A Comparative Study of the Influence of Various Liquid and Solid Vegetable Shortenings Upon Doughnut Physical Characteristics

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This comparative study was undertaken in order to investigate the effect

(a) of physical and chemical differences of vegetable shortenings upon the physical quality of doughnuts,

(b) and the effect of modifying the shortenings by the addition of fatty acids so as to obtain desired frying characteristics.

The paucity of published literature on the subject, and the widely divergent results obtained, indicated the need for an investigation of these factors as they occur in the manufacture of surface fried, machine made doughnuts.

Doughnut Physical Quality

The physical quality of a doughnut may best be judged by the outer configuration and internal structure. These two characteristics are dependent upon the quality of the ingredients, their proportions in the mix, and the method of blending; also upon certain mechanical details of the cutting mechanism of the doughnut machine. Another important factor in obtaining desired physical characteristics is the action of the frying shortening upon the developing doughnut.

Desired Shortening Characteristics

Frying shortenings in order to produce the best quality doughnuts must have the following three characteristics: First, they should impart no undesirable flavors to the finished products. Practically all present day shortenings are so refined as to keep well within this type of specification. Second, they should enhance and not deter normal structural development of the doughnut as it occurs in the frying process. The third property sought is the resistance of the frying shortening to rapid hydrolysis.

Types of Shortenings Tested

Four types of shortenings, varying exceedingly in degree of saturation and in the active oxygen hour ratings, were chosen for this work. They were

(a) a refined, bleached, deodorized corn oil;

(b) the same corn oil plus 15% peanut stearin;

(c) a partially hydrogenated all cottonseed shortening containing free oil and stearin;

(d) an all hydrogenated cottonseed shortening.

The characteristics of the four shortenings are as follows:

(a) Corn Oil: Iv—122.2, Pv—1.6, FFA—.02, Active Oxygen Hours—12.

(b) Corn Oil Plus 15% Stearin: Iv—106.6, Pv—1.0, FFA—.01, Congeal—43.2° C., Active Oxygen Hours—12.

(c) Partially Hydrogenated Shortening: Iv—85.2, Pv—1.0, FFA—.04, Congeal—33.8° C., Wiley MP—43.9° C., Active Oxygen Hours—45.

(d) All hydrogenated Shortening: IV—60.4, Pv—4.0, FFA—.02, Congeal—27° C., Wiley MP—40.5° C., Active Oxygen Hours—125.

Doughnut Formula

A dry doughnut mix prepared from a standard formula was used in this investigation. A quantity was secured at one time from regular plant production to suffice for the entire experimental period and so eliminate any variables that might otherwise occur.

Method of Testing

In each case when tests were begun, the machine would be filled with the requisite amount of shortening at the correct temperature. Ten pounds of the dry mix were then made into a dough under standard conditions, so that each batch absorbed the same amount of water. This was then fried so as to obtain the maximum number of proper size doughnuts. They were then counted and weighed when the receiving tray was full (fifteen minutes from the time the first doughnut came out of the machine—two trays being required per batch). All doughnuts produced were made so as to have an average weight of 283.7 grams (ten ounces) per dozen.

The frying fat remaining in the machine was sampled, and the amount absorbed by the doughnuts was determined by weighing into the machine enough shortening at the proper temperature to bring the fat level up to the correct point. A correction for the amount of sample taken out was made in all instances. The shortening would then be mixed by operating the machine for ten minutes without permitting any dough to enter. This procedure was followed until the absorption records showed that sufficient fat had been used to entirely replace the original amount. This length of time accounted for a total heating time on each shortening, of twenty-eight hours.

The samples taken after every batch were analyzed for peroxide value and free fatty acid content. In addition, the active oxygen hours for each sample were determined according to King, Roschen and Irwin on the Swift stability apparatus.

Discussion of Results

(1) Peroxide Value

From the peroxide results, we have concluded that neither the peroxide values on the original fats nor

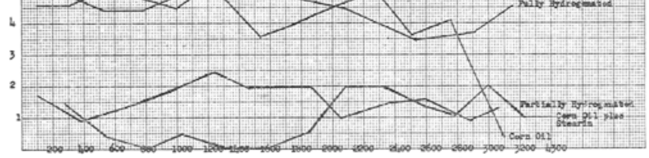

FIG. 1. Peroxide Value Curves.

their active oxygen hour ratings before and during their use are of positive value in judging the frying quality of a shortening for doughnuts. Figure 1 shows the course of the peroxide value as it varies from batch to batch for the first four types of shortenings. Our findings do not corroborate those of Lowe and co-workers (2), who found that the peroxide value increased with increased frying time of the shortening as well as with increased frying temperatures.

Oxygen Hour Results

There was a marked decrease in the active oxygen hours on all of the shortenings after they had been subjected to frying conditions for one-half hour. The fully hydrogenated shortening of 125 active oxygen hours showed a decrease to 15 hours. The partially hydrogenated type of shortening of 45 active oxygen hours showed a decrease to 10 hours, while the corn oil and oil and stearin active oxygen hours dropped to 3 and 4 respectively.

It is significant that the lowering of active oxygen hours does not lead to early oxidation of the fat absorbed by the doughnuts. This holds true for doughnuts from the half hour frying period as well as those made at the end of twenty-eight hours. Extensive work on fats extracted from one day to two week old doughnuts prepared in all kinds of frying shortenings at different periods of their frying life have shown that the peroxide value does not exceed five and that rancidity is not apparent to the taste.

Fat Absorption

In this study, the average fat absorbed averaged 3 gms. plus/minus per doughnut for each type of shortening tested, corresponding to 1.2 ounces for a dozen of 10 ounce doughnuts. The results of the fat absorption studies are shown in Figure 2. The amount of fat absorbed by the doughnut and its control is of prime

FIG. 2.

CORN OIL

Gms. Fat Absorbed		Number of Doughnuts
610		259
784		265
825		252
933		262
765		267
803	Average fat	275
725	absorption	258
752	3.03 grms.	241
666	per doughnut	226
770		229
709		233
604		218
750		230
780		233
10476		3448

PARTIALLY HYDROGENATED COTTONSEED SHORTENING

Gms. Fat Absorbed		Number of Doughnuts
768		203
750		213
720		240
760		235
760		257
750	Average fat	228
710	absorption	231
690	3.02 grms.	243
662	per doughnut	246
687		243
743		260
739		254
788		256
760		228
10087		3337

Average weight of all doughnuts 283.7 gms. per dozen.

CORN OIL PLUS 15% STEARIN

740		253
740		257
756		256
790		249
750	Average fat	245
771	absorption	241
797	3.07 gms.	273
876	per doughnut	255
865		256
694		234
850		256
750		253
700		259
10079		3277

FULLY HYDROGENATED COTTONSEED SHORTENING

760		240
750		248
815		256
683		230
700	Average fat	240
745	absorption	258
740	3.09 gms.	230
850	per doughnut	260
830		250
727		244
790		251
745		248
750		243
9885		3198

importance in the control of the doughnut physical quality. These tests are, therefore, of particular interest at the present time since they indicate that the degree of saturation of the shortening is of no consequence in relation to fat absorption. This finding is in agreement with those of Thiessen, E. J. (3). Further, it is indicated that over a range of 0.6% FFA whether the acid content be derived by natural hydrolysis of the shortening or by addition of fatty acids that there is no increase in fat absorption.

Free Fatty Acid

The results shown in Figure 3 indicate that there is a definite, yet steady rise in free fatty acid content in all of the shortenings during the frying period. It will be noted that the increase was more pronounced in the fully hydrogenated and partially hydrogenated cottonseed shortenings. There appears to be a relationship between the degree of saturation and titrable free fatty acid. This does not necessarily mean that the greater the degree of unsaturation the more resistant the frying shortening is to hydrolysis; rather that in the less saturated frying shortenings in which there is also substantially more polymerization, some of the more unsaturated free fatty acids may be broken down to form volatile products as suggested by Lea (6) or polymerized as suggested by Hilditch (5).

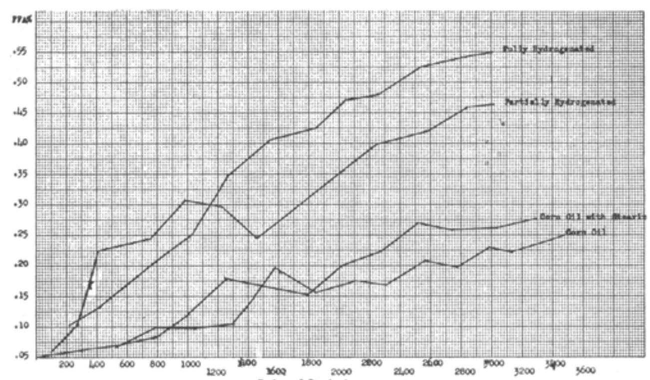

FIG. 3. Free Fatty Acid Calculated as Oleic.

Characteristics of New Frying Shortenings

A new frying shortening does not function to allow proper development of the doughnut, necessitating a period of frying time varying with the individual shortening before normally shaped doughnuts result. This is of particular importance in commercial doughnut frying because of the rapid replacement of shortening due to the number of doughnuts fried. The replacement period averages less than ten hours in machines that produce from 400 dozen doughnuts to 600 dozen doughnuts per hour. In a test conducted in a commercial doughnut frying unit, using a machine holding 385 lbs. of shortening and producing 400 dozen per hour, complete fat replacement had occurred after production of 4,000 dozen doughnuts, representing a heating time of ten hours. The titrable free fatty acid at this point was 0.5%. After 8,000 dozen had been made in a twenty hour heating period, the free fatty acid had dropped due to replacement to 0.32%. When 12,000 dozen had been fried the fat had been replaced three times and the free fatty acid was 0.61%. The appearance of the point in usage at which the shortening functions properly is called the quality period and may be correlated with the increase in free fatty acid, but there is no particular percentage of free fatty acid which indicates this point for all shortenings. We have established by frying tests that the greater the degree of saturation, the longer the pre-quality period. In the case of the fully hydrogenated cottonseed shortening, a free fatty acid of 0.35% was reached before quality doughnuts resulted. The partially hydrogenated cottonseed shortening developed a free fatty acid of 0.25% before it functioned normally. The corn oil and oil and stearin mixtures were satisfactory at 0.1% free fatty acid. These relationships hold in all cases of machine made doughnuts.

Fatty Acid Added to Accelerate Quality Period

In order to accelerate appearance of the quality period, fatty acids prepared from partially hydrogenated cottonseed shortening were added to the same type shortening in amount calculated to produce a fatty acid content of 0.5%. Doughnuts were fried in this shortening and the length of the pre-quality period noted as well as the rate of fatty acid increase. As was expected, the smoke point decreased, but there was no acceleration of the free fatty acid development. Due to the addition of the free fatty acid there was practically no pre-quality period, as the doughnuts began to develop normally almost immediately and were of the same quality as those fried in a shortening that had reached its quality stage. This subject is still under investigation. It should be noted at this point that although the absorption of the shortening by the frying doughnut is for all purposes constant, we do not advocate the use of oil in the frying of doughnuts because of organoleptic reasons. The desired characteristics of frying shortenings for doughnuts will be found to lie between the oil and all hydrogenated shortening.

Conclusions

1. Neither the peroxide value nor active oxygen hour rating are indicative for quality of frying shortenings used in preparing doughnuts.
2. Fat absorption is not a function of the degree of saturation of frying shortenings.
3. Fat absorption is not a function of the free fatty acid below 0.6%.
4. Added fatty acids decrease the pre-quality period of frying shortenings.
5. The active oxygen hour rating of a frying shortening before and during frying is not indicative of incipient rancidity in absorbed doughnut shortening.

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The Phosphatides and Fats in Brewers' and Vinegar Yeast

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There are a large number of investigations (1) and publications about the fat contents of the most common yeast, bakers' yeast, especially the work of F. Salisbury and R. J. Anderson and M. S. Newman (2). These authors also mention that this yeast contains a considerable quantity of lecithin as well as of kephalin, and that the phosphatides of bakers' yeast consist of about 80% of lecithin and 20% of kephalin.

Hitherto there have been no statements about the composition of the fatty matter, especially of the phosphatides in other yeast species. In recent times, however, brewers' yeast has been increasingly important. In a dried form it is used in ever increasing quantities as a medicine because of its extraordinary high contents of vitamins of the B_1 group and as an autolysed extract it is used in the kitchen as a valuable condiment.

Vinegar yeast occupies a singular position because it is an organism living in a strongly acid medium. It was therefore important to discover whether phosphatides could be developed under such extreme conditions and to what extent.

The behavior of fats and phosphatides of brewers' yeast, which was allowed to undergo autolysis at 58° C., was also included in these investigations, whether they would remain in the non-autolysed remnant of yeast to be stored there, or, whether they would be destroyed by the enzymes of the living yeast.

The effect of the "debittering" on the phosphatides was also investigated. All the brewers' yeast, intended for food purposes, must undergo such a process to remove the bitter taste of the hops. For this purpose the yeast is washed with a weakly alkaline medium.

It has frequently been noticed previously that the fats and the phosphatides could only be removed from the raw material to a small degree if they are extracted, after careful drying under a high vacuum, in the usual way, with petrol ether. Even an extensively protected extraction with this solvent only yields relatively small amounts of extract. A second extraction was therefore added to the first. It was carried out with a mixture of 80 parts benzine and 20 parts alcohol—accompanied by heat—and was continued as long as traces of fatty matter would go into solution. To separate out unwanted by-products, especially sugars, the extract was dried under vacuum and treated with pure ether. The clear etherical solution was used for further investigations; but even now all fatty substances had not been removed from the yeast. It is known that 1% HCl solution in alcohol will dissolve out further small quantities of fatty matter. This method was, therefore, used as third extraction. It was naturally expected that this treat-