5-1-1963

Influence of repeated use for cooking on some changes in composition of frying fats

Ann R. Stasch

Lois Kilgore

BULLETIN 662 MAY 1963

Influence Of Repeated Use For Cooking On Some Changes In Composition Of Frying Fats

By

Ann R. Stasch

and

Lois Kilgore

Mississippi State University

AGRICULTURAL EXPERIMENT STATION

HENRY H. LEVECK, Director

STATE COLLEGE MISSISSIPPI

TABLE OF CONTENTS

INFLUENCE OF REPEATED USE FOR COOKING ON SOME CHANGES IN COMPOSITION OF FRYING FATS

By ANN R. STASCH and LOIS KILGORE

Heating of fats during their use for frying causes changes in their composition. During normal use of a fat these changes are slight, but overheating or overlong use of a fat may cause drastic changes. During commercial manufacturing processes involving frying, the changes found in fats appear to be very slight in comparison with those occurring during the use of fats under ordinary home kitchen conditions. One reason for this is the larger volume of fat used. Another reason is the rapid turnover of fat during continuous commercial operation. In the home kitchen the volume of food cooked in fat is small, the fat is used only at irregular intervals and temperature control may not be exact. Although fats and oils should not be abused during use, no evidence has been presented to show that occasional use of drastically heated fats has any damaging effects on health.

Previous work in this laboratory has shown some changes taking place in fats which had been heated for various periods of time in metal and non-metal containers, but in which no food had been cooked. This study was undertaken to determine similar changes in the composition of fats when successive batches of either chicken or potatoes were fried under various conditions simulating those found in ordinary home kitchens.

REVIEW OF THE LITERATURE

Commercially Used Fats and Oils

Changes in composition of oils used for the commercial production of potato chips have been investigated by Melnick (36) and Melnick et al. (37). Small increases in carbonyl compounds and free fatty acids were found to occur in such oils along with slight increases in the conjugated dienoic acid content, but no significant increase in trans-fatty acids was noted. Both linoleic acid content and iodine values of the oils decreased during use. Although decreases in iodine values found in corn, cottonseed and hydrogenated oils were statistically significant, they amounted to only about one per cent and were, therefore, assumed to be of no nutritional significance. This assumption was based on the work of Lassen et al. (28), comparing digestibility of unsaturated oils with increasing degree of polymerization, represented by a drop in iodine value. A drop in iodine value of at least five per cent was found to be necessary before a measurable decrease in the coefficient of digestibility occurred.

In general, the composition of oils after their use in potato chip manufacture was found to be very similar to that of fresh, unheated oil. One explanation given for the small change in composition is a rapid turnover of the oil due to continual replenishment with fresh oil. Another factor which may be important here is volatilization of water from the potato slices during cooking, resulting in a steam deodorization and refining process while the fat is being used.

Samples of used fats, obtained from restaurants, bakeries and potato chip producers, have been studied by Rice et al. (43) and Poling et al. (41) to determine nutritive value. Fats subjected to even the most severe usage showed only slight decreases in caloric availability to rats. Slight increases in liver size of the rats were noted, also. The conclusion reached by these workers was that conditions of commercial usage of fats do not result in serious heat damage, although serious damage may occur in fats heated under arbitrarily chosen laboratory conditions. Keane et al. (24) showed that, whereas oil heated in the laboratory had a lowered caloric availability to rats, the same oil heated under conditions of commercial use did not change in caloric availability.

Chalmers (9) compared laboratory and commercially used oils and found a higher free fatty acid content, but lower peroxide values, in the commercially heated oil. Change in iodine value was less in the commercially heated oil, also. The difference was explained as being due to a greater volume of fat in the commercial fryer, resulting in relatively less surface exposure of the oil. Rice et al. (44) have also noted that change in amount of fat heated per unit of surface area has a greater influence than temperature on change in composition of a frying fat.

Laboratory Experiments on Heated Fats

Fats and oils have been heated in the laboratory under various conditions to determine the degree of severity of change. With care, laboratory data may be used to interpret changes which might be expected to occur under conditions of actual use.

Kritchevsky et al. (27) studied the hydrolysis of triglycerides to release free fatty acids during short-term heating experiments conducted on various fats. The temperature of the fat was maintained at 235 ± 5° C. Samples were titrated for free fatty acids after 20, 40, 60, 90 and 120 minutes. The extent of hydrolysis varied widely among the various fats used. For example, olive oil did not change at all, whereas the free fatty acid content of coconut oil increased 180 fold. However, very little change was noted in any fat until after at least one hour of heating. No apparent correlation was found between the initial and final free fatty acid content of the fats, but the amount of hydrolysis was closely related to temperature, duration of heating and water content of the fat.

The importance of water in breakdown of fats had been noted previously by Porter et al (42). When water was dripped continuously into a fat during heating, a much larger increase in free fatty acids occurred than when the fat was simply heated. Bito and Yamamoto (8) reported that the accelerated oxidation of a fat which results from frying foods of high water content was especially notable at lower temperatures. The water formed during autoxidation itself may be an important factor here, also (25).

Although hydrolysis of a fat is regarded as a sign of degradation, Hall et al. (19) showed that this reaction is related also to development of flavor in fried foods. The initial development of free fatty acids during deep fat frying of potatoes was accompanied by an increased flavor score on the cooked potatoes. The flavor of french-fried potatoes reached a maximum rating after 16 frying periods, when the acid number of the fat reached approximately 5.5. After this time, a rapid increase in fat acidity occurred, along with a rapid decline in the desirability of the fat flavor. Each of the 16 frying periods consisted of three hours of preheating at 93° C, 15 minutes to raise the temperature of the fat to 185° C, and two hours at 185° C, followed by another 2 3/4 hours at 93° C. The free fatty acid content of the potatoes was assumed to be even higher than that of the frying fat, since carboxyl groups would be preferentially absorbed.

King et al. (26) had demonstrated previously that the free fatty acid content of fat extracted from fried potatoes was, indeed, higher than that of the frying fat. Increases were noted in levels of free fatty acids and peroxides, while iodine values decreased, in various lards, cottonseed, corn and peanut oils used to fry successive batches of potatoes. All fats were heated to 185° C in five quart iron kettles. A decrease in general quality of the potato chips occurred as the number of fryings increased.

As a test of flavor during successive frying, Goodman and Block (18) fried two lots of doughnuts—one in fresh oil, and the other in the same oil after it had been used in a continuous frying kettle at a doughnut bakery. One of each of these doughnuts was fed to 100 people. Thirty-eight preferred the doughnut fried in fresh fat, 40 preferred the doughnut fried in commercial fryer fat, and 22 had no preference.

Chang et al. (10) periodically analyzed samples of lard in which doughnuts were cooked and corn oil in which potato chips were cooked. The iodine values of both fats were found to decrease with increased use, while the amount of conjugated dienoic acid increased. In corn oil, the amount of linoleic acid decreased, but the amount of linolenic acid increased, with increased use of the fat. The peroxide value of lard increased rapidly and then decreased to a negligible value, indicating that peroxide destruction occurs more rapidly than peroxide formation at 180° C. Although the peroxide content of lard increased during overnight storage, heating again lowered these values to negligible levels.

Rice et al. (44) fried five pounds of potato chips twice a day in refined cottonseed oil at 182° C. After two days use (48 hours), the fat was foaming violently. Potato chips, cooked in the fat while it was foaming, were fed to rats at a level to supply 20 per cent of fat in the diet. Weight gains of these rats were smaller than those of rats fed the same amount of fresh fat. A continuous decrease in caloric availability of the heated cottonseed oil to rats was noted in the fat after each day of use, up to 120 hours. However, the same fat, heated for 120 hours with no potatoes fried in it, had an even lower caloric availability than that in which potatoes were fried. The onset of foaming in fats is, therefore, related to the beginning of biological changes in rats. Goodman and Block (18) showed that the time of appearance of foaming in commercial fats varied between 10 and 21 hours of heating at 375° F.

Color changes in fats, mainly toward the development of reds and yellows, occurred during their use. Such changes are affected by the kind of food cooked. Bennion and Hanning (6) have found that the frying of a fritter-type batter produced a greater degree of darkening than the frying of french-fried potatoes. Color changes in fats do not affect flavor, but they give an undesirable appearance to the fat.

Hydrogenated cottonseed oil, which had been used for 80 hours at 190° C for deep fat frying, was distilled by Kaunitz et al. (23), who then fed the distillate to rats. The net energy value of this diet was found to be lower than that of a diet containing distillate from fresh oil.

Aside from lowered caloric value of heated fats, other biological effects have been noted. Recently, Nishida et al. (39) fed heated corn oil to chickens at a level of 15 per cent in the diet. This diet depressed serum cholesterol and beta-lipoprotein levels, but did not appear to affect the incidence of atherosclerosis.

Home Cooking Processes

Custot (15) reviewed some of the changes in heated fats from the standpoint of the hazards involved in poorly controlled frying of foods. In experiments where peanut oil was used for 30 successive fryings, changes in the fat were found to be much more severe under household use than under laboratory conditions. Tests showed that polymerization had occurred in the oil used under ordinary home kitchen conditions, but not in the laboratory used oil. The greater change in oil used under household conditions was attributed to poor control of frying conditions, including temperature. Further study of changes occurring in fats used in the home seems warranted, as this situation exemplifies the fact that laboratory obtained data may not be used directly to interpret changes occurring under other conditions.

The nutritional value of fats in meats cooked under simulated home conditions has been studied by Warner et al. (48). Conventional household equipment was used, but the meats were slightly overcooked to exaggerate any change occurring. Fats extracted from the cooked meats were fed to rats. Cooked pork from ham, bacon or spareribs promoted better weight gain in rats than fresh fat did. However, rats receiving fat from cooked lamb, beef or poultry gained less weight than control rats fed fresh fat. These workers concluded that the conditions needed to produce a palatable product in home kitchens are such as to minimize opportunities for decreased nutritive value of a fat. Onset of foaming and color change, as well as production of off-flavors in the cooked product, act as safeguards against overlong use of a fat.

The nutritive value of fat in cooked foods is related to the amount of essential fatty acids present, as well as to caloric availability. Essential fatty acids are highly unsaturated and, therefore, susceptible to oxidation at temperatures used in meat cookery. Chang and Watts (11) studied the change in essential fatty acid content of some meats and poultry during cooking. Of all meats cooked roast chicken was the only one which did not show a loss in total unsaturation during cooking. The loss in unsaturation exceeded two per cent in the case of roast pork loin and leg of lamb, both of which showed considerable peroxide formation during cooking. Losses in oleic acid were mainly responsible for the overall loss in unsaturated fatty acids. Linolenic and arachidonic acids were present in very small amounts (fractions of one per cent) even in the fresh fat.

Chicken fried in vegetable oil, and cooked bacon, contained the largest amounts of linoleic acid, whereas beef and lamb contained the smallest amounts of this acid. In general, these workers concluded that the fatty acid content of meats and poultry is not changed substantially by cooking.

Some Factors Affecting the Stability of Fats

Fats recovered from fried or roasted meats have been shown to have good resistance to oxidation, although they are highly colored and have a strong odor and flavor (29). Stabilization of oils has been accomplished by heating them at either atmospheric or reduced pressure with a sugar plus various other substances, such as proteins, amino acids, and aromatic or aliphatic acids. Increased keeping quality has been claimed for certain fats heated with spice residues, finely divided peanut or soybean flour, molasses and irradiated yeast. Butter oil kept better when the whole butter had been heated at 205° C or when the butter oil had been heated with skim milk powder at 205° C. The storage life of lard has been increased by heating it under vacuum to 288-296° C with 0.1 to 0.5 per cent of various protein and carbohydrate materials, of which dried whey was the most effective. Although an undesirable color and odor were produced in the lard by this process, bleaching and deodorizing to a bland, light-colored product resulted in a loss of most of the added stability.

The frying of vegetables rich in vitamin C has been shown to be effective in retarding the oxidation of frying oils, as has the addition of salt (8). Mabrouk and Dugan (32) have shown, however, that the effect of salt is not direct, but decreases the amount of oxygen available for reaction. Coe's work (12) showed that light in the blue end of the spectrum and the presence of metallic catalysts, like iron, both hastened the onset of rancidity.

Marcuse (33, 34, 35) studied the effects of various amino acids on autoxidation. Alanine, histidine, cysteine, tryptophan, methionine, glycine, proline, serine, lysine, asparagine, valine, phenylalanine, arginine and threonine were all shown to have a potential antioxidative activity. The antioxidative effect was pH dependent, with cysteine showing a strong pro-oxidative tendency under certain conditions. Saunders et al. (45) showed that the presence of histidine, at certain pH values, greatly enhanced the pro-oxidative effect of ionic iron. Histidine, combined with ionic iron, may exert a pro-oxidative effect when it is involved in hydroperoxide decomposition, and an antioxidative effect when it is involved in chain termination. Becker et al. (5) reported that proteins inactivate oxidation promoting metals below pH 5 but not between pH 5 and 7. The metal inactivating effect of proteins accounts for at least a part of the stabilizing effect which occurs when fats are heated with protein containing materials.

The rate of oxidation of a fat, which increases with increasing unsaturation of the fat, can be markedly accelerated by the presence of copper or iron at concentrations of one part per million or less. As Lundberg (30) has pointed out, acceleration of oxidation by metals is extremely important in regard to the problem of rancidity in food. Certain iron-containing biologic substances, such as cytochrome C and hemoglobin, were noted by Lundberg (31) to be effective catalysts of lipid oxidation, also.

Evans et al. (16) studied the effect of trace metals on the flavor stability of soybean oil. In commercial fats, flavor stability values did not correlate with metal content of the fat because of the addition of metal deactivators during processing. Iron is a high temperature catalyst and is very detrimental at deodorization temperatures (210° C). The temperature of deep fat frying (180°-190° C) is sufficiently close to deodorization temerature for iron frying pans to exert a catalytic effect on oxidation. In soybean oil, iron catalyzed the formation of high peroxide levels, but other metallic catalysts did not show this effect. Previous work in this laboratory (47) showed that heating fats in iron frying pans resulted in an increase in the amount of total carbonyl compounds present. Harada et al. (20) showed that the action of iron from a container used for heating was minimized by the presence of an oxidized film of oil on the surface of the container.

The effects of both iron and aluminum containers on cottonseed oil used to fry potato chips were investigated by Chalmers (9). The oils were used for a total of seven hours heating time. Both free fatty acid content and peroxide values were found to be higher in cottonseed oil heated in the iron vessel, but iodine values decreased to a greater extent in the oil heated in the aluminum vessel.

MATERIALS AND METHODS

This study was divided into two parts. In Part 1 successive batches of chicken or potatoes were fried in four kinds of fat in both iron and glass ceramic frying pans. Neither the fat absorbed by the food cooked, nor the fat lost due to sampling were replaced. Therefore, the volume of fat used for frying decreased during each successive frying period. In Part 2 chicken was fried in two kinds of fat in both iron and glass ceramic frying pans. Fresh fat was added at the beginning of each frying period to replace that absorbed by the food and that lost by sampling. Therefore, a constant volume of fat was maintained throughout all frying periods.

Part 1. Repeated Use of the Same Frying Fat

A. Successive fryings of potatoes in various fats.

Preparation of fats. Four kinds of fat were used — a lard, a cottonseed oil, a hydrogenated vegetable shortening and a hydrogenated animal-vegetable combination shortening. All fats were purchased from shelf supplies at local markets. A homogeneous mixture was made from 21 pounds of each fat. Cotton seed oil was mixed without warming. All the other fats, which were solid at room temperature, were heated just enough to liquefy them, and were mixed in the liquid state. The same amount of each of the fats, approximately 2.4 pounds, was used in each frying pan.

Frying pans. Eight frying pans were used with each of the above fats—four of cast iron and four of glass ceramic composition. The experiment was run as two replicates, each consisting of two cast iron and two glass ceramic frying pans. In each replicate, one pan of each kind, called the scoured pan, was scoured with steel wool and cleanser after each use. The other pans, called unscoured pans, were wiped with paper toweling after every second hour of use, instead of being scoured. Since the fat in each pan was heated twice each day, that in the unscoured pans was allowed to remain in the frying pan between the first and second heating each day.

Potatoes. Idaho potatoes were pur-purchased in 100 pound lots at a local market. After peeling, the potatoes were cut by hand into strips of approximately ¼ by ½ inch. Although the length of the strips varied with the size of the potato, this dimension was generally four to six inches. The potato strips were weighed into one pound lots which were placed in two approximately equal portions on enamelled trays. Each portion was fried separately.

Frying periods. The fats were heated on a conventional, four burner, electric kitchen range. Into each pan a thermometer was placed, serving both as a stirrer and as a means of measuring temperature. Temperature in each pan was controlled by adjustment of burner heat controls. Time required for the fat in each pan to reach a temperature of 180° C was not recorded. Each frying period consisted of one hour, beginning when the temperature of the fat first reached 180° C. For 10 minutes after timing began the temperature of each fat was maintained at 185° ± 5° C. Then, one-half of the potato slices were fried for 12 minutes. During much of this time, the temperature of the fat was below 180° C, although by the end of 12 minutes, the fat had regained a temperature of 185° ± 5° C. This temperature was maintained for another 10 minutes, after which the second half of the potato strips were fried for 12 minutes. After removal of the second batch of potatoes from the frying pan, the temperature of the fat was maintained for an additional 16 minutes. The frying pan was then removed from the range and placed on an asbestos mat, where the fat was allowed to cool under an air draft. Two frying periods were conducted each day with each fat. After the second heating each day, all fats were poured into glass beakers, cooled to room temperature and stored, uncovered, overnight at 9° C.

Sampling. A sample of the original homogeneous mixture of each fat was saved for analysis. Fat samples, removed from each frying pan after the fifth and tenth frying periods, were stored in brown bottles at 9° C until they were analyzed. A composite sample of fried potatoes was collected from those fried in all pans during the fifth and the tenth frying periods. The potato samples were stored in plastic freezer bags at -20° C until they were analyzed.

Analyses. All fat samples were analyzed, in duplicate, for peroxide values (4), total carbonyl compounds (22), Hanus iodine values (2), free fatty acids (3), and **in vitro** hydrolysis by pancreatic lipase (21). Total fat was extracted from the potato sample after it had been ground in a food chopper (1). Some of this fat was analyzed subsequently for iodine values by the above method. All data were analyzed statistically by analysis of variance.

B. Successive fryings of chicken in various fats.

Preparation of fat. The fat mixtures were prepared in the same manner as above, using different lots of each fat.

Frying pans. Frying pans were set up in the same way as above, with one exception. The residue from the fried chicken showed such a tendency to stick to the pans, that the method of wiping out pans with paper toweling was not satisfactory. Therefore, the "scoured" frying pans were scoured with steel wool and cleanser after each frying period, whereas the "unscoured" pans were scoured after every other frying period.

Chickens. Chickens were purchased from the Poultry Department at the Mississippi Agricultural Experiment Station. All chickens which were to be fried in any one kind of fat were obtained from the same lot. The birds were sawed in half while frozen and the two halves packaged together. After thawing, each half chicken was cut up into the usual frying pieces—wing, leg, thigh, breast and back pieces. No breading or flouring of any sort was used in preparing the chicken for frying, nor was salt added to them.

Frying periods. The temperature of each fat was raised to 180° C exactly as in Part 1. Ten minutes after the temperature of the fat in each pan reached 180° C, one-half of a chicken was fried for 30 minutes. The opposite half of each of the chickens was fried in the corresponding pan in the replicate experiment. After the chicken was removed, the temperature of the fat was maintained at 185° ± 5° C for an additional 20 minutes before the frying pan was removed from the range.

Sampling and analyses were conducted in exactly the same manner as in Part 1 A.

Part 2. Repeated Use of Frying Fat with Periodic Addition of Fresh Fat

Preparation of fat. Lard and cottonseed oil, purchased from the shelf supplies in a local market, were used in this part of the study. Homogeneous mixtures of the fats were prepared as in Part 1. Nine hundred and fifty grams of each fat was placed in each frying pan initially. A sufficient quantity of each fat was prepared so that the weight of fat in each pan could be maintained at 950 grams throughout the experiment.

Frying pans. The experiment was replicated, each replicate consisting of one iron and one glass ceramic frying pan. All the pans were scoured with steel wool and cleanser after each frying period.

Chickens. Whole, frozen chickens were purchased from one lot raised by the Poultry Department of the Experiment Station. After thawing, the chickens were cut up into the same frying pieces as before, except for the back. The back was divided into breast and rear portions, one of which was fried with each half of the chicken. The pieces from each chicken half were prepared for frying by shaking them in a paper bag containing one-half cup of enriched, all-purpose flour and one-half teaspoon of salt.

Frying periods. As before, the temperature of the fat in each pan was raised to 180° C. and maintained at 185° ± 5° for 10 minutes, before the chicken was placed in the pan. Half of each chicken was fried in an iron pan and its opposite half was fried in a glass ceramic pan. The chicken was fried for 24 minutes, removed, and the fat maintained at 185° ± 5° C for 21 minutes. Another half chicken was then fried for 24 minutes, removed, and the fat temperature maintained for an additional 11 minutes before the pan was removed from the burner. Each frying period, therefore, consisted of a total of 90 minutes.

After removal from the range, the fat from each frying pan was poured into a glass beaker and the pans were cleaned. The fats were cooled almost to room temperature and stored overnight at 9° C. The weight of fat in each pan was made up to 950 grams at the beginning of each frying period with fat from the original homogeneous mixture. The procedure was repeated five times, making a total heating time of 7.5 hours.

Sampling. A sample of each fat was taken from the unheated, homogeneous fat mixtures and from each frying pan at the end of each frying period. Fat samples were stored in brown bottles, under nitrogen, at -20° C until analyzed. A sample of chicken, comprising the breast, leg, thigh and wing portions, was taken from each batch of chicken fried in each pan. All chicken samples were stored in plastic freezer bags, under nitrogen, at -20° C until analyzed.

Analyses. Fat samples were analyzed, in duplicate, for iodine values and free fatty acids. All methods of analysis were the same as those used in Part 1.

Chicken samples were thawed. All meat and skin was cut from the bones, which were discarded. The chicken was ground once through a coarse cutter plate and twice through a fine cutter plate of an electric food grinder. The material was thoroughly mixed after each grinding. The ground chicken was dried for 6 hours at 100° C in a forced draft oven, after which fat was extracted. Some of this extracted fat was analyzed immediately for free fatty acids. The rest of the fat was stored in small vials, under nitrogen, at -20° C until it could be analyzed for iodine values and **in vitro** hydrolysis by pancreatic lipase.

All data was analyzed statistically, using analysis of variance procedures.

RESULTS AND DISCUSSION

Results obtained from both parts of this study are reported together, since, in many cases, the discussion involves a comparison between both sets of data. Some qualitative observations of the physical characteristics of the fats during use are reported because changes in appearance of a fat can be observed easily by a homemaker in her own kitchen. All data was tested by analysis of variance to determine statistical significance. Tables of F values are given in the Appendix. These tables, and further tests for significance among the various treatment means, when necessary, were used in making the interpretations of the data discussed herein.

Color Changes

All of the fats darkened slightly during the first frying period. The change in color was always more pronounced when fats were heated in iron frying pans, although intensity of the color increased in all fats with increased length of time of use. When floured chicken was fried in fat maintained at a constant volume, color changes were not as pronounced.

Foaming

Both kind of food fried and kind of fat in which it is fried were found to affect the length of time a fat can be used before onset of foaming. When potatoes were fried in cottonseed oil, a slight foam occurred after four hours of use. After seven hours of use, foaming in this fat was so severe that extreme caution was necessary when raw potatoes were added to avoid overflow of foam from the pan. The other fats in which potatoes were fried — lard, hydrogenated vegetable shortening and hydrogenated animal-vegetable combination shortening—began to foam slightly after six hours of use and were foaming violently after nine hours of use.

When chicken was fried in these same kinds of fat, none of them began to foam until after nine hours of use. Even then, foaming was not severe. No foaming was evident in either lard or cottonseed oil used 7.5 hours to fry floured chicken when a constant volume of fat was maintained. Flouring of chicken, therefore, does not hasten the onset of foaming in fats.

Onset of foaming occurred in these fats sooner than it has been reported to occur in commercially used fats. Since conventional kitchen frying pans were used in these studies, the volume of fat was less than that found in a commercial fryer. Other factors influence onset of foaming however, since it occurs at variable times even during commercial use.

Proteins are known to stabilize fat during heating. The fact that onset of foaming occurred more rapidly when fats were used to fry potatoes than when they were used to fry chicken may be explained, in part, on the basis of the respective protein contents of these two foods. According to Watt and Merrill (49), chicken contains approximately ten times as much protein as potatoes do.

Other factors are important in fat stability, also. Foods with high water content hasten degradation of a fat. The water content of potatoes (77.8%) is slightly higher than that of chicken (74.7%).

Compositional Changes

1. **Peroxide values.** Results obtained from analysis of peroxide values on the various fats used to fry both chicken and potatoes are given in Table 1. Peroxide values of all fats heated in glass ceramic pans were higher after potatoes were fried, whereas peroxide values of fats heated in iron pans were higher after chicken was fried. Maximum rates of oxidation are reported to occur in fats heated in metal containers at high temperatures for long periods of time, such as occur during frying (46). Iron is known to be a high temperature catalyst of fat oxidation and has been reported to catalyze peroxide formation, in particular. Hemoglobin present in the drip or "weep" fluid from the cut up chicken pieces might be expected to hasten the process of oxidation in fats. "The "weep" fluid also contained other protein or amino acid constituents. As Bishov et al. (7) have pointed out, the presence of proteins nullifies the catalytic effect of hemoglobin.

The fact that these results do not show that all fats heated in iron pans have higher peroxide values may be of little actual significance. Since peroxides are destroyed as rapidly as they are formed at frying temperatures, any analysis of peroxide values in a fat represents only the situation present at the time of analysis. Even though peroxides are produced in the fat during cooling, the same catalytic effects may not be operative at this time.

2. **Free fatty acids.** The free fatty acids found in the four fats used to fry chicken and potatoes are reported in Table 2. Significant increases in free fatty acids occurred in all fats with increased length of time of use. Fats in which chicken was fried contained lower amounts of free fatty acids than fats in which potatoes were fried. Potatoes, therefore, caused hydrolysis of fats to occur at a greater rate than chicken.

When chicken was fried, the kind of frying pan used had no effect on free fatty acid content of any of the fats. The greatest production of free fatty acids occurred in lard, and the least in cottonseed oil.

When potatoes were fried some interaction occurred between the kind of fat and the kind of frying pan used. In this case, use of scoured iron pans resulted in the production of a high free fatty

Table 1.—Peroxide values of various fats before and after frying successive batches of chicken or potatoes.

Frying pan	Food fried: Hours fat used:	Chicken 0	Chicken 5	Chicken 10	Potatoes 0	Potatoes 5	Potatoes 10
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
				Cottonseed oil			
Scoured iron		1.55	3.99	4.79	0.97	4.34	8.29
Scoured glass ceramic		1.55	4.00	5.37	0.97	4.73	8.03
Unscoured iron		1.55	5.07	5.31	0.97	1.95	6.41
Unscoured glass ceramic		1.55	6.18	5.49	0.97	1.06	7.08
				Lard			
Scoured iron		1.20	5.28	4.36	5.27	4.24	4.87
Scoured glass ceramic		1.20	7.77	2.15	5.27	8.76	3.65
Unscoured iron		1.20	6.39	6.05	5.27	5.64	4.45
Unscoured glass ceramic		1.20	9.07	2.58	5.27	6.52	7.70
				Hydrogenated vegetable shortening			
Scoured iron		0.36	4.66	4.90	0.27	4.62	2.98
Scoured glass ceramic		0.36	4.37	6.70	0.27	7.14	7.82
Unscoured iron		0.36	4.72	3.99	0.27	6.59	1.46
Unscoured glass ceramic		0.36	5.95	4.93	0.27	6.79	6.98
				Hydrogenated animal-vegetable combination shortening			
Scoured iron		0.45	7.03	7.09	0.53	5.67	1.69
Scoured glass ceramic		0.45	11.07	9.00	0.53	7.66	6.37
Uncoured iron		0.45	9.36	9.04	0.53	7.65	1.25
Unscoured glass ceramic		0.45	10.93	9.62	0.53	8.05	6.23

Table 2.—Free fatty acid[1] content of various fats before and after successive batches of chicken or potatoes.

Frying pan	Food fried: Hours fat used:	Chicken 0	Chicken 5	Chicken 10	Potatoes 0	Potatoes 5	Potatoes 10
		%	%	%	%	%	%
				Cottonseed oil			
Scoured iron		0.04	0.26	0.50	0.05	0.18	0.56
Scoured glass ceramic		0.04	0.28	0.53	0.05	0.20	0.40
Unscoured iron		0.04	0.40	0.50	0.05	0.20	0.44
Unscoured glass ceramic		0.04	0.29	0.47	0.05	0.20	0.40
				Lard			
Scoured iron		0.42	0.64	0.89	0.40	0.68	0.98
Scoured glass ceramic		0.42	0.67	0.93	0.40	0.66	1.24
Unscoured iron		0.42	0.66	0.66	0.40	0.62	1.16
Unscoured glass ceramic		0.42	0.64	0.96	0.40	0.66	1.22
				Hydrogenated vegetable shortening			
Scoured iron		0.20	0.42	0.75	0.17	0.36	0.70
Scoured glass ceramic		0.20	0.37	0.72	0.17	0.42	0.84
Unscoured iron		0.20	0.38	0.88	0.17	0.38	0.86
Unscoured glass ceramic		0.20	0.40	0.60	0.17	0.44	0.76
				Hydrogenated animal-vegetable combination shortening			
Scoured iron		0.12	0.37	0.85	0.09	0.42	0.98
Scoured glass ceramic		0.12	0.41	0.76	0.09	0.45	1.02
Unscoured iron		0.12	0.38	0.71	0.09	0.44	1.02
Unscoured glass ceramic		0.12	0.36	0.73	0.09	0.44	1.00

[1]Calculated as oleic acid.

acid content in cottonseed oil and a low free fatty acid content in lard.

The free fatty acids found in both the fat from the frying pans and in the fat extracted from floured chicken fried in lard or cottonseed oil, maintained at constant volume, are given in Table 3. A comparison of the data in Tables 2 and 3 shows that the addition of fresh fat each time a fat is used results in a much lower production of free fatty acids. The fact that the chicken was floured in this

Table 3.—Free fatty acid[1] content of lard and cottonseed oil and of fat extracted from chicken fried in each.

Times fat used	Fat: Cotttonseed oil		Chicken fat		Lard		Chicken fat	
Frying pan:	Iron	Glass ceramic	Iron	Glass ceramic	Iron	Glass ceramic	Iron	Glass ceramic
0	0.06	0.06	......	......	0.34	0.34	......	......
1	......	......	1.32	1.22	......	......	1.05	1.22
2	0.14	0.13	1.10	0.98	0.40	0.40	1.22	1.83
3	......	......	0.91	1.34	......	......	1.07	1.02
4	0.18	0.16	1.11	0.83	0.44	0.44	1.68	2.20
5	......	......	1.14	1.12	......	......	1.41	1.64
6	0.25	0.22	1.08	1.30	0.46	0.49	1.61	1.02
7	......	......	1.07	1.09	......	......	0.89	1.01
8	0.28	0.25	1.28	1.19	0.57	0.52	1.69	2.42
9	......	......	1.34	1.02	......	......	1.14	1.02
10	0.28	0.23	1.40	1.03	0.55	0.54	0.88	1.30

[1]Calculated as oleic acid.

Table 4.—Total carbonyl compounds[1] in various fats before and after frying successive batches of chicken or potatoes.

Food fried:	Chicken			Potatoes		
Frying pan / Hours fat used:	0	5	10	0	5	10
	%	%	%	%	%	%
			Cottonseed oil			
Scoured iron	0.00	0.40	1.02	0.01	0.36	0.60
Scoured glass ceramic	0.00	0.62	1.00	0.01	0.36	0.49
Unscoured iron	0.00	0.74	1.11	0.01	0.36	0.70
Unscoured glass ceramic	0.00	0.84	0.98	0.01	0.42	0.46
			Lard			
Scoured iron	0.01	0.46	0.55	0.04	0.36	0.32
Scoured glass ceramic	0.01	0.58	0.53	0.04	0.28	0.23
Unscoured iron	0.01	0.48	0.54	0.04	0.28	0.19
Unscoured glass ceramic	0.01	0.42	0.50	0.04	0.26	0.14
			Hydrogenated vegetable shortening			
Scoured iron	0.00	0.36	0.55	0.00	0.30	0.53
Scoured glass ceramic	0.00	0.52	0.66	0.00	0.22	0.36
Unscoured iron	0.00	0.47	0.44	0.00	0.23	0.41
Unscoured glass ceramic	0.00	0.54	0.44	0.00	0.19	0.44
			Hydrogenated animal-vegetable combination shortening			
Scoured iron	0.17	0.37	0.74	0.02	0.30	0.44
Scoured glass ceramic	0.17	0.40	0.45	0.02	0.22	0.37
Unscoured iron	0.17	0.41	0.55	0.02	0.30	0.36
Unscoured glass ceramic	0.17	0.42	0.50	0.02	0.28	0.36

[1]Calculated as n — heptaldehyde.

case may also have exerted a stabilizing effect on the frying fat.

The fat extracted from the fried chicken is found to contain much larger amounts of free fatty acids than the fat in the pan. The content of free fatty acids in the chicken fat averaged 5.6 times the free fatty acid content of cottonseed oil from the pan and 3.3 times that of lard from the pan. A significant correlation ($r=.51$) was found between the free fatty acid contents of the pan fat and fat extracted from the chickens. Since lard originally contained much more free fatty acids, use of lard resulted in a significantly larger amount of free fatty acids in chicken fat than that which was found when cottonseed oil was used.

Kind of frying pan used had no effect on free fatty acid content of fat in the chicken when cottonseed oil was the frying medium. However, chicken fried in lard contained more free fatty acids when glass ceramic rather than iron pans were used. This difference cannot be due to differences in chickens, as halves of the same chickens were fried in glass ceramic and iron pans.

3. **Carbonyl compounds.** Amounts of total carbonyl compounds found in the various fats used to fry chicken and potatoes are shown in Table 4. Total carbonyl compounds increased in all fats as the length of time of use increased. After ten hours of use, cottonseed oil contained larger amounts of carbonyl compounds than any of the other fats, regardless of whether they had been used to fry chicken or potatoes. Kind of frying pan did not affect production of total carbonyl compounds when chicken was fried. However, when potatoes were fried, all fats heated in scoured iron pans contained significantly higher amounts of carbonyl compounds (one per cent level) than those heated in any of the other pans.

According to Farmer (17), metals promote decomposition of peroxides to carbonyl groups. Piper et al. (41) reported that iron acts as a decarboxylation catalyst to promote formation of aliphatic ketones from free fatty acids. Obviously

Table 5.—Iodine values (Hanus) of various fats before and after frying successive batches of chicken or potatoes.

Frying pan	Food fried: Chicken, Hours fat used: 0	5	10	Potatoes 0	5	10
			Cottonseed oil			
Scoured iron	91.4	87.4	68.1	81.0	74.5	71.0
Scoured glass ceramic	91.4	81.1	72.6	81.0	76.4	74.9
Unscoured iron	91.4	83.0	75.3	81.0	73.9	74.7
Unscoured glass ceramic	91.4	87.2	83.0	81.0	83.6	75.9
			Lard			
Scoured iron	43.6	55.2	53.3	54.9	49.6	49.4
Scoured glass ceramic	43.6	53.3	51.6	54.9	49.0	48.4
Unscoured iron	43.6	53.2	49.2	54.9	49.4	47.6
Unscoured glass ceramic	43.6	52.6	49.8	54.9	49.1	45.4
			Hydrogenated vegetable shortening			
Scoured iron	69.8	71.5	67.4	59.7	57.2	50.4
Scoured glass ceramic	69.8	69.3	67.1	59.7	59.0	52.3
Unscoured iron	69.8	69.7	68.2	59.7	55.2	51.8
Unscoured glass ceramic	69.8	68.8	66.9	59.7	56.4	54.7
			Hydrogenated animal-vegetable combination shortening			
Scoured iron	55.3	56.2	55.3	48.8	48.1	37.4
Scoured glass ceramic	55.3	55.6	54.8	48.8	47.2	39.3
Unscoured iron	55.3	57.5	55.1	48.8	47.8	40.4
Uncoured glass ceramic	55.3	53.9	55.0	48.8	47.2	44.5

Table 6.—Iodine values (Hanus) of lard and cottonseed oil and of fat extracted from chicken fried in each.

Fat:	Cottonseed oil				Lard			
	Pan fat		Chicken fat		Pan fat		Chicken fat	
Hours fat used / Frying pan:	Iron	Glass ceramic	Iron	Glass ceramic	Iron	Glass ceramic	Iron	Glass ceramic
0.00	90.3	90.3	......	......	48.2	48.2	......	......
0.75	......	......	87.5	85.9	......	......	61.1	61.7
1.50	88.6	87.6	84.3	88.4	48.1	47.9	59.4	44.6
2.25	......	......	89.4	90.1	......	......	59.5	56.5
3.00	87.9	86.3	83.4	85.7	47.9	47.9	55.5	51.2
3.75	......	......	86.6	89.2	......	......	62.6	61.4
4.50	87.2	86.8	87.9	83.6	47.9	48.3	67.6	59.4
5.25	......	......	89.1	88.5	......	......	64.3	61.3
6.00	85.1	86.0	82.7	82.5	47.6	46.5	53.9	54.2
6.75	......	......	82.2	88.4	......	......	61.2	62.7
7.50	85.2	83.3	84.5	89.2	48.0	47.6	67.3	59.6

the iron frying pan exerts a catalytic effect on production of carbonyl compounds in frying fats. The fact that scoured iron pans did not produce larger amounts of carbonyl compounds when chicken was fried is believed to be due to the greater protein content of the chicken. Cooney et al. (13) have reported that heating of fats promotes stability by releasing metallic ions from a complex so that they can react with metal inactivating agents. The metal inactivating effect of the protein would complement that of other metal inactivating agents naturally present or added to the fat during processing.

No catalytic effect on production of carbonyl compounds occurred in fats heated in unscoured metal pans because the metal surface of the pan was covered, in this case, by a layer of oxidized fat.

Possible implications for flavor development in fats as a result of the presence of larger amounts of total carbonyl compounds have been discussed in a previous publication (47).

4. Iodine values. Iodine values of fats before and after frying chicken or potatoes are given in Table 5. When potatoes were fried, all fats except lard showed a significant decrease in iodine value with increased length of time of use. The iodine value of lard decreased significantly during the first five hours of use, but showed no further change during the next five hours. The decreases in iodine value of all fats exceeded the five percent change necessary for lowered digestibility. When chicken was fried, cottonseed oil was the only fat which decreased in iodine value during use.

The lack of change in iodine values of these fats when chicken is fried is presumed to be due to dilution of the frying fat with fat from the chicken, which contains large amounts of linoleic acid. Lard provides an extreme example of the difference in change of iodine value caused by chicken and potatoes. When chicken was fried, the iodine value of lard increased to a value 12.8 to 22.2 per cent above the original value. However, when potatoes were fried the iodine value of lard decreased to a level 10.0 to 17.3 per cent below the original value. Dilution of frying fat by chicken fat may have been most notable in lard because this fat originally contained the least unsaturation, measured by iodine values. By the same reasoning, the dilution of cottonseed oil with chicken fat would have produced the least effect on iodine values, since cottonseed oil is more highly unsaturated than chicken fat. Whereas dilution of a less unsaturated fat (lard) by chicken fat raised its iodine value, dilution of a more unsaturated fat (cottonseed oil) by chicken fat lowered its iodine value. Other factors than linoleic acid may be involved here. Coons (14) has cautioned against the use of iodine value of a fat as an index of its linoleic acid content.

Table 6 shows the results of iodine values determined both on the frying fat and on fat extracted from floured chicken fried in lard and cottonseed oil. A comparison of these results with those given in Table 5 shows that a much smaller decrease in iodine value occurs when the frying fat is maintained at constant volume, just as was noted in the case of free fatty acids. In contrast to the results obtained above, where no turnover of fat occurred, iodine values of both cottonseed oil and lard decreased with use. The decreases in iodine value of lard were very small — 0.4 per cent in the iron pan and 1.2 per cent in the glass ceramic pan. These results support the explanation given for change in iodine values of the various fats in which chicken had been fried. In this case, addition of fresh cottonseed oil at the beginning of each frying period counteracts some of the effects of oxidation, resulting in only a slight change in iodine value. Dilution of lard with the more highly unsaturated chicken fat again results in an increased iodine value.

Although the kind of frying pan used

had a statistically significant effect on change in iodine number when either chicken or potatoes were fried, the effect was erratic. No trend toward greater change in any one kind of pan could be established. Interference with the determination of iodine values by other materials present in variable quantities in these foods may well have been responsible for these effects.

Unless the flavor is affected, change in the frying fat is not noticed by the consumer of fried products. However, changes in the fried food may reflect changes in the frying fat. Iodine values of fat extracted from chicken and potatoes fried in various fats are given in Table 7. This data, and that reported in Table 6 for fried chicken, shows that iodine values of fats extracted from cooked food are higher, in general, than iodine values of the fats in which the food was fried. Fat from chicken fried in cottonseed oil was the only food fat found to be lower in iodine value than the frying fat after ten hours use. Even in this case, however, the iodine value of the cooked chicken fat was greater than that of the fat from raw chicken, and was also greater than that of chicken fried in lard or hydrogenated animal-vegetable combination shortening.

When cottonseed oil was used as the frying medium, and a constant volume of fat was maintained through periodic addition of fresh oil, iodine values of cooked chicken fat were considerably higher than those of raw chicken, and in fact, approached that of the cottonseed oil itself. When lard was used in the same way, iodine values of the cooked chicken were generally about the same as that of raw chicken, a value considerably higher than that of lard itself. Iodine values of fat extracted from fried chicken, therefore, may or may not resemble those of the fat in which they are cooked. The use of a more highly unsaturated fat for frying results in a fried chicken end product which is more highly unsaturated. The kind of pan used has no effect on the iodine value of fried chicken fat.

Iodine values of fat extracted from fried potatoes bear a definite relationship to iodine values of the fats in which they were fried. Iodine values of both potato and pan fats increase in the following order: hydrogenated animal-vegetable combination shortening, lard, hydrogenated vegetable shortening and cottonseed oil. Most of the fat present in fried potatoes is that which was absorbed from the pan fat, as raw potatoes contain very little. Therefore, no interchange of fat occurs between that in the food and that in the frying pan as it does in the case of chicken. The absorption of fat is either selective toward absorption of more highly unsaturated fat or fatty acids from the pan, or other substances present cause misleadingly high iodine values, because iodine values of fat extracted from the potatoes are higher than those of the fats in which they are fried. Other protective agents against oxidation of fats, which may also be present in foods, may account for part of this effect.

Amount of Fat in Cooked Food

The amount of fat extracted from chicken and potatoes fried in various fats is given in Table 8. The amount of fat found in chicken fried in lard and cottonseed oil maintained at constant vol-

Table 7.—Iodine values (Hanus) of fat extracted from chicken and potatoes cooked in various fats.

Food:	Chicken		Potatoes	
Frying fat — Hours fat used:	5	10	5	10
Cottonseed oil	87.1	70.0	97.5	81.4
Lard	51.3	66.7	49.2	50.6
Hydrogenated vegetable shortening	77.9	74.4	64.6	58.7
Hydrogenated animal-vegetable combination shortening	66.4	66.4	49.0	47.9

Table 8.—Amount of fat extracted from chicken and potatoes cooked in various fats.

Frying fat	Hours used	Food: Chicken	Potatoes
		%	%
Cottonseed oil	0	6.58	0.16
	5	9.11	6.25
	10	14.56	9.39
Lard	0	6.58	0.16
	5	15.70	5.68
	10	14.22	6.60
Hydrogenated vegetable shortening	0	6.58	0.16
	5	13.68	9.36
	10	17.04	6.91
Hydrogenated animal-vegetable combination shortening	0	6.58	0.16
	5	13.42	7.60
	10	14.46	6.86

Table 9.—Amount of fat extracted from chickens fried successively in lard or cottonseed oil maintained at constant volume with fresh fat.

Hours fat used	Fat: Cottonseed oil, Frying pan: Iron	Cottonseed oil, Glass ceramic	Lard, Iron	Lard, Class ceramic
	%	%	%	%
0.75	27.4	27.0	27.4	27.9
1.50	28.5	28.4	26.4	26.0
2.25	29.2	28.6	31.4	30.6
3.00	30.0	28.0	29.0	27.8
3.75	28.4	29.4	26.9	26.1
4.50	26.4	27.0	26.0	27.2
5.25	26.2	24.8	31.0	30.4
6.00	27.2	28.3	23.8	22.8
6.75	27.3	26.9	27.4	27.2
7.50	25.4	24.4	25.4	24.8

ume is given in Table 9. Fried chicken always contained more fat than fried potatoes, since chicken has a higher fat content to begin with. When values for the amount of fat extracted from cooked chicken were corrected for the amount of fat present in raw chicken, increases in amount of fat closely approached the values noted for potatoes.

Potatoes fried in hydrogenated animal-vegetable combination shortening contained more fat than those fried in any other fat after five hours of use. After all fats had been used for ten hours, potatoes fried in cottonseed oil had the highest fat content. An increase in the fat content of potatoes fried in lard and cottonseed oil occurred between five and ten hours use, whereas a decrease in fat content occurred during this time in potatoes fried in either of the hydrogenated shortenings. Fat content of chickens fried in all fats except lard increased between five and ten hours. Fat content of chicken fried in lard decreased during this time.

Each successive batch of chicken fried in cottonseed oil or lard, maintained at constant volume, contained slightly less fat than the preceding batch. Although this difference was statistically significant, inspection of the data, presented in Table 9, shows that the change was very slight. Neither kind of fat nor kind of pan used had any effect on the amount of fat present in the fried chicken.

Morgan and Cozens (38) have stated that a greater absorption of fat occurs when food is cooked in fat of lower free fatty acid content. Loss of water, as well as absorption of fat, affects the percentage of fat found in cooked food. Furthermore, interchange occurs between fat in the chickens and in the pans. There-

Table 10.—Amount of lipase hydrolysis occurring in vitro in fats used to fry successive batches of chicken or potatoes.

Frying fat	Hours fat used	Food fried: Pan:	Chicken Iron	Chicken Glass ceramic	Potatoes Iron	Potatoes Glass ceramic
			%	%	%	%
Cottonseed oil	0		8.90	8.90	9.64	9.64
	5		6.71	6.48	6.71	6.55
	10		6.58	4.79	4.80	4.54
Lard	0		7.96	7.96	9.66	9.66
	5		8.30	6.76	5.30	4.77
	10		8.14	7.73	4.72	3.66
Hydrogenated vegetable shortening	0		6.05	6.05	6.82	6.82
	5		6.50	7.38	4.58	4.76
	10		6.95	7.17	5.35	5.76
Hydrogenated animal-vegetable combination shortening	0		7.07	7.07	5.55	5.55
	5		7.79	7.96	5.26	5.88
	10		7.97	6.14	3.51	3.23

Table 11.—Amount of lipase hydrolysis occurring in vitro in fat extracted from successive batches of chicken fried in lard or cottonseed oil.

Frying pan	Hours fat used	Frying fat:	Cottonseed oil	Lard
Iron	0.75		22.3	18.8
	3.75		24.7	28.3
	6.75		25.0	21.2
Glass ceramic	0.75		23.3	13.0
	3.75		26.4	25.4
	6.75		22.4	27.1

fore, the total amount of fat extracted from fried chicken and potatoes, even when corrected for original amounts present, cannot be considered to be absorbed fat. A significant negative correlation ($r = -.58$) was found to exist between the free fatty acid content of the pan fat and the amount of fat extracted from the chicken. Approximately the same degree of correlation ($r = -.54$) was found to exist between the actual increase in free fatty acid content of the pan fat and the amount of fat in the fried chicken each time.

Hydrolysis of Fat in vitro by Pancreatic Lipase

Fat used to fry chicken and potatoes was hydrolyzed **in vitro** by reaction for 30 minutes with pancreatic lipase. Results obtained are given in Table 10. In general, the amount of hydrolysis by pancreatic lipase decreased with increased length of time of use of the fat. The total amount of hydrolysis occurring in all fats was higher after chicken was fried than after potatoes were fried. This result supports other data, such as free fatty acid content, which show a greater breakdown of fat when potatoes are fried.

When chicken was fried in iron pans, hydrolysis of all fats except cottonseed oil increased during the first five hours of heating. A further increase in hydrolysis occurred in the hydrogenated shortenings between five and ten hours of use but hydrolysis of both lard and cottonseed oil decreased during this time. When glass ceramic pans were used, hydrolysis of both hydrogenated shortenings increased during the first five hours of heating, while that of both lard and cottonseed oil was less than the original. Between five and ten hours all fats except lard decreased in amount of hydrolysis.

Fat extracted from the first, fifth and ninth batches of chicken fried in both lard and cottonseed oil was tested for amount of hydrolysis by lipase **in vitro.**

The results are given in Table 11. Chicken fried in lard in glass ceramic pans or fried in cottonseed oil in iron pans increased in hydrolysis each time a sample was tested. Cottonseed oil heated in glass ceramic pans and lard heated in iron pans increased in amount of hydrolysis between the first and the fifth fryings and decreased between the fifth and the ninth fryings. At the end of the ninth time of use of both fats in both pans, amount of hydrolysis was either about the same as, or higher than, after the first time the fat was used.

The activity of pancreatic lipase has been reported by Weinstein and Wynne (50) to be inhibited by the presence of carbonyl compounds. However, no correlation was found between the amount of carbonyl compounds present and the degree of hydrolysis occurring in these fats. A highly significant negative correlation ($r = - .32$) was found between the amount of hydrolysis by lipase and the free fatty content of the fats. This may have resulted from the fact, as Youngs (51) has reported, pancreatic lipase reacts primarily with the fatty acids in the 1 and 3 positions on the triglyceride molecules. These fatty acids are also the ones most susceptible, or most exposed to oxidation. Therefore, a decreased lipase activity could result from the fact that acids in these positions were already oxidized and changed. The fact that the greatest decrease in hydrolysis occurred in cottonseed oil, which was the most highly unsaturated fat tested, is evidence for the above statement.

SUMMARY AND CONCLUSIONS

Simulation of home frying procedures is difficult since many variable factors are involved. The frequency of use of the fat, the temperature at which it is stored between uses, the kind of container in which it is stored, the degree of scouring to which the frying pan is subjected, the kind of food fried and the preparation which the food undergoes before it is fried are some of the factors which may vary from one home kitchen to another.

Two simulated home kitchen frying procedures were chosen arbitrarily for use in this study. The effect of metal and non-metal (glass ceramic) frying pans on changes in composition of the fats were investigated in each case.

The first method involved the use of four different kinds of fats (lard, cottonseed oil, hydrogenated vegetable shortening and hydrogenated animal - vegetable combination shortening), to cook chicken or potatoes. Different batches of fat were used to fry each of these foods in both scoured and unscoured iron and glass ceramic frying pans. Each fat, in each kind of pan, was used to fry ten successive batches of either chicken or potatoes during a total heating time of ten hours. No fresh fat was added to replace either fat lost on removal of the fried food or that lost as a result of taking out samples of fat for later analysis. Therefore, each succeeding batch of chicken or potatoes was cooked in a smaller volume of the same fat. Samples of each fat, and of fried chicken and potatoes, were analyzed after five and ten hours use of the fats. After every second hour of use, all fats were stored overnight at 9° C in glass beakers.

The second method involved the use of only two kinds of fat (lard and cottonseed oil) in which ten successive batches of chicken were fried. The total heating time was 7.5 hours, divided into five frying periods. Chicken pieces were floured and salted before frying, and each frying pan was scoured after every second batch of chicken fried. At the beginning of each frying period, sufficient fresh fat from the original mixture was added to each pan to maintain a constant volume. Samples were analyzed from each batch of chicken fried and from fat at the end of each frying period. After each frying period, all fats were poured into glass beakers and stored overnight at 9° C.

The changes in composition of fats which occurred during repeated use were dependent upon the method used for frying, the kind of fat used, the kind of food fried and, to a limited extent, the kind of frying pan which was used for frying.

When fats were used to fry potatoes, a greater degradation of the fat occurred, through hydrolysis to form free fatty acids, than when the same fats were used to fry chicken.

Changes in iodine values of fats in which chicken was fried depended on the original iodine values of the fats. When chicken was fried in a fat which was more saturated than chicken fat itself, that is, one which had a lower iodine value than that of chicken fat, dilution by fat from the chicken raised the iodine value (increased the degree of unsaturation) of the fat in the frying pan. However, when chicken was fried in a more highly unsaturated fat, that is, one whose iodine value exceeded that of chicken fat, dilution by chicken fat had no ameliorating effect and the iodine value of the fat in the frying pan decreased (became less unsaturated).

Iodine values, or the degree of unsaturation, of fat extracted from fried chicken were also dependent upon iodine values of the frying fat. Although the iodine values of fat extracted from fried chicken were always at least as high as those from raw chicken, these values were much higher than those in raw chicken when an unsaturated fat like cottonseed oil was used as the frying fat. Iodine values of fat extracted from fried potatoes were also related to, but higher than, iodine values of the fat used for frying.

Well-scoured iron frying pans exerted a catalytic effect toward promoting larger amounts of carbonyl compounds in fats heated in them. Unscoured iron pans did not show this effect because their iron surface is coated with a thin layer of oxidized fat.

In general, the amount of hydrolysis taking place in frying fats when they are reacted with pancreatic lipase, **in vitro**, decreased slightly with increasing use of the fat. Hydrolysis of fats in which chicken was fried was always greater than that of fats in which potatoes were fried. Onset of foaming in these fats, which is associated with biologically significant changes, also occurred much more rapidly when potatoes were fried than when chicken was fried.

Occasional use of fats which have been used for too long a time at too high a temperature, probably will not cause any discomfort or harm to the person who eats the fried food. However some simple precautions can be taken to guard against abuse of fats used for frying. The following recommendations are made:

1. Discard a frying fat when it begins to foam severely when food is added to it.

2. Discard a frying fat when color changes become pronounced.

3. Use the largest amount of fat the frying container will hold and add fresh fat to maintain this volume each time the fat is used again for frying.

LITERATURE CITED

1. Assoc. Official Agr. Chemists. Official Methods of Analysis, 8th ed., p. 386 (1955).
2. Ibid., p. 464.
3. Ibid., p. 470.
4. Am. Oil Chemists' Soc. Official and Tentative Methods, 2nd ed., Method Cd 8-53 (1946).
5. Becker, E., K. F. Gander and W. Heimann. Masking of pro-oxygen heavy metal ions in protein containing emulsions. Fette Seifen Anstrichmittel **59**, 599 (1957).
6. Bennion, M. and F. Hanning. Color changes of fats involved in the frying of a fritter-type batter. Food Technol. **10**, 290 (1956).
7. Bishov, S. J., A. S. Henick and R. B. Koch. Oxidation of fat in model systems related to dehydrated foods. Food Research **25**, 174 (1960).
8 Bito, T. and A. Yamamoto. Influence of fried food materials on oxidation of oil. Yakagaku **9**, 41 (1960).
9. Chalmers, J. G. Heat transformation products of cottonseed oil. Biochem. J. **56**, 487 (1954).
10. Chang, I. C. L., L. I. Y. Tchen and B. M. Watts. The fatty acid content of selected foods before and after cooking. J. Am. Oil Chemists' Soc.**29**, 378 (1952).
11. ——————. and B. M. Watts. The fatty acid content of meat and poultry before and after cooking. J. Am. Oil Chemists' Soc. **29**, 334 (1952).
12. Coe, M. R. The rancidity problem and new developments with particular reference to the effect of light. Cereal Chem. **11**, 241 (1934).
13. Cooney, P. M., C. D. Evans, A. W. Schwab and J. C. Cowan. Influence of heat on oxidative stability and on effectiveness of metal-inactivating agents in vegetable oils. J. Am. Oil Chemists' Soc. **35**, 152 (1958).
14. Coons, C. M. Fatty acids in foods. J. Am. Dietetic Assoc. **34**, 242 (1958).
15. Custot, F. Toxicity of heated fats: The problem of frying oils. Journees sci. centre natl. coordination etudes et recherches nutrition et aliment **2**, 417 (1958).
16. Evans, C. D., P. M. Cooney, H. A. Moser, J. E. Hawley and E. H. Melvin. The flavor problem of soybean oil. X. Effects of processing on metallic content of soybean oil. J. Am. Oil Chemists' Soc. **29**, 61 (1952).
17. Farmer, E. H. Peroxidation in relation to olefinic structure. Trans. Faraday Soc. **42**, 228 (1946).
18. Goodman, A. H. and Z. Block. Problems encountered in the commercial utilization of frying fats. J. Am. Oil Chemists' Soc. **29**, 616 (1952).
19. Hall, J. D., D. L. Harrison and D. L. Mackintosh. Effect of free fatty acid on flavor of fat. J. Agr. Food Chem. **10**, 97 (1962).
20. Harada, I., Y. Saratani and M. Ishikawa. Color reversion of refined and deodorized soybean oil. III. Influence of iron and antioxidants on color reversion. Nippon Nogei Kagaku Kaishi **34**, 558 (1958).
21. Hawk, P. B., B. L. Oser and W. H. Summerson. Practical Physiological Chemistry, 13th ed., p. 402 (1954).
22. Henick, A. S., M. F. Benca and J. H. Mitchell, Jr. Estimating carbonyl compounds in rancid fats and foods. J. Am Oil Chemists' Soc. **31**, 88 (1954).
23. Kaunitz, H., C. A. Slanetz, R. E. Johnson, J. Guilmain, H. B. Knight, D. H. Saunders and D. Swern. Nutritional properties of the molecularly distilled fractions of autoxidized fats. J. Nutrition **60**, 237 (1956).
24. Keane, K. W., G. A. Jacobson and C. H. Krieger. Biological and chemical studies on commercial frying oils. J. Nutrition **68**, 57 (1959).
25. Khan, N. A., J. B. Brown and F. E. Deatherage. Autoxidation of methyl oleate, methyl sterolate and methyl-9, 10-dideutero-oleate. J. Am. Oil Chemists' Soc. **28**, 105 (1951).
26. King, F. B., R. Loughlin, R. W. Riemenschneider and N. R. Ellis. The relative value of various lards and other fats for the deep-fat frying of potato chips. J. Agr. Research **53**, 369 (1936).
27. Kritchevsky, D., S. A. Tepper and J. Langan. Influence of short-term heating on composition of edible fats. J. Nutrition **77**, 127 (1962).
28. Lassen, S., E. K. Bacon and H. J. Dunn. The digestibility of polymerized oils. Arch. Biochem. **23**, 1 (1949).
29. Lips, H. J. Effects of heat treatment on the stability of lard. J. Am. Oil Chemists' Soc. **28**, 58 (1951).
30. Lundberg, W. O. Autoxidation. J. Am. Oil Chemists' Soc. **31**, 523 (1954).

31. ——————. Lipids of biologic importance. Peroxidation products and inclusion compounds of lipids. Am. J. Clinical Nutrition **6**, 601 (1958).
32. Mabrouk, A. F. and L. R. Dugan. A kinetic study of the autoxidation of methyl linoleate and linoleic acid emulsions in the presence of sodium chloride. J. Am. Oil Chemists' Soc. **37**, 486 (1960).
33. Marcuse, R. Action of amino acids in oxidation of fats. Fette Seifen Anstrichmittel **63**, 547 (1961).
34. ——————. Action with amino acids during fat oxidation. II. Investigations with linoleate. Fette Seifen Anstrichmittel **63**, 940 (1961).
35. ——————. The effect of some amino acids on the oxidation of linoleic acid and its methyl ester. J. Am. Oil Chemists' Soc. **39**, 97 (1962).
36. Melnick, D. Absence of thermal polymers in potato chip frying oils. J. Am. Oil Chemists' Soc. **34**, 351 (1957).
37. ——————, F. H. Luckmann and C. M. Gooding. Composition and control of potato chip frying oils in continuing commercial use. J. Am. Oil Chemists' Soc. **35**, 271 (1958).
38. Morgan, A. F. and E. R. Cozens. Changes in physical and chemical constants of fat used for frying a standard dough. J. Home Economics **11**, 394 (1919).
39. Nishida, T., F. Takenaka, F. A. Kummerow. Effect of dietary protein and heated fat on serum cholesterol and betalipoprotein levels, and on the incidence of experimental atherosclerosis in chicks. Circulation Research **6**, 194 (1958).
40. Piper, S. H., A. C. Chibnall, S. J. Hopkins, A. Pollard, J. A. B. Smith and E. F. Williams, CCXXV. Synthesis and crystal spacings of certain long chain paraffins, ketones and secondary alcohols. Biochem. J. **25**, 2072 (1931).
41. Poling, C. E., W. D. Warner, P. E. Mone and E. E. Rice. The influence of temperature, heating time, and aeration upon the nutritive value of fats. J. Am. Oil Chemists' Soc. **39**, 315 (1962).
42. Porter, F. R., H. Michaelis and F. G. Shay. Changes in fats during frying. Ind. Eng. Chem. **24**, 811 (1932).
43. Rice, E. E., P. E. Mone and C. E. Poling. Effect of commercial frying operations on nutritive value of fats. Fed. Proc. **16**, 398 (1957).
44. ——————, C. E. Poling, P. E. Mone and W. D. Warner. A nutritive evaluation of overheated fats. J. Am. Oil Chemists' Soc. **37**, 607 (1960).
45. Saunders, D. H., J. E. Coleman, J. W. Hampson, P. A. Wells and R. W. Riemenschneider. Autoxidation of fatty acids in emulsions. I. Pro-oxidant effect of histidine and trace metals in the oxidation of linoleate eters. J. Am. Oil Chemists' Soc. **39**, 434 (1962).
46. Schultz, H. W. ed. Symposium on Foods: Lipids and their oxidation. p. 40 (1962).
47. Stasch, A. R. and L. Kilgore. Some factors affecting chemical changes occurring in fats at the temperature used in deep-fat frying. Miss. Agr. Exp. Stn. Bull. **641**, 15 pp. (1962).
48. Warner, W. D., P. N. Abell, P. E. Mone, C. E. Poling and E. E. Rice. Nutritional value of fats in cooked meats. J. Am. Dietetic Assoc. **40**, 422 (1962).
49. Watt, B. K. and A. L. Merrill. Composition of foods — raw, processed, prepared. U. S. Dept. Agr., Agr. Handbook No. 8, 147 pp. (1950).
50. Weinstein, S. S. and A. M. Wynne. Studies on pancreatic lipase. II. Influence of various compounds on the hydrolytic activity. J. Biol. Chem. **112**, 649 (1935).
51. Youngs, G. C. Determination of the glyceride structure of fats. J. Am. Oil Chemists' Soc. **38**, 62 (1961).

APPENDIX. TABLES OF STATISTICAL ANALYSES

Table I.—F ratios obtained from analysis of variance of data from four fats used to fry chicken and potatoes.

Source	Degrees of freedom	F ratios: Iodine values	Total carbonyl compounds	Free fatty acids	Peroxide values
Kind of food fried (A)	1	952.399**	244.707**	20.361**	10.558**
Length of time fat used (B)	2	199.748**	805.718**	2935.431**	604.460**
Kind of frying pan (C)	3	3.200*	<1***	1.995***	20.701**
Kind of fat used (D)	3	3898.002**	60.263**	787.074**	19.066**
A x B Interaction	2	46.843**	54.454**	43.782**	1.516***
A x C Interaction	3	1.460***	2.404***	2.327***	6.727**
B x C Interaction	6	4.062**	3.737**	1.233***	5.590**
A x D Interaction	3	164.690**	7.900**	23.119**	20.484**
B x D Interaction	6	37.125**	33.626**	43.330**	27.177**
C x D Interaction	9	5.491**	2.058*	2.030*	3.454**
A x B x C Interaction	6	1.121***	1.541***	1.307***	6.555**
A x B x D Interaction	6	55.054**	10.647**	12.728**	19.069**
A x C x D Interaction	9	1.788***	1.024***	1.846***	2.706**
B x C x D Interaction	18	2.849**	1.226***	3.440**	2.955**
A x B x C x D Interaction	18	1.955*	<1***	1.480***	1.679***
Replicates	1	<1***	<1***	<1***	<1***
Error	95				
Total	191				

**Significant at the 1% level.
*Significant at the 5% level.
***Not significant.

Table II.—Mean peroxide values[1] for each fat used to fry chicken in each pan at all sampling times.

Kind of fat / Frying pan:	Scoured iron	Unscoured iron	Scoured Glass ceramic	Unscoured Glass ceramic
Cottonseed oil	3.44a	3.98a	3.64a	4.41a
Hydrogenated vegetable shortening	3.31a	3.02a	3.81a	3.75a
Hydrogenated animal-vegetable combination shortening	4.86a	6.28a,b	6.84b	7.00b
Lard	3.61a	4.55a	3.71a	4.28a

[1]Values not followed by the same letter differ significantly from one another at the 1% level.

Table III.—Mean peroxide values[1] for each fat used to fry potatoes in each pan at all sampling times.

Kind of fat / Frying pan:	Scoured iron	Unscoured iron	Scoured Glass ceramic	Unscoured Glass ceramic
Cottonseed oil	4.53a	3.11a	4.58a	3.04a
Hydrogenated vegetable shortening	2.62a	2.77a	5.08b	5.20b
Hydrogenated animal-vegetable combination shortening	2.63a	3.14a	4.85b	4.94b
Lard	2.43a	3.94b	5.50b	4.77b

[1]Values not followed by the same letter differ significantly from one another at the 1% level.

Table IV.—Mean peroxide values[1] for each fat used to fry chicken at each sampling time in all pans.

Kind of fat / Time:	0	5	10
Cottonseed oil	B 1.56a	A 4.81b	B 5.24b
Hydrogenated vegetable shortening	A 0.36a	A 4.92b	B 5.13b
Hydrogenated animal-vegetable combination shortening	A 0.45a	C 9.60b	C 8.69b
Lard	A,B 1.20a	B 7.13b	A 3.78c

[1]Values in columns not preceded by the same letter differ significantly from one another at the 5% level. Values in rows not followed by the same letter differ significantly from one another at the 5% level.

Table V.—Mean peroxide values[1] for each fat used to fry potatoes at each sampling time in all pans.

Kind of fat	Time: 0	5	10
Cottonseed oil	A 0.97a	A 3.02b	C 7.46c
Hydrogenated vegetable shortening	A 0.26a	B 6.68b	A,B 4.81c
Hydrogenated animal-vegetable combination shortening	A 0.53a	B 7.26b	A 3.88c
Lard	A 0.41a	B 6.29b	B 5.77b

[1]Values in columns not preceded by the same letter differ significantly from one another at the 5% level. Values in rows not followed by the same letter differ significantly from one another at the 5% level.

Table VI.—Mean peroxide values[1] for all fats used to fry chicken in each pan at each sampling time.

Frying pan	Time: 0	5	10
Scoured iron	0.89	A 5.24	A 5.28
Unscoured iron	0.89	A 6.38	A 6.10
Scoured glass ceramic	0.89	B 6.80	A 5.81
Unscoured glass ceramic	0.89	B 8.03	A 5.66

[1]Values not preceded by the same letter differ significantly (1% level) from other values in the same column.

Table VII—Mean peroxide values[1] for each fat used to fry chicken in each pan after 5 hours use.

Frying pan	Fat: Cotton-seed oil	Hydrogenated vegetable shortening	Hydrogenated animal-vegetable shortening	Lard
Scoured iron	4.17	A 4.64	A 6.35	A 4.76
Unscoured iron	3.51	A,B 5.65	B 8.50	A,B 6.02
Scoured glass ceramic	4.37	A,B 5.76	B 9.37	C 8.27
Unscoured glass ceramic	3.62	A,B 7.16	B 9.49	B,C 7.80

[1]Values not preceded by the same letter differ significantly (1% level) from other values in the same column.

Table VIII.—Mean peroxide values[1] for each fat used to fry chicken in each pan after 10 hours use.

Frying pan	Fat: Cotton-seed oil	Hydrogenated vegetable shortening	Hydrogenated animal-vegetable shortening	Lard
Scoured iron	6.54	A 3.94	A 4.39	A 3.50
Unscoured iron	5.86	A 2.72	A 5.14	B 5.91
Scoured glass ceramic	6.70	B 7.26	B 7.68	A,B 4.74
Unscoured glass ceramic	6.29	B 6.00	B 7.93	A,B 4.97

[1]Values not preceded by the same letter differ significantly (1% level) from other values in the same column.

Table IX.—F ratios obtained from separate analyses of variance of free fatty acids[1] of all fats used to fry chicken or potatoes.

Source	Degrees of freedom	F ratios	
		Chicken[2]	Potatoes[3]
Length of time fat was used (B)	1	391.16**	1159.40**
Kind of frying pan (C)	3	1.84***	3.68*
Kind of fat used (D)	3	109.86**	379.12**
C x D interaction	9	1.35***	2.24*
B x C Interaction	3	<1***	0.00***
B x D Interaction	3	6.84**	29.32**
B x C x D Interaction	9	2.00***	3.80**
Error	32		
Total	63		

[1]Calculated as oleic acid.
[2]LSD_{05} is .06; LSD_{01} is .08.
[3]LSD_{05} is .10; LSD_{01} is .14.
***Not Significant.
*Significant at the 5% level.
**Significant at the 1% level.

Table X.—F ratios obtained from separate analyses of variance of total carbonyl compounds[1] of all fats used to fry chicken or potatoes.

Source	Degrees of freedom	F ratios	
		Chicken[2]	Potatoes[3]
Legth of time fat was used (B)	1	29.78**	55.44**
Kind of frying pan (C)	3	<1***	7.69**
Kind of fat used (D)	3	39.46**	39.15**
C x D Interaction	9	1.59***	1.34***
B x C Interaction	3	3.30*	1.66***
B x D Interaction	3	6.79**	19.625**
B x C x D Interaction	9	<1***	1.81*
Error	32		
Total	63		

[1]Calculated as n - heptaldehyde.
[2]LSD_{05} is .11; LSD_{01} is .15.
[3]LSD_{05} is .06; LSD_{01} is .08.
***Not significant.
**Significant at the 1% level.
*Significant at the 5% level.

Table XI.—F ratios obtained from separate analyses of variance of iodine values (Hanus) of all fats used to fry chicken or potatoes.

Source	Degrees of freedom	F ratios	
		Chicken[1]	Potatoes[2]
Length of time fat was used (B)	1	51.91**	66.57**
Kind of frying pan (C)	3	1.32***	3.46*
Kind of fat used (D)	3	534.83**	837.72**
C x D Interaction	9	4.32**	2.29*
B x C Interaction	3	3.11*	1.24***
B x D Interaction	3	14.02**	7.19**
B x C x D Interaction	9	2.21*	1.91***
Error	32		
Total	63		

[1]LSD_{05} is 4.5; LSD_{01} is 6.0.
[2]LSD_{05} is 1.9; LSD_{01} is 2.7.
***Not significant.
*Significant at the 5% level.
**Significant at the 1% level.

Table XII.—F ratios obtained from analysis of variance of data from lipase hydrolysis of all fats used to fry chicken and potatoes.

Source	Degrees of freedom	F ratios	
		Chicken[1]	Potatoes[2]
Times fat used (B)	1	6.12*	12.28**
Kind of frying pan (C)	3	4.34*	<1***
Kind of fat used (D)	3	18.58**	3.54*
C x D Interaction	9	3.63**	1.31***
B x C Interaction	3	2.30***	<1***
B x D Interaction	3	4.06*	4.52**
B x C x D Interaction	9	5.81**	<1***
Replicates	1		
Error	31		
Total	63		

[1] LSD_{05} is 1.21 ; LSD_{01} is 1.63.
[2] LSD_{05} is 1.21; LSD_{01} is 1.62.
*Significant at the 5% level.
**Significant at the 1% level.
***Not significant.

Table XIII.—F ratios obtained from analysis of variance of data from fat extracted from chicken fried in lard and cottonseed oil.

Source	Degrees of freedom	F ratios		
		Amount of fat	Iodine values	Free fatty acids
Kind of fat used (D)	1	<1***	229.22**	3.79***
Kind of frying pan (C)	1	<1***	<1***	<1***
D x C Interaction	1	<1***	<1***	1.32***
Replicates	1	<1***	2.55***	2.60***
Error a	3			
Times fat used (B)	9	4.05**	3.46**	1.83***
D x B Interaction	9	3.42**	1.11***	2.33*
C x B Interaction	9	<1***	<1***	<1***
D x C x B Interaction	9	<1***	<1***	1.03***
Error b	36			
Duplicates	80			
Total	159			

***Not significant.
**Significant at the 1% level.
*Significant at the 5% level.

Table XIV.—F ratios obtained from analysis of variance of data when lard and cottonseed oil were used to fry chicken.

Source	Degrees of freedom	F ratios	
		Iodine values	Free fatty acids
Times fat used (B)	4	5.76**	71.00**
Kind of frying pan (C)	1	<1***	6.50*
Kind of fat used (D)	1	25443.75**	1792.25**
C x D Interaction	1	1.12***	1.75***
B x C Interaction	4	<1***	1.75***
B x D Interaction	4	17.84**	1.88***
B x C x D Interaction	4	1.75***	1.50***
Replicates	1	2.67***	0.12***
Error	19		
Duplicates	40		

***Not significant.
*Significant at the 5% level.
**Significant at the 1% level.

Table XV.—F ratios obtained from analysis of variance of data from lipase hydrolysis of fat extracted from chicken fried in lard and cottonseed oil.

Source	Degrees of freedom	F ratios
No. of times fat used (B)	2	22.10**
Kind of fat used (D)	1	4.07***
Kind of frying pan (C)	1	<1***
C x D Interaction	1	<1***
B x D Interaction	2	9.30**
B x C Interaction	2	1.92***
B x C x D Interaction	2	7.88**
Error	12	
Total	23	

***Not significant.
**Significant at the 1% level.