THE EFFECT OF TWO METHODS OF CARE FOR FAT USED IN DEEP FRYING

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INTRODUCTION

Foods cooked in deep fat have long been generally accepted. The home-sized thermostatically-controlled electric fryer has become a popular appliance. Formerly deep fried foods were obtained principally in commercial restaurants. Now they are among the favored foods prepared at home.

One of the problems encountered in deep fat cookery has been natural development of rancidity in the fat. Chemists working with fats have agreed that rancidity is a predictable change which takes place within the fat molecule under certain conditions. These scientists are further agreed that the development of rancidity may be retarded but not halted.

Various recommendations to retard the development of rancidity have been made for the care of frying fat. In most instances these included filtering and covering the fat, refrigerating it during storage, then replenishing that lost before the next use.

In correspondence with owners of electric fryers, manufacturers found that many homemakers do not follow all, if any, of the recommendations for fat care. Some of these homemakers reported that they kept the fat in the fryer between uses. After repeated fryings, when the fat became sufficiently rancid to affect the flavor of the food cooked, it was discarded.

Extensive investigation has been done on the proper cooking temperature and methods of deep frying necessary to decrease fat absorption in the food. Several studies have been reported on

the characteristics of a good frying fat. However, no work concerned with a comparison of practices for the care of frying fat was found in the literature. The purposes of this investigation were: (1) to determine the effect that two methods of care for fat would have on the usable life of the fat for frying doughnuts, (2) to ascertain the concentration of free fatty acids in the fat at the time unacceptable palatability occurs in the doughnuts, and (3) to observe changes that occur in the fat and the doughnuts.

REVIEW OF LITERATURE

Chemical and Physical Properties of Fat

True fats and oils, as defined by Peterson and Strong (1953), are the esters of the trihydroxy alcohol, glycerol, and the higher fatty acids. They limited fats to those which are solid or plastic at 20° C., while oils are liquid at this temperature.[2]

The smoke point of some edible fats and oils, as listed by Vail and Hilton (1943), showed fat, as a class, to have higher smoke points than oils. Hydrogenated vegetable fats showed higher smoke points than the animal fats studied. In testing frying fats for commercial use, Block (1951) found that hydrogenated fats maintained the higher smoke point for a longer period of time than vegetable oils. Shortly before this Kuhrt and Welch (1950) reported that the addition of molecularly distilled monoglycerides lowered the initial smoke point of fat. However, other possible effects of the monoglycerides were not reported in the literature.

Chemical Changes in Fats Used for Deep Frying

Hilditch (1940) stated that fats are relatively inert chemically but that under given conditions certain chemical changes take place, one of which may be rancidity. Heat, light, moisture, and air were given as four important factors in the development of rancidity in fats. Rancidity was defined by Lowe (1943) as the development of any disagreeable odor or flavor in fats and oils. However, in further discussion she limited this definition to apply only to rancidity brought about by oxidative or hydrolytic changes.

The first step in oxidative rancidity was explained by Peterson and Strong (1953) as the addition of hydroperoxides to the carbon atoms adjacent to the double bonds. These hydroperoxides accelerated other changes in the fat such as the development of volatile free fatty acids, aldehydes, and ketones. This type of rancidity is brought about by atmospheric oxygen and is catalyzed by heat, moisture, light, and free fatty acids.

Hydrolytic rancidity according to Markley (1947) is the splitting of fatty acids from the glycerol portion of the molecule. Hydrolytic rancidity in pure fat may be caused by heat and increased at high temperatures. After the process has started, moisture, air, and the free fatty acids present serve as catalysts to accelerate it. Lowe (1943) reported that foreign particles in the fat, such as flour and other foods, appeared to increase the rate of hydrolysis. Morgan and Cozens (1919) found

that fat showed consistent increase in free fatty acids when a standard dough was cooked for three minutes. Heating the fat alone for the same period did not cause as rapid an increase in hydrolysis.

Problems arising from the thermal reactions of deep frying fats were studied by Carlin, et al. (1954). They found that fatty acids increased rapidly with the use of fat. The rate of increase was accelerated after sufficient fat additions were made to equal the original weight of the fat. When this point was reached, nothing was found that would reduce the rate of hydrolysis. It was their recommendation that, after fat additions equalled the original weight of the fat, no more fat be added.

Jamieson (1932) said that there was no known method of halting the development of either hydrolytic or oxidative rancidity in fat and oils. He listed high temperature and the presence of foreign matter, air, and light as the four most important factors in the initial development of rancidity. He further stated that temperatures over the melting point of fat and a high concentration of free fatty acids will catalyze the reaction. He also said that excessive foaming of a fat is visible evidence of rapid hydrolysis. Carlin, et al. (1954) observed that excessive foaming had a close relationship to the development of oxidative rancidity.

Both Bloor (1943) and Markley (1947) observed that when the induction period for the development of free fatty acids had

passed and the fat was in the period of rapid breakdown, objectionable odors developed. These odors were present at low temperatures and increased in intensity as the temperature was elevated. Lowe (1943) attributed some of the disagreeable odors to the breaking of glycerol to form acrolein and water. Objectionable odors were noted by all investigators who worked with fat at elevated temperatures.

Carlin, et al. (1954) found that the breakdown of fat was a complex problem with many interdependent reactions taking place simultaneously and that the separation and identification of cause and effect were impossible. The changes they noted by organoleptic methods were confirmed by the chemical testing for free fatty acids and hydroperoxides.

Factors Affecting Doughnut Acceptability

Methods of making doughnuts of low fat absorption were listed by Denton and Pritchett (1921).[11] They found that fat absorption increased with additional use of the frying fat. Lowe (1943) concurred with this. However, she found that the loss of fat from the kettle was small even though with increased use of fat, there was a deeper penetration of fat into the doughnuts.

One of the characteristics of a fat as given by Bloor (1943) is its insolubility in water. Markley (1947) stated that free fatty acids are more soluble in water than fats due to the increased number of polar groups. This characteristic was given[12] by Duirman, et al. (1948) as a possible cause of the deeper

penetration of broken-down fat into the doughnuts.

Duirman, et al. (1948) reported that doughnuts cooked at 170° C. for three minutes had a higher acceptability than doughnuts cooked at higher temperatures for a shorter period of time. Lowe (1943) pointed out the marked preference given lightly colored doughnuts.

Denton and Pritchett (1921) found that by increasing the proportion of water in doughnut batter, doughnuts with a crisp crust were produced. The increased proportion of water also increased the amount of fat absorbed. Lantz and Carlin (1938) reported a preference for fried foods having an average amount of fat absorption over those with low fat absorption. Block (1951) said that broken-down fat produced foods of higher fat absorption; sometimes going beyond the point of consumer acceptability. He stated further that foods fried at a high temperature for a short time did not have the consumer acceptability of foods fried at a slightly lower temperature for a longer time. The color of the crust and the increased amount of fat absorption with the longer frying were given as reasons for this preference.

Selection of the Fat

The selection of the fat, regardless of the product to be cooked, was considered of prime importance by Block (1952). He described an ideal frying fat as one that was flavorless, odorless, colorless, liquid or plastic at 20° C., resistant to foaming, and that had a high smoke point. Arenson (1950) agreed with

this but further stated that no one fat had all of these desirable characteristics.

According to Lowe (1943) an ideal frying fat should not impart a flavor of its own to the food cooked in it. Even though pure fats are without flavor, the flavor of foods cooked in fat is enhanced.

Care of Frying Fat

To prolong the usable life of fat, Arenson (1950) recommended the filtering of fat between fryings. This was to remove the foreign matter. Block (1951) favored the filtering of frying fat after every one to two hours of use. Arenson (1950) advised that additions be made to the original volume of fat. His study indicated that this practice would increase the life of the frying fat.

Lantz and Carlin (1938) believed that the storing of fats at low temperatures and the exclusion of air are two of the most important means of retarding rancidity development. Lowe (1943) summarized the important factors for prolonging the usable life of frying fat as the exclusion of light and circulating air, and low temperature storage.

MATERIALS AND METHODS OF PROCEDURE

Fat and Its Care

A commercial hydrogenated cottonseed oil was used for the frying fat and was purchased locally in three-pound vacuum

containers. Sufficient fat for the entire investigation was purchased at one time, and care was taken to obtain that processed in the same batch. After purchasing, the fat was stored under refrigeration until used.

Two methods of care for fat between fryings of doughnuts were used in this study. In Method I the fat was filtered, covered, and refrigerated during storage. The fat loss was replenished before the next use. In Method II the fat remained covered in the fryer at laboratory temperature between fryings, and was used without replenishment until the volume was no longer sufficient for frying.

Control of Frying Temperatures of the Fat

A model F4 Dulane Fryrite electric fryer was used for all of the frying. During preliminary work the accuracy of the thermostatic control was checked and the allowable variation in temperature of the fat was determined, when four doughnuts, approximately 30 grams each were being fried. The point on the control dial of the fryer was established when a temperature of 183° to 187° C. was maintained. A centigrade thermometer was suspended into the fat, in the corner of the fryer, one inch from each side of the fryer well, so that the bulb was one inch from the bottom of the fryer. The temperature of the fat in this area registered seven degrees higher than the temperature of the fat at the center of the fryer. However, in order to avoid interference while frying, the thermometer was placed as designated and

remained there throughout the investigation.

By preliminary experimentation it was established that 2800 grams of fat was the maximum load for the fryer. This weight of fat was maintained during the testing for Method I and was the initial weight of fat for Method II. During preliminary work, it was ascertained that 15 to 25 minutes were required to heat the fat to the desired temperature. The time required was directly dependent on the amount of fat and its initial temperature.

Ingredients and Preparation of Doughnut Recipe

A doughnut recipe and the method of mixing were standardized during the preliminary experimentation. The recipe was sufficient for 30 doughnuts of approximately 30 grams each. The recipe used throughout the investigation was:

Ingredients	Weights (g)	Measurements
All-purpose flour	420	3 7/8 cups
Sugar	200	1 cup
Non-fat milk solids	26	2 tablespoons
Eggs	96	2
Baking powder	16	4 teaspoons
Salt	4	2/3 teaspoon
Fat	25	2 tablespoons
Water	250 ml	1 cup + 1 tablespoon
Nutmeg		1/4 teaspoon
Cinnamon		1/4 teaspoon

All ingredients, except the water and spices, were weighed on a torsion balance. The dry ingredients were mixed and sifted twice through a fine sieve. Before weighing, the eggs were mixed with a fork until homogeneous. The fat was weighed, melted, and allowed to cool to 40° C. so that it would be liquid during the mixing. Two hundred and fifty milliliters of fresh tap water were poured into a graduate, and allowed to stand 15 minutes at room temperature; if necessary the volume was corrected. All ingredients, excepting the fat, were at room temperature when mixed.

The eggs, fat, and water were mixed together in a small bowl and whipped for 15 secondswith a rotary egg beater to insure thorough blending. The sifted dry ingredients were placed in the mixing bowl of a model K5 KitchenAid mixer and pushed to the side of the bowl with a rubber spatula. The blended liquid ingredients were poured into the bowl, which was then placed on the mixer, and the ingredients mixed for 15 seconds at the lowest speed. This was followed by 15 seconds of mixing at the highest speed.

Schedule for Experimental Work

The experimental work was divided into a series of three hour periods and, herein, referred to as frying periods. Five dozen doughnuts were fried at each period. Two separate lots of the recipe were required and are designated as lot 1 and lot 2. The schedule of work for each frying period was:

0 to 15 minutes	Preparing fat
15 to 45 minutes	Heating fat to frying temperature, weighing ingredients for lots 1 and 2, mixing lot 1
45 to 90 minutes	Frying lot 1
90 to 100 minutes	Mixing lot 2
100 to 145 minutes	Frying lot 2
145 to 165 minutes	Continuing to heat fat, scoring doughnuts
165 to 180 minutes	Weighing and caring for fat

Method I required nine frying periods and Method II, four. The first testing of each method was designated as A and the second testing as B. Two lots were fried at each period.

Procedure for Frying Doughnuts

After mixing the first recipe the weight of batter was recorded. The batter was poured into a Popseil doughnut maker which was held so that the bottom of it was approximately one inch above the surface of the fat. The batter for four doughnuts was dropped into the fat. After rising to the surface, each doughnut was turned every 30 seconds and removed from the fat after three minutes of cooking. As each doughnut was removed, another was dropped into the fat to replace it. The doughnuts, after removal from the fat, were turned six or seven times on four thicknesses of paper toweling to remove excess fat. They were then transferred to a single thickness of paper toweling and arranged in the order of frying. This procedure was repeated until 30 doughnuts were fried. The weights of the bowl and the

doughnut maker with any remaining batter in them were recorded.

Procedure Following the Frying of Doughnuts

After the completion of doughnut frying, the fat was kept at frying temperature until a total of 120 minutes had elapsed. This included the pre-heating, frying, and post-heating time. As soon as the fryer was disconnected, 25 grams of fat were removed and put into a small screw-top bottle to be used for free fatty acid analysis.

During the heating time the temperature of the fat was recorded at 10-minute intervals. The temperature of the fat during frying varied from 183° to 187° C. In the post-frying period, when no doughnuts were in the fat, the temperature fluctuated between 186° and 190° C.

The last 12 doughnuts fried at each period were set aside to be scored by a committee of six for appearance, odor, texture, and flavor. The score card used is given in Form I, Appendix.

Free Fatty Acid Analysis

The 25-gram samples of fat were frozen and stored until analyzed for free fatty acid content.

Just prior to analyzing, the samples were thawed at room temperature. Ten grams of the fat, 50 grams of anhydrous sodium sulfate, and 80 milliliters of ethylene dichloride were combined in the screw-top container of a Waring Blendor. The mixture was blended for three minutes; then filtered into a 50-milliliter

Erlenmeyer flask. Fifteen milliliters of the ethylene dichloride extract were added to 50 milliliters of neutral 95 percent ethyl alcohol. The alcohol was neutralized after adding three drops of phenophthalein indicator by titrating to a permanent faint pink color with 0.05N sodium hydroxide. The ethylene dichloride extract and alcohol mixture was titrated to a permanent faint pink color with 0.05N sodium hydroxide. Free fatty acids were determined for duplicate aliquots of the extract. The amount of fat in one milliliter of ethylene dichloride extract was determined in duplicate by evaporating the solvent and weighing the residue until constant weight was obtained. The free fatty acid concentration was computed and expressed as milligrams of potassium hydroxide required to neutralize the free fatty acid in one gram of fat.

Procedures for Method I

When caring for the fat by Method I, the liquid fat was ladled and filtered through two thicknesses of cheesecloth into a pre-weighed clean can, which had a tight-fitting cover, immediately after the heating period. The can and fat were weighed and the amount of fat necessary to return the weight to the original 2800 grams was calculated according to the following method:

Weight of fat and can - weight of can = weight of residue fat

2800 grams - weight of residue fat = weight of fat loss.

The weight for the fat loss included the fat lost during frying, the 25-gram sample, and that lost in transfer.

The fat was cooled to room temperature and placed under refrigeration until the next frying period. At the beginning of each period the fat was removed from the refrigerator and placed in the fryer. An amount of new fat, equal to the weight of the fat loss at the previous period, was added before connecting the fryer. This method of fat care was repeated between each frying period.

Procedures for Method II

When Method II was used to care for the fat, 2800 grams of fat were placed in the fryer. At the end of 120 minutes of heating, the fryer was disconnected and 25 grams of fat removed and put in a small screw-top bottle. The cover was placed on the fryer, and the fryer containing the fat stored in the laboratory until the next frying period. The fat was used until the volume was insufficient for further frying. The residue was weighed at the end of the fourth and final period.

RESULTS AND DISCUSSION

Fat and Its Care

Five dozen doughnuts were fried in hydrogenated vegetable fat at each frying period. Two methods of care for the fat between frying periods were used. Method I consisted of filtering and covering the fat, refrigerating it during storage, and

replenishing the fat loss. Method II consisted of leaving the fat in the fryer, covering it, and storing at laboratory temperature between frying periods. No fat replenishments were made and the fat was used until the volume was reduced to such an extent that no further fryings could be done.

The doughnuts, all made from a drop-batter, were formed by the same mechanical apparatus under standard operation procedure. They appeared to be of similar shape and size when dropped into the fat although it was impossible to control completely the weight of each doughnut.

Table 1 gives the total weight of batter fried at each period. The batter weights used in individual frying periods ranged from 1754.2 to 1930.7 or 176.5 grams. The total mean weight of the doughnuts was 30.4 $\pm$ .2 grams.

Fat Losses

When Method I was used the fat loss was calculated at the completion of each frying period. Table 2 shows a range of fat loss from 568.1 to 622.3 grams or 54.2 grams. The mean weight of fat loss for Method I was 597.4 grams. No consistent increase or decrease of fat loss was shown with the increasing hours of fat use.

Twenty-eight hundred grams of fat were used for every four frying periods when Method II for fat care was being tested. The total fat loss for Method II A was 2021.0 grams and for II B, 2003.4 grams (Table 2). The remaining fat in each instance was

Table 1. Batter weights, in grams, for each frying period.

Type of fat care	Frying periods									Total batter weights	Mean doughnut weights
	I	II	III	IV	V	VI	VII	VIII	IX		
Method I	-	-	-	-	-	-	-	-	-	32763.9	30.4
A	1881.2	1792.9	1852.5	1782.5	1851.1	1814.3	1770.4	1866.5	1845.0	16456.4	30.5
B	1807.6	1807.1	1789.0	1837.0	1837.3	1836.4	1779.4	1797.8	1815.9	16307.5	30.2
Method II	-	-	-	-	-	-	-	-	-	14571.1	30.4
A	1794.7	1930.7	1754.2	1821.3	-	-	-	-	-	7300.9	30.4
B	1788.0	1775.3	1881.2	1825.7	-	-	-	-	-	7270.2	30.3
Mean for Methods I and II	-	-	-	-	-	-	-	-	-	-	30.4

Table 2. Fat losses, in grams, for each frying period.

Type of fat care	Frying periods									Total fat loss	Mean loss per frying
	I	II	III	IV	V	VI	VII	VIII	IX		
Method I	-	-	-	-	-	-	-	-	-	10752.7	597.4
A	593.9	619.5	577.9	610.8	568.1	613.7	622.3	588.2	597.8	5392.2	599.1
B	591.1	573.0	618.4	614.3	598.1	583.7	588.0	595.1	598.8	5360.5	595.6
Method II	-	-	-	-	-	-	-	-	-	4024.4	503.0
A	-	-	-	-	-	-	-	-	-	2021.0	505.2
B	-	-	-	-	-	-	-	-	-	2003.4	500.8

insufficient for further frying and standard operating procedures could not be maintained.

Method II showed a mean fat loss per frying period of 503.0 grams. This was 94.4 grams less than the mean fat loss per period for Method I. This difference was less than one-half cup of fat. There was an undetermined loss of fat, possibly due to transferring and filtering of the fat for Method I, which might account for the difference in fat loss.

When Method I A was used to care for the fat, 7594.4 grams of fat were used and 2202.2 grams were discarded after the ninth period. This fat was no longer acceptable for frying. When Method I B was used to care for the fat, a total of 7561.7 grams of fat were used and 2201.2 grams were discarded. It, too, was no longer acceptable for frying. When Method II was used to care for the fat, 772.0 grams of fat were discarded in test A and 796.6 in test B (Table 8, Appendix).

Changes in the Fat

The smoke point of the fat was not determined in this study, but it was noted that the fat smoked while doughnuts were being fried during the last two periods for care of the fat by Method I. Vail and Hilton (1943) found when studying the smoke point of edible fats and oils, that the initial smoke point was lowered with increasing use of the fat.

All reported studies made on frying fats have referred to the progressive darkening of the fat with use. A similar

observation was made during this study. The color of the fat became a deeper tan after each successive frying period. It was noted in the ninth period, when caring for the fat by Method I, that the fat was so dark in color the doughnuts could not be seen when they were at or near the bottom of the frying well. Carlin, et al. (1954) commented on the black char-like deposits which appeared on the fryer well, but no deposits of this nature were noted in the present study.

An undesirable odor from the fat developed after the fourth period when the fat was cared for by Method I and after the second period by Method II. At each successive period the odor became more pronounced and disagreeable. During the final periods for both methods of fat care, the odor, in addition to being disagreeable, was sharp and irritating to the nostrils. One cause of the sharp and irritating odor, as given by Lowe (1943), was the forming of acrolein from the decomposition of glycerol. Hilditch (1940) found that in decomposing fat, the higher fatty acids would break-up into volatile fatty acids, which have disagreeable odors.

Changes in the Doughnuts

Changes were noted in the behavior of the doughnuts as the hours of use for the fat increased. When the fat was fresh, the doughnuts were extremely buoyant in that they rose rapidly to the surface after being dropped into the fat. During the last three periods in that part of the experiment in which Method I was

used to care for the fat, the doughnuts appeared to have lost much of this buoyancy. More time was required for them to rise and they did not appear to float as high on the surface as they did in fresh fat. In these three periods the frying was also accompanied by excessive foaming. Though foaming always was observed in the near vicinity of each doughnut, the foaming present at this time involved the entire volume of fat. An identical observation was reported by Carlin, et al. (1954).

The doughnuts cooked during the first five periods in the part of the experiment using Method I for fat care and in the first two periods using Method II were symmetrical and browned evenly. In subsequent periods there was a progressive increase in the number of misshapen doughnuts fried at each period. These misshapen doughnuts were lopsided and had many bubble-like protuberances, formed by a rupturing of the crust with an outward flow of the fluid batter from the interior of the doughnut. In the final periods, when Method I was used for fat care, less than one-fifth of the doughnuts were symmetrical. Occasionally, the outer or inner edge of a doughnut was darker brown than the rest of the surface. The committee made notations regarding the variation in color and the unsymmetrical shape of the doughnuts from the final frying periods. Their observations concurred with the report made by Block (1951) that doughnuts cooked in broken-down fat exhibited tendencies to be misshapen and to brown irregularly.

Palatability of the Doughnuts

Odor, appearance, flavor, and texture were the factors scored by the palatability committee. Each of the six members judging, scored two of the twelve doughnuts presented. The doughnuts were rated superior, good, average, poor, or unacceptable (Form I, Appendix). Since the doughnuts were prepared and fried by a standard method, the assumption was that variations in the finished product were due to changes in the frying fat.

A total score of 16 points was the highest possible, and zero was the lowest. Superior doughnuts received total scores of 14 or more points, good doughnuts 11 to 13, average doughnuts 7 to 10, poor doughnuts 4 to 6, and unacceptable doughnuts less than four. Accompanying the score card was a sheet listing the characteristics of doughnuts for each of the score levels (Form II, Appendix).

Mean scores of the palatability committee were computed for the doughnuts cooked at each period and are given in Table 3. Here is shown the overall decline in scoring for the individual factors and for total scores for each successive frying period.

The odor of the doughnuts declined with additional use of the fat (Table 3). This overall decline was not always consistent from one period to another. When Method I for care of the fat was used, there was a higher rating for odor of the doughnuts from the second period than from the first. Also, in the eighth period the odor was superior to the seventh. A possible explanation of this increase in score was that the weather had been

Table 3. Mean palatability scores for the doughnuts when two methods of care for frying fat were used. (Highest possible score for individual characteristic, 4.0)

Method	Characteristics	Frying periods I	II	III	IV	V	VI	VII	VIII	IX
I	Odor	3.40	3.45	3.25	2.75	2.60	2.25	2.10	2.25	1.20
	Appearance	3.00	3.15	2.70	2.35	2.05	1.90	1.50	1.70	0.90
	Flavor	3.35	3.15	2.95	2.60	2.50	2.20	1.75	1.60	0.60
	Texture	3.20	2.95	2.70	2.40	2.30	2.05	1.45	1.45	0.50
	Total	12.95	12.70	11.60	10.10	9.45	8.40	6.80	7.00	3.20
II	Odor	3.55	3.00	3.00	2.25	-	-	-	-	-
	Appearance	3.20	2.50	2.15	1.60	-	-	-	-	-
	Flavor	3.35	2.75	2.35	2.00	-	-	-	-	-
	Texture	3.20	2.85	2.65	2.20	-	-	-	-	-
	Total	13.30	11.10	10.15	8.05	-	-	-	-	-

unseasonably hot and dusty for several days prior to a sudden change to cool and rainy. Both times that increase in scoring occurred there had been a quick change. Even with this discrepancy, there was a total overall loss of 2.20 points. The greatest drop between any two periods was between the eighth and ninth when the mean score dropped from 2.25 to 1.20, a loss of 1.05.

When the fat was cared for by Method II, the mean score for odor of doughnuts showed less overall decline and in no case was the score in any period higher than the preceding one (Table 3). However, the scores for odor of doughnuts from the second and third periods were identical. There was a loss of 1.30 points from the first through the fourth periods, and the greatest loss between any two periods, 0.75, was between the third and fourth. The mean score for odor of doughnuts for the fourth and final period, using fat cared for by Method II, was 0.50 lower than that for the fourth period, using fat cared for by Method I, and was identical to that for periods six and eight in which fat was cared for by Method I.

The appearance factor included both external and internal appearance. The score cards from the fourth period using fat cared for by Method II and those from the last four periods, using that cared for by Method I had remarks made by the palatability committee regarding the increased depth of fat penetration into the doughnut. This penetration increased the thickness of the crust and became so pronounced in doughnuts from the ninth

period, in which Method I was used to care for the fat, that the crust was easily peeled from the doughnuts. This hard, fat-soaked crust was one-fourth to one-half inch thick.

Although the decline of the mean score in appearance was greater than that for odor, the pattern was much the same when Method I was used to care for the fat. The total decline for appearance from the first through the ninth periods was 2.10. The greatest loss between any two consecutive periods was between the eighth and ninth with a loss of 0.80.

The mean score for appearance of doughnuts declined with each successive period when Method II was used to care for the fat (Table 3). These scores showed an overall loss of 1.60. The greatest loss was 0.55 which occurred between the third and fourth periods. In the fourth period the mean score was 1.60 which was 0.75 lower than the fourth period when the fat was cared for by Method I. The score of the doughnuts from the fourth period, when using Method II for care of the fat was 0.10 higher than that at the seventh period when fat cared for by Method I was used.

The flavor of the doughnuts declined with each subsequent period when the fat was cared for by Method I (Table 3). These scores dropped 2.75 points from the first through the ninth periods. The greatest drop was between the eighth and ninth periods and was 1.00.

The decline in flavor of doughnuts, as shown by the mean score when Method II was used for care of the fat, dropped from

a high of 3.35 for the first period to a low of 2.00 for the fourth period. This was a loss of 1.35.

The mean score for flavor of doughnuts during the fourth period, when the fat was cared for by Method II, was 0.60 lower than the score for the fourth period, when Method I was used for fat care (Table 3). However, the score of 2.0 was between the scores of the sixth and seventh periods.

The mean palatability scores for texture followed the same pattern as flavor scores for both methods of fat care (Table 3). The loss in points scored from the first through the ninth periods for doughnuts, using Method I to care for the fat, was 2.70 with the greatest loss between the eighth and ninth periods. The mean texture scores of doughnuts for the four testing periods, when using Method II to care for the fat, dropped 1.00. The greatest loss was shown between the third and fourth periods.

Table 3 indicated that no doughnuts received sufficiently high scores to be classed as superior. Upon examining the individual score cards it was revealed that some doughnuts received total scores of 14 and 15, and a few as high as 16 points. One member of the palatability committee scored all doughnuts extremely low for all factors, but was consistent in her scoring. Consequently, the mean scores of doughnuts were lowered from 1.0 to 1.5 points for all periods excepting the ninth, when the fat was cared for by Method I. All members of the committee scored the doughnuts from this period low.

The mean total scores for doughnuts, using fat cared for by Method I, showed a steady decline from one period to the next

until the eighth (Table 3). This period received a 0.20 increase in total score over the seventh period. The drop between the eighth and ninth was 3.80 points. The scores dropped from low-average to unacceptable. In the last three periods for doughnuts, in which Method I was used to care for the fat, all members of the palatability committee rated some doughnuts poor and others unacceptable.

The mean scores for doughnuts, in which Method II was used for care of the fat, showed that all fried were rated as average or good (Table 3). An examination of the individual scores revealed that few poor and no unacceptable doughnuts were produced by this method.

Members of the palatability committee noted the "soapy" taste of doughnuts from the eighth and ninth periods, in which Method I was used to care for the fat. According to these notations the off-flavor became pronounced with doughnuts from the ninth period. The committee also noted that doughnuts from the last three periods, when Method I was used to care for the fat, had a pronounced "fried" taste and were fat-soaked. These doughnuts tended to coat the mouth with fat and sometimes had a bitter after taste.

Development of Free Fatty Acids

The mean free fatty acid value for the fat was computed from samples obtained at each frying period. The values showed a progressive increase in concentration with each additional period (Table 4). The free fatty acid values found in this study were in agreement with the findings of Carlin, et al. (1954) in that

Table 4. Mean free fatty acid values, expressed as milligrams of potassium hydroxide per gram of fat, for each frying period.

Type of fat care	Frying periods								
	I	II	III	IV	V	VI	VII	VIII	IX
Method I	1.625	2.195	3.720	4.060	4.335	5.215	6.630	8.755	13.445
Method II	1.530	2.520	3.985	10.755	-	-	-	-	-

the free fatty acids increased with the use of the fat.

Carlin, et al. (1954) also found that the rate of free fatty acid development was greatly accelerated after sufficient additions of fresh fat to equal the original weight of the fat. This study gave support to such a finding. At the beginning of the sixth period, when the fat was cared for by Method I, almost 3000 grams of fresh fat had been added. It was in the four final periods that the free fatty acid concentration increased rapidly. In the first five periods the increase was slight (Table 4).

The rate of free fatty acid development in the fat, when cared for by Method I, agreed with the findings of other studies. Jamieson (1932) emphasized the need for retarding the initial development and gave low storage temperature, foreign matter, air, and light as important factors to control. These four factors were taken into consideration in caring for the frying fat in Method I of the present study. The replenishments with fresh fat, the filtering and covering, and refrigerated storage doubtless contributed to the retarding of the development of free fatty acids during the first five and possibly six periods (Table 4).

The free fatty acids developed at a more rapid rate during the first three periods of Method II than they did for the first three periods of Method I. The concentration of free fatty acids at the end of the fourth period of Method II almost tripled that shown at the end of the third period (Table 4).

Analysis of Findings

The decline in the scores of the palatability committee and

the rate of increase in free fatty acid concentration for both methods of fat care are shown in Figs. 1 and 2. As the palatability scores declined, the free fatty acid values increased. The last three periods, using fat cared for by Method I, produced low quality doughnuts and it was questionable if the fat was acceptable for use during these periods. The free fatty acid concentration for periods seven and eight of Method I were high, though not as high as the concentration for the fourth period of Method II. The doughnuts from period four of fat cared for by Method II received higher scores than did the doughnuts from periods seven and eight of that cared for by Method I. The complex problems involved in the decomposition of fats have been noted repeatedly by investigators and most recently by Carlin, et al. (1954), who stated that their findings indicated complex problems. In the present study there were indications of changes in the doughnuts that could not be explained by the available data.

The number of comments by the palatability committee regarding the "soapy" flavor of the doughnuts from the last three frying periods, using fat cared for by Method I, suggested that saponification was taking place. According to Kerr and Sorber (1923) certain conditions would cause saponification of fats; such as a high concentration of free fatty acids, the presence of sodium salts, and heat. Though no chemical tests for saponification were made in this study to confirm such a statement, the three conditions were known to be present in the three final periods of frying, using fat cared for by Method I, and in the final period of frying, using fat cared for by Method II. The

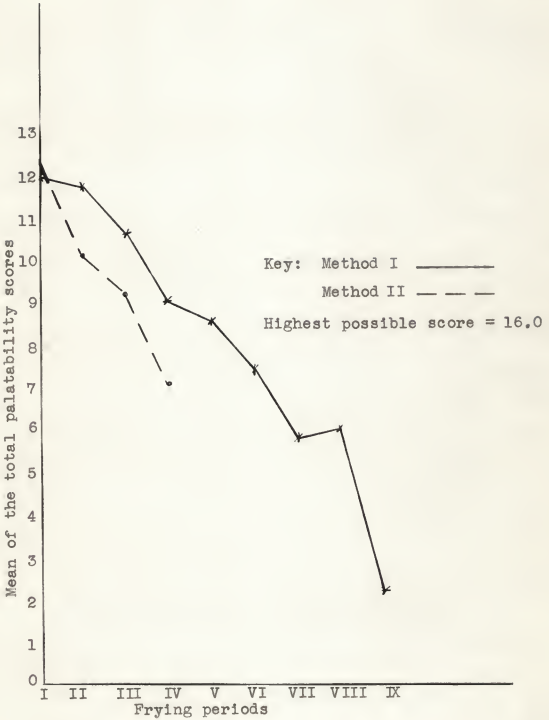

Fig. 1. Mean palatability scores for doughnuts at each frying period.

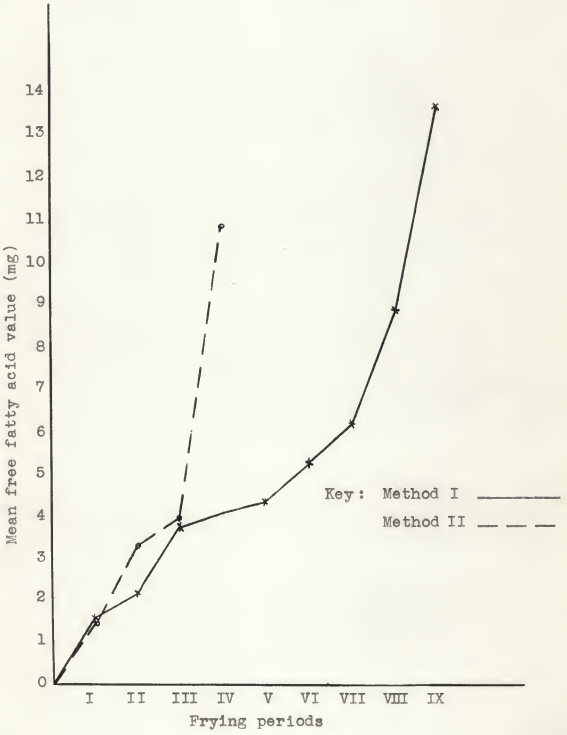

Fig. 2. Mean free fatty acid values, in milligrams of potassium hydroxide per gram of fat, for each frying period.

acceptability of the fat for frying during these periods was questionable because the doughnuts received low palatability scores and had a "soapy" flavor.

As stated earlier, no increase or decrease in fat losses was noted with the increased use of the fat. According to the palatability scores and the comments of the committee, the doughnuts showed deeper penetration of fat with increased use of the frying fat. Seemingly greater fat absorption was taking place, though an increase in fat loss did not occur. This apparently contradictory finding was noted by Lowe (1943) and again by Duirman, et al. (1948). According to Peterson and Strong (1953) soap is a superior wetting agent. It could be assumed from this that a probable cause of the deeper penetration of fat was the formation of soap by the free fatty acids and the sodium salts of the baking powder.

This study showed little difference between the two methods of fat care in respect to the fat requirement per doughnut and/or the palatability of the doughnuts. The available data tended to indicate that the care given the fat in Method I did not increase the life of the fat sufficiently to reduce the fat requirement per doughnut. However, the induction period for free fatty acid development was prolonged by the care given the fat in Method I.

SUMMARY

The effect of two methods of caring for frying fat were investigated. Method I consisted of filtering, covering, and storing under refrigeration between frying periods. The fat loss

from cooking, sampling for chemical test, and transferring was replenished before additional use. In Method II the fat was allowed to remain in the fryer at laboratory temperature between frying periods.

Using a standard procedure, doughnuts were fried in fat cared for by the two methods. In the part of the experiment in which Method I was used to care for the fat, there were nine frying periods. At each frying period two lots of the same doughnut recipe were fried, and the fat was held between 183° and 187° C. for a total of 120 minutes, including preheating and frying times. When the fat was cared for by Method II, two lots of the same doughnut recipe were fried at each of four frying periods and the fat was held between 183° and 187° C. for a total of 120 minutes, including preheating and frying times.

Fat losses for each frying period, using fat cared for by Method I, showed little variation with no increase of fat loss due to increased use of the fat. Fat losses in Method II were comparable to the losses in Method I. Negligible variation in the fat requirement per doughnut, fried by the two methods, was noted.

Foaming of the fat increased with its use and doughnuts fried in the later periods were often misshapen. The fat became darker and developed an undesirable odor which increased with the use of the fat.

The doughnuts were scored for odor, appearance, flavor, and texture by a palatability committee of six members. Doughnuts

fried in fresh fat received higher palatability scores than doughnuts fried in successive periods. The scores of the committee decreased as the use of the fat increased and the decline for all four factors was at much the same rate. None of the doughnuts made, using fat cared for by Method II, received as low a palatability score as the doughnuts fried in the last three periods in which Method I was used in caring for the fat.

Doughnuts, fried in the later periods, when either method of fat care was used, appeared to have deeper penetration of fat which increased with use. However, actual fat losses did not increase and showed no relationship to the apparent increased penetration.

The free fatty acid concentration increased rapidly, after additions of fat totaling 2800 grams were made, when fat was cared for by Method I. Prior to this the development was gradual. When the fat was cared for by Method II, a rapid increase of free fatty acid concentration was found during the fourth and final frying period. There was an inverse relationship between the scores of the palatability committee and the concentration of free fatty acids.

The method of fat care used for Method I seemed to extend the usable life of the fat. Also, the data obtained in this study indicated that the development of rancidity was prolonged sufficiently to double the hours of use of the fat. However, this required over 5000 grams of fat in addition to the original 2800 grams. A total of 45 dozen doughnuts were cooked in the

nine frying periods, using fat cared for by Method I, and samples from the last dozen fried were scored as poor or unacceptable. This might have been an indication that the fat was not acceptable for frying during the last three periods. Twenty dozen doughnuts were fried in the 2800 grams of fat in which Method II was used for care of the fat. These doughnuts received ratings of average or better.

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APPENDIX

APPENDIX I

SCORECARD FOR DOUGHNUTS

Form I

Name	Date			
ODOR				
APPEARANCE				
FLAVOR				
TEXTURE				
TOTAL				

KEY: 4 Superior
3 Good
2 Average
1 Poor
0 Unacceptable

COMMENTS:

APPENDIX II

DOUGHNUT CHARACTERISTICS

Form II

ODOR

SUPERIOR
Pleasing cake-like, spicy, no appreciable odor of fat.

GOOD
Pleasing, cake-like, mild odor of fat.

ACCEPTABLE
Pronounced sweet odor, not objectionable, but a definite "fried" odor.

POOR
Strong "fried" odor.

UNACCEPTABLE
May have burned odor, very pronounced objectionable "fried" odor, may have sharp or stinging sensation to nose.

APPEARANCE

SUPERIOR
Even golden brown, light and fluffy, no trace of fat on surface, very thin crust, no evident penetration of fat beyond crust.

GOOD
Golden brown, light and fluffy, no trace of fat on surface, thin crust, slightly crisp, very slight penetration of fat beyond crust.

ACCEPTABLE
Golden brown, light and fluffy, show some fat on surface, thin crisp crust, slight penetration of fat beyond crust.

POOR
Somewhat golden brown, but darker near hole, may show charred pieces adhering, crisp but thick crust, marked penetration of fat beyond crust.

Form II (concl.).

UNACCEPTABLE
Pronounced fried appearance, charred pieces adhering, uneven browning, thick crust, deep penetration of fat, crust and fat soaked portion can be peeled from center.

FLAVOR

SUPERIOR
Pleasing cake-like, very spicy, no appreciable flavor of fat.

GOOD
Pleasing cake-like, mild flavor of fat.

ACCEPTABLE
Pronounced sweet flavor, not objectionable flavor of fat, but definite "fried" taste.

POOR
No objectionable flavor of fat but pronounced "fried" taste.

UNACCEPTABLE
May taste burned, have objectionable "fried" taste, bitter after taste, or slight astringency.

TEXTURE

SUPERIOR
Cake-like, no appreciable oily feeling in mouth or to finger tips.

GOOD
Cake-like, velvety feeling to mouth or tongue, very slight oily feel.

ACCEPTABLE
Velvety but slight oily feel.

POOR
Greasy, oily feel, very crumbly.

UNACCEPTABLE
Oily enough that it gives a definite coating of fat to mouth and tongue.

Table 5. Palatability scores for the doughnuts when Method I was used to care for frying fat. (Highest possible score for individual characteristic, 4.0)

Method I	Characteristics	Frying periods								
		I	II	III	IV	V	VI	VII	VIII	IX
A	Odor	3.2	3.3	3.5	2.8	2.6	2.3	2.0	2.6	1.2
	Appearance	2.7	2.8	2.8	2.3	2.1	2.0	1.2	2.0	0.8
	Flavor	2.0	2.9	3.2	2.7	2.5	2.5	1.9	1.7	0.5
	Texture	2.8	3.0	3.1	2.4	2.6	2.3	1.3	1.8	0.3
	Total	10.7	12.0	12.6	10.2	9.8	9.1	6.4	8.1	2.8
B	Odor	3.6	3.6	3.0	2.7	2.6	2.2	2.2	1.9	1.2
	Appearance	3.3	3.5	2.6	2.4	2.0	1.8	1.8	1.4	1.0
	Flavor	3.7	3.4	2.7	2.5	2.5	1.9	1.6	1.5	0.7
	Texture	3.6	2.9	2.3	2.2	2.2	1.8	1.6	1.1	0.7
	Total	14.2	13.4	10.6	9.8	9.3	7.7	7.2	5.9	3.6

Table 6. Palatability scores for the doughnuts when Method II was used to care for frying fat. (Highest possible score for individual characteristic, 4.0)

Method II	Characteristics	Frying periods I	II	III	IV
A	Odor	3.4	2.7	2.8	2.5
	Appearance	2.8	2.0	2.0	2.2
	Flavor	3.0	2.3	2.2	2.4
	Texture	3.0	2.5	2.5	2.7
	Total	12.2	9.5	9.5	9.8
B	Odor	3.7	3.3	3.2	2.0
	Appearance	3.6	3.0	2.3	1.0
	Flavor	3.7	3.2	2.5	1.6
	Texture	3.4	3.2	2.8	1.7
	Total	14.4	12.7	10.8	6.3

Table 7. Free fatty acid value, expressed as mg potassium hydroxide, for each frying period.

Type of fat care	Frying periods								
	I	II	III	IV	V	VI	VII	VIII	IX
Method I	1.625	2.195	3.720	4.060	4.335	5.265	6.130	8.755	13.445
A	1.62	2.14	3.75	4.01	4.06	5.15	6.54	8.32	13.37
B	1.63	2.25	3.69	4.11	4.61	5.38	6.72	9.19	13.52
Method II	1.530	3.220	3.985	10.755	-	-	-	-	-
A	1.64	3.75	4.06	11.17	-	-	-	-	-
B	1.42	2.69	3.91	10.34	-	-	-	-	-

Table 8. Fat losses, fat discarded, and total fat used for two methods of care for fat used in deep frying.

Type of care	Fat losses	Fat discarded	Total fat used
Method I			
A	5292.2	2202.2	7594.4
B	5360.5	2201.2	7561.7
Method II			
A	2021.0	779.0	2800.0
B	2003.4	796.6	2800.0

THE EFFECT OF TWO METHODS OF CARE FOR FAT USED IN DEEP FRYING

by

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AN ABSTRACT OF A THESIS

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1954

INTRODUCTION

The purposes of this investigation were: (1) to determine the effect that two methods of care for fat would have on the usable life of the fat for frying doughnuts, (2) to find the concentration of free fatty acids in the fat at the time unacceptable palatability of the doughnuts was noted, and (3) to observe changes that occurred in both the fat and the doughnuts.

EXPERIMENTAL PROCEDURES

The methods of care for the frying fat were designated as Method I and Method II. Method I consisted of filtering, covering, and storing the fat under refrigeration between frying periods. The fat loss from frying, sampling for chemical test, and transferring from one receptacle to another was replenished before additional use. Method II consisted of leaving the fat covered in the fryer at laboratory temperature between frying periods. The procedure for preparation and frying of the doughnuts was the same for both methods of fat care. There were nine periods in the part of the experiment in which Method I was used to care for the fat and four periods in which Method II was used. Each part was carried through twice.

The following data were obtained: temperature of the fat, observations of the physical behavior of the fat and the doughnuts, weight of batter for every five dozen doughnuts cooked, fat losses for each frying period when the fat was cared for by

Method I, total fat losses when Method II was used in caring for the fat, free fatty acid concentration at the close of each frying period, and acceptability of the doughnuts as determined by a palatability committee of six.

RESULTS

Foaming of the fat increased with its additional use and doughnuts fried in the later frying periods were often misshapen and irregularly browned. Furthermore, the fat became darker and developed an undesirable odor which increased with use of the fat.

Doughnuts fried in the later frying periods appeared to have deeper penetration of fat, which increased with added use of the fat. When Method I was used, fat losses did not increase with the use of the fat and showed no relationship to the apparent increased penetration. Both methods required approximately the same amount of fat per doughnut.

Odor, appearance, flavor, and texture were the palatability factors for which the doughnuts were scored. Doughnuts fried in fresh fat received higher palatability scores than doughnuts fried in successive frying periods. The scores of the palatability committee decreased as the use of the fat increased, and all four factors declined at much the same rate.

The free fatty acids developed rapidly, after additions of fat totaling 2800 grams had been made, when the fat was cared for by Method I; but prior to this the development was gradual. When

the fat was cared for by Method II, it showed a rapid increase in concentration of free fatty acid during the fourth and final frying period. There was an inverse relationship between the scores of the palatability committee and the concentration of free fatty acids.

When the fat was cared for by Method I, the induction period for free fatty acid concentration was increased. However, after additions of fat totaling 2800 grams or more were made, the care given the fat appeared to have little effect on the retarding of free fatty acid concentration.

There were some indications in this study that, when the fat was cared for by Method I, the usable life of the fat was not materially increased, but due to insufficient data, generalizations regarding this could not be made.