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Some chemical, physical, and palatability changes in certain fats after prolonged storage

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SOME CHEMICAL, PHYSICAL, AND PALATABILITY CHANGES IN CERTAIN FATS AFTER PROLONGED STORAGE

by

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INTRODUCTION

Fats are rather unstable food materials, subject to physical and chemical changes. Alterations in flavor and odor occur upon storage. Decrease of palatability may be due to absorption of flavors, or to chemical changes in the fat itself. Such changes may be brought about through a variety of conditions; but after the fat reaches the retail market or the home, they may be hastened by poor storage conditions such as high temperature, exposure to air or light, or by heating the fat during cooking processes. Fat may be incorporated in a food which is to be cooked; or fat may be used as a frying medium. A comparison of the work of Masters and Smith (23), Lowe, Nelson and Buchanan (21), Morgan and Cozens (24), and Woodruff and Blunt (31) indicates that the use of fats for frying causes greater breakdown of the fat than occurs in fats incorporated in foods such as pastry; though fat absorbed by food during the process of frying appears to undergo greater change than does the fat in which the food was fried.

Long storage might be expected to result in deleterious effects on flavor and odor of a fat, since rancidity, which occurs sooner or later in nearly all fats, involves flavor and odor deterioration as well as chemical changes. Lea (19) says that "under normal conditions the amount of chemical change necessary to make an edible fat rancid is very small. A perceptible 'off' flavor can be observed in beef-kidney or butter fat when only about one-thousandth part of its substance has undergone chemical change".

Reports in the literature (12) (14) indicate that the chemical changes involved in rancidity, such as development of free fatty acids or the formation of peroxides, might be expected to accelerate further chemical changes such as may take place in a fat during its use in cooking processes. Hilditch (14) says that the progress of oxidation of heated oils is stimulated by the presence of free fatty acids, and still more by oxidation products.

The purposes of this study were to determine (1) the extent of some of the chemical changes in several fats after long storage, (2) the extent and rapidity of these chemical changes during use of the fats for frying doughnuts before and after the storage period, (3) some of the chemical changes which had occurred in fat absorbed by the doughnuts, (4) as nearly as possible the comparative palatability of doughnuts fried in each fat before and after the fats were stored.

REVIEW OF LITERATURE

Studies reported in the literature pertinent to the present investigation deal with (1) the changes in fats during heating or frying; (2) factors affecting the physical characteristics and palatability of doughnuts; (3) the effect of storage on fats.

The Changes in Fats during Heating or Frying

If fats are heated alone, the changes are less marked than if they are used for frying. The reported changes, which take place in different degrees due to a variety of circumstances, are: increase of specific gravity and refractive index; increase of free fatty acids; increase of peroxide content; decrease of iodine number; lowering of the smoking point; darkening of the fat, and palatability changes.

The effect on fat of heat alone, of heat plus evaporation of water from the fat, and of use of the fat for frying purposes have been investigated.

Fulmer and Manchester (11) studied the effect of temperature and time of heating on some of the chemical constants of cottonseed oil. They found that specific gravity and refractive index increased; and iodine number decreased as the temperature of heating increased. Free fatty acids showed no increase when the oil was heated at 180° C or 220° C for 10 or 30 minutes. When heated at 270° C, the increase in free fatty acids was very marked; and was greater for the oil heated

30 minutes than for the oil heated 10 minutes. The free fatty acid content increased from 0.060% to 0.530% when the oil was heated 10 minutes at 270° C and to 0.880% when heated 30 minutes at 270° C. The iodine number was decreased by 1.6 when the oil was heated 30 minutes at 220° C; and by 3.8 when heated 30 minutes at 270° C.

Morgan and Cozens (24) report the chemical changes occurring in fats when heated alone, as compared with fats used for frying a standard dough. They conclude that "fats heated alone for the same length of time as those used for frying show no consistent change in acidity but considerable decrease in iodine number." The fats used for frying showed decreases in iodine number, lowering of melting point, and increases in acidity and refractive index.

Porter, Michaelis and Shay (25) compared the viscosity and free fatty acid content of several fats when heated only; or when heated plus continuous water evaporation. Continuous water evaporation was obtained by introducing measured quantities of water through a pipe which opened at the bottom of the kettle. The most striking result of their work was that free fatty acids formed rapidly when water was evaporated from the fat during heating. The amount of free fatty acid formed was closely related to the amount of water evaporated. A bakery study in which 100 dozen doughnuts per day were fried gave a curve for free fatty acid formation which was very similar to that resulting when water was evaporated in increasing amounts from the test fat. They conclude that "the breaking down of a fat involving the formation of acid is a direct result of a reaction with water at elevated temperatures."

Arenson and Heyl (4) studied fat losses, other than absorption by doughnuts, during frying, using a hydrogenated vegetable shortening. The two possibilities for the loss of fat during frying were the formation of volatile products, and the polymerization of fats and fatty acids. They found that polymer formed to the amount of 0.18% of the total fat used; and volatile materials were collected amounting to 0.09% of the total fat used. The chemical nature of these materials was not stated.

Factors Affecting the Physical Characteristics and Palatability of Doughnuts

Doughnut characteristics and palatability are affected by the kind and proportions of ingredients in the recipe, by handling of the dough, by surface area, by period of standing before frying, by temperature of dough, by the temperature of the fat used for frying, by the length of time of frying, and by the kind of fat used.

The effect of varying the proportions of ingredients in a recipe has been reported in several studies.

McKee (22) found that varying the recipe made a marked difference in the amount of fat taken up during frying. An increase of egg or flour caused a decrease in fat absorption; whereas an increase of sugar or fat caused an increase in fat absorption. McKee points out that an increase of egg caused the dough to become softer, so it was necessary to increase flour to obtain a dough that could be handled.

Denton, Wangel and Pritchett (10) found that the inclusion of egg in the recipe, as compared to an eggless recipe, caused higher fat absorption. They found that the volume of doughnuts was greater, and crust formation was slower when egg was included in the recipe. They found that softer doughs, soft flour, the use of fat in the recipe, increase of sugar in the recipe, the use of milk in place of water, the substitution of corn starch for part of the flour, coarse sugar and roughening of the dough, or cracking of the doughnuts, caused an increase in fat absorption. A decrease in fat absorption occurred if the flour were cooked or mashed potatoes were included as part of the recipe. Allowing the dough to stand for an hour or so caused decreased fat absorption.

Lowe, Nelson and Buchanan (21) studied the frying performance of a large number of fats. The following observations on doughnuts were made: if dough temperature were near 24° C. the doughnuts absorbed more fat, and did not expand as much as if dough temperature were near 26° C. The more the dough was handled (studied by means of rerolls and re-rerolls) the lower the fat absorption. The first doughnuts cooked in a fat were generally more palatable than those cooked after the fat had been used for some time. The observation was made that scores for doughnuts cooked in hydrogenated fats and corn oils were higher than were those for doughnuts cooked in various lards. Fats having high smoking points were more desirable than those having low smoking points since they were more pleasant to use for frying.

There are differences of opinion as to the relation between doughnut characteristics and the chemical constants of the frying fat.

The smoking point of the fat and the per cent of free fatty acids are reported to have a relationship to the amount of fat absorbed by doughnuts. Lowe, Nelson and Buchanan (2) observed a relationship between high smoking point of the frying fat and low fat absorption by doughnuts. Blunt and Feeney (6) studied some of the factors involved in the smoking temperatures of fats. They found that the temperatures at which fats smoke vary with: the acidity of the fat, the size of the surface exposed, and the presence in the fat of finely divided foreign particles. An increase in acidity, an enlarged surface, and the presence of finely divided particles in the fat caused a lowering of the smoking point.

Morgan and Cozens (24) reported a higher fat absorption by a standard dough when the frying fat had a lower content of free fatty acids.

Arenson and Heyl (3) stated that over a range of 0.6% free fatty acid, there was no increase in fat absorption. They found by frying tests on a commercial scale that doughnut quality was higher, particularly in regard to shape, if the frying fat contained certain percentages of free fatty acids. The percentage of free fatty acid which was most desirable differed for different fats: the fully hydrogenated cottonseed shortening required a free fatty acid content of 0.35%, the partially hydrogenated cottonseed shortening required a free fatty acid content of 0.25%, and corn oil and stearin mixtures required a free fatty acid content of 0.1% before they functioned properly in producing high quality doughnuts.

Some of the characteristics of fat extracted from cooked doughnuts and pastry have been reported. Masters and Smith (23) used pastry as the test material to determine whether changes took place in fats during the process of cooking. They found that only in thin, overcooked pastry, did changes take place in the fats. In such cases, they observed a decrease in iodine number, an increase in refractive index and a slight increase in acidity.

Woodruff and Blunt (31) compared some of the chemical constants of fats used for frying with those of fats extracted from the fried foods. They concluded that the fat absorbed by foods during frying underwent greater changes than did the fat in which the food was fried.

Powick (26) studied many of the compounds that had been isolated from rancid fats, noting particularly their odor and their response to the Kreis test. He found that two compounds, nonylic aldehyde and heptylic aldehyde, were largely responsible for the odor of rancid fats. It is probable that such compounds as these, or others found in rancid fats, would affect the flavor of fried foods.

Lowe, et al (21) observed that palatability scores for doughnuts cooked in a fat were generally lower after the fat had been used for frying about eight hours than when the doughnuts were cooked in a fresh sample of the same fat. However, doughnuts cooked in some fats scored higher after the fat had been used about eight hours for frying. It was suggested that undesirable odors originally present in the fat might have volatilized during the heating period.

The Effect of Storage on Fats

According to Hilditch (14) the changes most likely to occur in fats are due to atmospheric oxidation and enzyme action. Enzyme action might be caused by microorganisms or by enzymes present in fatty tissue. Lea (19) says that decomposition by microorganisms can occur only when the necessary moisture, nitrogenous substances and mineral salts are present; whereas atmospheric oxidation occurs spontaneously when any material containing unsaturated fat is exposed to the air. Lipases or lipoxidases which occur in plant or animal tissues are heat labile (19). Even though present in the fat tissue or oil, the processes of rendering or hydrogenation would probably destroy such enzymes.

Greenbank (12) studied the influence on oxidation of fat (butter-fat) during storage, of light, heat, air, several plant pigments, and several free fatty acids. He found that the rate of oxidation of the fat increased under any of the following conditions: the presence of light, moisture, air, heat, free fatty acids or lipochromes. In the presence of air, light was found to be the most powerful accelerator, followed by moisture and heat in the order given. A fat stored in the dark at 0° C retained 64% of its original induction period after three months storage; at 22° C it retained 27% of its original induction period, and at 32° C it retained only 17% of its original induction period after three months storage.

The fatty acids which make up a fat would have an influence on keeping quality. Lea (19) says that fatty acids in general tend to become more reactive towards oxygen as the number of double bonds in the molecule increases. Holm, Greenbank and Deysher (15) found that linoleic acid absorbed oxygen more rapidly than did oleic acid.

Stirton, Turer and Riemenschneider (29) determined that the rate of oxidation of methyl linolenate was very much faster than the rate for methyl linoleate. The rate for methyl linoleate was much faster than that for methyl oleate; whereas the oxidation of methyl stearate was very slow. They found that the rate of oxidation of mixtures of the esters depended on the proportion of the individual esters present.

Lard has been reported by Hilditch (13) to contain unsaturated acids in the following percentages: oleic, 41.3-61.5%; linoleic, 0.8-15.6%; C_{20-22}, 0.9-2.1%. Stirton et al (29) distilled methyl esters of lard, determining the composition to be: saturated compounds, 39.1%; oleic acid, 48.1%; linoleic acid, 12.8%.

Judging from the proportion of unsaturated acids present, lard might be expected to oxidize readily. Though some differences in speed of oxidation have been shown by different lards, lard has been shown to be comparatively unstable (19). Many vegetable oils have been shown to be highly resistant to oxidation because of the presence of naturally occurring antioxidant substances.

The stability of fats may be improved by hydrogenation, the addition of antioxidants, and storage at low temperatures.

Hilditch (14) has pointed out that hydrogenation is selective. If a fat or oil containing a mixture of linoleic and oleic acids is hydrogenated, the linoleic acid will be hydrogenated to oleic acid before an appreciable amount of oleic is hydrogenated to stearic acid. Since linoleic acid is much more subject to oxidation than oleic, a fat such as lard which contains linoleic acid, should be more resistant to oxidative rancidity after hydrogenation. Elaidic acid, an isomer of oleic acid, formed to some extent in processes of hydrogenation, has been shown to be much more resistant to oxidation than oleic acid. Thus, the lessening of linoleic acid as well as the formation of elaidic acid should improve the stability of hydrogenated fats.

Inhibitors of oxidation, designated as antioxidants, may occur naturally in fats or oils, or may be added.

Storage at room temperature, approximately 25° C, would be expected to cause more rapid deterioration of fats than storage at refrigerator temperature (12). Lea (19) has pointed out that the rate of oxidation of a fat exposed to air is increased by raising the temperature and decreased by reducing it. The effect of temperature on the oxidative reaction is of the order usually found for chemical processes; specifically, for fats, the rate of oxidation is approximately doubled for each 10° C rise in temperature.

PROCEDURE

Four fats were selected for a study of their comparative keeping quality and frying performance, and their effect on palatability of doughnuts: a prime steam rendered lard, a hydrogenated shortening, a processed lard (7) identified as G.M.12, and a processed pork fat (7) identified as G.M.U.

The four fats were studied as to (1) some chemical changes during frying of successive batches of doughnuts; (2) some of the chemical characteristics of fats extracted from successive fryings of doughnuts; and (3) the effect of the different fats on palatability of doughnuts in February-March 1942. Fats from the same lots were studied again with emphasis on the same tests in May 1944.

The procedure followed in 1944 was as nearly as possible identical with the procedure followed in 1942.

Before starting the test series, doughnuts were made in a preliminary study until the techniques of mixing, handling, and frying were standardized.

Formula: Doughnuts

A doughnut formula described by Lowe et al (21) was used for all experiments.

Ingredients	Weight or measure
Sugar, fine granulated berry	200 g.
Fat[1]	25 g.
Eggs, fresh shell	96 g.
Flour, general purpose[2]	560 g.
Milk, liquid, whole	244 g.
Baking Powder, tartrate[3]	21 g.
Salt, fine table	4 g.
Nutmeg	1/8 tsp.
Cinnamon	1/8 tsp.

Ingredients

Fats from the same lots were used in both the 1942 test period and in the 1944 test period. The prime steam lard[4] and vegetable shortening[5] were kept under refrigeration during the two-year storage period. The G.M.U. and G.M.12 fats were stored at room temperature during the two-year storage period in accordance with the recommendation of the manufacturer.

All other ingredients except the eggs and milk were ordered in sufficient quantities to last throughout each test period, but no ingredients other than the fats were carried over from 1942 to 1944. In each period, flour and sugar were stored in large, tightly covered cans in the laboratory. All ingredients except the eggs and milk were incubated overnight. Incubation temperatures for the 1942 series ranged from 24.5 to 25.0° C. Ingredients used in the 1944 series were incubated at temperatures ranging from 25.0 to 28.0° C, with most temperatures from 26.0 to 27.0° C. Ingredients were removed from the incubator

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[1]G.M.U.
[2]Gold Medal
[3]Royal
[4]Armour's Star
[5]Crisco

just before they were used. The eggs, in sufficient quantity for a day's tests, were beaten together and placed in the refrigerator overnight. Before using, the milk and eggs were brought to 25.0° C by placing the container holding them in warm water, and stirring with a thermometer.

Mixing

A method of mixing described by Lowe et al (21) was used.

A three-quart bowl and beater of a KitchenAid were used for mixing the dough. The sugar, salt, and fat were creamed together for one minute, with the beater at medium speed. The egg was poured into the creaming mixture without stopping the machine, and stirring was continued for three minutes at medium speed. The machine was stopped, and approximately one-half the flour mixture (flour, baking-powder, and spices) and one-half the milk were added. Mixing was continued for one minute at slow speed. The machine was stopped, the remaining milk and flour were added and mixed at slow speed for 20 seconds. The machine was stopped, and the dough was again scraped down from the sides of the mixing bowl. Mixing was continued for 15 seconds at slow speed, and the dough was again scraped down from the sides of the bowl. Mixing was continued at slow speed for 10 seconds.

A new mix was prepared for each dozen doughnuts to be fried.

One tablespoon of the flour mixture was reserved for rolling the 12 doughnuts.

Rolling

A method of rolling based on that described by Lowe et al (21) was used.

All the dough was immediately turned out on the board which had been sprinkled with the flour reserved from the flour mixture and rolled lightly by hand into a long, narrow strip. Enough dough was cut off this strip for three doughnuts. This was rolled between metal cleats on a metal board. The cleats were 3/8 inch in height. The diameter of the cutter was 2 1/4 inches, with a center hole of 1 inch.

The 12 doughnuts cut from each mix were all first rollings. The six first cut, designated as Lot 1 from a certain batch, were set aside on a weighed paper towel until the second six, designated as Lot II from a given batch, were rolled and cut. They in turn were set aside on a weighed paper towel until the first six doughnuts had been fried. Weighings were made of each lot of six doughnuts on the paper towel before and after cooking.

Frying

A method of frying described by Lowe et al (21) was used.

Round-bottomed, iron kettles having a diameter of 9 3/4 inches were used for frying.

At the beginning of the test period, each fat was melted, and a sample taken for chemical analysis; then 2500 grams of fat were weighed into each kettle.

The fat was heated to 187° C, the first doughnut added, and the temperature then maintained at 185° C. The doughnuts were placed in the fat at 15-second intervals, and kept in order around the edge of the kettle. As soon as each doughnut was placed in the kettle, the one preceding it was turned. At the end of 90 seconds, the doughnut which had been placed in the fat first was turned and the others were turned at 15-second intervals in the same order that they were added to the fat. At the end of 180 seconds the first doughnut was removed from the fat; the others were removed in order at 15-second intervals.

Twelve dozen doughnuts were fried in each fat; and measured samples of the melted fat were collected after frying each dozen doughnuts. These samples were stored in small covered beakers, or in stoppered bottles at temperatures of 2.0-5.0° C; then at -18.0° C, until they could be analyzed for chemical and physical changes.

The order of use of each fat for frying was rotated, in order to equalize any unconscious variation in technique which might coincide with the position of any fat in the series.

During intervals between frying tests, the fats were stored in enamel pitchers and were kept at room temperature.

The total time during which the fats were heated for both test periods (1942 and 1944) was 14 hours and 3 minutes. All the fats were heated the same length of time each day.

Recording of fat absorption

The kettle of fat was weighed before and after frying each lot of six doughnuts and the difference in weight was recorded as the fat absorbed by the doughnuts.

Denton, Wengel and Pritchett (10) showed that the gain in weight of fat by doughnuts, determined by ether extraction, was in very good agreement with the loss in weight of the fat in the kettle.

The change in weight of the doughnuts was due partly to absorption of fat and partly to loss of moisture.

Recording of temperatures

The temperature of the room, incubator and dough directly after mixing were recorded.

Doughnuts for scoring and tests

Doughnuts were cooked in all four fats each day that tests were run. Two lots of six doughnuts from each mix were fried but only the first lot was used for scoring and chemical tests. The first two doughnuts of each dozen cooked in the fat were stored in a refrigerator at 2.0-5.0° C. until the fat could be extracted for chemical and physical tests. The remaining four doughnuts from lot I were used for scoring; each judge being given a half doughnut for this purpose.

Chemical and physical tests

The iodine number, Hanus(5), the free fatty acids (as per cent oleic) (1), and the refractive index (5) were determined on samples of fat taken at the start of each test period (1942 and 1944) and on samples taken after frying each dozen doughnuts. Volatile acids (5) were determined on samples of the prime steam lard taken at the start of the 1944 test period and on samples taken after frying each dozen doughnuts. The smoking point (1) was determined on samples of fat taken at the start of each test period and on samples taken after frying six dozen doughnuts and after frying twelve dozen doughnuts. The stability to oxidation was determined on samples taken at the beginning of each test period by means of the Swift Stability test (18).

The fat was extracted from two of the first lot of each dozen doughnuts, beginning with series no. 7 through 12 in 1942, and series no. 1 through 12 in 1944. The doughnuts to be extracted were dried for 24 hours at 70° C. in an oven maintaining a vacuum of 25 inches. The fat was extracted with distilled petroleum ether for 24 hours using soxhlet extractors. Excess petroleum ether was removed by distillation. Drying of the extracted fat was completed under 25 inch vacuum at 50° C. for 24 hours. The iodine number, the free fatty acid content and the refractive index were determined on the extracted fat. Volatile acids were determined on the 1944 series of fats extracted from doughnuts fried in prime steam lard.

RESULTS

Temperature

1942: The temperature of the incubator was 24.5° to 25.0° C. Room temperature was maintained at 24.5° to 25.0° C with very few exceptions. Dough temperatures ranged from 23.5° to 25.0° C, with most being 24.5° to 25.0° C.

1944: Temperatures of the incubator varied more than in the previous test period, from 25.0° to 28.0°; usually 26.0° to 27.0° C. Room temperatures varied from 24.0° to 27.0° C with nearly all mixes prepared at room temperatures of 25.0° to 26.0° C. Dough temperatures ranged from 25.0° to 27.0° C, with most at 26.0° to 26.5° C. In nearly all cases the temperature of the dough was the same or lower than the average of room and incubator temperature. The list of temperatures of room, incubator and dough which were recorded for each batch are given in the Appendix, Tables 50 and 51.

Characteristics of Fats from Observation

Color

The color of the melted fats varied from almost colorless to deep yellow.

The melted prime steam lard and vegetable shortening were yellow at the beginning of the tests. The melted G.M.U. and G.M.12 fats were almost colorless at the beginning of the tests. After being used 12 times for frying, the melted G.M.12 and G.M.U. fats were still light, although they had developed a yellowish tinge. The other fats had developed a much deeper yellow than their initial color.

Odor

The fats had distinctive odors when heated to frying temperature. The prime steam lard gave off an unpleasant odor during heating. The vegetable shortening did not have a strong odor, but the odor was distinct and was not pleasing. The G.M.U. and G.M.12 fats had some odor at first; neither pleasant nor disagreeable, but rather pungent. After being used two or three times for frying this odor decreased. No unpleasant odor was noticeable at any time. Hilditch (14) mentions the fact that hydrogenated fats frequently acquire unnatural flavors from the absorbent used in clarifying the fat. The odor of the hydrogenated fats might have been due to this cause.

Smoke

Neither the G.M.U. nor G.M.12 fats smoked at the frying temperature used. The prime steam lard and the vegetable shortening smoked the first time they were heated to 185° C; the prime steam lard smoked more profusely each time it was used. The smoke from the vegetable shortening was not as objectionable as that from the prime steam lard.

Foam

All the fats tended to foam a little after being used a few times.

None of the fats foamed badly at any time.

The observations in regard to color of the melted fats, and in regard to odor, smoke and foam of the fats when heated to frying temperature, were the same in 1944 as in 1942.

Fat Absorption

The amount of fat absorbed has been shown to correlate with surface area of doughnuts; the larger the area, the greater the amount of fat absorbed (10).

In the present study the surface area for fat absorption should have been approximately the same for every doughnut, since the dough was always rolled to the same thickness, and the same cutter was used. The amount of fat absorbed by a given number of doughnuts standardized as to surface area should provide a better comparison than would fat absorption by a given weight of doughnuts. Analysis of means of fat absorption was made on the basis of grams of fat absorbed by each mix of twelve doughnuts. The total fat absorbed by all doughnuts fried in a given fat was divided by twenty-four to give the average fat absorption of six doughnuts. This is the average fat absorption given in table 1.

The mean differences between grams of fat absorbed by doughnuts fried in the different fats were small. Doughnuts fried in the prime steam lard, which had highest fat absorption averaged only 2.2 g. of fat per six doughnuts higher than those fried in the vegetable shortening, which gave lowest fat absorption. The differences were consistent.

Table 1. FAT ABSORPTION, 1942 - Significance of mean differences between grams of fat absorbed per six doughnuts fried in the different fats

	Fat	Fat	Vegetable shortening	G.M.12	G.M.U.	Prime steam lard
			Lowest absorption →			Highest absorption
		g. of fat absorbed	49.1	49.8	50.8	51.3
Highest absorption	Prime steam lard	51.3	2.2**	1.5**	0.5	
↓	G.M.U.	50.8	1.7**	1.0*		
	G.M.12	49.8	0.7			
Lowest absorption	Vegetable shortening	49.1				

**highly significant
*significant

Table 2. FAT ABSORPTION, 1944 - Significance of mean differences* between grams of fat absorbed per six doughnuts fried in the different fats

	Fat	Fat	G.M.U.	G.M.12	Prime steam lard	Vegetable shortening
			Lowest absorption →			Highest absorption
		g. of fat absorbed	45.3	46.4	46.8	46.9
Highest absorption	Vegetable shortening	46.9	1.6	0.5	0.1	
↓	Prime steam lard	46.8	1.5	0.4		
	G.M.12	46.4	1.1			
Lowest absorption	G.M.U.	45.3				

*differences are not significant

In 1944, as in 1942, the mean differences between grams of fat absorbed by doughnuts fried in the different fats were small. The position of the fats with relation to each other is changed, since in 1942 doughnuts fried in the vegetable shortening showed lowest fat absorption, whereas those fried in G.M.U. fat showed almost as high fat absorption as did those fried in the prime steam lard. In 1944 doughnuts fried in the vegetable shortening and in the prime steam lard showed highest fat absorption, and those fried in G.M.U. showed the lowest absorption. The difference was slight, being 1.56 g. per six doughnuts. Analysis of means in 1944 showed no significant difference in fat absorption between fats. As a matter of interest, the per cent of fat absorbed on the basis of cooked weight and on the basis of raw weight are given in table 3. On the basis of cooked weight nearly one-fourth of the weight of the doughnuts was absorbed fat.

In 1942, the fat absorbed on the basis of uncooked weight, ranged from 28.1 to 29.4 per cent; and on the cooked weight from 23.9 to 24.8 per cent. In 1944, the fat absorbed on the basis of uncooked weight, ranged from 26.7 to 27.7 per cent; and on the cooked weight from 23.3 to 24.1 per cent.

Analysis of variance showed no significant relationship between fat absorption and free fatty acid content of the fats in which the doughnuts were fried, either in the 1942 series or in the 1944 series.

Detailed data on fat absorption are given in the <u>Appendix</u>, tables 20-28.

Table 3. FAT ABSORPTION - Weight of Doughnuts Before and After Cooking, with Total Fat Absorbed by All Doughnuts

Fat	Wt. of doughnuts before frying	Wt. of doughnuts after frying	Fat absorbed		
			grams	per cent	
				Uncooked weight	Cooked weight
	grams	grams			
1942 Series					
G.M.U.	4184.0	4962.5	1219.5	29.1	24.5
Vegetable shortening	4197.1	4921.1	1178.5	28.1	23.9
Prime steam lard	4195.1	4966.1	1232.0	29.4	24.8
G.M.12	4196.3	4942.3	1194.0	28.4	24.1
1944 Series					
G.M.U.	4078.8	4665.3	1087.0	26.7	23.3
Vegetable shortening	4064.3	4665.8	1124.5	27.7	24.1
Prime steam lard	4064.8	4657.3	1124.0	27.7	24.1
G.M.12	2081.3	4679.6	1114.5	27.3	23.8

Chemical and Physical Constants of the Fats

Stability test

The chemical compounds which cause rancid odor and flavor in animal fats have not been positively identified, though oxidation of fats seems to correlate with the flavor changes involved in rancidity (19) (26) (28). For this reason the initial oxidation of the fats and their resistance to oxidation are of interest.

A comparison of the rates of oxidation of the fats used in this study was made by means of the Swift stability test (18). The number of hours of heating at a temperature of 98.0° C with aeration at a rate of 2.33 cc of air per second required to bring about a peroxide value equal to 20 me of peroxide per 1000 g. of fat is taken as the point of inception of rancidity for the different fats. This is an arbitrary point, which is recognized as being more applicable to lards than to other fats. It is, nevertheless, rather commonly used as a reference point for rancidity.

Table 4. Period of Incubation in Swift Stability Apparatus Required to Produce a Peroxide Value of 20 me. per 1000 g. of Fat

Fat	1942	1944
	hrs	hrs
G.M.U.	30.5	0.0 (original value, 24.8 me)
Vegetable shortening	31.0	27.5
Prime steam lard	0.0 (original sample rancid)	0.0 (original value, 27.5 me)
G.M.12	33.5	0.0 (original value, 36.1 me)

As has been previously stated, the prime steam lard and the vegetable shortening were stored at a temperature close to 2° C (35° F ± 1° F) whereas the G.M.U. and G.M.12 fats were stored at room temperature, usually 25° C, or somewhat higher, for the storage period of more than two years. Since the fats had been received in October 1941, the total storage period up to the 1944 test period was two and one-half years.

The oxidation of fats is accelerated by increases of temperature. Lea (19) has stated that the speed of oxidation is approximately doubled with each 10° C rise in temperature.

Although the stored fats all showed higher peroxide values than did the same fats two years before, there was no rancid odor or taste in the stored G.M. fats. For this reason, they were subjected to aeration and heating as mentioned above until a rancid odor could be detected.

G.M.U. had a rancid odor after 14 hours of incubation, when the peroxide value was 80.1 me/1000 g. fat. G.M.12 had a rancid odor after 12 hours of incubation at 98.0° C, when the peroxide value was 100.9 me/1000 g. of fat. These values correspond rather closely to the peroxide level of 100 me/1000 g. of fat suggested as the point of inception of rancidity in hydrogenated fats by the Committee on Analysis of Commercial Fats and Oils (27).

The vegetable shortening was very stable even after the long period of storage. No rancid odor could be detected until the thirtieth hour of incubation. At this time the peroxide value was 25.9 me/1000 g. fat.

<u>Free fatty acids</u>

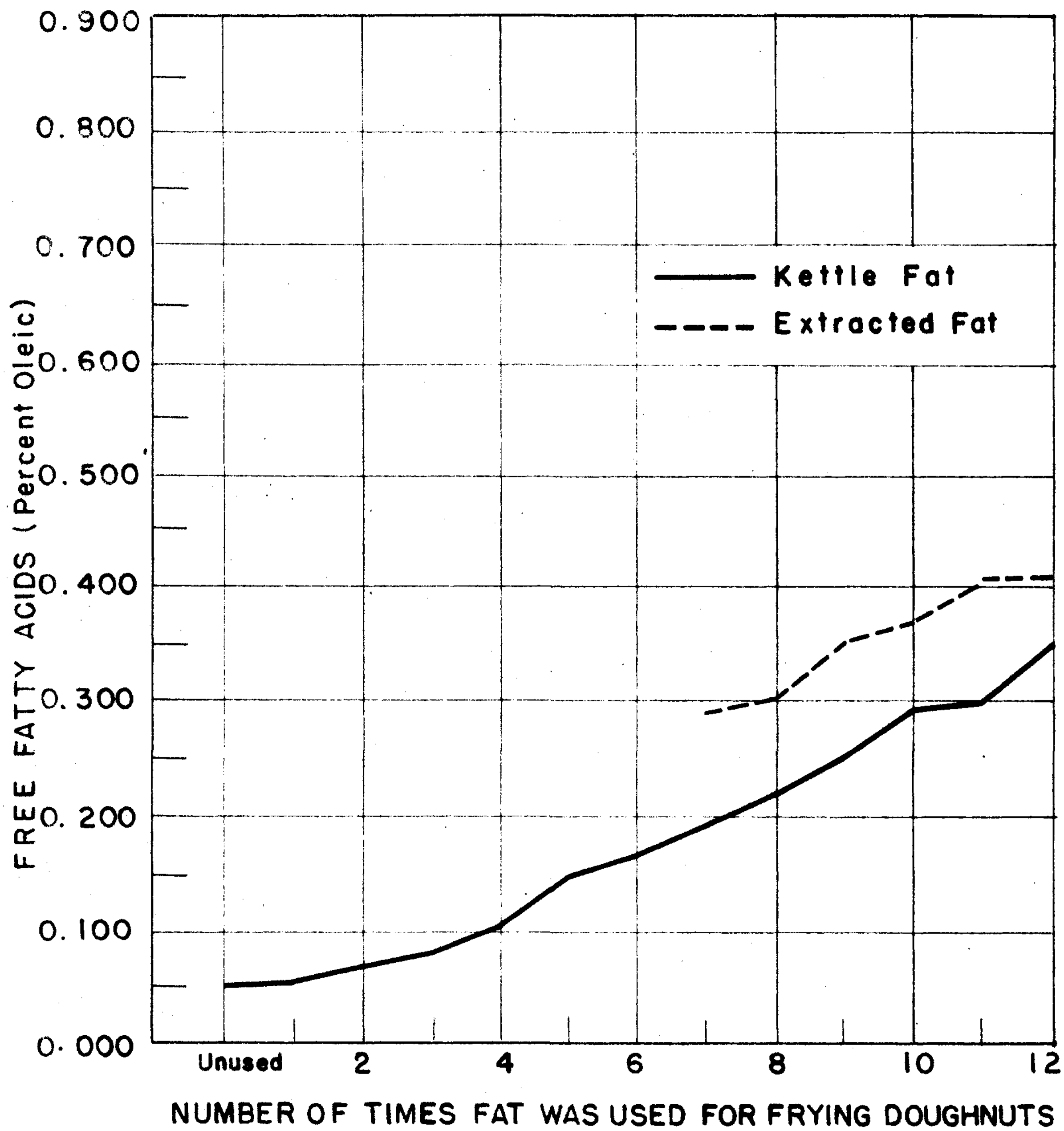
The fats differed from each other in original free fatty acid content, although the G.M.U. and G.M.12 fats were very similar. Of the unused fats the prime steam rendered lard had the highest value, both in 1942 and in 1944.

The initial free fatty acid content of the fats in 1942 was similar to the content of the same fats after the storage period of more than two years, except for the prime steam lard, which showed a definite increase after storage. (Table 5 and the Appendix Tables 29-32)

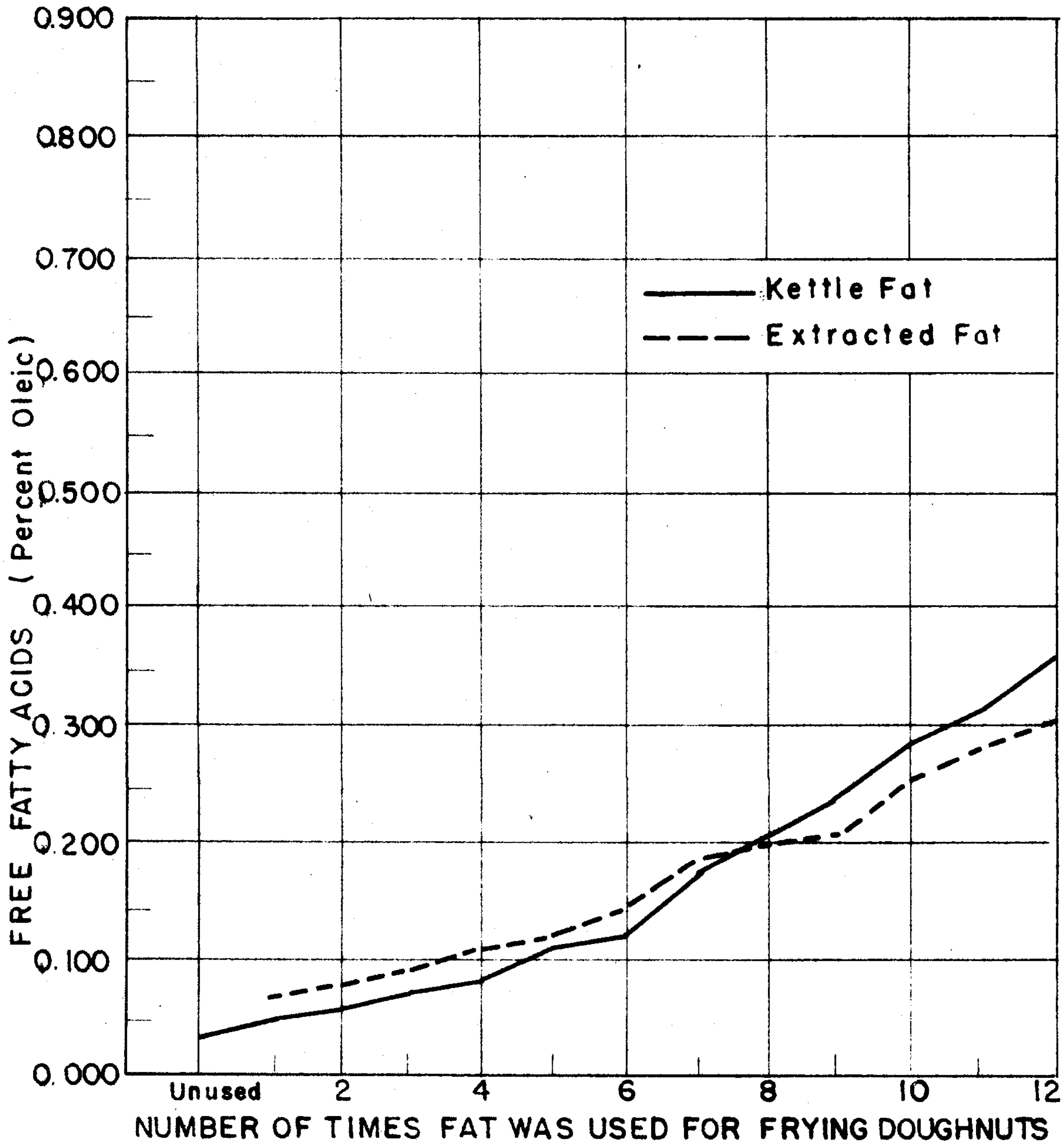
Free fatty acids of kettle fats

The free fatty acid content of the fats showed a definite upward trend as successive batches of doughnuts were fried. The marked tendency for free fatty acids to increase as the fat was used is shown in graphs 1 through 8 and in the Appendix tables 29 and 31. The irregularities in the free fatty acid curves may be due to breakdown of the more unsaturated free fatty acids to form volatile products or to polymerization (3).

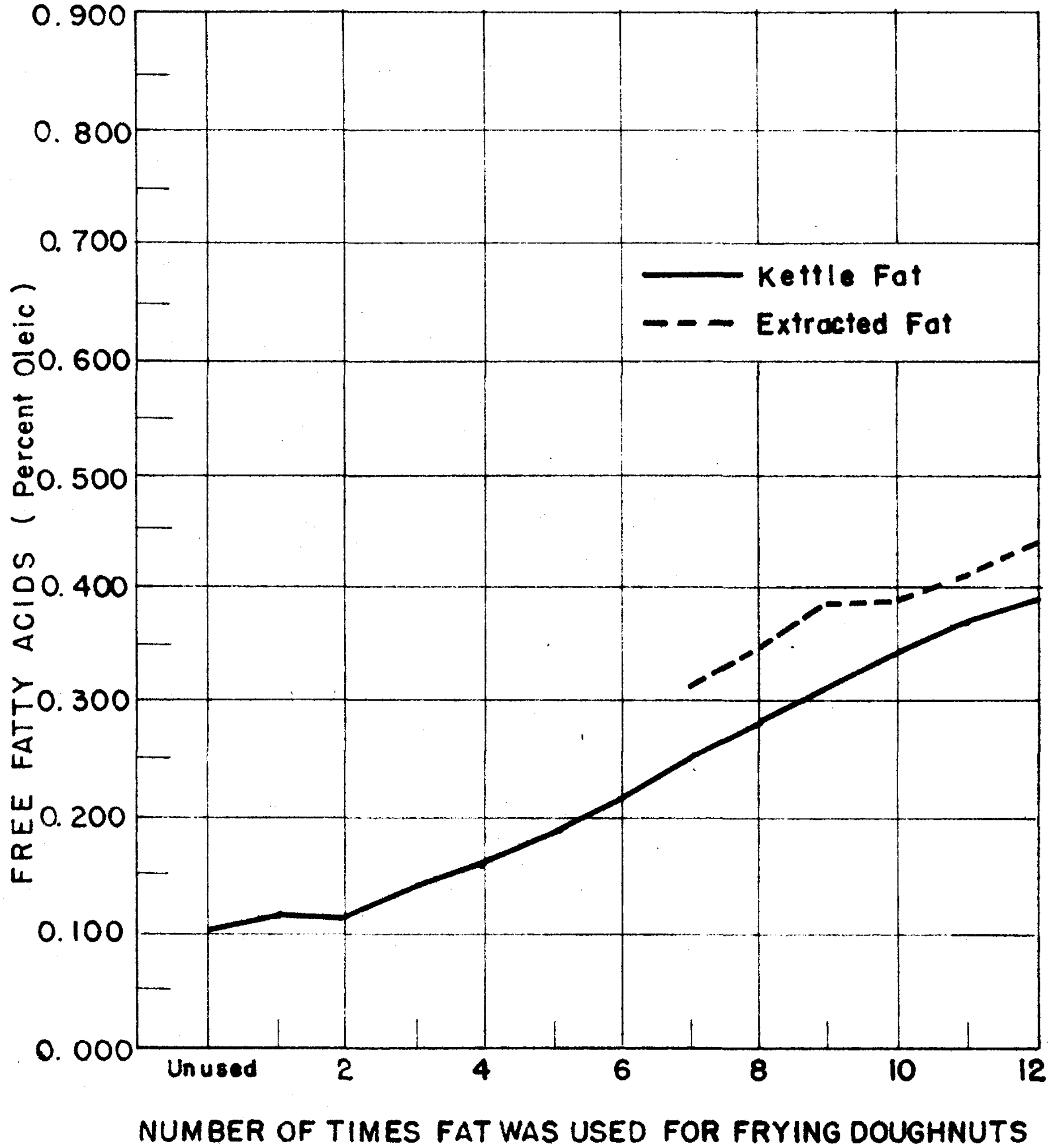
After twelve dozen doughnuts had been fried the free fatty acid contents of different fats in the 1942 series ranged from 1.3 to 9.7 times greater than the initial values. In the 1944 series, the free fatty acid contents ranged from 1.4 to 13.7 times the initial values. The increases in free fatty acids were similar in the two years. The prime steam rendered lard had the highest initial value, and also the highest value after being used for frying, both in 1942 and in 1944. Although the initial free fatty acid content of the prime steam lard was high, the free fatty acid content at the end of the frying period was only 1.3-1.4 times greater than at the beginning. The increase in free fatty acids during frying was much greater in fats having a low initial value. G.M.12, with the lowest initial content showed an increase in free fatty acid of 13.7 times (1944). The extent to which free fatty acids increased in the different fats after being used for frying twelve dozen doughnuts is shown in table 5.



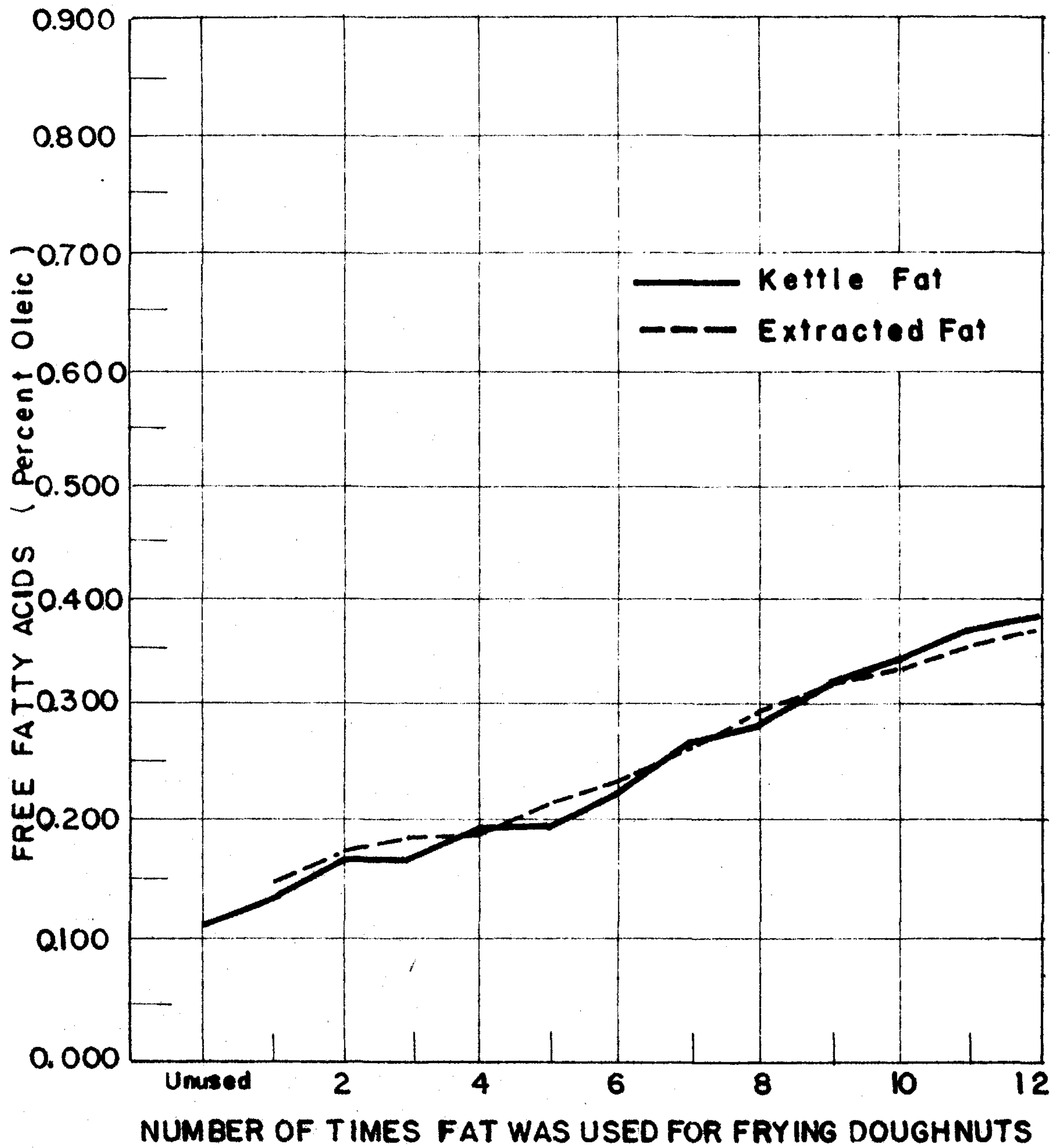
Graph I. Fat, GMU, 1942. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



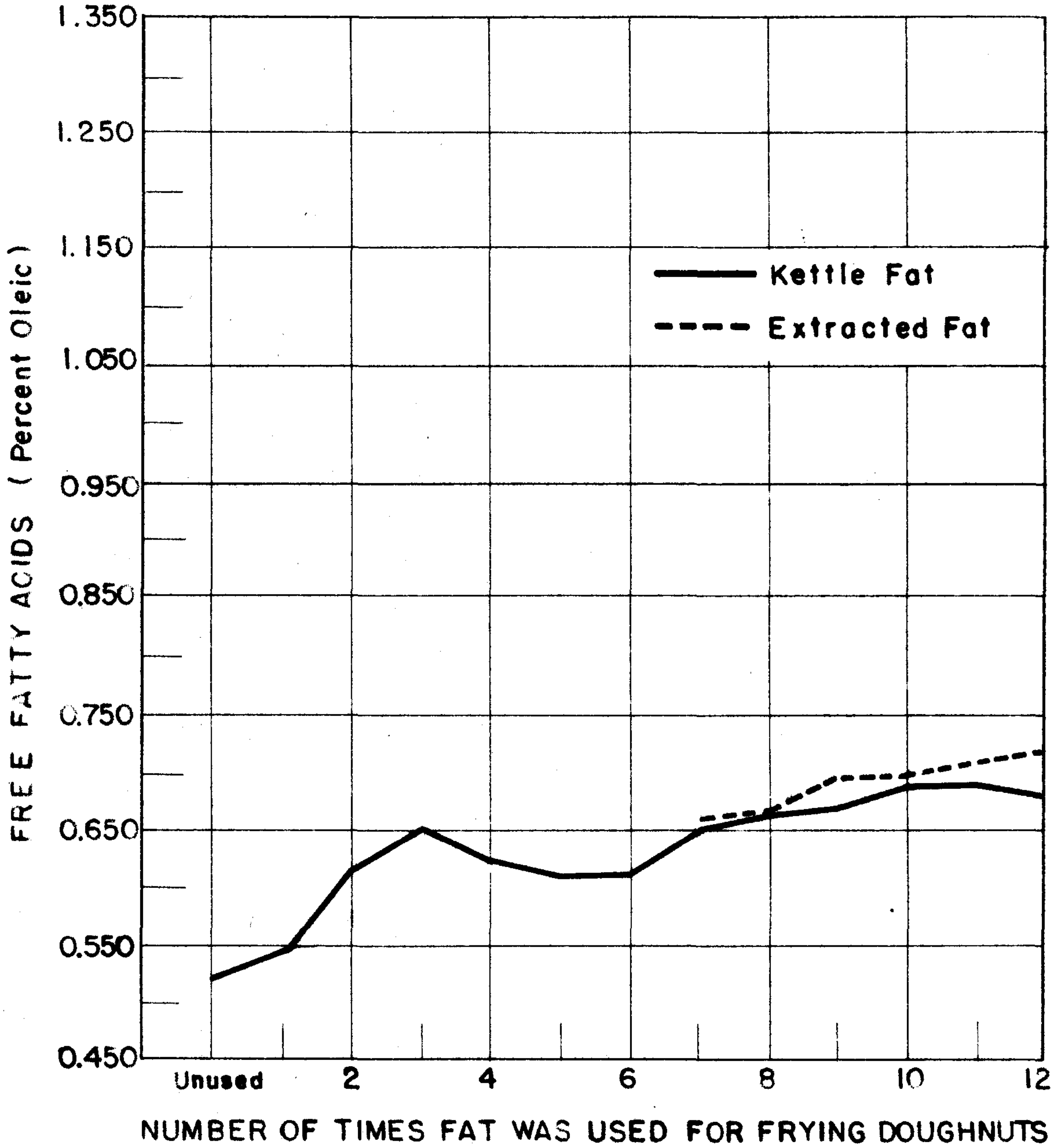
Graph 2. Fat, GMU, 1944. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



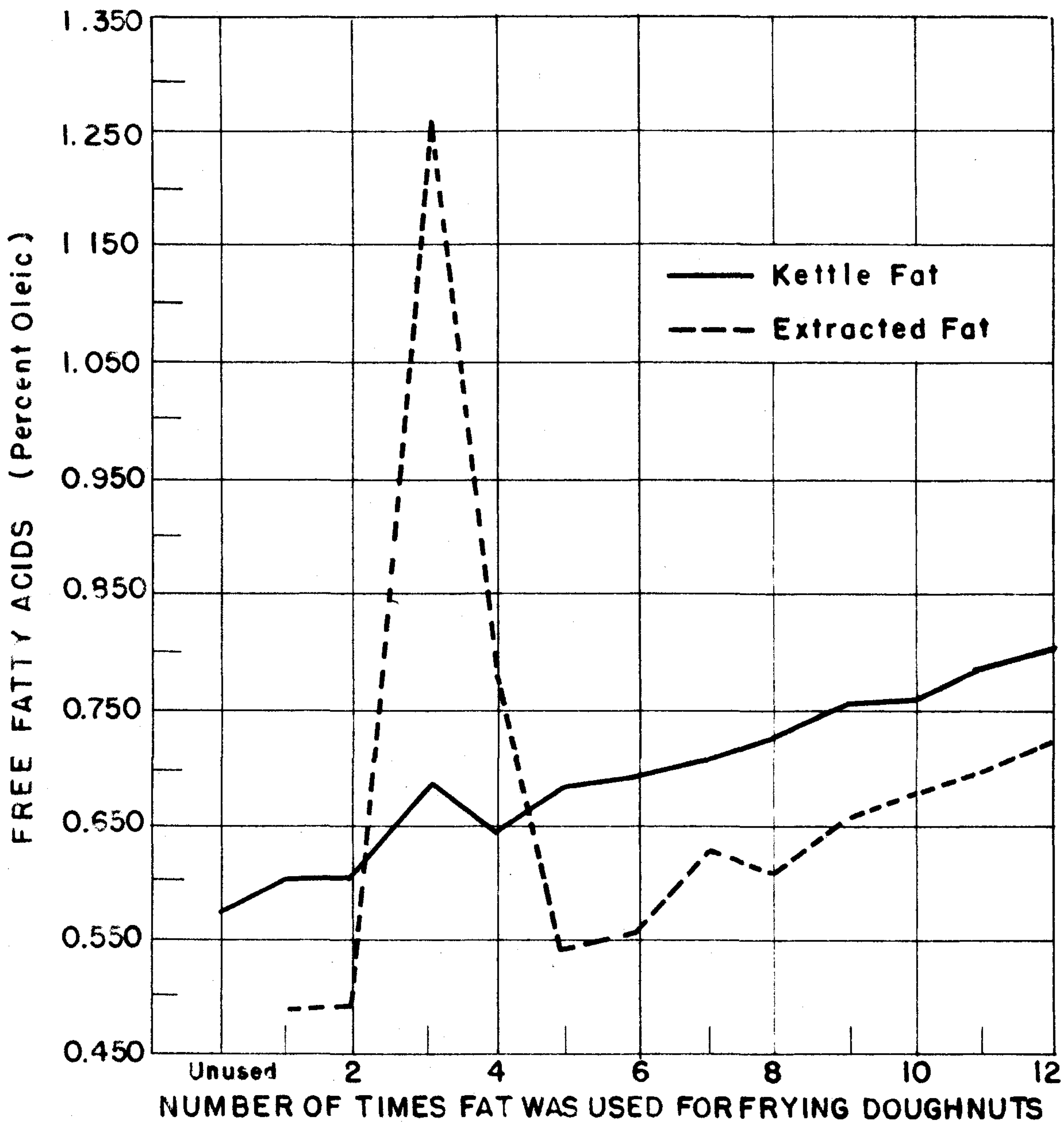
Graph 3. Fat, VEGETABLE SHORTENING, 1942. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



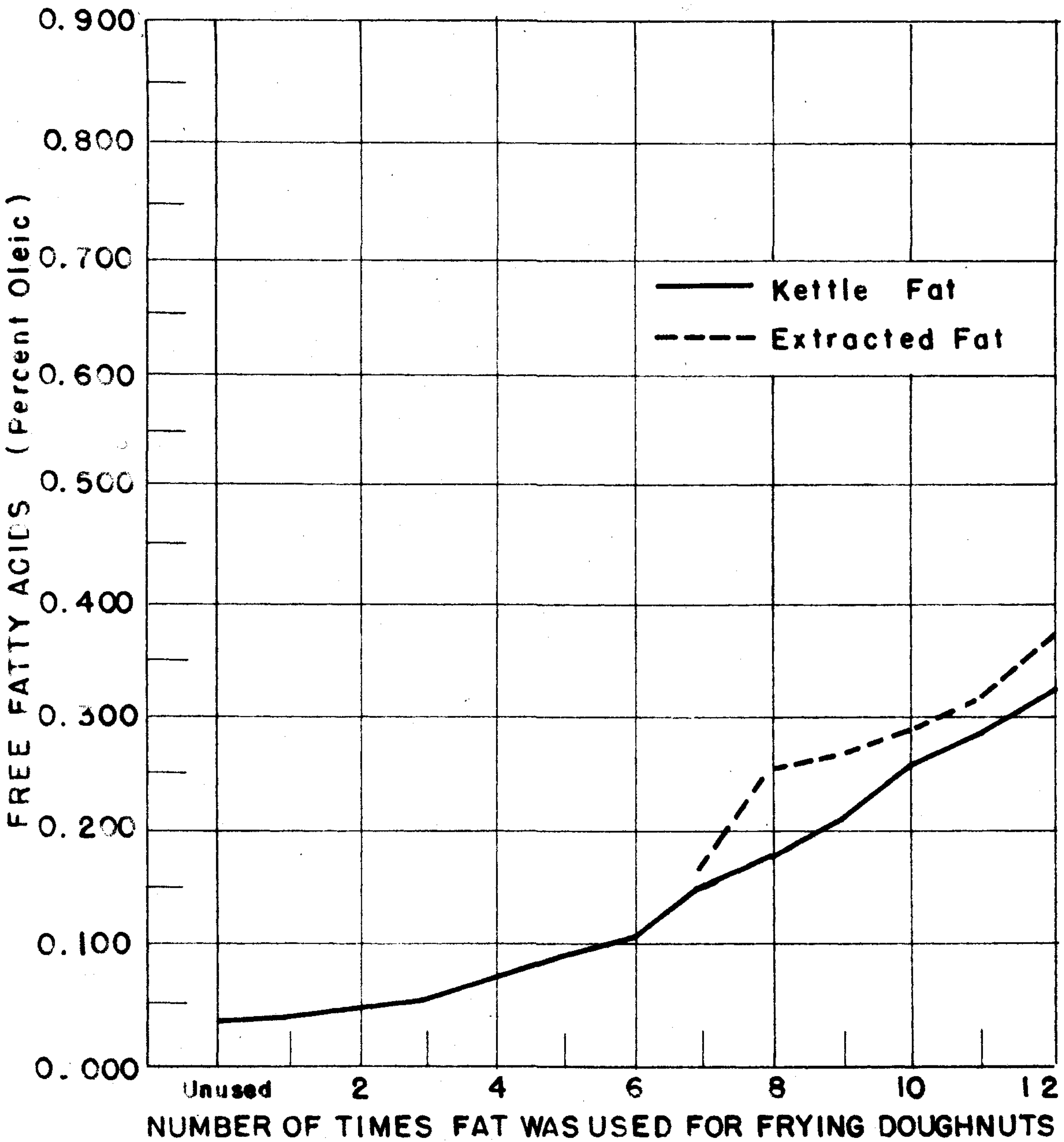
Graph 4. Fat, VEGETABLE SHORTENING, 1944. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



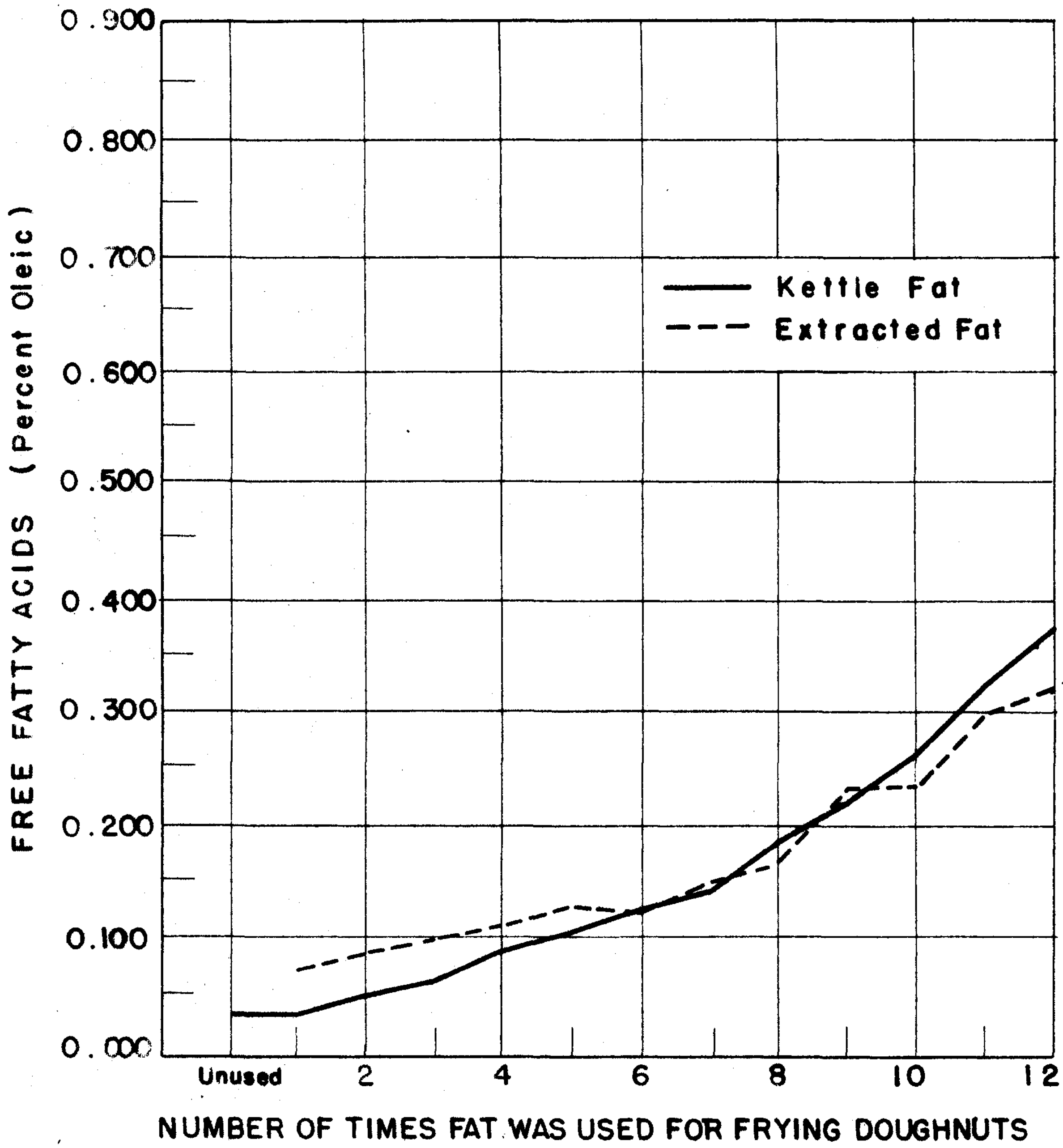
Graph 5. Fat, PRIME STEAM LARD, 1942. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



Graph 6. Fat, PRIME STEAM LARD, 1944. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



Graph 7. Fat, GM12, 1942. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and and of fat extracted from successive batches of doughnuts.



Graph 8. Fat, GM 12, 1944. The FREE FATTY ACIDS of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.

Table 5. *FREE FATTY ACIDS* (Per cent oleic). Increase of Free Fatty Acids in Fats Used for Frying Doughnuts

Fat	Initial value	Final value	Increase	No. of times the final value increased over initial value
1942 Series				
G.M.U.	0.047	0.346	0.299	7.4
Vegetable shortening	0.104	0.386	0.282	3.7
Prime steam lard	0.521	0.682	0.161	1.3
G.M.12	0.033	0.321	0.288	9.7
1944 Series				
G.M.U.	0.031	0.360	0.329	11.6
Vegetable shortening	0.112	0.387	0.275	3.4
Prime steam lard	0.574	0.798	0.224	1.4
G.M.12	0.027	0.371	0.344	13.7

Free fatty acids of fats extracted from doughnuts

Free fatty acids showed a marked increase in the fats extracted from each succeeding lot of doughnuts. The definite upward trend in free fatty acid content of the extracted fats is shown in graphs 1 through 8 and in the Appendix tables 30 and 32.

Volatile acids

The volatile acid content of the prime steam lard (1944) was determined for the kettle fat and for the fat extracted from the doughnuts. The plotted data of the water soluble volatile acids form a curve which follows very closely the shape of the free fatty acid curve both for the kettle fat and the extracted fat (graph 11). This is particularly noticeable in the extracted fats through the first nine frying periods and appears to be quite consistent for the kettle fats through the twelve frying periods.

Iodine numbers (Hanus)

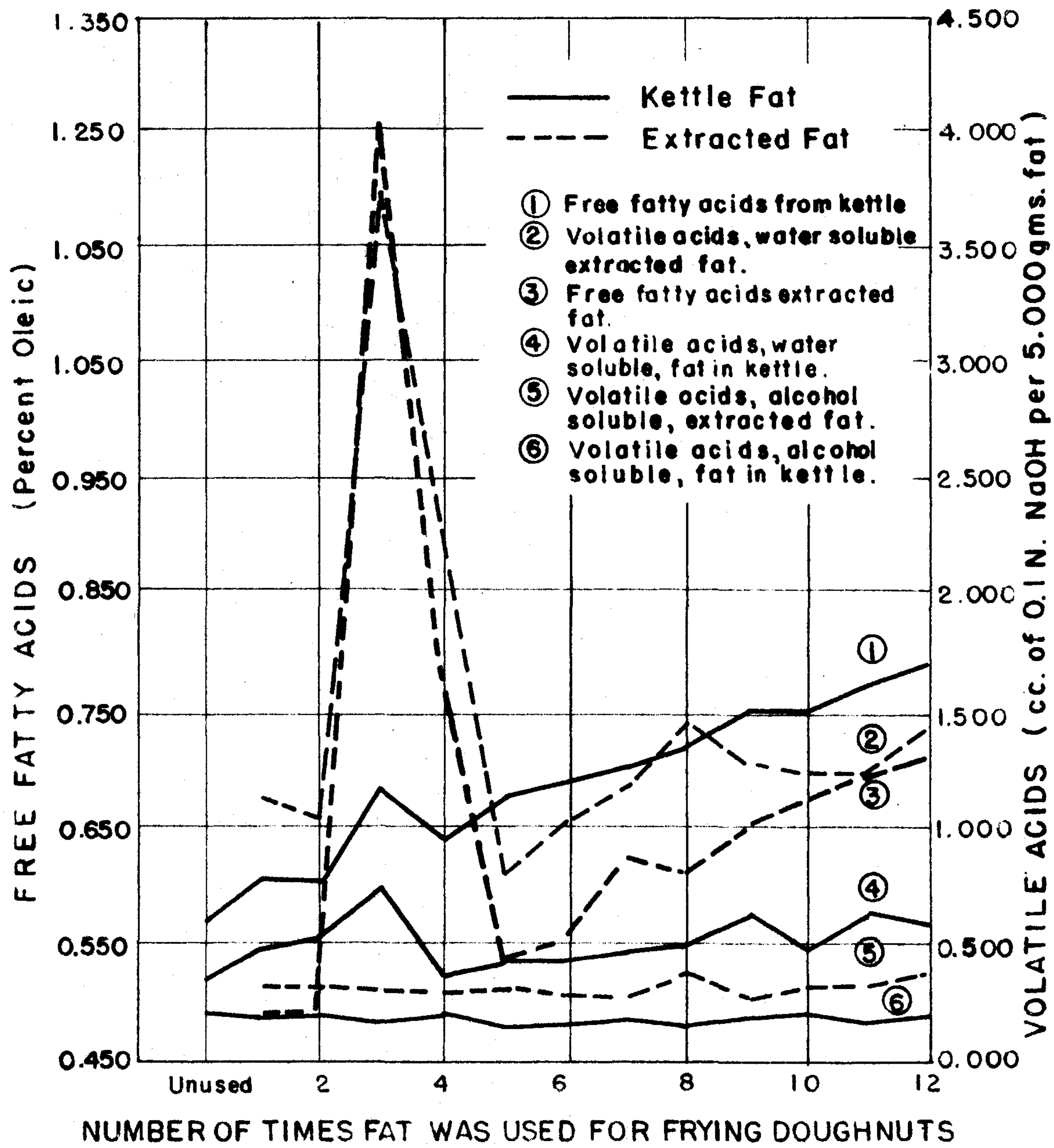
The initial iodine numbers were practically identical for the unstored and stored fats.

With use, the iodine numbers of each fat were lowered, though the extent of the change varied for the different fats. The direction and extent of change for each fat with use for frying were almost identical in the two test periods.

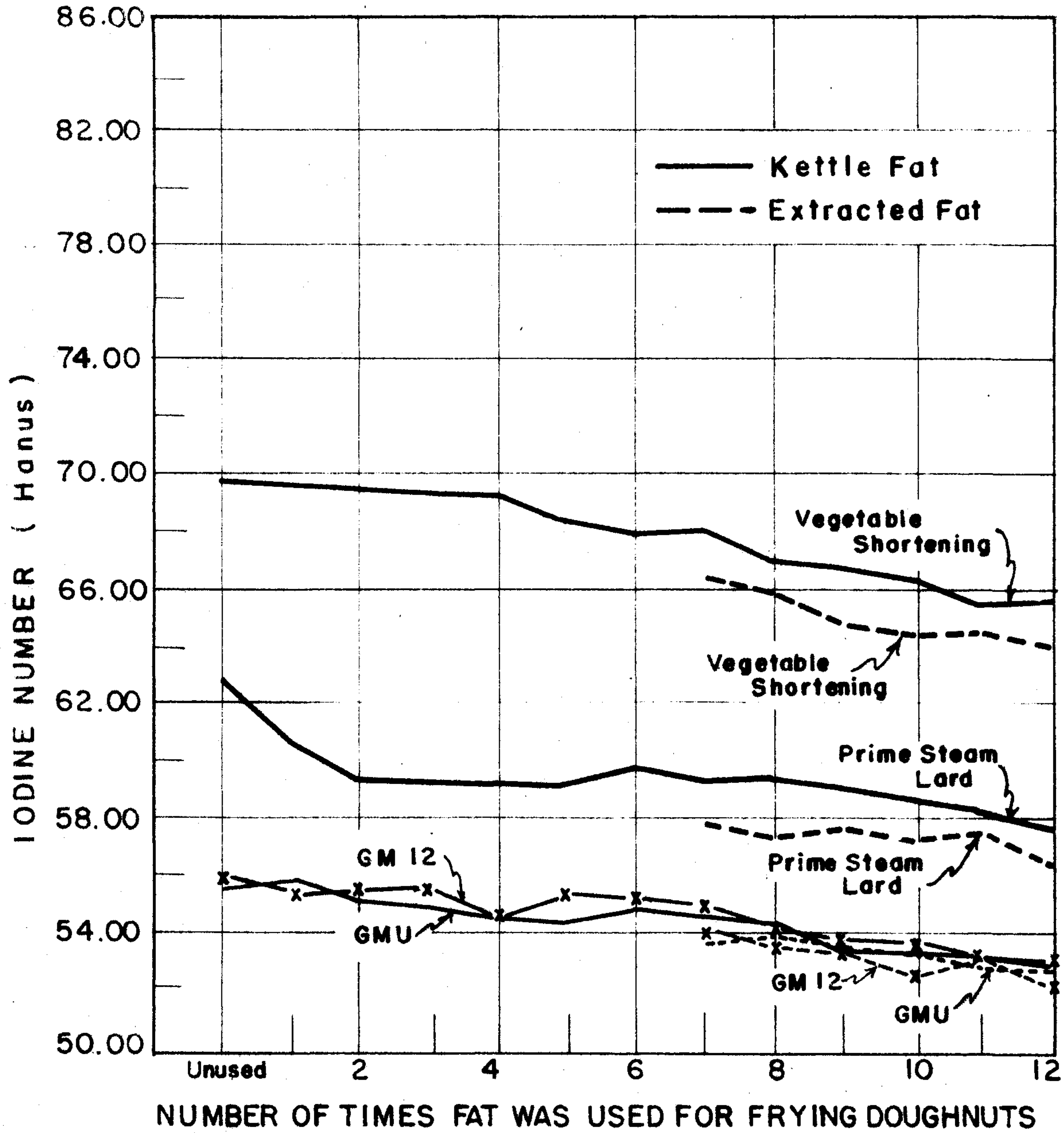
In nearly every case the fat extracted from doughnuts had lower iodine numbers than did the corresponding fat in which the doughnuts were fried. There were three exceptions: G.M.U., 1942, 9th batch; G.M.12, 1942, 11th batch; and G.M.12, 1944, 7th batch of doughnuts.

A definite downward trend of the iodine numbers of kettle and extracted fats is shown in both test periods in graphs 10 and 11 and in the Appendix tables 34 to 37.

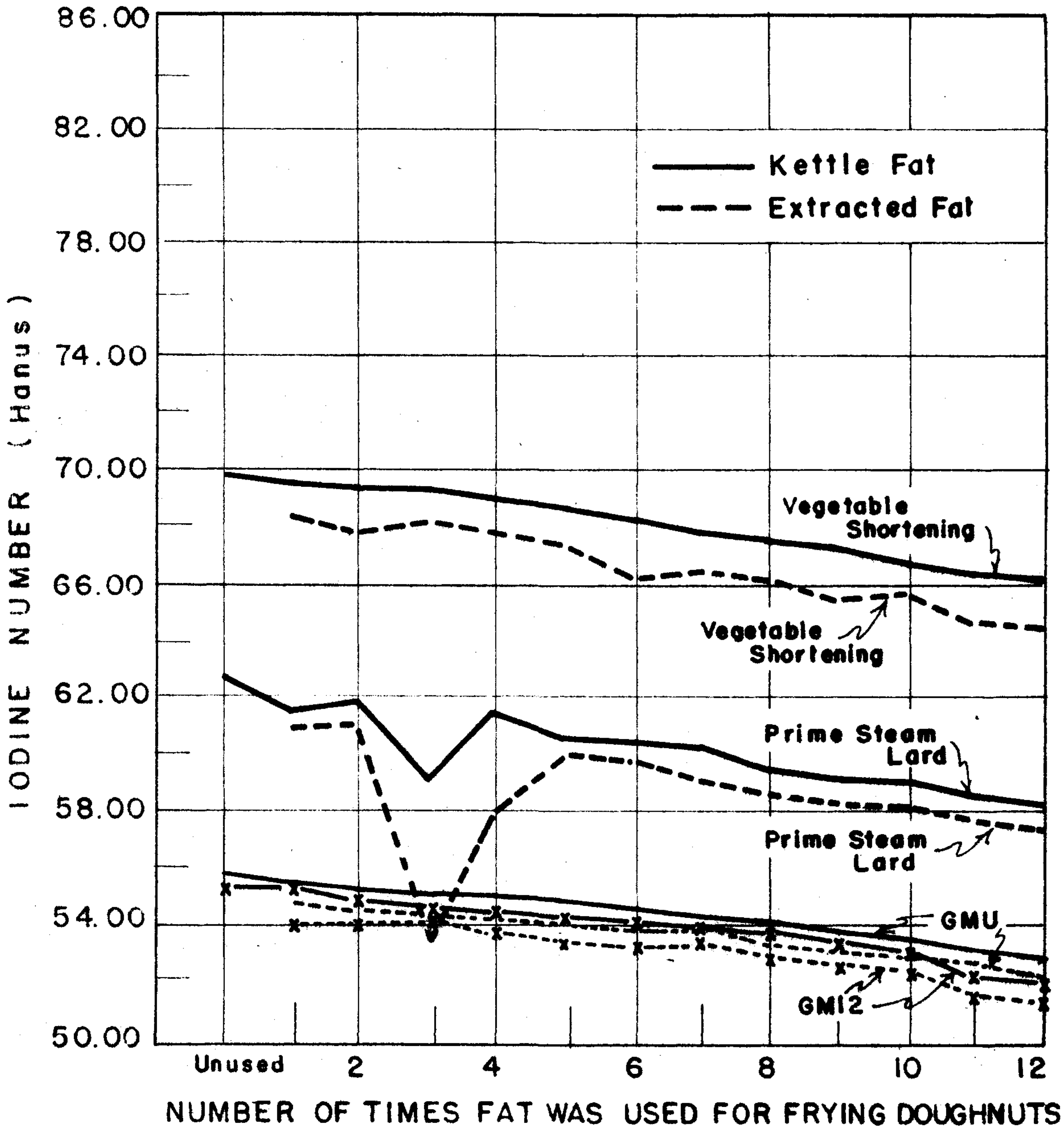
The decrease of iodine numbers which occurred with increased use of all fats is summarized in table 6.



Graph 9. PRIME STEAM LARD, 1944. The FREE FATTY ACIDS and VOLATILE ACIDS, alcohol soluble and water soluble, of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



Graph 10. The IODINE NUMBERS, 1942 series, of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.



Graph II. The IODINE NUMBERS, 1944 series, of fat in kettle after frying successive batches of doughnuts and of fat extracted from successive batches of doughnuts.

Table 6. IODINE NUMBERS (Hanus) - Decrease of Iodine Numbers of Fats Used for Frying and of Fats Extracted from Doughnuts

	Iodine numbers			
	G.M.U.	Vegetable shortening	Prime steam lard	G.M.12
<u>1942 Series</u>				
Kettle fats				
Initial value	55.6	69.8	62.7	55.9
Value after frying 12 batches	53.0	65.5	57.5	53.2
Decrease after frying 12 batches	2.6	4.3	5.2	2.7
Extracted fats				
7th batch	53.6	66.4	57.8	54.0
12th batch	52.8	64.0	56.4	52.3
Decrease 7th to 12th batch	0.8	2.4	1.4	0.7
<u>1944 Series</u>				
Kettle fats				
Initial value	55.7	69.9	62.8	55.4
Value after frying 12 batches	53.1	66.1	58.3	52.0
Decrease after frying 12 batches	2.6	3.8	4.5	3.4
Extracted fats				
Initial value	54.6	68.4	61.0	54.0
7th batch	53.8	66.7	59.1	53.3
12th batch	52.1	64.6	57.4	51.3
Decrease 7th to 12th batch	1.7	2.1	1.7	2.0
Decrease 1st to 12th batch	2.5	3.8	3.6	2.7

Refractive index

The refractive index of all the fats tended to increase as they were used for frying, and tended to increase in the fats extracted from each succeeding lot of doughnuts. A definite upward trend of refractive index for kettle and extracted fats in both test periods is shown in the Appendix, tables 38 to 41. The increases of refractive index observed for the kettle and extracted fats before and after the two-year storage period are shown in table 7.

Smoking point

The temperatures at which the fats smoked were similar before and after storage.

The smoking points were lowered with increased use of the fats; and the drop in temperature after frying was almost the same for a given fat in the two different test periods.

The fats having the highest initial smoking points showed the greatest drop. The prime steam lard and vegetable shortening had low initial smoking points; and their smoking points dropped only a few degrees, 6.0 to 7.0° C, after being used for frying twelve dozen doughnuts. The G.M.U. and G.M.12 fats had much higher initial smoking points than did the prime steam lard or the vegetable shortening and their smoking points had dropped 27.0 and 39.0° C, respectively, by the end of the frying period.

The prime steam lard and vegetable shortening smoked from the beginning at the frying temperature used, i.e. 185° C. The G.M.U. and

Table 7. REFRACTIVE INDEX - Increase of Refractive Index of Fats Used for Frying and of Fats Extracted from Doughnuts

	Refractive index			
	G.M.U.	Vegetable shortening	Prime steam lard	G.M.12
<u>1942 Series</u>				
Kettle fats				
Initial value	1.45977	1.46113	1.46060	1.45977
Value after frying 12 batches	1.46063	1.46225	1.46187	1.46060
Increase after frying 12 batches	0.00086	0.00112	0.00127	0.00083
Extracted fats				
7th batch	1.45974	1.46170	1.46114	1.46012
12th batch	1.46012	1.46188	1.46164	1.46029
Increase 7th to 12th batch	0.00038	0.00018	0.00050	0.00017
<u>1944 Series</u>				
Kettle fats				
Initial value	1.45848	1.46000	1.45949	1.45846
Value after frying 12 batches	1.45930	1.46109	1.46020	1.45934
Increase after frying 12 batches	0.00082	0.00109	0.00071	0.00088
Extracted fats				
Initial value	1.45836	1.45997	1.45950	1.45861
7th batch	1.45886	1.46032	1.45983	1.45900
12th batch	1.45900	1.46071	1.46013	1.45921
Increase 7th to 12th batch	0.00014	0.00039	0.00030	0.00021
Increase 1st to 12th batch	0.00064	0.00074	0.00063	0.00060

G.M.12 fats did not smoke at this temperature even after being used for frying twenty-four lots of doughnuts.

In table 8 the smoking points of the different fats are shown before use, after being used for frying six dozen doughnuts (twelve lots), and after being used for frying twelve dozen doughnuts (twenty-four lots).

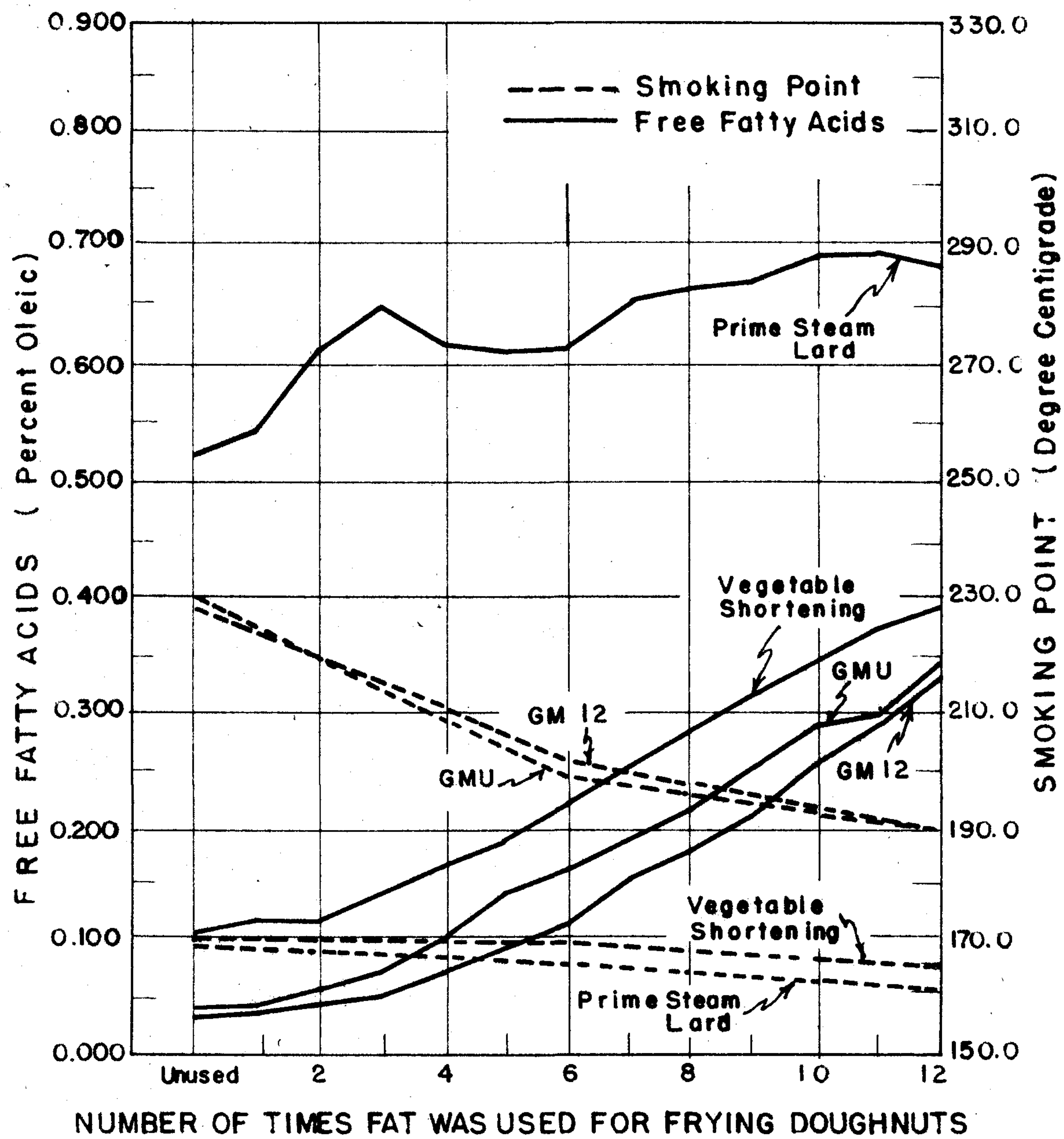
Table 8. SMOKING POINTS, °C. - Initial Values, Values after Frying the Sixth and Twelfth Dozen Doughnuts, and Total Decrease in Smoking Point

Fat	Initial value	Value after frying 6 batches	Value after frying 12 batches	Decrease after frying 12 batches
1942 Series				
G.M.U.	229.0	199.0	190.0	39.0
Vegetable shortening	171.0	169.0	165.0	6.0
Prime steam lard	169.0	165.0	162.5	6.5
G.M.12	228.0	204.0	190.0	38.0
1944 Series				
G.M.U.	224.0	204.0	186.0	38.0
Vegetable shortening	170.5	166.0	164.0	6.5
Prime steam lard	168.0	163.0	160.5	7.0
G.M.12	225.0	206.0	188.0	37.0

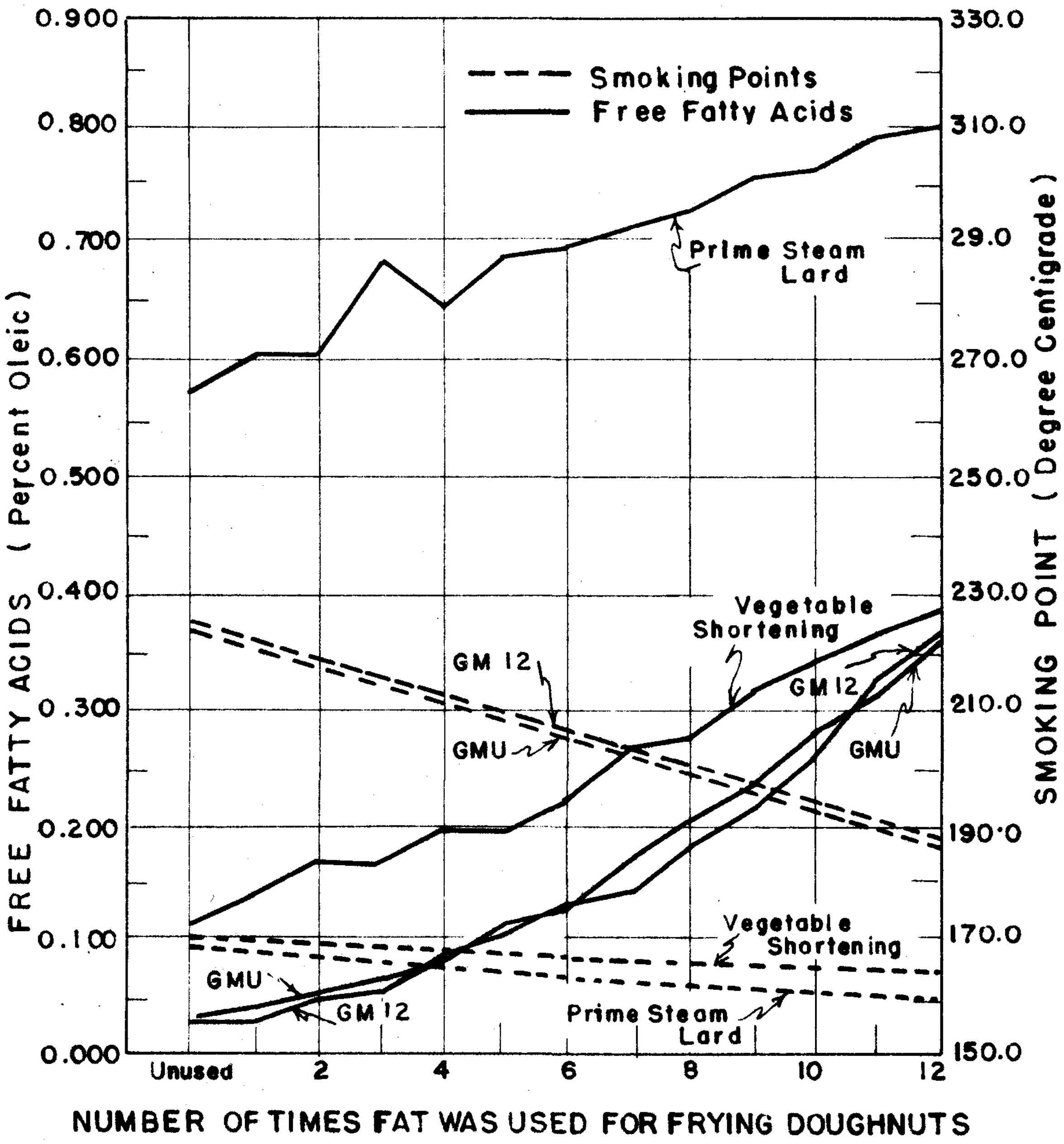
Relation of smoking point to free fatty acid content

Lowe et al (21) observed a correlation between low smoking points and high free fatty acid content of fats. The relationship of free fatty acids to the smoking point was not determined statistically in the present study because of the small number of data on smoking points. The plotted data indicate a relationship between low free fatty acid content and high smoking point (graphs 12 and 13). Fats G.M.U. and G.M.12 with low free fatty acid contents had the highest smoking points, whereas the prime steam rendered lard with the highest free fatty acid content had the lowest smoking point both in 1942 and in 1944 (tables 5 and 8). The vegetable shortening although having a low free fatty acid content also had a low smoking point. This is not in agreement with the above observation. The low smoking point of the vegetable shortening may be accounted for by the presence of an "addition agent", probably a hydroxy fatty ester which is incorporated during the manufacture of the fat (9). Substances such as this are used by certain firms for the improvement of their shortenings for cake-making. The presence of such materials increases the water and sugar holding capacity of the cake batter, and decreases the tendency of the cake to shrink during baking and cooling.

There appeared to be a relationship between rapidity of increase in free fatty acid content and the extent to which the smoking point was lowered after use of a fat for frying. G.M.U. and G.M.12 developed increased free fatty acids to the extent of 7.4 and 9.7 times their initial values in the 1942 series, and 11.6 and 13.7 times in the 1944 series. The corresponding smoking points dropped 39.0° and 38.0° in 1942, and 38.0° and 37.0° in 1944. On the other hand, the prime steam rendered lard had small increases of free fatty acids amounting to 1.3



Graph 12. 1942. FREE FATTY ACIDS and SMOKING POINTS of fats after frying successive batches of doughnuts.



Graph 13. 1944. FREE FATTY ACIDS and SMOKING POINTS of fats after frying successive batches of doughnuts.

times the initial value in the 1942 series and 1.4 times in 1944. The corresponding smoking points showed a decrease of only 6.5° in 1942, and 7.0° in 1944. The vegetable shortening had an increase in free fatty acid intermediate between the G.M. fats and the prime steam rendered lard amounting to 3.7 times the initial value in 1942 and 3.4 times the initial value in 1944. The corresponding smoking point showed a drop of 6.0 and 6.5° C.

Palatability Scores

Five judges scored the doughnuts in 1942; and six judges scored in 1944. Of the six judges who scored the doughnuts in the second year, three had scored in the previous period. The scores of individual judges are given in the Appendix, tables 42-49. Each palatability factor was rated 1 to 10, lower scores indicating less desirable and higher scores more desirable qualities.

Total scores

Average scores for the characteristics of doughnuts fried in the different fats are shown in table 9.

Prime steam lard had the lowest total scores in both test periods; the G.M. fats had the highest scores in both periods. The total scores for doughnuts fried in each fat were as high or higher in the second test period as in the first.

Appearance

The appearance of the doughnuts first cooked in all fats was similar, regardless of the fat in which they were cooked. As the fats were used,

Table 9. Average Scores for Doughnuts Cooked in Each Fat

Fat	Appearance	Greasiness	Odor	Flavor	Texture	Total
<u>1942</u>						
G.M.U.	7.8	7.0	6.7	6.1	7.3	34.9
Vegetable shortening	7.7	6.8	6.4	5.4	7.3	33.6
Prime steam lard	7.9	6.3	5.9	4.7	7.0	31.8
G.M.12	7.7	6.8	6.8	6.3	7.0	34.6
<u>1944</u>						
G.M.U.	7.7	7.9	7.3	6.2	7.8	36.9
Vegetable shortening	7.6	6.5	7.1	6.0	7.7	34.9
Prime steam lard	7.5	6.2	6.4	4.0	7.7	31.8
G.M.12	7.6	7.3	7.3	6.6	7.6	36.4

brown specks appeared to a noticeable extent in series six. After storage of the fats, brown specks appeared on the surface of the doughnuts fried in prime steam lard the first time it was used. The specks appeared on doughnuts fried in G.M.12 and vegetable shortening after the third time they were used; and by the fifth time the fats were used, all the doughnuts showed brown specks, though the least noticeable were on doughnuts fried in G.M.12 and G.M.U. fats.

In 1942, the lowest average score for appearance was 7.7, and the highest, 7.9. The range between the lowest and highest scores was 0.2. In 1944, the lowest average score for appearance was 7.5, and the highest, 7.7. The range between the lowest and highest scores was 0.2. The mean differences between scores for appearance of doughnuts fried in the different fats were not significant in either test period.

Greasiness

Analysis of mean scores for greasiness shows the following relationships:

Table 10. Significance of Mean Differences between Scores for Greasiness for the Different Fats - 1942

	Fat		Lowest score →			Highest score
		Fat	Prime steam lard	G.M.12	Vegetable shortening	G.M.U.
		Av. score	6.3	6.8	6.8	7.0
Highest score	G.M.U.	7.0	0.7**	0.2	0.2	
↓	Vegetable shortening	6.8	0.5**	0.0		
	G.M.12	6.8	0.5**			
Lowest score	Prime steam lard	6.3				

**Highly significant

Table 11. Significance of Mean Differences between Scores for Greasiness for the Different Fats - 1944

	Fat		Lowest score →			Highest score
		Fat	Prime steam lard	Vegetable shortening	G.M.12	G.M.U.
		Av. score	6.2	6.5	7.3	7.9
Highest score	G.M.U.	7.9	1.7**	1.4**	0.6**	
↓	G.M.12	7.3	1.1**	0.8**		
	Vegetable shortening	6.5	0.3			
Lowest score	Prime steam lard	6.2				

**Highly significant

Doughnuts fried in G.M.U. fat had the highest average score, and those fried in prime steam lard had the lowest score in regard to greasiness in both 1942 and 1944. In the 1942 series, the mean differences between scores for doughnuts fried in prime steam lard and those fried in the other fats were highly significant. The average score for doughnuts fried in the prime steam lard was lower than those for doughnuts fried in the other fats. The scores for doughnuts fried in the three other fats did not differ significantly among themselves. In the 1944 series the mean scores for doughnuts fried in both the prime steam lard and the vegetable shortening were lower than those for doughnuts fried in the G.M. fats.

Odor

Analysis of mean scores for odor shows the following relationships:

Table 12. Significance of Mean Differences between Scores for Odor for the Different Fats - 1942

	Fat	Fat	Lowest score → Prime steam lard	Vegetable shortening	G.M.U.	Highest score G.M.12
		Av. score	5.9	6.4	6.7	6.8
Highest score	G.M.12	6.8	0.9*	0.4	0.1	
	G.M.U.	6.7	0.8	0.0		
↓	Vegetable shortening	6.4	0.5			
Lowest score	Prime steam lard	5.9				

*Significant

Table 13. Significance of Mean Differences between Scores for Odor for the Different Fats - 1944

	Fat	Fat	Lowest score → Prime steam lard	Vegetable shortening	G.M.12	Highest score G.M.U.
		Av. score	6.4	7.1	7.3	7.3
Highest score	G.M.U.	7.3	0.9**	0.2	0.0	
	G.M.12	7.3	0.9**	0.2		
↓	Vegetable shortening	7.1	0.7*			
Lowest score	Prime steam lard	6.4				

**Highly significant
*Significant

Doughnuts fried in G.M.12 and G.M.U. fats had the highest average scores for odor, both in 1942 and 1944. The judges detected greater differences in odor in 1944 than in 1942 between doughnuts fried in prime steam lard and in the other fats. This is shown by the fact that the differences between scores for doughnuts fried in G.M.U., G.M.12 and prime steam lard were highly significant, and the difference between scores for doughnuts fried in vegetable shortening and prime steam lard was significant in 1944; whereas in 1942, doughnuts fried in G.M.12 were the only ones to score significantly higher in odor than those fried in prime steam lard.

Flavor

Analysis of mean scores for flavor shows the following relationships:

Table 14. Significance of Mean Differences between Scores for Flavor for the Different Fats - 1942

	Fat	Fat	Lowest score → Prime steam lard	Vegetable shortening	Highest score G.M.U.	G.M.12
		Av. score	4.7	5.4	6.0	6.3
Highest score	G.M.12	6.3	1.6**	0.9	0.3	
↓	G.M.U.	6.0	1.3*	0.6		
	Vegetable shortening	5.4	0.7			
Lowest score	Prime steam lard	4.7				

**Highly significant
*Significant

Table 15. Significance of Mean Differences between Scores for Flavor for the Different Fats - 1944

	Fat	Fat	Lowest score → Prime steam lard	Vegetable shortening	Highest score G.M.U.	G.M.12
		Av. score	4.0	6.0	6.2	6.6
Highest score	G.M.12	6.6	2.6**	0.6	0.4	
↓	G.M.U.	6.2	2.2**	0.2		
	Vegetable shortening	6.0	2.0**			
Lowest score	Prime steam lard	4.0				

**Highly significant

In the first test period doughnuts fried in G.M.12 fat had the highest average score for flavor, whereas those fried in prime steam lard had the lowest. The mean difference between scores for these two fats was highly significant. The difference between doughnuts fried in G.M.U. and those fried in prime steam lard was significant. The doughnuts fried in vegetable shortening were not significantly better or worse than those fried in the other fats. In other words, the judges preferred the flavor of doughnuts fried in the G.M. fats, though not one over the other.

The fats hold the same position in regard to flavor after storage as they did before storage. Doughnuts fried in G.M.12 fat had the highest average score for flavor, though there is no significant difference between scores for doughnuts fried in G.M.12 or G.M.U. fats. Doughnuts fried in prime steam lard scored lower in flavor than did those fried in any of the other fats.

Though the extent of flavor memory may be a question for speculation, the author felt that doughnuts fried in the different fats tasted very much the same as had doughnuts fried in the same fats two years before. The average scores for flavor are actually higher the second year than the first, except for doughnuts fried in prime steam lard, which scored lower in flavor in the second series than in the first.

These observations lead to the supposition that doughnuts fried in the fats, especially G.M.U., G.M.12 and the vegetable shortening, were but little different in flavor after the fats had been stored for two years. The prime steam lard appears to be less desirable after the two-year storage period.

Texture

Analysis of mean scores for texture shows the following relationships:

Table 16. Significance of Mean Differences* between Scores for Texture for the Different Fats - 1942

	Fat	Fat	Lowest score → Prime steam lard	G.M.12	G.M.U.	→ Highest score Vegetable shortening
		Av. score	7.0	7.0	7.3	7.3
Highest score	Vegetable shortening	7.3	0.3	0.3	0.0	-
↓	G.M.U.	7.3	0.3	0.3	-	
	G.M.12	7.0	0	-		
Lowest score	Prime steam lard	7.0	-			

*No significant differences

Table 17. Significance of Mean Differences between Scores for Texture for the Different Fats - 1944

	Fat	Fat	Lowest score → G.M.12	Vegetable shortening	Prime steam lard	→ Highest score G.M.U.
		Av. score	7.6	7.7	7.7	7.8
Highest score	G.M.U.	7.8	0.2*	0.1	0.1	-
	Prime steam lard	7.7	0.1	0.0	-	
↓	Vegetable shortening	7.7	0.1	-		
Lowest score	G.M.12	7.6	-			

*Significant

The average scores for texture in the 1942 series showed no significant differences between doughnuts fried in the different fats. In the second test period, doughnuts fried in G.M.U. fat scored higher for texture than did doughnuts fried in the other fats. The differences between average scores were slight.

DISCUSSION

It has been suggested by Hilditch (14) and Greenbank (12) that the chemical changes occurring as a fat becomes rancid accelerate further change. It might be expected that a long period of storage of fats would result in an accumulation in the fats of products of rancidity, such as increased peroxide content or increased free fatty acids, which in turn would accelerate the breakdown of the fats during use for frying.

The fats all had higher peroxide values after the two-year storage period; but did not show consistent differences in free fatty acid content. The breakdown of the fats during use for frying appeared to be no more rapid after storage than before.

The most striking observation on the stored fats as compared to those not stored is the relatively slight difference between the two, either in chemical composition or in palatability. This is especially remarkable in the case of the processed pork fat (G.M.U.) and the processed lard (G.M.12) which had been stored at room temperature for more than two years. The exceptional keeping quality of these fats is probably due to a combination of factors, including the removal during processing of metallic contaminants, partial hydrogenation, and the addition of ascorbic acid and a tocopherol concentrate which inhibit the oxidation of the fat (2) (16) (30).

It should be remarked that if the prime steam rendered lard had been newly rendered and sweet when the first series of tests were run, the palatability tests for this fat after two years storage might have been expected to show greater differences. As it was, when the first test period started, the lard was already off flavor and rancid according to the peroxide test, as well as being high in free fatty acids.

A number of the observations made in this study confirm findings reported by others:

There appeared to be a correlation between high smoking point and low free fatty acid content of the frying fat. This observation is in agreement with that of Blunt and Feeney (6) and Lowe et al (21).

Iodine numbers decreased, whereas refractive indices increased with increased use of the fats for frying. These observations agree with those of Fulmer and Manchester (11), Morgan and Cozens (24) and Lowe et al (21).

Free fatty acids increased with use of the fat for frying. This observation agrees with that of Morgan and Cozens (24), and Porter, Michaelis and Shay (25), Lowe et al (21), and Jordan (17).

In general, the iodine numbers were lower and refractive indices higher in fats extracted from doughnuts than in the corresponding kettle fats. This observation agrees with that of Woodruff and Blunt (31).

Fat absorption by doughnuts fried in the different fats varied in 1942 and in 1944. The total fat absorbed by doughnuts fried in each fat was lower in 1944 than in 1942. This might be explained by the fact that ingredients for the doughnuts were incubated at higher temperatures in 1944 than in 1942. The dough temperatures were, therefore, higher in 1944. Lowe et al (21) observed a lower fat absorption when dough temperature was near 26° C than when dough temperature was near 24° C. In addition, different lots of flour were used in the two periods. This might cause a difference in fat absorption by the doughnuts.

There appeared to be no correlation between fat absorption by doughnuts and the smoking point or free fatty acid content of the frying fats in 1942 or 1944. This is in agreement with the observation by Arenson and Heyl (3) who reported no correlation between free fatty acid content of the frying fat up to 0.6 per cent and fat absorption by doughnuts. Three of the fats used in the present study had free fatty acid contents less than 0.6 per cent throughout the frying period. One fat (prime steam lard) had a free fatty acid content greater than 0.6 per cent during most of the frying period.

Oxidation and hydrolysis might be expected to proceed rapidly in fats used for frying. The high temperature used, the large surface of fat exposed to the air, and the presence of moisture which evaporated from the doughnuts during frying, together with the effect of metal from cooking in an iron kettle, would all probably contribute to rapid breakdown of the fats.

That these factors were operating to cause breakdown of the fats is indicated by the chemical changes that took place.

The increase of free fatty acids during use for frying could be accounted for by hydrolysis of the fats or by oxidation and breaking of the carbon chain, resulting in the accumulation of acids of low molecular weight, or by a combination of these factors.

At the same time that free fatty acids increased, iodine numbers decreased. The decrease in iodine numbers indicated a lowering of the degree of unsaturation of the fats, which in turn may be accounted for by a breaking of the fatty acid chains at unsaturated linkages to yield acids of lower molecular weight, further products of oxidation such as acids or aldehydes of still lower molecular weight, and/or by polymerization.

Since iodine numbers of all fats dropped and free fatty acids increased during frying, it should be of interest to see to what extent these factors might be interrelated.

The iodine numbers before and after frying the 1944 series of doughnuts were:

	Original value	Final value
G.M.U.	55.7	53.1
Vegetable shortening	69.9	66.1
Prime steam lard	62.8	58.3
G.M.12	55.4	52.0

The free fatty acids, per cent oleic, before and after frying the 1944 series of doughnuts were:

	Original value	Final value
G.M.U.	0.031	0.360
Vegetable shortening	0.112	0.387
Prime steam lard	0.574	0.798
G.M.12	0.027	0.371

In comparing the lowering of the iodine numbers with increases of free fatty acids, the following assumptions may be made in regard to the products of decomposition present in the fat:

(1) They must be derived originally from splitting of the carbon chains at unsaturated -C:C- linkages; otherwise, the iodine number would not be affected.

(2) They must be compounds having a chain length of nine carbons or less, since the unsaturated fatty acid molecules which predominate in lard or vegetable oil have a chain length of eighteen carbons, with double bonds present between the ninth and tenth carbon atoms (oleic acid) or between the ninth and tenth and twelfth and thirteenth (linoleic acid).

In order to facilitate a comparison of the lowering in iodine numbers with the increase in free fatty acids, the following calculations were made on the basis of the grams of iodine per 100 grams of fat (which, by definition, is the iodine number) equivalent to grams of oleic acid per 100 grams of fat (per cent).

The following formula was used to convert grams of iodine per 100 grams of fat to an equivalent weight of oleic acid:

$$\frac{(\text{grams } I_2)(282.27)}{253.84} = \text{grams of oleic acid equivalent to the iodine number,}$$

where 282.27 is the molecular weight of oleic acid and 253.84 is the molecular weight of iodine.

The results of these calculations are shown in table 18.

The comparison of drop in iodine numbers with the increase of free fatty acids which took place in the fats used for frying, shows that according to this calculation, only a small part of the drop in iodine number may be accounted for by the increase in free fatty acids. This calculation which was based on the assumption that all the free

Table 18. Relation between Lowering of Iodine Numbers and Increase of Free Fatty Acids Observed after Frying Twelve Dozen Doughnuts - Prime Steam Lard, 1944

Fat	Drop in iodine number (g/100 g fat)	Grams oleic acid/100 g. fat equivalent to change in iodine no.	Increase of free fatty acids (g. oleic acid/100 g. fat)	Drop in iodine number not accounted for by increase in free fatty acids		Drop in iodine number accounted for by increase in free fatty acids
				Difference II - III	Grams I_2 per 100 g. fat	
	I	II	III	IV	V	VI
G.M.U.	2.6	2.891	0.329	2.562	2.3	0.3
Vegetable shortening	3.8	4.226	0.275	3.951	3.6	0.2
Prime steam lard	4.5	5.004	0.224	4.780	4.3	0.2
G.M.12	3.4	3.781	0.344	3.437	3.1	0.3

fatty acids were present as oleic acid, does not take into account the presence of acids of lower molecular weight which were undoubtedly present. Among the probable acidic decomposition products of a fat containing oleic and linoleic acid would be acids containing from one to nine carbons (19).

The fact that such low molecular weight acids were present is shown by the analysis of water and alcohol soluble volatile acids of prime steam lard (table 33, graph 9). The analysis of steam volatile acids involved saponification of the fat, with subsequent acidification to release the fatty acids. The mixture was then steam distilled. The steam volatile acids which were collected in the distillate were acids composed of ten carbon atoms or less. Since the fat was saponified prior to steam distillation, fragments of fatty acids that had been jointed to the glycerol radical, if of sufficiently low molecular weight, would have distilled with the steam.

Since more -C:C- bonds were destroyed than can be accounted for by the increase in free fatty acids present in the fat, the drop in iodine number must be accounted for in other ways:

(1) Decomposition products such as aldehydes and ketones probably developed.

(2) Some of the volatile acids formed during frying of the doughnuts may have been carried away in the moisture which evaporated from the doughnuts and from the hot fat during cooking.

(3) Polymerization of the fats.

The formation of polymers probably contributed to the lowering of the iodine number, although three of the fats were hydrogenated, which would decrease the extent of polymerization. The work of Arenson and Heyl (4) in which it was found that polymers formed during frying of doughnuts in a hydrogenated vegetable shortening indicates that the formation of polymers was a possibility. That some polymerization did occur was shown by the fact that there was gum formation on the inside of the kettles during use of the fats for frying.

The analysis of volatile acids and free fatty acids from the prime steam lard kettle and extracted fats, provides material for some interesting speculation as to the kind of breakdown which took place in that fat during frying of doughnuts.

The free fatty acid content of prime steam lard after its use for frying doughnuts, and of the fat extracted from successive fryings of doughnuts, is compared with the content of volatile fatty acids in table 19. The comparison is made on the basis of cc. of 0.1 N NaOH required to neutralize the acids of 1 gram of fat.

The cc. of 0.1 N NaOH required to titrate the alcohol soluble volatile acids varied but little either in fat taken from the kettle after frying successive batches of doughnuts or in the fat extracted from these doughnuts.

The cc. of 0.1 N NaOH required to titrate the alcohol soluble volatile acids in general paralleled the amount required to titrate the volatile acids from the kettle fat after frying successive batches of doughnuts, except that the cc. were always greater for the acids from the extracted fat. The water soluble portion of the volatile acids in

Table 19. Free Fatty Acids and Volatile Acids of Prime Steam Lard after Frying Successive Batches of Doughnuts and of Fat Extracted from Successive Batches of Doughnuts, 1944
cc. of 0.1 N NaOH per 1 gram fat

Number of times fat was used for frying	Kettle fats			Extracted fats		
	Free fatty acids	Volatile acids water soluble	Volatile acids alcohol soluble	Free fatty acids	Volatile acids water soluble	Volatile acids alcohol soluble
Unused	0.204	0.075	0.045	----	----	----
1	0.214	0.100	0.039	0.173	0.231	0.074
2	0.214	0.103	0.044	0.174	0.214	0.073
3	0.244	0.148	0.038	0.447	0.747	0.063
4	0.229	0.075	0.044	0.279	0.450	0.061
5	0.243	0.095	0.031	0.192	0.174	0.071
6	0.245	0.095	0.032	0.197	0.206	0.054
7	0.252	0.097	0.040	0.221	0.233	0.057
8	0.257	0.100	0.033	0.216	0.291	0.084
9	0.268	0.129	0.039	0.231	0.260	0.053
10	0.269	0.097	0.040	0.240	0.249	0.069
11	0.279	0.128	0.033	0.248	0.249	0.062
12	0.283	0.120	0.040	0.256	0.296	0.077

general followed the same trend as the free fatty acids both in kettle and extracted fats.

Total volatile acids (water and alcohol soluble) amounted to approximately one-half of the free fatty acids of kettle fats; but in the extracted fats, the volatile acids exceeded the free fatty acids in every case.

Freshly rendered pork fat contains only minute quantities of short carbon chain acids, such as would be volatile in steam. The analysis of volatile acids, which involved saponification of the fat as a first step, includes the naturally occuring short chain acids and fragments of broken carbon chains which had remained joined to the glycerol molecule as well as short chain acids which were free in the fat.

The fact that the volatile acids of fat extracted from doughnuts exceeded the free acids, indicates that glycerol radicals carrying numerous fragments of broken carbon chains were absorbed by the doughnuts during frying; or that glycerol radicals carrying oxidized fatty acid chains had been absorbed by the doughnuts, followed by splitting of the carbon chains during the cooking process.

Since fatty acids are surface active, and since doughnuts, as well as possessing a large surface area, float on the surface of the fat during frying, the larger amounts of volatile acids in fat extracted from the doughnuts might be partly accounted for by absorption of free short chain acids during frying. If mono-or diglycerides of oxidized fatty acids, or glycerol combined with fragments of broken carbon chains were present in the fat, these would tend to accumulate at the surface, and doughnut-fat interface, and would tend to be absorbed in comparatively large quantities by the doughnuts during frying. The oxidized fatty acids when subjected to the effects of heat and moisture during the cooking process, might be expected to break, thus forming short chain acids, part of which might then be present as free acids, and part might remain attached to the glycerol radical.

It has been previously mentioned that the prime steam lard smoked at the frying temperature used, that the smoke increased during use of the fat for frying, and that the odor of the smoke was sharp and pungent.

All fats, if heated to a sufficiently high temperature, will give smoke similar in odor to that of the prime steam lard.

The odor can be accounted for by the volatile decomposition products of fats, which include low molecular weight acids, aldehydes, ketones, carbon dioxide and hydrogen gas. Part of these products are derived from breaking of the carbon chains; part are derived from the glycerol present in the fat, as a result of hydrolytic splitting of glycerides. Glycerol, when heated, loses two molecules of water, with the formation of acrolein. Acrolein is a volatile aldehyde, irritating to the mucous membranes of the eyes, nose and throat.

The smoking of prime steam lard at the frying temperature used, indicated the presence of comparatively large quantities of fat decomposition products. In view of the high free fatty acid content of this fat, it is probable that hydrolytic cleavage had occurred to a greater extent than in the other fats. The glycerol formed as a result of such cleavage would undoubtedly be an important contributor to the pungent odor of smoke from this fat.

SUMMARY

Four fats, a prime steam lard, a hydrogenated vegetable shortening, a processed pork fat and a processed lard, have been studied before and after a storage period of more than two years as to:

(1) the extent and rapidity of some chemical changes during use of the fats for frying doughnuts

(2) some of the chemical characteristics of fat absorbed by successive fryings of doughnuts

(3) the comparative palatability of doughnuts fried in each fat.

A total of twelve batches of doughnuts of one dozen per batch were fried in each fat.

The iodine number (Hanus), the free fatty acids (per cent oleic) and the refractive index were determined on samples of each fat taken at the start of each test period (i.e. before and after storage) and on samples taken after frying each dozen doughnuts. Volatile acids were determined on samples of the prime steam lard taken at the start of the test period after storage, and on samples taken after frying each dozen doughnuts. The smoking point was determined on samples of fat taken at the start of each test period and on samples taken after frying six dozen doughnuts and after frying twelve dozen doughnuts. The stability to oxidation was determined on samples taken at the beginning of each test period by means of the Swift Stability test.

The iodine number, refractive index and free fatty acids were determined on fat extracted from doughnuts. Volatile acids were

determined on fat extracted from doughnuts fried in prime steam lard after the storage period.

Palatability of doughnuts fried in the different fats was determined by scoring.

The following observations were made:

1. Changes in the fats in the two-year period were slight, either in chemical constants or in palatability. The chief difference in chemical constants was a higher peroxide value of all fats after two years of storage.

2. The fats were as stable to chemical change during frying of doughnuts as judged by lowering of iodine number, lowering of smoking point, increase in refractive index and increase in free fatty acids, after two years of storage as when tested before storage.

3. When used for frying the following trends in chemical constants were observed:

   a. Iodine numbers decreased with increased use of each fat. The same trend appeared in fat extracted from successive lots of doughnuts.

   b. Refractive index increased with increased use of each fat, both for kettle fats and fat extracted from the doughnuts.

   c. Free fatty acids increased with increased use of each fat, both for kettle fat and extracted fat.

   d. Some breakdown of the carbon chain of prime steam lard during use of the fat for frying doughnuts is indicated by the presence of volatile acids both in the fat used

for frying and in the fat extracted from doughnuts.
The plotted data of the volatile acids follow the curve of the total free fatty acids, indicating a relationship between the two.

e. The smoking point was lowered with increased use of each fat for frying.
A high smoking point appeared to correlate with a low free fatty acid content of the fat.
The rapidity of increase of free fatty acids appeared to be related to rapidity of drop in smoking point.
Free fatty acids increased more rapidly and smoking point dropped more rapidly with use of the fats for frying when the initial free fatty acid content of the fats was low and initial smoking point high.

4. The fats extracted from doughnuts showed lower iodine numbers, higher refractive indices than corresponding kettle fats.

5. No significant relationship was found between fat absorption of doughnuts and free fatty acid content of the fats in which the doughnuts were fried.

CONCLUSIONS

A storage period of more than two years did not affect the desirability of hydrogenated, or otherwise stabilized fats, for use in frying doughnuts. The storage period caused some loss of desirability of prime steam lard.

The storage period did not appreciably affect the chemical constants of the fats, except for prime steam lard in which free fatty acids increased.

The storage period did not affect the rapidity with which chemical constants of the fats changed during use for frying doughnuts.

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APPENDIX

Table 20. Fat, G.M.U., 1942 - The uncooked and cooked weights of each lot and batch of doughnuts with grams of fat absorbed and the percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	basis raw wt.	basis cooked wt.
	grams	grams	grams	grams	grams	grams	grams	grams	grams		
1	171.6	207.1	52.5	170.5	200.5	49.5	342.1	407.6	102.0	29.8	24.9
2	171.0	204.5	51.0	173.7	205.7	49.0	344.7	410.2	100.0	29.0	24.3
3	175.0	207.0	49.0	171.4	200.9	49.0	346.4	407.9	98.0	28.3	24.0
4	174.7	208.7	52.5	169.5	201.0	50.5	344.2	409.7	103.0	29.9	25.1
5	171.7	205.2	52.0	170.4	201.4	48.5	342.1	406.6	100.5	29.4	24.7
6	170.0	203.5	53.0	171.0	201.5	51.0	341.0	405.0	104.0	30.5	25.6
7	173.0	207.0	51.5	174.0	207.5	52.5	347.0	414.5	104.0	30.0	25.0
8	178.4	211.4	51.0	175.5	205.0	47.5	353.9	416.4	98.5	27.8	23.6
9	175.4	208.4	51.5	173.0	203.0	48.0	348.4	411.4	99.5	28.6	24.1
10	178.0	213.0	52.5	181.5	213.0	49.5	359.5	426.4	102.0	28.4	23.9
11	178.4	211.9	52.5	179.4	211.4	50.5	357.8	423.3	103.0	28.8	24.3
12	176.5	210.5	53.5	180.4	213.4	51.5	356.9	423.9	105.0	29.4	24.7
Total	2093.7	2498.2	622.5	2090.3	2464.3	597.0	4184.0	4962.5	1219.5	---	---
Av.	174.5	208.0	51.9	174.2	205.4	49.8	348.7	413.5	101.6	29.1	24.5

Table 21. Fat, VEGETABLE SHORTENING, 1942 - The uncooked and cooked weights of each lot and batch of doughnuts, with grams of fat absorbed and the percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Basis raw wt.	Basis cooked wt.
	grams	grams	grams	grams	grams	grams	grams	grams	grams		
1	173.6	204.6	50.0	173.4	202.4	48.0	347.0	407.0	98.0	28.2	24.0
2	177.1	209.1	50.5	168.5	197.0	48.0	345.6	406.1	98.5	28.5	24.2
3	175.5	205.5	48.0	172.4	200.1	47.0	347.9	405.9	95.0	27.3	23.4
4	174.3	206.3	50.5	170.5	202.5	50.0	344.7	408.8	100.5	29.2	24.5
5	172.8	203.8	49.5	176.1	204.1	47.5	348.9	407.9	97.0	27.8	23.7
6	172.0	204.0	53.5	170.5	200.0	47.5	342.5	404.0	101.0	29.5	25.0
7	174.9	206.4	50.0	169.9	197.9	47.0	344.8	404.3	97.0	28.1	24.0
8	179.4	212.4	52.0	170.5	199.5	47.0	349.9	411.9	99.0	28.3	24.0
9	178.5	209.5	49.5	176.4	204.9	47.0	354.9	414.4	96.5	27.2	23.2
10	178.0	211.5	54.0	174.0	203.0	49.5	352.0	414.5	103.5	29.4	24.9
11	179.0	210.0	48.0	177.0	204.5	47.5	356.0	414.5	95.5	26.8	23.0
12	180.4	211.4	49.5	182.4	210.4	47.5	362.8	421.8	97.0	26.7	22.9
Total	2115.5	2494.5	605.0	2081.6	2426.6	573.5	4197.1	4921.1	1178.5	28.1	23.9

Table 22. Fat, PRIME STEAM LARD, 1942 - The uncooked and cooked weights of each lot and batch of doughnuts, with grams of fat absorbed and percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Basis raw wt.	Basis cooked wt.
	grams	grams	grams	grams	grams	grams	grams	grams	grams		
1	169.4	203.4	53.0	172.4	203.4	50.0	341.8	406.8	103.0	30.1	25.3
2	174.5	207.0	50.0	174.5	203.5	49.0	349.0	410.5	99.0	28.4	24.1
3	172.1	204.1	50.0	173.6	203.6	48.5	345.7	407.7	98.5	28.5	24.1
4	166.4	200.9	52.0	170.0	202.0	50.0	336.4	402.9	102.0	30.3	25.3
5	173.5	209.5	53.0	176.1	209.1	51.0	349.6	418.6	104.0	29.7	24.8
6	173.9	209.4	54.0	170.5	201.5	51.0	344.4	410.9	105.0	30.5	25.5
7	175.4	210.9	56.0	176.5	209.0	50.0	351.9	419.9	106.0	30.1	25.2
8	175.2	207.7	53.0	175.4	205.9	49.5	350.6	413.6	102.5	29.2	24.7
9	173.5	206.5	52.5	174.3	204.3	49.0	347.8	410.8	101.5	29.2	24.7
10	176.2	209.7	53.0	180.1	211.6	50.5	356.3	421.3	103.5	29.0	24.5
11	178.0	212.0	52.5	178.3	209.8	50.5	356.3	421.8	103.0	28.9	24.4
12	178.5	213.0	54.0	176.8	208.3	50.0	355.3	421.3	104.0	29.3	24.6
Total	2096.6	2494.1	633.0	2098.5	2472.0	599.0	4195.1	4966.1	1232.0	29.4	24.8

Table 23. Fat, G.M.12, 1942 - The uncooked and cooked weights of each lot and batch of doughnuts, with grams of fat absorbed and percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying	Wt. after frying	Fat ab-sorbed	Wt. before frying	Wt. after frying	Fat ab-sorbed	Wt. before frying	Wt. after frying	Fat ab-sorbed	Basis raw wt.	Basis cooked wt.
	grams	grams	grams	grams	grams	grams	grams	grams	grams		
1	176.4	209.9	50.0	172.6	202.6	48.5	349.0	412.5	98.5	28.2	23.8
2	177.5	207.0	47.5	174.0	193.5	48.0	351.5	400.5	95.5	27.2	23.8
3	174.1	204.6	46.0	171.6	199.1	46.5	345.7	403.7	92.5	26.8	22.9
4	172.7	206.2	51.5	172.5	204.0	50.0	345.2	410.2	101.5	29.4	24.7
5	174.5	208.0	50.0	171.5	203.5	51.0	346.0	411.5	101.0	29.2	24.5
6	170.0	203.0	51.5	170.5	201.5	49.0	340.5	404.5	100.5	29.5	24.8
7	177.9	211.4	51.5	175.5	206.0	49.0	353.4	417.4	100.5	28.4	24.0
8	172.4	205.4	52.0	174.5	201.5	45.5	346.9	406.9	97.5	28.1	23.9
9	172.1	204.6	51.0	176.5	206.5	48.0	348.6	411.1	99.0	28.4	24.0
10	180.5	214.5	52.5	181.9	211.9	49.0	362.4	426.4	101.5	28.0	23.8
11	174.0	207.5	53.0	180.9	211.9	49.5	354.9	419.4	102.5	28.9	24.4
12	175.4	209.4	54.5	176.8	208.8	49.0	352.2	418.2	103.5	29.4	24.7
Total	2097.5	2491.5	611.0	2098.8	2450.8	583.0	4196.3	4942.3	1194.0	28.5	24.1

Table 24. Fat, G.M.U., 1944 - The uncooked and cooked weights of each lot and batch of doughnuts, with grams of fat absorbed and percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Basis raw wt.	Basis cooked wt.
	grams	grams	grams	grams	grams	grams	grams	grams	grams		
1	176.7	204.2	53.5	170.7	197.7	49.5	347.4	401.9	103.0	29.6	25.6
2	176.2	201.2	44.5	169.7	193.2	45.5	345.9	394.4	90.0	26.0	22.8
3	169.7	195.7	45.5	164.7	189.2	46.0	334.4	384.9	91.5	27.4	23.8
4	171.7	195.2	42.5	166.2	189.2	45.5	337.9	384.4	88.0	26.0	22.9
5	168.7	192.7	45.5	165.2	187.7	43.0	333.9	380.4	88.5	26.5	23.3
6	166.7	190.2	44.5	164.7	186.7	42.5	331.4	376.9	87.0	26.3	23.1
7	175.2	199.2	43.0	171.2	197.2	46.0	346.4	396.4	89.0	25.7	22.5
8	174.2	199.2	43.5	170.2	194.2	43.5	344.4	393.4	87.0	25.3	22.1
9	167.2	190.7	43.5	168.2	191.2	45.0	335.4	381.9	88.5	26.4	23.2
10	175.2	202.2	49.0	168.2	192.2	46.0	343.4	394.4	95.0	27.7	24.1
11	169.2	193.2	44.0	166.2	188.2	43.0	335.4	381.4	87.0	25.9	22.8
12	172.7	198.2	46.0	170.2	196.7	46.5	342.9	394.9	92.5	27.0	23.4
Total	2063.4	2361.9	545.0	2015.4	2303.4	542.0	4078.8	4665.3	1087.0	26.6	23.3

Table 25. Fat, VEGETABLE SHORTENING, 1944 - The uncooked and cooked weights of each lot and batch of doughnuts, with grams of fat absorbed and percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Basis raw wt.	Basis cooked wt.
	grams	grams	grams	grams	grams	grams	grams	grams	grams		
1	174.2	204.2	54.0	174.2	201.7	50.5	348.4	405.9	104.5	30.0	25.7
2	173.7	197.2	43.0	167.2	192.2	45.5	340.9	389.4	88.5	26.0	22.7
3	169.2	196.7	49.5	161.2	186.7	47.0	330.4	383.4	96.5	29.2	25.2
4	165.2	190.7	48.0	162.2	187.2	46.0	327.4	377.9	94.0	28.7	24.9
5	169.7	196.7	48.5	167.7	191.2	43.5	337.4	387.9	92.0	27.3	23.7
6	172.7	195.2	46.0	168.7	190.2	43.0	341.4	385.4	89.0	26.1	23.1
7	170.7	194.2	47.5	170.7	193.2	43.5	341.4	387.4	91.0	26.7	23.5
8	168.2	192.7	46.0	167.2	189.7	45.0	335.4	382.4	91.0	27.1	23.8
9	171.2	198.2	49.0	168.7	192.7	45.5	339.9	390.9	94.5	27.8	24.2
10	169.2	196.7	48.5	166.2	191.7	50.0	335.4	388.4	98.5	29.4	25.4
11	171.2	198.2	48.5	171.7	194.7	43.0	342.9	392.9	91.5	26.7	23.3
12	173.2	197.7	45.5	170.2	196.2	48.0	343.4	393.9	93.5	27.2	23.7
Total	2048.4	2358.4	574.0	2015.9	2307.4	550.5	4064.3	4665.8	1124.5	27.7	24.1

Table 26. Fat, PRIME STEAM LARD, 1944 - The uncooked and cooked weights of each lot and batch of doughnuts, with grams of fat absorbed and percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Wt. before frying	Wt. after frying	Fat absorbed	Basis raw wt.	Basis cooked wt.
	grams	grams	grams	grams	grams	grams	grams	grams	grams		
1	173.7	200.7	50.0	173.7	198.7	48.0	347.4	399.4	98.0	28.2	24.5
2	178.2	203.2	45.0	168.2	192.7	48.5	346.4	395.9	93.5	27.0	23.6
3	169.2	193.7	42.5	163.2	184.7	44.0	332.4	378.4	86.5	26.0	22.9
4	165.7	190.2	46.0	165.7	192.2	52.0	331.4	382.4	98.0	29.6	25.6
5	167.7	193.2	47.0	168.2	191.2	44.5	335.9	384.4	91.5	27.2	23.8
6	169.2	194.7	49.0	169.7	193.7	47.0	338.9	388.4	96.0	28.3	24.7
7	171.7	194.7	43.5	170.2	192.2	42.5	341.9	386.9	86.0	25.2	22.2
8	173.7	196.2	42.0	173.2	192.2	41.0	346.9	388.4	83.0	23.9	21.4
9	171.7	196.7	48.0	169.7	194.7	47.0	341.4	391.4	95.0	27.8	24.3
10	166.7	192.7	49.0	164.2	190.7	49.5	330.9	383.4	98.5	29.8	25.7
11	166.7	194.2	50.5	168.2	192.7	46.0	334.9	386.9	96.5	28.8	24.9
12	167.2	196.2	51.5	169.2	196.2	50.0	336.4	392.4	101.5	30.2	25.9
Total	2041.4	2346.4	564.0	2023.4	2311.9	560.0	4064.8	4658.3	1124.0	27.7	24.1

Table 27. Fat, G.M.12, 1944 - The uncooked and cooked weights of each lot and batch of doughnuts, with grams of fat absorbed and percentage of fat absorbed

Batch no.	First six doughnuts from each batch (Lot 1)			Second six doughnuts from each batch (Lot 2)			Sum of lots 1 and 2 from each batch; 12 doughnuts			Fat absorbed per cent	
	Wt. before frying grams	Wt. after frying grams	Fat absorbed grams	Wt. before frying grams	Wt. after frying grams	Fat absorbed grams	Wt. before frying grams	Wt. after frying grams	Fat absorbed grams	Basis raw wt.	Basis cooked wt.
1	173.2	197.7	47.0	171.2	193.7	44.5	344.4	391.4	91.5	26.6	23.4
2	174.2	200.2	49.0	165.2	192.2	50.5	339.4	392.4	99.5	29.3	25.4
3	171.7	200.2	49.5	165.2	190.7	48.5	336.9	390.9	98.0	29.1	25.1
4	171.7	199.2	49.5	169.2	194.7	48.0	340.9	393.9	97.5	28.6	24.8
5	172.2	197.2	45.5	172.2	196.7	46.0	344.4	393.9	91.5	26.6	23.2
6	172.2	201.5	47.0	167.2	192.7	46.0	339.4	394.2	93.0	27.4	23.6
7	176.7	196.7	39.5	171.2	190.2	41.5	347.9	386.9	81.0	23.3	20.9
8	173.7	197.7	44.0	170.7	195.2	46.5	344.4	392.9	90.5	26.3	23.0
9	177.7	205.2	45.0	168.7	192.7	46.0	346.4	397.9	91.0	26.3	22.9
10	169.7	198.2	49.5	164.7	193.2	51.0	334.4	391.4	100.5	30.1	25.7
11	163.7	183.7	41.5	163.7	182.7	42.0	327.4	366.4	83.5	25.5	22.8
12	167.7	195.2	49.5	167.7	192.2	47.5	335.4	387.4	97.0	28.9	25.0
Total	2064.4	2372.7	556.5	2016.9	2306.9	558.0	4081.3	4679.6	1114.5	27.3	23.82

Table 28. Summary: Fat absorption for each batch of doughnuts fried in each fat

Batch no.	Grams of fat absorbed by each batch of twelve doughnuts							
	1942				1944			
	G.M.U.	Vegetable shortening	Prime steam lard	G.M.12	G.M.U.	Vegetable shortening	Prime steam lard	G.M.12
1	102.0	98.0	103.0	98.5	103.0	104.5	98.0	91.5
2	100.0	98.5	99.0	95.5	90.0	88.5	93.5	99.5
3	98.0	95.0	98.5	92.5	91.5	96.5	86.5	98.0
4	103.0	100.5	102.0	101.5	88.0	94.0	98.0	97.5
5	100.5	97.0	104.0	101.0	88.5	92.0	91.5	91.5
6	104.0	101.0	105.0	100.5	87.0	89.0	96.0	93.0
7	104.0	97.0	106.0	100.5	89.0	91.0	86.0	81.0
8	98.5	99.0	102.5	97.5	87.0	91.0	83.0	90.5
9	99.5	96.5	101.5	99.0	88.5	94.5	95.0	91.0
10	102.0	103.5	103.5	101.5	95.0	98.5	98.5	100.5
11	103.0	95.5	103.0	102.5	87.0	91.5	96.5	83.5
12	105.0	97.0	104.0	103.5	92.5	93.5	101.5	97.0
Total	1219.5	1178.5	1232.0	1194.0	1087.0	1124.5	1124.0	1114.5
Av. absorption for six doughnuts	50.81	49.10	51.33	49.75	45.29	46.85	46.83	46.44

Table 29. The FREE FATTY ACIDS, as per cent oleic, of fat in the kettle after frying successive batches of doughnuts - 1942

Fat	Number of times fat used for frying doughnuts												
	Initial value	1	2	3	4	5	6	7	8	9	10	11	12
G.M.U.	0.047	0.049	0.064	0.076	0.101	0.146	0.162	0.190	0.218	0.256	0.293	0.296	0.346
Vegetable shortening	0.104	0.118	0.115	0.141	0.162	0.188	0.218	0.253	0.284	0.315	0.346	0.372	0.386
Prime steam lard	0.521	0.543	0.626	0.648	0.623	0.612	0.613	0.651	0.662	0.670	0.691	0.691	0.682
G.M.12	0.033	0.039	0.047	0.053	0.073	0.090	0.118	0.152	0.174	0.211	0.256	0.284	0.321

Table 30. The FREE FATTY ACIDS, as per cent oleic, of fat extracted from successive batches of doughnuts - 1942

Fat	Number of batch					
	7	8	9	10	11	12
G.M.U.	0.290	0.303	0.358	0.372	0.408	0.408
Vegetable shortening	0.318	0.352	0.388	0.388	0.414	0.442
Prime steam lard	0.659	0.665	0.698	0.698	0.707	0.722
G.M.12	0.166	0.253	0.267	0.287	0.321	0.377

Table 31. The FREE FATTY ACIDS, as per cent oleic, of fat in the kettle after frying successive batches of doughnuts - 1944

Fat	Initial value	Number of batch 1	2	3	4	5	6	7	8	9	10	11	12
G.M.U.	0.031	0.044	0.055	0.068	0.082	0.111	0.123	0.177	0.206	0.239	0.284	0.319	0.360
Vegetable shortening	0.112	0.136	0.168	0.165	0.198	0.197	0.223	0.268	0.278	0.315	0.340	0.367	0.387
Prime steam lard	0.574	0.604	0.603	0.689	0.645	0.684	0.692	0.711	0.723	0.757	0.760	0.789	0.798
G.M.12	0.027	0.027	0.051	0.059	0.084	0.101	0.125	0.138	0.186	0.219	0.259	0.325	0.371

Table 32. The FREE FATTY ACIDS, as per cent oleic, of fat extracted from successive batches of doughnuts - 1944

Fat	Number of batch											
	1	2	3	4	5	6	7	8	9	10	11	12
G.M.U.	0.068	0.078	0.091	0.109	0.129	0.145	0.189	0.200	0.205	0.253	0.285	0.303
Vegetable shortening	0.150	0.173	0.186	0.187	0.217	0.229	0.265	0.290	0.315	0.333	0.352	0.364
Prime steam lard	0.488	0.491	0.1260	0.788	0.542	0.557	0.624	0.610	0.652	0.678	0.699	0.721
G.M.12	0.071	0.086	0.097	0.106	0.123	0.120	0.149	0.164	0.233	0.230	0.299	0.315

Table 33. Fat, PRIME STEAM LARD, 1944 - The VOLATILE ACIDS of fat in kettle after frying successive batches of doughnuts, and of fat extracted from successive batches of doughnuts

	Initial	1	2	3	4	5	6	7	8	9	10	11	12
Kettle fat													
Water soluble	.374	.501	.517	.742	.377	.464	.465	.483	.502	.647	.487	.638	.599
Alcohol soluble	.213	.194	.219	.189	.222	.154	.161	.199	.165	.196	.201	.165	.198
Extracted fat													
Water soluble	—	1.154	1.069	3.737	2.249	.868	1.032	1.165	1.456	1.299	1.247	1.247	1.481
Alcohol soluble	—	0.370	.364	.315	.303	.354	.271	.286	.422	.265	.344	.308	.387

Table 34. The IODINE NUMBER (Hanus) of fat in the kettle after frying successive batches of doughnuts 1942

Fat	Initial value	Number of times fat used for frying doughnuts											
		1	2	3	4	5	6	7	8	9	10	11	12
G.M.U.	55.6	55.8	55.2	55.0	54.7	54.5	55.1	54.5	54.2	53.4	53.4	53.3	53.0
Vegetable shortening	69.8	69.6	69.5	69.4	69.3	68.4	67.9	68.0	67.0	66.7	66.4	65.5	65.5
Prime steam lard	62.7	60.5	59.4	59.3	59.2	59.0	59.8	59.2	59.3	59.1	58.6	58.2	57.5
G.M.12	55.9	55.5	55.6	55.6	55.0	55.5	55.4	55.0	54.1	53.7	53.7	53.3	53.2

Table 35. The IODINE NUMBER (Hanus) of fat extracted from successive batches of doughnuts - 1942

Fat	Number of batch					
	7	8	9	10	11	12
G.M.U.	53.6	53.9	53.5	53.3	52.7	52.8
Vegetable shortening	66.4	65.9	64.8	64.4	64.6	64.0
Prime steam lard	57.8	57.3	57.6	57.3	57.4	56.4
G.M.12	54.0	53.6	53.4	52.6	53.3	52.3

Table 36. The IODINE NUMBER (Hanus) of fat in the kettle after frying successive batches of doughnuts 1944

Fat	Initial value	Number of times fat used for frying doughnuts											
		1	2	3	4	5	6	7	8	9	10	11	12
G.M.U.	55.7	55.6	55.4	55.2	55.1	54.9	54.6	54.2	54.1	53.8	53.5	53.2	53.1
Vegetable shortening	69.9	69.6	69.4	69.3	69.0	68.5	68.2	67.8	67.6	67.3	66.9	66.4	66.1
Prime steam lard	62.8	61.6	61.9	59.3	61.5	60.7	60.5	60.3	59.7	59.2	59.1	58.5	58.3
G.M.12	55.4	55.4	54.8	54.5	54.4	54.1	54.0	53.8	53.6	53.2	53.0	52.4	52.0

Table 37. The IODINE NUMBER (Hanus) of fat extracted from successive batches of doughnuts - 1944

Fat	Number of batch											
	1	2	3	4	5	6	7	8	9	10	11	12
G.M.U.	54.6	54.2	54.2	54.1	53.9	53.7	53.8	53.2	53.0	52.8	52.6	52.1
Vegetable shortening	68.4	67.8	68.1	67.8	67.3	66.4	66.7	66.1	65.7	65.9	64.7	64.6
Prime steam lard	61.0	61.0	53.4	57.9	60.0	59.9	59.1	59.0	58.4	58.2	57.8	57.4
G.M.12	54.0	54.1	54.1	53.7	53.4	53.2	53.3	52.9	52.5	52.3	51.7	51.3

Table 38. The REFRACTIVE INDEX of fat in the kettle after frying successive batches of doughnuts
1942

Fat	Initial value	Number of times fat used for frying doughnuts 1	2	3	4	5	6	7	8
G.M.U.	1.45977	1.45972	1.45968	1.45979	1.46007	1.46004	1.46029	1.45993	1.46022
Vegetable shortening	1.46113	1.46120	1.46142	1.46139	1.46120	1.46141	1.46155	1.46142	1.46180
Prime steam lard	1.46060	1.46113	1.46138	1.46165	1.46150	1.46118	1.46140	1.46151	1.46167
G.M.12	1.45977	1.45989	1.45995	1.46012	1.45980	1.45939	1.46019	1.46007	1.46021

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Table 38.
Continued from last page

Fat	Number of times fat used for frying doughnuts			
	9	10	11	12
G.M.U.	1.46021	1.46025	1.46015	1.46063
Vegetable shortening	1.46212	1.46242	1.46184	1.46225
Prime steam lard	1.46170	1.46177	1.46159	1.46187
G.M.12	1.46021	1.46081	1.46067	1.46060

Table 39. The REFRACTIVE INDEX of fat extracted from successive batches of doughnuts 1942

Fat	Number of batch					
	7	8	9	10	11	12
G.M.U.	1.45974	1.46003	1.45993	1.46029	1.46005	1.46012
Vegetable shortening	1.46170	1.46158	1.46195	1.46199	1.46211	1.46188
Prime steam lard	1.46114	1.46112	1.46133	1.46147	1.46168	1.46164
G.M.12	1.46012	1.46007	1.46018	1.46028	1.46038	1.46029

Table 40. The REFRACTIVE INDEX of fat in the kettle after frying successive batches of doughnuts 1944

Fat	Initial value	Number of times fat used for frying doughnuts							
		1	2	3	4	5	6	7	8
G.M.U.	1.45848	1.45861	1.45870	1.45878	1.45880	1.45893	1.45894	1.45897	1.45904
Vegetable shortening	1.46000	1.46009	1.46011	1.46019	1.46024	1.46032	1.46061	1.46074	1.46076
Prime steam lard	1.45949	1.45985	1.45987	1.46005	1.45984	1.46005	1.45998	1.45998	1.46008
G.M.12	1.45846	1.45851	1.45854	1.45862	1.45865	1.45870	1.45879	1.45878	1.45899

Continued on next page

Table 40.
Continued from last page

Fat	Number of times fat used for frying doughnuts			
	9	10	11	12
G.M.U.	1.45903	1.45917	1.45920	1.45930
Vegetable shortening	1.46086	1.46088	1.46096	1.46109
Prime steam lard	1.46013	1.46014	1.46019	1.46029
G.M.12	1.45908	1.45903	1.45920	1.45934

Table 41. The REFRACTIVE INDEX of fat extracted from successive batches of doughnuts - 1944

Fat	Number of batch											
	1	2	3	4	5	6	7	8	9	10	11	12
G.M.U.	1.45836	1.45846	1.45851	1.45854	1.45856	1.45877	1.45886	1.45887	1.45891	1.45894	1.45898	1.45900
Vegetable shortening	1.45997	1.46004	1.46015	1.46012	1.46017	1.46026	1.46032	1.46039	1.46049	1.46054	1.46062	1.46071
Prime steam lard	1.45950	1.45951	1.46085	1.46008	1.45984	1.45982	1.45983	1.45998	1.45997	1.46003	1.46006	1.46013
G.M.12	1.45861	1.45868	1.45873	1.45886	1.45887	1.45876	1.45900	1.45888	1.45899	1.45904	1.45903	1.45921

Table 42. G.M.U. 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	9	9	9	9	7	43	
	H	8	7	8	8	9	40	
	S	8	9	8	7	8	40	
	P	9	8	8	7	8	40	
	L	8	7	7	6	8	36	
Total		42	40	40	37	40	199	39.8
Av.		8.4	8.0	8.0	7.4	8.0		
2	O	9	9	8	7	7	40	
	H	8	7	4	5	7	31	
	S	7	6	6	6	8	33	
	P	8	4	7	5	8	32	
	L	7	8	6	5	8	34	
Total		39	34	31	28	38	170	34.0
Av.		7.8	6.8	6.2	5.6	7.6		
3	O	9	8	8	7	8	40	
	H	7	6	8	6	7	34	
	S	8	7	7	7	7	36	
	P	7	9	8	6	7	37	
	L	8	8	7	7	8	38	
Total		39	38	38	33	37	185	37.0
Av.		7.8	7.6	7.6	6.6	7.4		
4	O	8	8	8	7	8	39	
	H	8	6	6	7	7	34	
	S	8	8	7	6	8	37	
	P	7	7	8	6	6	34	
	L	8	8	8	5	8	37	
Total		39	37	37	31	37	181	36.2
Av.		7.8	7.4	7.4	6.2	7.4		
5	O	9	8	8	8	8	41	
	H	8	5	6	4	4	27	
	S	8	7	6	6	8	35	
	P	8	5	7	6	7	33	
	L	7	8	6	6	7	34	
Total		40	33	33	30	34	170	34.0
Av.		8.0	6.6	6.6	6.0	6.8		
6	O	9	8	8	7	8	40	
	H	8	5	7	4	7	31	
	S	7	7	6	6	7	33	
	P	8	8	6	5	7	34	
	L	7	7	6	6	8	34	
Total		39	35	33	28	37	172	34.4
Av.		7.8	7.0	6.6	5.6	7.4		

Table 42 (contd.). G.M.U. 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	7	8	8	7	38	
	H	7	5	6	5	5	28	
	S	8	7	8	8	8	39	
	P	8	7	7	6	6	34	
	L	7	8	5	6	7	33	
Total		38	34	34	33	33	172	34.4
Av.		7.6	6.8	6.8	6.6	6.6		
8	O	8	8	8	7	8	39	
	H	8	5	6	5	5	29	
	S	8	8	7	6	8	37	
	P	7	7	7	7	8	36	
	L	7	8	6	6	8	35	
Total		38	36	34	31	37	176	35.2
Av.		7.6	7.2	6.8	6.2	7.4		
9	O	8	9	8	8	8	41	
	H	8	6	6	6	7	33	
	S	8	7	7	7	8	37	
	P	8	6	6	5	6	31	
	L	7	8	6	7	7	35	
Total		39	36	33	33	36	177	35.4
Av.		7.8	7.2	6.6	6.6	7.2		
10	O	8	9	8	8	7	40	
	H	8	5	5	6	5	29	
	S	8	7	6	3	8	32	
	P	7	6	6	5	7	31	
	L	7	7	5	3	8	30	
Total		38	34	30	25	35	162	32.4
Av.		7.6	6.8	6.0	5.0	7.0		
11	O	8	8	8	8	7	39	
	H	7	6	5	6	6	30	
	S	7	7	4	4	8	30	
	P	8	6	6	4	6	30	
	L	7	6	6	5	8	32	
Total		37	33	29	27	35	161	32.2
Av.		7.4	6.6	5.8	5.4	7.0		
12	O	7	6	9	8	7	37	
	H	7	6	4	5	6	28	
	S	8	6	5	6	8	33	
	P	8	7	5	4	7	31	
	L	7	6	4	4	8	29	
Total		37	31	27	27	36	158	31.6
Av.		7.4	6.2	5.4	5.4	7.2		

Table 43. VEGETABLE SHORTENING, 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	9	8	9	7	8	41	
	H	8	8	8	6	7	37	
	S	7	7	7	7	8	36	
	P	8	6	8	6	8	36	
	L	8	8	8	7	8	39	
Total		40	37	40	33	39	189	37.8
Av.		8.0	7.4	8.0	6.6	7.8		
2	O	9	8	9	6	7	39	
	H	8	6	4	6	7	31	
	S	8	7	8	8	8	39	
	P	8	4	7	4	7	30	
	L	7	8	6	4	8	33	
Total		40	33	34	28	37	172	34.4
Av.		8.0	6.6	6.8	5.6	7.4		
3	O	9	7	8	5	8	37	
	H	8	7	7	5	6	33	
	S	7	7	6	6	6	32	
	P	8	7	6	6	7	34	
	L	7	7	8	5	8	35	
Total		39	35	35	27	35	171	34.2
Av.		7.8	7.0	7.0	5.4	7.0		
4	O	8	8	8	4	8	36	
	H	8	6	5	6	6	31	
	S	8	7	7	7	8	37	
	P	7	4	6	6	7	30	
	L	8	7	7	3	7	32	
Total		39	32	33	26	36	166	33.2
Av.		7.8	6.4	6.6	5.2	7.2		
5	O	9	8	6	7	8	38	
	H	8	5	6	5	6	30	
	S	8	7	7	6	7	35	
	P	8	8	8	7	7	38	
	L	7	7	5	2	7	28	
Total		40	35	32	27	35	169	33.8
Av.		8.0	7.0	6.4	5.4	7.0		
6	O	9	7	7	4	8	35	
	H	8	4	6	4	5	27	
	S	7	7	6	5	8	33	
	P	8	6	6	6	7	33	
	L	7	8	6	6	8	35	
Total		39	32	31	25	36	163	32.6
Av.		7.8	6.4	5.2	5.0	7.2		

Table 43 (cont'd). VEGETABLE SHORTENING, 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	6	6	5	7	32	
	H	8	6	5	5	5	29	
	S	8	6	7	8	8	37	
	P	8	8	7	5	7	35	
	L	7	6	4	4	8	29	
Total		39	32	29	27	35	162	32.4
Av.		7.8	6.4	5.8	5.4	7.0		
8	O	8	8	6	4	8	34	
	H	7	6	6	6	6	31	
	S	7	7	6	4	8	32	
	P	8	8	7	4	7	34	
	L	6	7	5	4	7	29	
Total		36	36	30	22	36	160	32.0
Av.		7.2	7.2	6.0	4.4	7.2		
9	O	8	9	6	4	8	35	
	H	8	6	6	6	7	33	
	S	8	6	5	6	8	33	
	P	8	7	6	4	8	33	
	L	7	7	6	6	8	34	
Total		39	35	29	26	39	168	33.6
Av.		7.8	7.0	5.8	5.2	7.8		
10	O	8	8	8	5	7	36	
	H	7	4	6	6	7	30	
	S	8	5	8	6	8	35	
	P	8	7	6	5	8	34	
	L	7	7	7	5	8	34	
Total		38	31	35	27	38	169	33.8
Av.		7.6	6.2	7.0	5.4	7.6		
11	O	8	9	8	7	7	39	
	H	7	5	6	7	7	32	
	S	8	7	7	7	8	37	
	P	8	7	7	7	7	36	
	L	7	6	6	3	8	30	
Total		38	34	34	31	37	174	34.8
Av.		7.6	6.8	6.8	6.2	7.4		
12	O	7	7	8	5	7	34	
	H	7	7	4	4	5	27	
	S	8	6	6	6	8	34	
	P	8	8	7	3	7	33	
	L	7	7	4	6	8	32	
Total		37	35	29	24	35	160	32.0
Av.		7.4	7.0	5.8	4.8	7.0		

Table 44. PRIME STEAM LARD, 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	9	7	9	6	8	39	
	H	8	6	7	8	8	37	
	S	6	7	7	7	7	34	
	P	8	5	4	3	6	26	
	L	8	8	8	5	8	37	
Total		39	33	35	29	37	173	34.6
Av.		7.8	6.6	7.0	5.8	7.4		
2	O	9	9	9	8	7	42	
	H	8	5	7	7	6	33	
	S	8	7	7	8	8	38	
	P	8	4	7	3	7	29	
	L	8	8	8	6	8	38	
Total		41	33	38	32	36	180	36.0
Av.		8.2	6.6	7.6	6.4	7.2		
3	O	9	7	9	4	8	37	
	H	8	4	4	4	5	25	
	S	8	7	7	8	8	38	
	P	8	4	2	1	5	20	
	L	8	7	8	5	8	36	
Total		41	29	30	22	34	156	31.2
Av.		8.2	5.8	6.0	4.4	6.8		
4	O	8	7	6	3	8	32	
	H	8	6	3	3	4	24	
	S	8	6	6	5	7	32	
	P	7	4	2	1	5	19	
	L	8	7	5	4	8	32	
Total		39	30	22	16	32	139	27.8
Av.		7.8	6.2	4.4	3.2	6.4		
5	O	9	7	7	5	8	36	
	H	8	4	4	4	5	25	
	S	8	6	7	5	8	34	
	P	8	4	2	2	7	23	
	L	7	8	6	5	7	33	
Total		40	29	26	21	35	151	30.2
Av.		8.0	5.8	5.2	4.2	7.0		
6	O	9	6	8	5	7	35	
	H	8	6	4	5	6	29	
	S	8	7	6	7	8	36	
	P	9	5	3	2	6	25	
	L	8	8	7	5	7	35	
Total		42	32	28	24	34	160	32.0
Av.		8.4	6.4	5.6	4.8	6.8		

Table 44 (cont'd). PRIME STEAM LARD, 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	6	7	6	7	34	
	H	7	6	5	5	5	28	
	S	7	6	6	6	8	33	
	P	7	7	7	3	6	30	
	L	8	6	7	5	7	33	
Total		37	31	32	25	33	158	31.6
Av.		7.4	6.2	6.4	5.0	6.6		
8	O	8	7	7	6	8	36	
	H	7	4	5	5	5	26	
	S	8	6	1	1	8	24	
	P	8	6	7	4	7	32	
	L	7	5	5	3	7	27	
Total		38	28	25	19	35	145	29.0
Av.		7.6	5.6	5.0	3.8	7		
9	O	8	7	7	5	8	35	
	H	8	6	5	4	7	30	
	S	8	7	6	7	8	36	
	P	8	7	5	5	6	31	
	L	7	7	5	4	7	30	
Total		39	34	28	25	36	162	32.4
Av.		7.8	6.8	5.6	5.0	7.2		
10	O	8	7	6	5	7	33	
	H	8	5	4	4	7	28	
	S	8	7	5	3	8	31	
	P	8	7	6	3	7	31	
	L	8	6	7	5	7	33	
Total		40	32	28	20	36	156	33.2
Av.		8.0	6.4	5.6	4.0	7.2		
11	O	8	8	8	7	7	38	
	H	8	5	6	6	7	32	
	S	8	6	4	4	8	30	
	P	8	6	7	4	7	32	
	L	7	6	6	2	7	28	
Total		39	31	31	23	36	160	32.0
Av.		7.8	6.2	6.2	4.6	7.2		
12	O	7	7	9	6	7	36	
	H	8	7	5	4	8	32	
	S	7	6	5	5	8	31	
	P	8	7	5	2	5	27	
	L	7	6	6	7	8	34	
Total		37	33	30	24	36	160	32.0
Av.		7.4	6.6	6.0	4.8	7.2		

Table 45. G.M.12, 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	9	9	9	8	8	43	
	H	7	8	8	5	7	35	
	S	7	8	8	8	7	38	
	P	7	6	8	3	5	29	
	L	8	7	7	7	8	37	
Total		38	38	40	31	35	182	36.4
Av.		7.6	7.8	8.0	6.2	7.0		
2	O	9	9	9	8	7	42	
	H	8	6	6	7	6	33	
	S	8	7	8	8	8	39	
	P	8	7	6	5	7	33	
	L	8	8	8	7	8	39	
Total		41	37	37	35	36	186	37.2
Av.		8.2	7.4	7.4	7.0	7.2		
3	O	9	8	9	8	8	42	
	H	8	5	5	5	5	28	
	S	8	8	9	9	8	42	
	P	8	6	8	7	8	37	
	L	8	7	8	7	8	38	
Total		41	34	39	36	37	187	37.4
Av.		8.2	6.8	7.8	7.2	7.4		
4	O	8	8	8	9	8	41	
	H	7	5	4	5	6	27	
	S	8	7	6	6	7	34	
	P	7	4	6	4	6	27	
	L	7	6	5	5	8	31	
Total		37	30	29	29	35	160	32.0
Av.		7.4	6.0	5.8	5.8	7.0		
5	O	9	9	9	9	8	44	
	H	8	4	5	5	6	28	
	S	8	6	7	7	8	36	
	P	7	5	8	5	6	31	
	L	7	8	6	5	7	33	
Total		39	32	35	31	35	172	34.4
Av.		7.8	6.4	7.0	6.2	7.0		
6	O	9	8	8	7	8	40	
	H	8	7	6	7	7	35	
	S	8	8	7	7	8	38	
	P	7	7	8	6	5	33	
	L	8	8	7	6	8	37	
Total		40	38	36	33	36	183	36.6
Av.		8.0	7.6	7.2	6.6	7.2		

Table 45 (cont'd). G.M.12, 1942 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	8	8	9	7	40	
	H	8	5	6	6	4	29	
	S	8	7	7	8	8	38	
	P	8	6	7	5	5	31	
	L	7	8	5	4	8	32	
Total		39	34	33	32	32	170	34.0
Av.		7.8	6.8	6.6	6.4	6.4		
8	O	8	8	8	8	8	40	
	H	7	5	4	4	5	25	
	S	8	7	7	6	8	36	
	P	7	7	8	7	7	36	
	L	7	5	5	6	7	30	
Total		37	32	32	31	35	167	33.4
Av.		7.4	6.4	6.4	6.2	7.0		
9	O	8	9	8	9	8	42	
	H	7	5	6	5	5	28	
	S	7	7	7	6	8	35	
	P	7	6	7	7	7	34	
	L	6	8	5	4	7	30	
Total		35	35	33	31	35	169	33.8
Av.		7.0	7.0	6.6	6.2	7.0		
10	O	8	8	8	9	7	40	
	H	7	6	6	6	7	32	
	S	7	6	5	4	8	30	
	P	7	6	8	6	6	33	
	L	7	6	5	3	8	29	
Total		36	32	32	28	36	164	32.8
Av.		7.2	6.4	6.4	5.6	7.2		
11	O	8	8	8	9	7	40	
	H	8	6	6	5	4	29	
	S	7	6	6	7	7	33	
	P	8	5	6	6	6	31	
	L	7	5	4	4	8	28	
Total		38	30	30	31	32	161	32.2
Av.		7.6	6.0	6.0	6.2	6.4		
12	O	7	7	9	9	7	39	
	H	8	6	6	6	7	33	
	S	8	6	6	5	8	33	
	P	8	6	8	6	6	34	
	L	7	7	4	3	8	29	
Total		38	32	33	29	36	168	33.6
Av.		7.6	6.4	6.6	5.8	7.2		

Table 46. G.M.U., 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	8	7	9	5	8	37	
	H	7	8	6	4	6	31	
	M	9	9	10	7	9	44	
	L	8	9	6	6	8	37	
	P	8	7	6	4	7	32	
	Hood	9	8	7	7	9	40	
Total		49	48	44	33	47	221	36.8
Av.		8.2	8.0	7.3	5.5	7.8		
2	O	8	7	9	5	6	35	
	H	7	8	6	4	7	32	
	M	8	8	9	9	9	43	
	L	8	9	9	7	8	41	
	P	8	8	7	6	7	36	
	Hood	9	8	8	8	9	42	
Total		48	48	48	39	46	229	38.2
Av.		8.0	8.0	8.0	6.5	7.7		
3	O	8	8	6	3	7	32	
	H	5	6	7	5	7	30	
	M	8	9	8	7	9	41	
	L	8	8	8	8	8	40	
	P	9	8	8	6	7	38	
	Hood	9	8	8	7	9	41	
Total		47	47	45	36	47	222	37.0
Av.		7.8	7.8	7.5	6.0	7.8		
4	O	7	8	6	3	8	32	
	H	5	8	6	6	6	31	
	M	8	9	9	7	9	42	
	L	8	8	8	7	7	38	
	P	9	8	8	8	8	41	
	Hood	9	8	9	9	9	44	
Total		46	49	46	40	47	228	38.0
Av.		7.7	8.2	7.7	6.7	7.8		
5	O	8	8	9	5	8	38	
	H	5	6	4	5	5	25	
	M	9	8	7	7	9	40	
	L	8	8	7	7	8	38	
	P	8	9	7	6	8	38	
	Hood	9	8	9	8	9	43	
Total		47	47	43	38	47	222	37.0
Av.		7.8	7.8	7.2	6.3	7.8		
6	O	8	8	9	7	8	40	
	H	5	7	6	5	5	28	
	M	9	8	7	8	9	41	
	L	7	7	7	5	7	33	
	P	8	9	6	8	8	39	
	Hood	9	8	6	7	9	39	
Total		46	47	41	40	46	220	36.7
Av.		7.7	7.8	6.8	6.7	7.7		

Table 46 (cont'd). G.M.U., 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	8	8	8	8	40	
	H	6	7	7	3	9	32	
	M	8	8	8	8	9	41	
	L	7	8	6	5	8	34	
	P	8	8	8	8	8	40	
	Hood	9	9	8	7	9	42	
Total		46	48	45	39	51	229	38.2
Av.		7.7	8.0	7.5	6.5	8.5		
8	O	8	8	8	8	8	40	
	H	6	7	5	3	6	27	
	M	8	8	7	5	9	37	
	L	7	8	6	4	8	33	
	P	8	8	7	8	8	39	
	Hood	9	9	8	8	9	43	
Total		46	48	41	36	48	219	36.5
Av.		7.7	8.0	6.8	6.0	8.0		
9	O	8	8	8	8	8	40	
	H	5	7	4	4	5	25	
	M	9	9	8	8	8	42	
	L	7	8	7	7	8	37	
	P	8	8	8	5	8	37	
	Hood	9	8	7	8	9	41	
Total		46	48	42	40	46	222	37.0
Av.		7.7	8.0	7.0	6.7	7.7		
10	O	8	8	8	6	8	38	
	H	6	6	6	3	6	27	
	M	8	7	8	5	8	36	
	L	7	6	6	5	6	30	
	P	8	7	8	7	8	38	
	Hood	9	8	7	8	9	41	
Total		46	42	43	34	45	210	35.0
Av.		7.7	7.0	7.2	5.7	7.5		
11	O	7	8	8	7	7	37	
	H	5	8	7	5	7	32	
	M	8	8	8	6	9	39	
	L	7	8	7	6	8	36	
	P	8	8	7	6	8	37	
	Hood	9	8	8	8	9	42	
Total		44	48	45	38	48	223	37.2
Av.		7.3	8.0	7.5	6.3	8.0		
12	O	7	8	8	7	7	37	
	H	5	6	7	4	5	27	
	M	9	8	8	4	9	38	
	L	7	8	5	7	8	35	
	P	8	8	7	6	8	37	
	Hood	9	8	7	7	9	40	
Total		45	46	42	35	46	214	35.7
Av.		7.5	7.7	7.0	5.8	7.7		

Table 47. PRIME STEAM LARD, 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	8	6	5	5	7	31	
	H	5	6	7	3	8	29	
	M	7	8	6	3	9	33	
	L	8	8	7	7	8	38	
	P	9	7	7	6	7	36	
	Hood	9	5	8	2	9	33	
Total		46	40	40	26	48	200	33.3
Av.		7.7	6.7	6.7	4.3	8.0		
2	O	9	5	9	6	7	36	
	H	6	5	5	4	7	27	
	M	7	8	8	6	9	38	
	L	8	7	9	5	8	37	
	P	9	8	8	7	7	39	
	Hood	9	4	7	6	9	35	
Total		48	37	46	34	47	212	35.3
Av.		8.0	6.2	7.7	5.7	7.8		
3	O	7	8	8	5	8	36	
	H	5	5	6	1	5	22	
	M	7	8	8	4	9	36	
	L	8	8	7	7	8	38	
	P	9	8	8	5	8	38	
	Hood	9	5	8	5	9	36	
Total		45	42	45	27	47	206	34.3
Av.		7.5	7.0	7.5	4.5	7.8		
4	O	8	7	7	6	8	36	
	H	5	3	2	1	4	15	
	M	7	8	8	7	9	39	
	L	8	7	6	7	7	35	
	P	9	7	7	6	8	37	
	Hood	8	4	5	3	8	28	
Total		45	36	35	30	44	190	31.7
Av.		7.5	6.0	5.8	5.0	7.3		
5	O	8	7	6	0	8	29	
	H	6	5	3	4	4	22	
	M	6	5	4	4	9	28	
	L	8	6	8	5	8	35	
	P	8	7	8	5	7	35	
	Hood	9	5	4	2	9	29	
Total		45	35	33	20	45	178	29.7
Av.		7.5	5.8	5.5	3.3	7.5		
6	O	8	7	7	0	5	27	
	H	4	4	5	3	3	19	
	M	6	6	5	4	9	30	
	L	7	7	7	6	7	34	
	P	8	7	8	5	8	36	
	Hood	9	6	3	3	9	30	
Total		42	37	35	21	41	176	29.3
Av.		7.0	6.2	5.8	3.5	6.8		

Table 47 (cont'd). PRIME STEAM LARD, 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	6	6	1	8	29	
	H	6	7	6	4	8	31	
	M	6	6	6	4	9	31	
	L	7	6	7	7	7	34	
	P	8	7	7	6	7	35	
	Hood	9	8	6	5	9	37	
Total		44	40	38	27	48	197	32.8
Av.		7.3	6.7	6.3	4.5	8.0		
8	O	8	8	8	1	8	33	
	H	6	6	5	4	8	29	
	M	7	6	6	3	9	31	
	L	7	7	7	6	7	34	
	P	8	7	6	5	7	33	
	Hood	9	6	8	4	9	36	
Total		45	40	40	23	48	196	32.7
Av.		7.5	6.7	6.7	3.8	8.0		
9	O	8	6	8	0	8	30	
	H	6	6	4	2	7	25	
	M	7	7	4	3	8	29	
	L	7	6	7	5	8	33	
	P	8	6	5	4	8	31	
	Hood	9	6	5	3	9	32	
Total		45	37	33	17	48	180	30.0
Av.		7.5	6.2	5.5	2.8	8.0		
10	O	8	6	8	0	8	30	
	H	6	5	4	4	6	25	
	M	7	7	7	4	8	33	
	L	7	6	7	5	8	33	
	P	8	6	6	3	8	31	
	Hood	9	5	5	3	9	31	
Total		45	35	37	19	47	183	30.5
Av.		7.5	5.8	6.2	3.2	7.8		
11	O	7	5	7	0	7	26	
	H	6	4	5	3	5	23	
	M	7	6	5	3	9	30	
	L	7	6	7	6	7	33	
	P	8	6	8	5	8	35	
	Hood	9	6	5	4	9	33	
Total		44	33	37	21	45	180	30.0
Av.		7.3	5.5	6.2	3.5	7.5		
12	O	7	5	8	0	6	26	
	H	5	4	6	4	4	23	
	M	7	5	8	7	9	36	
	L	7	5	8	5	7	32	
	P	8	7	7	5	8	35	
	Hood	9	5	5	3	9	31	
Total		43	31	42	24	43	183	30.5
Av.		7.2	5.2	7.0	4.0	7.2		

Table 48. VEGETABLE SHORTENING, 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	8	7	9	7	6	37	
	H	7	7	7	5	6	32	
	M	9	8	10	9	9	45	
	L	9	8	8	8	8	41	
	P	8	6	8	8	7	37	
	Hood	9	6	8	7	9	39	
Total		50	42	50	44	45	231	38.5
Av.		8.3	7.0	8.3	7.3	7.5		
2	O	8	7	9	7	8	39	
	H	5	5	7	5	5	27	
	M	8	7	9	9	9	42	
	L	8	8	9	8	8	41	
	P	8	7	8	6	7	36	
	Hood	9	6	7	7	9	38	
Total		46	40	49	42	46	223	37.2
Av.		7.7	6.7	8.2	7.0	7.7		
3	O	7	6	9	7	7	36	
	H	4	5	5	4	7	25	
	M	7	7	8	7	9	38	
	L	8	7	8	8	8	39	
	P	9	7	7	8	7	38	
	Hood	9	5	7	5	9	35	
Total		44	37	44	39	47	211	35.2
Av.		7.3	6.2	7.3	6.5	7.8		
4	O	8	7	7	6	8	36	
	H	5	6	5	4	5	25	
	M	8	8	8	7	9	40	
	L	8	7	8	8	7	38	
	P	9	8	8	8	8	41	
	Hood	9	7	7	6	9	38	
Total		47	43	43	39	46	218	36.3
Av.		7.8	7.2	7.2	6.5	7.7		
5	O	8	7	9	6	8	38	
	H	5	6	3	4	4	22	
	M	9	7	8	6	9	39	
	L	8	6	7	5	7	33	
	P	8	8	7	5	7	35	
	Hood	9	5	9	7	9	39	
Total		47	39	43	33	44	206	34.3
Av.		7.8	6.5	7.2	5.5	7.3		
6	O	8	8	9	6	8	39	
	H	5	5	5	4	6	25	
	M	8	7	7	7	9	38	
	L	7	7	7	7	8	36	
	P	8	8	8	8	8	40	
	Hood	9	7	9	9	9	43	
Total		45	42	45	41	48	221	36.8
Av.		7.5	7.0	7.5	6.8	8.0		

Table 48 (cont'd). VEGETABLE SHORTENING, 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	8	6	6	8	36	
	H	6	6	5	3	8	28	
	M	6	6	7	5	9	33	
	L	7	6	7	7	7	34	
	P	8	7	6	5	7	33	
	Hood	9	6	6	7	9	37	
Total		44	39	37	33	48	201	33.5
Av.		7.3	6.5	6.2	5.5	8.0		
8	O	8	6	6	6	8	34	
	H	5	5	6	5	5	26	
	M	6	5	6	7	9	33	
	L	7	7	7	5	7	33	
	P	8	8	7	6	7	36	
	Hood	9	7	8	7	9	40	
Total		43	38	40	36	45	202	33.7
Av.		7.2	6.3	6.7	6.0	7.5		
9	O	8	7	8	6	7	36	
	H	6	6	5	3	5	25	
	M	7	6	6	7	8	34	
	L	7	6	8	5	7	33	
	P	8	6	7	4	8	33	
	Hood	9	5	8	7	9	38	
Total		45	36	42	32	44	199	33.2
Av.		7.5	6.0	7.0	5.3	7.3		
10	O	8	7	8	8	8	39	
	H	6	5	6	3	6	26	
	M	7	7	6	6	8	34	
	L	7	6	7	4	7	31	
	P	8	6	7	3	8	32	
	Hood	9	7	7	7	9	39	
Total		45	38	41	31	46	201	
Av.		7.5	6.3	6.8	5.2	7.7		
11	O	7	5	8	5	7	32	
	H	6	5	4	4	6	25	
	M	7	7	6	5	9	34	
	L	7	6	5	4	7	29	
	P	8	7	6	5	8	34	
	Hood	9	6	6	8	9	38	
Total		44	36	35	31	46	192	32.0
Av.		7.3	6.0	5.8	5.2	7.7		
12	O	6	6	7	6	7	32	
	H	6	6	6	2	5	25	
	M	7	7	7	7	9	37	
	L	7	6	7	5	8	33	
	P	8	6	7	5	8	34	
	Hood	9	7	8	6	9	39	
Total		43	38	42	31	46	200	33.3
Av.		7.2	6.3	7.0	5.2	7.7		

Table 49. G.M.12, 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
1	O	8	7	9	6	6	36	
	H	5	6	6	4	6	27	
	M	9	8	9	8	9	43	
	L	9	9	8	7	8	41	
	P	8	7	6	5	7	33	
	Hood	9	8	8	7	9	41	
Total		48	45	46	37	45	221	36.8
Av.		8.0	7.5	7.7	6.2	7.5		
2	O	8	7	9	6	6	36	
	H	4	4	7	5	4	24	
	M	9	7	9	9	9	43	
	L	9	8	9	7	8	41	
	P	8	8	6	7	5	34	
	Hood	9	7	8	7	9	40	
Total		47	41	48	41	41	218	36.3
Av.		7.8	6.8	8.0	6.8	6.8		
3	O	8	6	9	7	7	37	
	H	6	6	6	4	6	28	
	M	8	9	7	8	9	41	
	L	8	8	9	8	8	41	
	P	9	8	8	9	7	41	
	Hood	8	7	8	8	9	40	
Total		47	44	47	44	46	228	38.0
Av.		7.8	7.3	7.8	7.3	7.7		
4	O	7	8	8	7	8	38	
	H	5	8	5	4	7	29	
	M	8	8	9	8	9	42	
	L	8	8	8	7	8	39	
	P	9	7	8	7	7	38	
	Hood	9	8	9	9	9	44	
Total		46	47	47	42	48	230	38.3
Av.		7.7	7.8	7.8	7.0	8.0		
5	O	8	8	9	7	8	40	
	H	5	6	5	4	6	26	
	M	9	8	7	7	9	40	
	L	8	8	6	5	8	35	
	P	8	8	5	7	7	35	
	Hood	9	9	9	9	9	45	
Total		47	47	41	39	47	221	36.8
Av.		7.8	7.8	6.8	6.5	7.8		
6	O	8	7	9	7	8	39	
	H	5	5	4	4	4	22	
	M	7	7	7	7	9	37	
	L	8	7	7	7	7	36	
	P	8	8	7	8	8	39	
	Hood	9	8	8	5	9	39	
Total		45	42	42	38	45	212	35.3
Av.		7.5	7.0	7.0	6.3	7.5		

Table 49 (cont'd). G.M.12, 1944 - Scores of individual judges for each batch of doughnuts fried in each fat

Batch no.	Judge	Appearance	Greasiness	Odor	Flavor	Texture	Total	Av.
7	O	8	8	8	8	8	40	
	H	6	7	6	4	8	31	
	M	7	8	8	8	9	40	
	L	7	8	6	5	8	34	
	P	8	8	7	7	8	38	
	Hood	9	8	8	7	9	41	
Total		45	47	43	39	50	224	37.3
Av.		7.5	7.8	7.2	6.5	8.3		
8	O	8	8	8	8	8	40	
	H	6	6	6	5	7	30	
	M	8	8	8	8	9	41	
	L	7	8	8	8	7	38	
	P	8	7	7	8	8	38	
	Hood	9	8	8	8	9	42	
Total		46	45	45	45	48	229	38.2
Av.		7.7	7.5	7.5	7.5	8.0		
9	O	8	8	8	8	8	40	
	H	6	7	6	3	5	27	
	M	7	7	8	8	8	38	
	L	7	7	5	5	7	31	
	P	8	7	8	5	8	36	
	Hood	9	7	6	5	9	36	
Total		45	43	41	34	45	208	34.7
Av.		7.5	7.2	6.8	5.7	7.5		
10	O	8	8	8	8	8	40	
	H	6	7	5	4	6	28	
	M	7	7	7	6	8	35	
	L	7	7	7	6	8	35	
	P	8	7	6	4	8	33	
	Hood	9	6	8	8	9	40	
Total		45	42	41	36	47	211	35.2
Av.		7.5	7.0	6.8	6.0	7.8		
11	O	7	8	8	8	7	38	
	H	6	6	5	5	4	26	
	M	7	7	7	8	9	38	
	L	7	7	7	5	7	33	
	P	8	7	9	8	8	40	
	Hood	9	7	6	6	9	37	
Total		44	42	42	40	44	212	35.3
Av.		7.3	7.0	7.0	6.7	7.3		
12	O	7	5	8	8	7	35	
	H	5	7	6	5	4	27	
	M	7	6	7	5	9	34	
	L	7	7	7	4	7	32	
	P	8	8	8	7	8	39	
	Hood	9	7	7	8	9	40	
Total		43	40	43	37	44	207	34.5
Av.		7.2	6.7	7.2	6.2	7.3		

Table 5D. TEMPERATURES: Temperatures of room, incubator and dough for each mix of doughnuts - 1942

Mix no.		G.M.U.	Vegetable shortening	Prime steam lard	G.M.12
1	Room	25.0	25.0	25.0	24.5
	Incubator	24.5	24.5	24.5	24.5
	Dough	24.3	24.5	24.5	24.0
2	Room	25.0	24.5	25.0	24.5
	Incubator	25.0	24.5	25.0	24.5
	Dough	24.0	24.0	25.0	24.0
3	Room	25.0	24.5	25.0	24.5
	Incubator	24.5	24.5	24.5	24.5
	Dough	25.0	24.0	25.0	24.0
4	Room	25.5	25.0	25.0	24.5
	Incubator	24.5	24.5	24.5	24.5
	Dough	24.5	24.5	24.5	24.0
5	Room	25.0	24.5	25.0	25.0
	Incubator	24.5	24.0	24.5	24.5
	Dough	24.0	23.5	23.5	23.5
6	Room	25.0	24.5	25.0	25.0
	Incubator	24.5	24.5	24.5	24.5
	Dough	24.0	24.5	24.5	23.5
7	Room	23.5	23.0	23.0	23.0
	Incubator	25.0	25.0	25.0	25.0
	Dough	24.0	23.5	23.5	23.5
8	Room	26.0	25.5	25.0	24.5
	Incubator	25.0	25.0	25.0	25.0
	Dough	24.5	24.8	24.0	25.0
9	Room	25.0	25.0	25.0	25.0
	Incubator	25.0	25.0	25.0	25.0
	Dough	24.5	24.0	24.5	24.5
10	Room	25.0	25.0	25.0	24.0
	Incubator	24.5	24.5	24.5	24.5
	Dough	24.5	24.5	24.5	24.0
11	Room	24.5	25.0	25.0	26.0
	Incubator	25.0	25.0	25.0	25.0
	Dough	24.5	24.0	25.0	25.0
12	Room	23.0	23.0	23.0	23.0
	Incubator	25.0	25.0	25.0	25.0
	Dough	23.5	24.0	23.5	23.5

Table 51. TEMPERATURES: Temperatures of room, indubator and dough for each mix of doughnuts - 1944

Mix no.		G.M.U.	Vegetable shortening	Prime steam lard	G.M.12
1	Room	25.0	25.0	26.0	25.5
	Incubator	25.0	25.0	26.0	25.5
	Dough	25.5	26.0	25.0	25.5
2	Room	25.0	25.0	26.0	26.0
	Incubator	25.0	25.0	26.0	25.5
	Dough	25.5	25.0	25.5	25.5
3	Room	26.0	25.0	26.0	25.5
	Incubator	26.0	26.0	26.0	26.0
	Dough	26.0	25.5	26.0	25.5
4	Room	26.0	25.0	26.5	25.0
	Incubator	26.0	26.0	26.0	26.0
	Dough	26.0	25.5	26.5	25.5
5	Room	26.5	25.0	27.0	25.0
	Incubator	26.0	26.5	26.0	26.5
	Dough	26.5	25.5	27.0	26.0
6	Room	27.0	26.0	27.0	25.0
	Incubator	26.0	26.5	26.0	26.5
	Dough	26.0	26.5	26.5	26.0
7	Room	26.0	26.5	25.0	27.0
	Incubator	27.0	27.0	27.0	27.0
	Dough	26.0	26.0	25.5	27.0
8	Room	26.0	27.0	26.5	25.0
	Incubator	27.5	28.0	27.0	27.0
	Dough	26.0	26.5	26.5	26.5
9	Room	26.0	24.0	27.0	25.0
	Incubator	28.0	27.0	27.0	28.0
	Dough	26.5	25.5	26.0	26.0
10	Room	27.0	25.0	27.0	25.0
	Incubator	28.0	27.0	27.0	28.0
	Dough	26.0	26.0	26.0	26.0
11	Room	26.0	26.0	26.0	27.0
	Incubator	27.5	27.0	27.0	27.0
	Dough	26.0	26.5	26.0	27.0
12	Room	25.5	25.5	27.0	26.0
	Incubator	27.0	27.0	26.5	27.0
	Dough	26.0	26.0	26.0	27.0

SCORE CARD FOR DOUGHNUTS

Name______________________________ Date__________________

	Score from 1 to 10, with 10 high quality
	Sample number
Quality	
Appearance	
Fat absorption	
Odor	
Flavor	
Texture	
Eating quality: Summary of all qualities	

If flavor, odor, or fat absorption are outstanding for desirability or undesirability, give the number of the sample, and a word describing your impression.

	No.		No.	
Odor				
		Desirable Description		Undesirable Description
Flavor				
Fat absorption				

Preference: Sample number__________