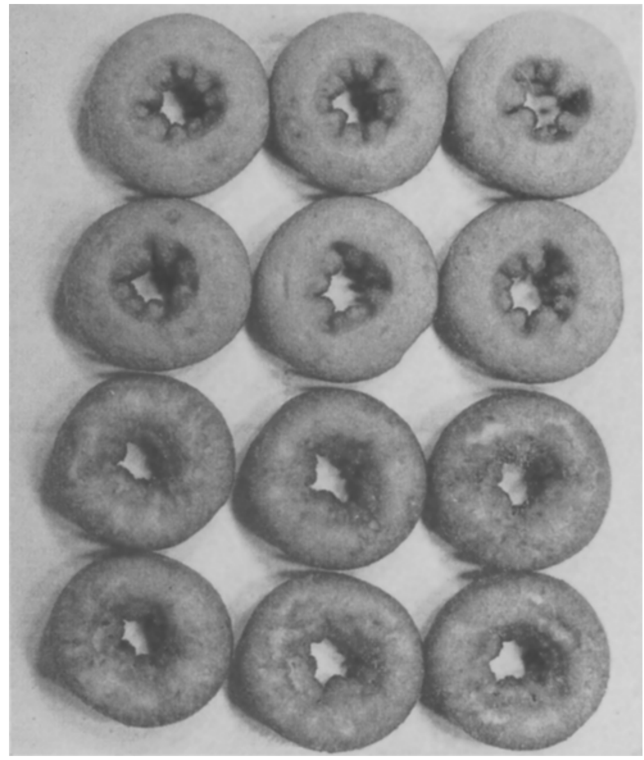

FIG. 3.

FIG. 2.

Discussion

It is quite evident that fat raised to a free fatty acid of 1.33% through simple, open air heating does drastically affect the shape and fat absorption of cake doughnuts.

Control fat reaching .74% FFA in the normal fashion exhibits none of the characteristics observed. Even at lower concentrations the effect of heating the fat is seen.

While commercial frying rarely produces doughnuts similar to those shown, symptoms of the same effect are frequently observed, such as cracking of crust, spottiness of crust, and higher fat absorption than is anticipated from laboratory control results.

Also dilution apparently is not a complete solution to this problem since, even at the .40% FFA level, the same phenomenon is observed.

An investigation of the decomposition products of frying fat and their specific effect on doughnut frying characteristics is certainly indicated from this study. It is not inconceivable that such an investigation could lead to possible methods for preventing the formation of the compounds responsible for this behavior and thus lead to an improved average doughnut frying picture in bakeries.

Variation in Frying Fats

Another problem which often faces the baker is that of variability in the supplied fat, particularly in the case of lard. The suitability of lard as a frying fat is the subject of controversy among doughout operators, particularly as regards fat absorption.

Laboratory frying tests usually do not reveal significant differences in fat absorptions between lard and other fats. However in a 7-month commercial test in 10 large-scale bakeries, covering 56 shipments of lard, the overall fat absorption was increased 8% and, upon return to hydrogenated lard, was correspondingly reduced as shown in Table II.

These figures however reveal some differences in response to this change in fat, with Shop F showing only about a 2½% reduction in fat absorption (a normal variation) as opposed to Shop D showing a 17.2% reduction in fat absorption. An explanation for this variation is illustrated in Table III. The data herewith presented indicates that the relationship between many of these samples is not much more than the labelling.

TABLE II

Fat Absorption Change (as Increase or Decrease From Norm) Expressed as Percent of Norm

Shift From Lard to Hydrogenated Lard			
Shop	April, All Lard	May, Lard and Hydro Lard	June, All Hydro Lard
A	+2.6	−0.7	−3.2
B	+0.6	−2.8	−4.2
C	−1.4	−6.2	−14.4
D	+1.8	−10.4	−14.4
E	−1.4	−14.4	−11.8
F	−12.2	−12.6	−15.0
G	+2.7	−8.5	−9.2
H	−0.7	−6.3	−2.1
I	+3.4	−2.5	−5.7
J	+0.5	−1.1	−3.5

TABLE III

Distribution of F.F.A., Melting Point, I.V.[a] 56 Frying Lard Samples

Free Fatty Acids		Melting Point		Iodine Number	
% F.F.A.	% Samples	°C.	% Samples	I.V.	% Samples
0-0.19	17.8	24.0-27.9	33.4	Below 53.9	13.0
.20-0.39	53.6	28.0-31.9	46.3	54.0-62.9	9.7
.40-0.59	26.8	32.0-35.9	9.3	63.0-68.9	77.3
Over 0.60	1.8	36.0-39.9	11.0		
Range: 0.09-0.69		Range: 24.0-39.0		Range: 52.0-68.0	

[a] Melt point determined through use of the Rask method (unpublished):

The sample is raised to câ 60°C., poured into machined cavity in a copper block, chilled to 0-9°C. A gash is cut in chilled fat disk, and block is permitted to rise in temperature at not more than 2°C./minute initially and at 1°C./minute when nearing melt point. Temperature is read when gash is completely filled with melted fat.

This method yields results câ 0.5-0.8°C. less than Wilĕy (sphere formation).

If temperature is read when fat becomes completely clear, reading will be câ 3°C. higher.

If one were to select lard for frying, graded as such, the characteristics that appear to be coincidental with good frying results are as follows:

FFA—less than 0.40%.
Melt point—95-100°F.(Wiley).
I_v—not less than 63.
Odor—bland, to slightly meaty—not piggy.

To this lard, stearine would be added to raise the melt point in order to avoid sugar yellowing or oiling through.

Frying Fat and Doughnut Coatings

Frying fat plays a critical role in the extent of adhesion and stability of doughnut coating sugars and glazes. Consumer acceptance of packaged cake doughnuts is dependent on the whiteness and smoothness of the applied coating. It has been established that low melt and congeal points, or low melt fractions, are responsible for frying fat damage to sugar coatings. The contact between frying fat and sugar takes place not only in the finished package but in the sugaring machine as well, where fat transfer to the coating sugar alters its properties. Brittle, high melt fats are known to reduce sugar adhesion and thus affect the stability of the sugar to aqueous solution. This problem, while in terms of cost is not as significant as fat absorption, nevertheless can be quite significant in terms of lost markets.

To the knowledge of the authors, the design of frying fats as a coating base for sugar, particularly with lower-priced fats, has not been the subject of much investigation. This is a major problem for those interested in frying technology.

Sugar glaze, which is usually applied to yeast raised doughnuts, sometimes exhibits a tendency to

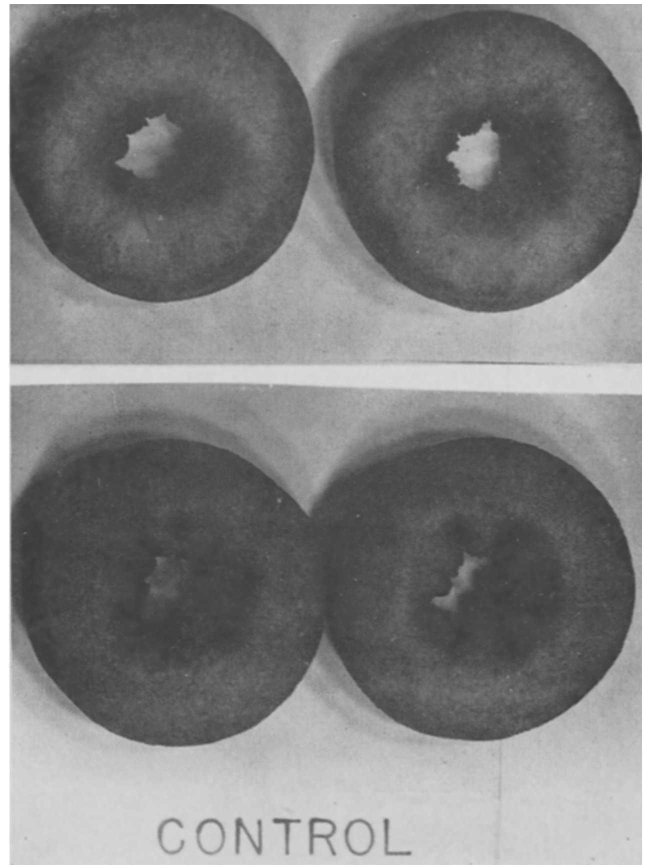

FIG. 4.

run off the doughnut with no adhesion whatever. From a purely empirical standpoint this problem has been corrected by replacing the fat in the fryer. The fat on the exterior of such doughnuts feels "tacky," but shows no deviation from normal in melt point, congeal point, I_v, surface tension, or interfacial tension with water.

This is an interesting problem, though not a particularly prevalent one.

Flavor

The major flavor contribution that a fat can make to doughnut flavor is probably nothing at all. However operators frequently encounter rancid or reverted flavors in their fried product. To establish the possibility of obtaining bland, neutral fat flavor in commercial production, the following test was performed. Fat was procured from a continuous frying kettle at a doughnut bakery. Simultaneously, the unused fat of the same source (hydrogenated soy oil) was likewise sampled. An identical doughnut mix was fried in each fat. One hundred people were sampled with one doughnut from each fat, labelled Y and Z. The taster was requested to record his answer to the question: "Which doughnut do you prefer?" Thirty-eight people preferred the doughnut fried in fresh fat and 40 in commercial fryer fat; 22 indicated no preference.

This seems to establish that it is possible to obtain fresh fat flavor in commercial frying, but it is nevertheless known that this is not always so. There exists a need for a simple test to determine whether a fat is acceptable for frying or not, from a flavor standpoint. Careful operators quite successfully control this through organoleptic means; however a more objective means, based upon detection of offending compounds, might be more useful.

Stability of Fried Product

In the case of yeast raised and cake doughnuts we are concerned with retention of moistness in the product. It has been observed that there is variation in effect of fat on this property. While this has not been studied carefully, it appears that fats with low melt point fractions, such as lard, do exert a greater effect upon moisture retention than other fats. This, while not a real problem, is an element to consider in frying fat investigations.

Summary

The user of frying fats must consider a number of elements in choosing the fat to be utilized. The relationships between fat composition and these factors appear not to be clearly known. Much can be contributed to frying technology through work in the field of fat composition and its relationship to quality frying factors.

Acknowledgment

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Effect of Heat on Solvent-Extracted Soybean Oil Meal

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ALTHOUGH all commercial methods of extracting oil from soybeans involve the application of some heat, the effect of this heat on the soybean oil meal protein is not well known. Since over 98% of the soybean oil meal produced in this country in the last three years was used as a protein supplement in livestock and poultry feeds (14), it is important to both the processors and consumers that it be given the proper heat treatment to obtain maximum nutritional value. Just what constitutes this optimum heat treatment is not known, but reports of feeding studies indicate that certain chemical characteristics of soybean oil meal may be correlated with its nutritional value when used in feeding chicks. While there is no indication that these correlations apply to other animals than chickens, it has seemed desirable to study the effect of heat on these chemical characteristics.

Commercial Processing

While in general the heat treatment received by the meal in the various solvent extraction processes is similar, the commercial processing data considered in this paper are specifically those from a 25-ton per day plant (Figure 1) of the type described by Sweeney and Arnold (13). All of the experimental results were obtained with trichloroethylene-extracted meal.

The first application of heat was the "tempering" treatment given to the cracked soybeans to render them plastic for flaking. Since the beans were not heated over 160°F. and for not more than 5 to 10 minutes, this tempering had little effect on the final characteristics of the meal. The same could be said for the slight heating the flaked beans underwent during the extraction where the retention time was 30 minutes and the highest temperature 135°F. The third heat treatment occurred in the desolventizers or dry-

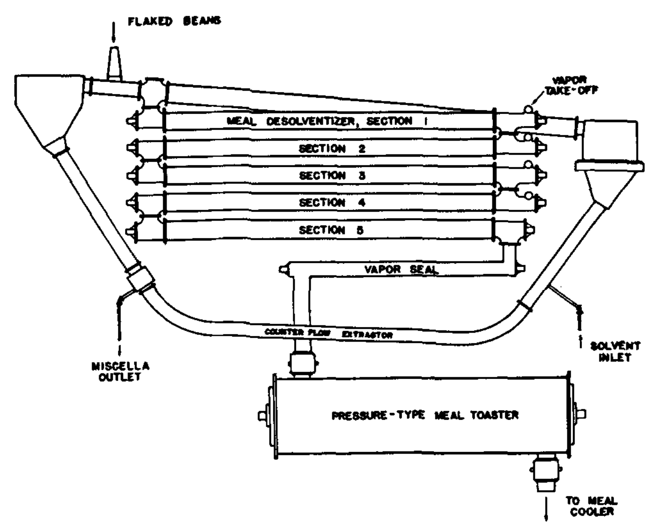

FIG. 1. Schematic flowsheet of commercial unit.

ers, which together with the extracting and toasting portions of the plant are shown in Figure 1.

The extractor was essentially a loop of 12-inch pipe about 20 feet high and 45 feet long through which the flaked beans were slowly conveyed by means of a continuous chain conveyor. The solvent entered the extractor at the opposite end to the flakes and flowed through the flakes counter-currently, emerging as a miscella at a point in the extractor loop below the flake entrance. The extracted flakes were carried up and out of the solvent into the horizontal top run of the loop, which was steam-jacketed to preheat the extracted flakes before they dropped into the desolventizer.

The desolventizer consisted of five steam-jacketed, 12-inch tubes through which the meal was conveyed and agitated by modified ribbon-type screw convey-

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