Changes in a Fat With Prolonged Storage and the Palatability of Doughnuts Cooked in the Fat[1]

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SOME chemical and physical changes in a fat used for cooking doughnuts are herein reported. These constants were determined before and after cooking a definite number of doughnuts in the fat. The doughnuts were cooked after the fat had been stored the following periods: 6 months, 2.5 years, and 3.5 years. In addition, the changes in the fat extracted from the doughnuts were determined as well as the palatability ratings of doughnuts cooked after storage of the fat for 6 months and 2.5 years.

The G. M. 12 fat, a processed lard, was packed in two-pound slip cover tin cans. All of the fat was stated to be from the same lot and was received directly from the manufacturer. The fat was held at room temperature (according to directions from the manufacturer) for 2.5 years. It was refrigerated during the last year. This fat had an antioxidant (a tocopherol concentrate) and a synergist (ascorbic acid) added to improve the keeping quality. It was partially hydrogenated, and the metallic contaminants had been removed during the processing. In processing, the fat was stirred in an atmosphere of nitrogen.

Experimental

A household doughnut formula was used throughout all the series. Flour, sugar, salt, and baking powder were purchased in large enough quantity for all the doughnuts cooked in a given year. No attempt was made to hold these ingredients from one year to the next. Changes would have occurred in the flour and baking powder over a 3.5-year period. Dehydrated eggs and milk could not have been held 3.5 years, even at a very low temperature, without deteriorative changes, hence fresh eggs and bottled milk were used. Milk and eggs from the same source were used in all batches of doughnuts mixed and cooked on a given day. The milk for all mixes of doughnuts made on a particular day was stirred, then the amount for each mix was weighed into a container, which was covered and stored until used. The egg magma was thoroughly blended, then divided for individual mixes. All the ingredients, with the exception of the eggs and milk, were incubated at approximately 25°C.(77°F.) previously to mixing. The eggs and milk were brought to 25°C. by placing the container into which each portion was weighed in warm water and stirring with a thermometer.

The mixing was standardized, a KitchenAid being used for the process. The doughnuts were rolled, cut, handled, and fried under standardized conditions. The size and thickness were practically constant. A household, round-bottom, iron kettle having a diameter of 8.75 inches was used to hold the fat for cooking. At the start of the tests the kettle was as full as it could be to cook the doughnuts without the fat running over the edge of the kettle. After cooking 24 lots of doughnuts and removing the necessary samples, the fat was less than half the depth of the kettle. Six doughnuts were cooked at a time and 12 doughnuts were obtained from a given mix of dough. In all 24 lots (6 doughnuts per lot) were cooked in the fat. The fat was heated to 185°C.(365°F.) and maintained at this temperature for cooking the doughnuts. The total heating and cooking time for the fat was 14 hours. Each doughnut was cooked 3 minutes, half of this time on each side. The doughnuts were put in the fat, turned, and removed at 15-second intervals.

After storage for 6 months and 2.5 years a stability test was run on samples of the fat before cooking doughnuts in it. The peroxide value was obtained before use after the three periods of storage. The free fatty acid content, the iodine value, and the refractive index were determined on each fat before use for cooking and after every second lot of doughnuts was cooked. The same tests (with exception noted) were also made on the fat extracted from doughnuts cooked in the fat. Fat was extracted from two of the six doughnuts cooked from each odd numbered lot. The other four doughnuts of these lots were used for palatability ratings, each scorer receiving half a doughnut. The tests at the 6-month period were not started on the extracted fat until the thirteenth lot of doughnuts had been cooked.

The free fatty acids were calculated as oleic, the iodine value was determined as Hanus, the stability determined with the Swift apparatus, and for the smoke point and volatile acids A.O.C.S. methods were used.

Results

The Smoke Point. The smoke point was lowered with continued use of the fat. The lowering of the smoke point after frying 24 lots of doughnuts was nearly identical regardless of whether the fat was stored 6 months or 2.5 years. Because of insufficient material no smoke point determination was made after the fat had been stored 3.5 years.

Length of storage of fat	6 months	2.5 years
Smoke point, °C.		
Initial	228.0	225.0
After frying doughnuts	190.0	188.0

Iodine Number. The time fat was stored affected the iodine value very little. The values of the fat after storage for 6 months, 2.5, and 3.5 years, respectively, were 55.9, 55.4, and 55.1. With use of the fat for frying, however, the iodine value of the fat was consistently and gradually lowered (See Figure 1 and Table I). The iodine values of the fat extracted from the doughnuts were generally slightly lower than the iodine values of the corresponding fats in which the doughnuts were cooked for the 6-month storage period. There was no exception to this generalization for the data obtained after the fat had been stored for 2.5 years. After 3.5 years' storage

[1] Approved for publication by the director of the Iowa Agricultural Experiment Station as Journal Paper No. J-1388, Project 761.
This work was aided by a grant from General Mills inc.
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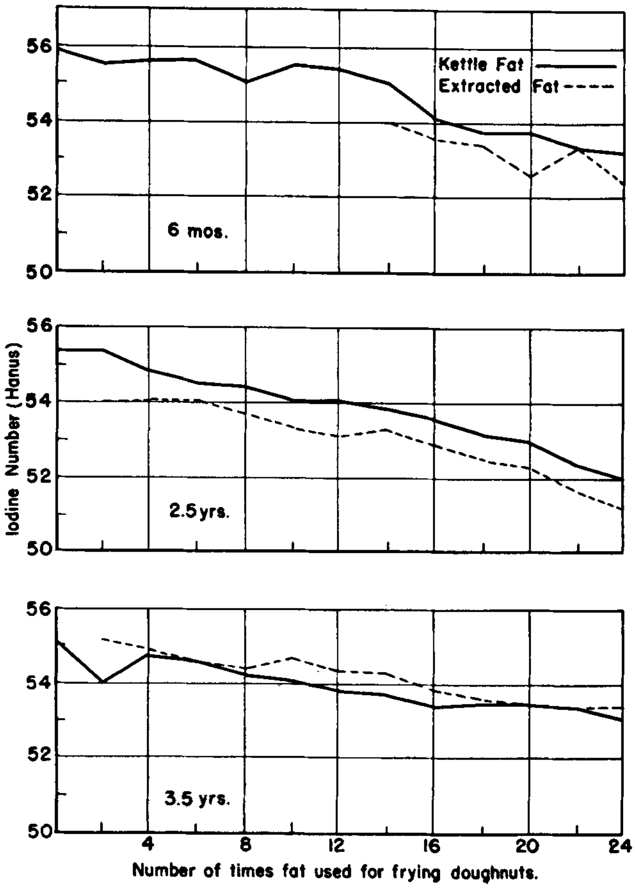

FIG. 1. Iodine numbers of fat in kettle after frying doughnuts and of fat extracted from doughnuts.

of the fat, however, the iodine values of the extracted fat were the same or slightly lower than those of the corresponding fat in which the doughnuts were cooked.

Refractive Index. The differences in refractive indices observed after the three different storage periods were small. With continued use of the fat for frying there was a tendency for the refractive index to increase. The differences, however, between the values before and after frying 24 lots of doughnuts were slight. The lowering of the refractive index was slightly greater in the fat extracted from the doughnuts than in the fat in which the doughnuts were cooked.

TABLE I

Iodine Number of Kettle Fat, Before and After Frying Doughnuts, and of Fat Extracted From the Doughnuts

Length of storage of fat	6 months	2.5 years	3.5 years
Kettle fat			
Initial	55.9	55.4	55.1
After frying doughnuts	53.2	52.0	53.1
Extracted fat			
1st lot of doughnuts	......	54.0	55.1
23rd lot of doughnuts	52.3	51.3	53.4

Stability Test. No peroxide value was determined for the fat after 6 months' storage but it must have been very low for it required 33.5 hours of incubation in the Swift Stability apparatus (temperature 98°C., regulated air flow through sample) to develop a peroxide value of 20 me H_2O_2/1000 g. fat. No rancid odor was detected until the 47th hour of incubation. At this time the peroxide value was 75. After storage for 2.5 years the peroxide value was 36. Although this was comparatively high, the fat had no rancid odor or flavor. With subjection to heat and aeration in the Swift Stability apparatus a distinctly rancid odor was obtained after 12 hours of incubation, at which time the peroxide value was 101. This value corresponds with a peroxide number of 100 which has been suggested as the point of incipient rancidity for hydrogenated fats. After 3.5 years' storage the peroxide number was 4. This was considerably lower than the value obtained a year earlier.

TABLE II

Refractive Index of Kettle Fat, Before and After Cooking Doughnuts, and of Fat Extracted From the Doughnuts

Length of storage of fat	6 months	2.5 years	3.5 years
Kettle fat			
Initial index	1.45977	1.45846	1.45821
After frying doughnuts	1.46060	1.45934	1.45886
Extracted fat			
1st lot of doughnuts	....	1.45861	1.45830
23rd lot of doughnuts	1.46029	1.45921	1.43887

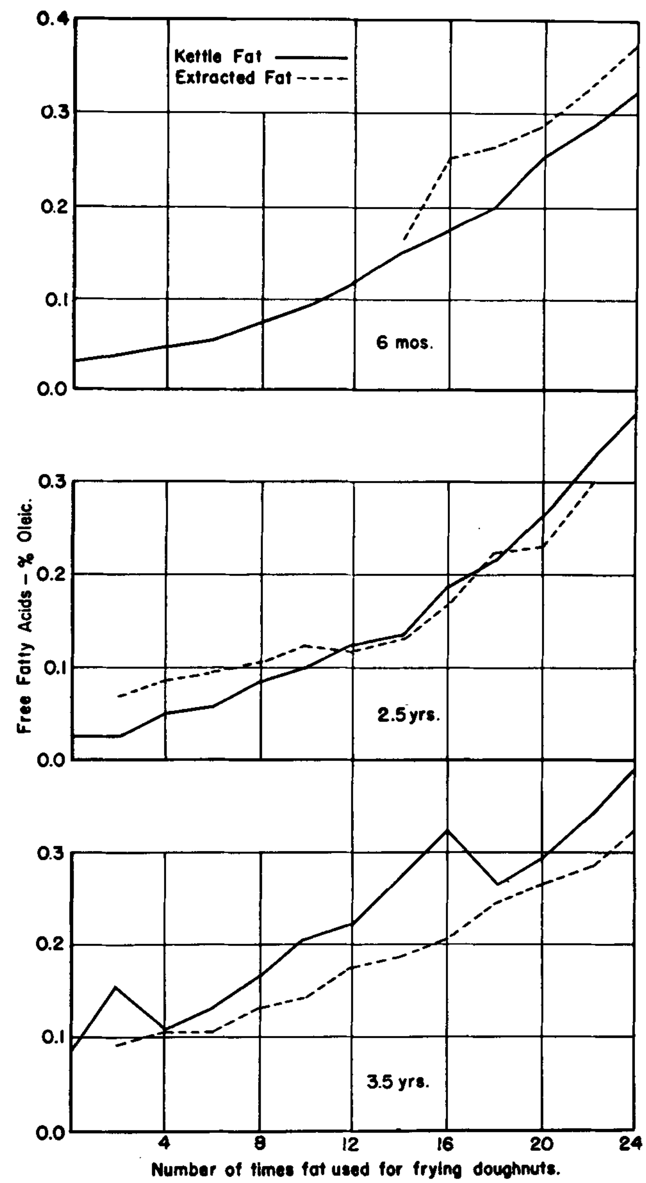

FIG. 2. Free fatty acids of fat in the kettle after frying doughnuts and of fat extracted from doughnuts.

Free Fatty Acids. The free fatty acid content after storage of the fat for 3.5 years, 0.081%, was greater than at 6 months, 0.033%. On the other hand the free fatty acid content after 2.5 years of storage was about the same as at 6 months.

Cooking of doughnuts in the fat resulted in a higher free fatty acid content of the kettle fat. The increase in the free fatty acid content was gradual and almost linear with increased use of the fat for frying, Figure 2. Increase was also noted in the free fatty acid content of the fat extracted from each succeeding lot of doughnuts.

TABLE III

Free Fatty Acid Content of Kettle Fat, Before and After Cooking Doughnuts, and of Fat Extracted From the Doughnuts (as % Oleic)

Length of storage of fat	6 months	2.5 years	3.5 years
Kettle fat			
Initial index	0.033	0.027	0.081
After frying doughnuts	0.321	0.371	0.390
Extracted fat			
1st lot of doughnuts	....	0.071	0.094
23rd lot of doughnuts	0.377	0.315	0.321

Volatile Fatty Acids. Volatile acids offer some evidence as to the type of breakdown which occurs in a fat. If the volatile acids content of the saponified fat exceeds the free fatty acids, it may be assumed that part of the free fatty acids were derived from splitting carbon chains, rather than hydrolysis. The short carbon chain fragments bound to the glycerol radical, when released through saponification followed by acidification, are steam volatile and titrate as acids, together with the steam volatile acids originally free in the fat.

The content of alcohol soluble volatile acids was lower than that of the water soluble volatile acids. The content of the water soluble volatile acids, both from the kettle fat and the fat extracted from the doughnuts fried in the fat after 3.5 years' storage exceeded the free fatty acids until eight lots of doughnuts had been cooked. With cooking of the tenth lot of doughnuts the water soluble volatile acids were the same as the free fatty acids content. During the cooking of the remainder of the 24 lots of doughnuts the content of the water soluble acids was about the same or slightly lower than that of the free fatty acids.

TABLE IV

The Free Fatty Acids and Volatile Acid (Water and Alcohol Soluble) of the Kettle Fat Before and After Frying Doughnuts, and of the Fat Extracted From Doughnuts (c.c. of 0.1 NaOH per 1 g. fat)

	Free fatty acids	Volatile acids (water soluble)	Volatile acids (alcohol soluble)
Kettle fat			
Initial index	0.029	0.066	0.019
After frying doughnuts	0.138	0.121	0.060
Extracted fat			
1st lot of doughnuts	0.033	0.079	0.040
23rd lot of doughnuts	0.144	0.123	0.060

Odor of Fat During Cooking. The odor of the fat was not objectionable during the cooking of the doughnuts even after it had been stored 2.5 years. After storage for 3.5 years the changes in the fat were great enough so that the odor was somewhat disagreeable during cooking and irritating to the membranes of the throat and nose.

Fat Absorption by Doughnuts. The fat absorption was determined for each lot of six doughnuts. The surface area of the uncooked doughnuts was practically the same since the dough was always rolled to the same thickness by use of metal cleats on a metal board and the doughnuts were cut the same size. The average fat absorption after each storage period follows. The variation after storage for different periods was probably caused by the difference in ingredients from one year to the next.

TABLE V

Average Fat Absorption of Doughnuts After Various Storage Periods of the Fat (Per Six Doughnuts)

Length of Storage of fat	6 months	2.5 years	3.5 years
Fat absorption, gms	49.8	46.4	58.4

Palatability of Doughnuts. The doughnuts were rated for appearance, lack of oiliness, odor, flavor, and texture. Each factor was scored from 1 to 10, with 10 high. The total score was the sum of the five factors.

The doughnuts cooked in the fat after it had been held for 2.5 years were considered as palatable as those cooked after the fat had been held 6 months. The doughnuts cooked after the fat had been stored 3.5 years were not rated for palatability. If the average flavor scores of 6.3 and 6.6 do not appear high, it should be stated that the scorers were trained observers, therefore critical. Doughnuts were cooked in three other fats after the same storage periods. These fats included a hydrogenated vegetable oil and a Prime Steam rendered lard. The highest flavor scores for both storage periods were received by the doughnuts cooked in fat for which results are reported in this study.

TABLE VI

Average Palatability Scores

Time of storage of fat	Appearance	Oiliness	Odor	Flavor	Texture	Total score
6 mos.	7.7	6.8	6.8	6.3	7.0	34.6
2.5 yrs.	7.6	7.3	7.3	6.6	7.6	36.4

Discussion

The outstanding result of this study was that there was so little change in the chemical and physical constants (with exception of the peroxide value) of the fat or of flavor of the doughnuts cooked in the fat after it had been held at room temperature for 2.5 years.

The lowering of the smoke point and iodine number and the increase in free fatty acids and refractive index with use of for frying doughnuts or potato chips are similar to results reported in the literature by Blunt and Feeney (1), Morgan and Cozens (5), Woodruff and Blunt (7), Carlin and Lannerud (2), and Lowe, Nelson, and Buchanan (4).

Woodruff and Blunt (7) and King *et al.* (3) found that the fat absorbed by foods during frying underwent greater changes in chemical and physical constants than the fat in which the food was fried. Woodruff and Blunt used a dough and potato chips; King *et al.* used potato chips. In the present study, however, the iodine values of the extracted fat tended to parallel those of the fat in which the doughnuts were cooked. Although the differences were slight (Figure 1) the iodine values of the extracted fat were lower than those of the fat in which the doughnuts were cooked for the tests after storage of the fat for 6 months and 2.5 years. For the tests after the fat had been stored 3.5 years the iodine values of extracted fat were about the same as for the corresponding kettle fats.

The free fatty acid content of the extracted fat also paralleled that of the kettle fat in which the doughnuts were cooked. Although the differences were slight and probably not significant, the free fatty acid contents of the extracted fats and of the kettle fats during the cooking of the three series of doughnuts were interesting and may indicate a trend. Since no results of similar tests with fats stored for long periods have been found in the literature, some comments on them may be justified but only because practically the same results were obtained with three other fats.

The free fatty acid content of the extracted fat was greater than in the fat in which the doughnuts were cooked at the 6-month tests. After the fat had been stored 2.5 years, the free fatty acid content of the extracted fat was slightly higher than that of the kettle fat until half the doughnuts were cooked. Thereafter the free fatty acid content of the extracted fat was about the same or less than that of the kettle fat. After storage for 3.5 years the content of free fatty acids in the extracted fat was usually slightly lower than that of the kettle fat (Figure 2). Three other fats were used for frying doughnuts after holding for 6 months and 2.5 years. Similar results were obtained for all fats although the time at which the free fatty acid content of the extracted fat became lower than that of the kettle fat varied somewhat. For two of the fats, including the fat for which results are herein reported, the transition was about half way through the cooking period. For the hydrogenated vegetable shortening it was about one-third and for the fourth fat about two-thirds through the cooking period. The transition of the free fatty acid content of the extracted fat from more to less than that of the kettle fat could not be attributed to the ingredients of the doughnuts or the change would have occurred in all fats at the same time. There was enough of one of the fats to cook 10 lots of doughnuts after 3.5 years of storage. Here again the free fatty acid content of the extracted fat was slightly lower than that of the kettle fat.

One puzzling result is the peroxide value of 4 after the fat had been held 3.5 years. The peroxide value would be expected to increase at the 3.5-year over that of the 2.5-year period. No reason can be given for this result. One suggestion, given credence by the work of Triebold and Bailey (6), who found that fat in tin containers did not change as rapidly if never uncovered, is that the fat for this test was taken from a can that had never been opened during the 3.5 years of storage.

Summary

The storage for 2.5 years did not appreciably affect the smoke point, nor did storage for 3.5 years cause appreciable changes in the iodine value or the refractive index. There was a perceptible change in the free fatty acid content after storage for 3.5 years, but none after 2.5 years. The peroxide value was higher after 2.5 years' storage than at 6 months, but unaccountably was lower after 3.5 years than after 2.5 years' storage of the fat.

The chemical and physical constants of the fats were changed appreciably and, in general, consistently during the use of the fat for cooking 24 lots of doughnuts. The rapidity with which chemical changes took place in the fats during their use for cooking was not influenced by the length of time the fat had been stored previous to use.

In general, the constants of the fat extracted from the doughnuts closely paralleled the corresponding samples of fat in which the doughnuts were cooked. Iodine values of extracted fats tended to be lower than the kettle fats for the first two storage periods and about the same after 3.5 years. The free fatty acid content was slightly higher in the extracted fat than in the kettle fat at the 6-month period, and slightly lower at the 3.5-year period. Volatile acids were higher in extracted than in kettle fats.

The desirability of doughnuts fried in the fat was not affected by storage of the fat 2.5 years prior to use, but was lowered after the fat was stored for 3.5 years.

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