A Quantitative Study of Fat Losses Occurring During Doughnut Frying

S. W. ARENSON and E. G. HEYL
Doughnut Corporation of America, Ellicott City, Maryland

The object of this study was the quantitative determination of fat losses during surface frying of donuts in automatic donut machines.

The two possibilities for the loss of fat during donut frying result from the formation of volatile products of fat degradation, and polymerization of fats and fatty acids liberated as a result of hydrolysis.

EXPERIMENTAL

Equipment Used

In order to quantitatively evaluate the amount of volatile materials given off, it was necessary to evolve a means of trapping all the vapors and conducting them into a proper absorption system. To accomplish this, a conical shaped hood of 18 gauge black iron was constructed (see Figure 1), the bottom of which had straight sides flanged at the lower edge so that the whole apparatus could be bolted to the frying kettle of the Lincoln machine in which it was used. The hood was made in two parts so as to facilitate ease of disassembling and removal for inspection. At the front was an opening through which the ejector hand delivered the donuts. Due to the location of the dough cutting mechanism in front of the machine, it was necessary to have a complicated concave section built to fit in the cone and around the cutter, and through which the cutter could drop the dough rings into the frying fat. At the top was a cylindrical tube containing a two-holed rubber stopper, through which passed a thermometer and a glass tube leading to the absorption train. The volume of the whole unit was approximately 1.1 cubic feet as closely as could be measured. The final dimensions were as follows: diameter 19⅞", height 18⅞".

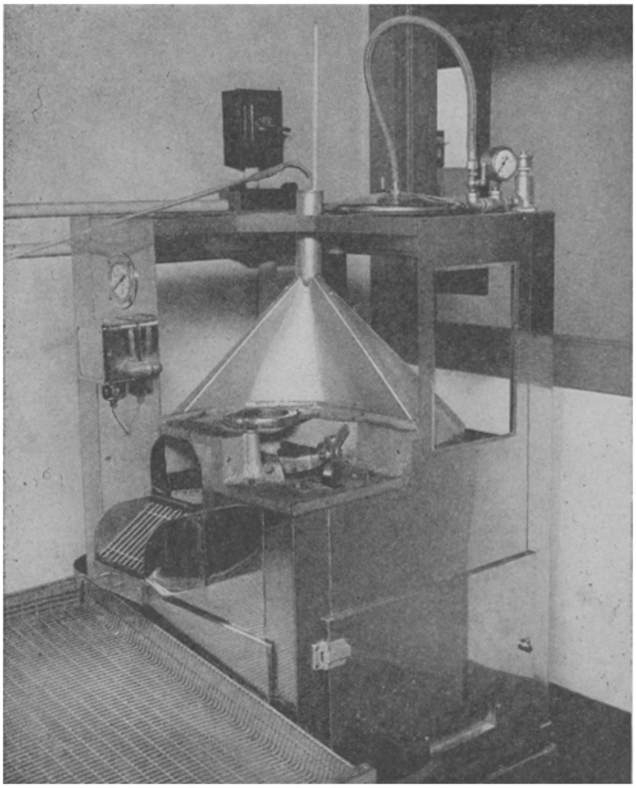
FIG. 1

All surfaces of the machine that were to come in contact with the fat were thoroughly clean at the beginning of the test. The frying kettle and "spider" (which moved the donuts through the fat) were of cast iron with a white nickel plating, the turner and ejector hands were of cast aluminum, while the immersion heating unit had a nickel plated, copper sheath. This type of construction is representative of machines now in use, although some of the larger machines have stainless steel kettles.

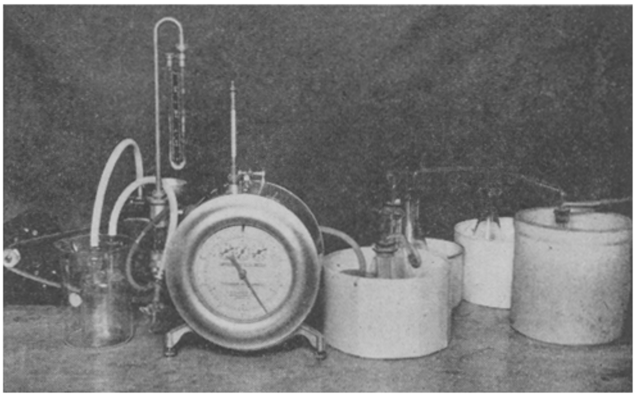
FIG. 2

The absorption train (see Figure 2) consisted of a series of five flasks encased in ice baths, a gas flow meter and a vacuum pump for moving the vapors from the hood through the system. The first flask contained 500 cc. of 95% ethanol as did the second, while the third contained 500 cc. of a 90/10 ethanol-ether solution. Flasks four and five were empty and served to trap any ethanol, ether or other vapors carried over by the air flow. Between the flow meter and the pump was an air inlet by means of which the rate of flow could be regulated. An additional trap was also installed at the same point to protect the pump. The tube connecting the conical hood with the train was approximately one meter in length and functioned as an air condenser for water vapor and some of the other volatile materials carried over, thus preventing excessive warming of the absorbent in flask No. 1.

Since the volume of the hood was 1.1 cubic feet and the rate of air flow was adjusted at 3.0 cubic feet per minute, it is apparent that the cone was swept clean a little more than two and a half times a minute. Since air could enter only at the point of ejection in the front, and at a small opening in the back necessitated by the mechanism of the turner hand, there was no loss of volatile material by dissipation into the air.

Materials Used

The donuts were all made from three hundred pounds of dry mix procured from regular production, so that unnecessary variables were eliminated, field conditions duplicated, and a constant water absorption obtained. These donuts were fried in an all hydrogenated vegetable shortening of the type widely used in the industry for this purpose. Its constants were Wiley M.P. 40° C.; Congeal 29.5° C.; iodine value (Hanus) 66; free fatty acid .03%.

Experimental Method

The kettle was filled with fat to the correct level at the proper frying temperature which was 191 ± 3° C., the temperature being thermostatically controlled at this level for the entire run. The amount of fat required was 9.42 kg.

Doughs were made from ten pounds of dry mix using a quantity of water calculated to produce an absorption of 42%, and the temperature of ingredients was controlled so that a dough temperature of 76° ± 1° F. resulted. Twenty-three batches were fried altogether, yielding 4,330 donuts, weighing 132.419 kg. or an average of 12.8 ounces per dozen. At the conclusion of each run, the fat was sampled and the percentage F.F.A. determined. Peroxide values were not determined for reasons pointed out in a previous paper (1).

The fat absorbed by the donuts was measured at the end of each fry by weighing the amount of replacement necessary to return the fat to the original level, a correction being applied for the sample removed. The total fat absorbed was 19.095 kg. or 1.85 ounces per dozen of 12.8 oz. donuts.

At the beginning of each day's run when heat was applied, the absorption train was also cut in, and the total heating time recorded, as well as the time of actual frying. The total heating time at a temperature of 191° C. was 3300 minutes, of which time 665 minutes were spent in frying. This frying was not continuous, but intermittent—usually three batches being fried in a day and run off at equally spaced intervals. At the top of the cone, the average temperature was 71.0° C.

As frying proceeded, the amount of water vapor evolved became sufficiently large to make its effect felt on the performance of the absorption system. As the percentage of alcohol in flask No. 1 dropped, due to increase in the water content, some of the volatile, alcohol soluble organic materials absorbed were thrown out of solution, and rose to the surface in the form of an oily, brown liquid. At the same time, it was observed that the remainder of the solution assumed a cloudy, yellow color. Much the same thing happened in flask No. 2, but to a much smaller extent. Flask No. 3 with use acquired a light yellow color, but remained clear. During the entire run, it was found necessary to change to fresh absorbents only once. At the conclusion all solutions were combined, and the materials sought extracted by the following method: Extraction with carbon tetrachloride in a separatory funnel completely removed all of the oily, brown material. The remaining solution containing water, ethanol, and ether plus the organic matter was distilled under reduced pressure to remove the two organic solvents. Extraction with carbon tetrachloride on the water solution remaining removed more of the organic material, and this was combined with the original carbon tetrachloride extraction. The water solution was then a clear, light orange as a result of this treatment. To complete the extraction, the ethanol-ether distillate was diluted with about four times its volume of distilled water, whereupon a white colloidal dispersion resulted. Subsequent extraction with ether removed all of this material to make a clear, yellow ether extract, leaving the dilute ethanol-water solution free of foreign materials. The three solvents were then evaporated, leaving (A) a clear, dark brown, oily liquid from the carbon tetrachloride; (B) a brown, amorphous solid from the water, and (C) a clear, light yellow, oily liquid from the ether. The yields of these materials were determined. No attempt was made to determine the nature of these compounds and they are being held for further investigation.

At the conclusion of the test period the hood was removed for examination. There was no condensation of any of the vapors on the inside surface. The polymer that formed was on the dome of the "spider" and on its arms. By removing the spider from the machine, it was possible to remove all polymer and weigh the production of this substance.

Discussion of Results

The volatile products produced in the heating and frying processes are formed in several ways. When fats split under the joint action of heat and moisture (from the dough) (2) glycerine and fatty acids are formed. Glycerine undergoes further decomposition to form acrolein and water, both of which were carried into the absorption system.

$$C_3H_5(OH)_3 \rightarrow C_3H_4O + 2H_2O$$

Oxidation of the heated fat at the surface and subsequent breakdown of the fatty peroxides, yields low molecular weight aldehydes, acids and ketones (3). It is known that the peroxides of oleic acid in particular are not very stable (3). It might also be possible that some of the aldehydes from fat oxidation polymerize.

Of the three materials recovered the clear, but dark brown, oily liquid had a mild odor rather difficult to describe; the clear, yellow, oily fraction possessed a somewhat sharp, "smoky" odor; while the amorphous, brown solid matter recovered from the water solution also had an odor that defied description. In addition this last named material showed a surprising tendency to carbonize at the temperature of boiling water. The amounts of volatile materials recovered by the absorption and extraction were as follows: (a) from the carbon tetrachloride 9.9 g., (b) from the water 10.4 g., (c) from the ether 6.8 g., totaling 27.1 g. or on the basis of the total fat used .09%.

The polymer is generally present in two forms. It will be found in a thin, hard brown film, and in the form of a weakly elastic, amorphous, brown substance. The amount of polymer formed was 53 g. which was 0.18% of the total fat used. Polymer formation results from the polymerization of the fat and the polymerization of the fatty acids (4) produced by the hydrolysis mentioned above. Regardless of the type formed, the total amount is a negligible factor as regards fat loss.

The production of free fatty acid followed the same trend as was suggested in an earlier communication from this laboratory (1). Our results indicate that no increase in polymerization therefore is to be expected from this cause in subsequent fryings.

The total of volatile materials and polymer formed was 0.27%, thus indicating that there is no appreciable loss of fat during surface frying of donuts.

REFERENCES

(1) Arenson and Heyl, Oil and Soap, Vol. XX, No. 8, p. 149-51, 1943.

(2) Porter, Michaelis and Shay, Ind. Eng. Chem., Vol. 24, No. 7, p. 811-13, 1932.

(3) Lea, C. H., Rancidity in Edible Fats, 1939.

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Book Review

Toxicology and Hygiene of Industrial Solvents. Edited by K. B. Lehmann and F. Flury. Translated by Eleanor King and H. F. Smyth, Jr. The Williams and Wilkins Company, 378 pp. Price $5.00.

According to the preface, this book forms a companion piece to "Chemical Technology of Solvents" by O. Jordon, and it is predominantly of a medical nature.

Development and organization of the information in the book was the result of an assignment entrusted to the medical committee of the German Society for the Protection of Labor. The literature and experimental work was divided and portions assigned to several members, several universities, the Imperial Health Office and the industrial hygiene laboratory of I. G. Farbenindustrie.

The results of laboratory experimental toxicological investigations, together with medical literature on solvents form the principal part of the book. There are also contributions by O. Jordon on chemistry and technology, by W. Frieboes and W. Schulze on skin injuries, by H. Engel and H. Prillwitz on dangers to health and protection, and by H. Engel on the German official regulations for protection of public and workers.

Since most fat and oil industries use organic solvents the book should be welcomed by the industry. Essential toxicological data on industrial solvents has been well organized by the authors. They also had the advantage of having access to abundant unpublished research information.

M. M. Piskur.

Abstracts

Oils and Fats

Edited by
M. M. PISKUR and SARAH HICKS

Refractive index nomograph for liquid fatty acids. D. S. Davis. *Ind. Eng. Chem. 35*, 1302 (1943).

The component fatty acids of human depot fat. D. L. Cramer and J. B. Brown. *J. Biol. Chem. 151*, 427-38 (1943). The methyl esters of the fatty acids from 2 specimens of human depot fat were separated by distillation through an efficient column into 6 or 7 relatively simple fractions; the main fractions representing esters of single carbon series were studies by crystallization procedures at low temp. Methyl myristate, palmitate, stearate, and oleate were isolated and identified as practically pure compds. The presence of tetradecenoic and hexadecenoic acids was demonstrated in this fat for the first time. The oleic and linoleic acids of human fat are the principal C_{18} unsatd. acids present, but they are found along with isomeric octadecenoic and octadecadienoic acids. The presence of arachidonic acid is confirmed. From the data obtained from crystallization studies on 2 specimens and from distn. data on 3 more, the fatty acid compn. of 5 specimens of human fat have been calculated and recorded. In the 5 specimens studied the linoleic (total octadecadienoic) acid contents ranged from 8.2 to 11.0%; the values for arachidonic acid fell between 0.3 and 1.0%.

The distribution of lipids in animal tissues. M. Kaucher, H. Galbraith, V. Button, and H. H. Williams. *Arch. Biochem. 3*, 202-15 (1943). The lipid [phospholipid (cephalin, lecithin, and sphingomyelin) free and combined cholesterol, cerebroside, and neutral fat] distribution in beef organs and muscles, in the muscles of other warm- and cold-blooded species, and in avian and reptilian eggs, was detd. The essential lipid concn. of the various tissues is related to the extent and variety of their physiological activities and confirms a similar relationship previously demonstrated for the phospholipids, which comprise the largest fraction of the essential lipid in all the tissues studied. The distribution of the other lipid fractions, as well as the individual phospholipid components appears to be more directly related to the particular types of functions performed by individual tissues.

Chemical and physical determinations of vitamin A in fish liver oils. B. L. Oser, D. Melnick, and M. Pader. *Ind. & Eng. Chem. Anal. Ed. 15*, 717-24 (1943). An improved method for plotting the ultraviolet absorption curves of vitamin A products is presented, and applied in studies of crystalline vitamin A acetate, fish liver oils, and concs. to evaluate factors which cause distortions in the curves. Emphasis is placed on the importance of conducting the detn. on the unsaponifiable fraction of oils regardless of their potency. The U.S.P. reference cod liver oil No. 2 is shown to be unsuited as a spectrophotometric or colorimetric standard. The estimation of vitamin A in food product. B. L. Oser, D. Melnick, and M.