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FOOD LIPIDS AS AFFECTED BY CERTAIN PREPARATION AND PRODUCTION PROCEDURES

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SUMMARY

Selected practices in the preparation and production of food were studied in relation to their effects on lipid components. The study was conducted in four parts:

I. Re-use of frying fats. Potatoes and red salmon steaks were fried in cottonseed oil and hydrogenated cottonseed oil heated in the laboratory for periods totalling 60 hr. Five cooperating food service establishments provided information concerning their frying practices and permitted the frying of shrimp in their fat at intervals, as well as collection of fat samples for analysis. The establishments varied considerably as to the frying fat used and other frying practices. Frying fats and lipids extracted from the fried foods were analyzed for fatty acid content. Under the conditions of the study, the over-all effect of the re-use of frying fat was not pronounced. The major effect on the frying fats was a decrease in linoleate concentration, particularly in the more polyunsaturated fats, and the fried foods reflected the composition of the frying fats.

II. Microwave vs conventional baking of pastry made from different shortenings. Pastry wafers were made from lard, hydrogenated cottonseed oil and cottonseed oil. Lipids were extracted from unbaked wafers and from wafers baked in a microwave oven and in a conventional electric oven. Gas liquid chromatographic analysis of the extracted lipids indicated no effect of either baking method on relative fatty acid concentrations, regardless of the shortening used.

III. Effect of cooking on beef phospholipids. Lipids were extracted from raw ground beef chuck and from the corresponding cooked samples and drip. Total phospholipid in the extracted lipid was determined and the phospholipids were fractionated into three major classes. Results indicated that apparent differences between raw and cooked beef with respect to phospholipid concentration reflect changes in water and neutral lipid content more than actual quantitative change in phospholipid. The major effect of heating on phospholipid classes appeared to be some loss of cephalins from the ground beef into the drip.

IV. Grass vs. grain finishing of beef. Lipid was extracted from ground beef samples from four locations in a pair of Hereford steers, one finished on grass and one on grain. Extracted lipid was fractionated into neutral lipids and phospholipids, and each fraction was analyzed for fatty acid content. The four muscles varied considerably

as to total lipid concentration, and phospholipid expressed as percent of total lipid varied inversely with lipid expressed as percent of wet weight. Expression of phospholipid concentration as percent of tissue weight greatly reduced differences among muscles. Fatty acid concentration also varied somewhat between muscles. Type of finish did not seem to influence concentrations of the lipid components in four muscles of the one pair of animals.

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FOOD LIPIDS AS AFFECTED BY CERTAIN PREPARATION AND PRODUCTION PROCEDURES

by Mary Ann Harvey Smith[1], Kitty Roberts Coffey[2], Ada Marie Campbell[3]

Information concerning food lipids is important because of the nutritional implications of dietary lipid intake. When this study was initiated, much more research had been concerned with nutritional effects of specific lipids than with the extent to which food lipids are influenced by treatments to which foods may be subjected before they are consumed. Selected practices in the preparation and production of food, therefore, were studied in relation to their effects on lipid components. The study was conducted in four parts:

I. Re-use of frying fats: effects on the frying fats and on lipids extracted from the fried foods.
   A. Laboratory frying studies.
   B. Frying in a variety of food service situations: composition of the heated fats and of lipids extracted from shrimp fried in them.
II. Microwave vs conventional baking of pastry made from different shortenings: effects on fatty acids.
III. Cooking of beef: effects on phospholipids.
IV. Grass vs grain finishing of beef: effects on fatty acids of the neutral lipids and phospholipids.

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Each part will be reported separately. References for all parts are at the end of the bulletin.

I. RE-USE OF FRYING FATS

Frying studies previously reported involved a variety of heating conditions. Material of which the fryer is made may affect the carbonyl content of heated fats; iron catalyzes oxidative change, particularly if the surface is well-scoured (Stasch and Kilgore, 1963). The relationship between volume and surface area of frying fat has been varied; decreased fat volume per unit of surface area resulted in increased rate of deterioration (Rice **et al.**, 1960).

Frying effects on fats of different fatty acid composition have been observed; of four frying fats used by Stasch and Kilgore (1963), the highly unsaturated oil showed higher accumulations of carbonyl compounds but lower concentrations of free fatty acids than did the hydrogenated fats. Carlin and Lantz (1938) and Thiessen (1939) also reported that saturated fats developed free fatty acids at more rapid rates than did less saturated fats.

Intermittent and continuous heating have been compared. Sims and Stahl (1970), in a discussion of commercial frying, stated that intermittent heating of fat without protection between uses results in more deterioration than does continuous use with rapid fat turnover. Sahasrabudhe and Bhalerao (1963), on the other hand, reported that in a laboratory situation intermittent heating resulted in lower yields of polymerized material than did continuous heating.

There is some evidence that commercially-used frying fats may deteriorate at a less rapid rate than those used for small-scale frying, as in the home, because of the rapid fat turnover in commercial situations (Custot, 1959; Poling **et al.**, 1960). Thompson **et al.** (1967) found commercially-used frying fats to vary greatly as to extent of deterioration, depending on the treatment received in use. Under conditions of commercial use, fats are exposed to varying quantities of water, to foodstuffs of various types, and to varying amounts of agitation; they may or may not be purified by decanting or filtration; and they often are supplemented with fresh fats to an extent which, in some applications, as the frying of potato chips, results in a rapid turnover of the frying fat. Any or all of these conditions could alter the effect of heat on fat. Extrapolation of data from laboratory-heated fat to commercially-used fat is not meaningful because of the extreme variability in conditions of commercial use.

Analyses providing the criteria of change in frying fat with use have varied among studies. In early work free fatty acid concentrations, iodine number, and peroxide values were the chief chemical analyses reported; smoke point, refractive index, viscosity, color and foaming tendency were the physical properties most frequently observed. More recently chromatographic and spectroscopic methods have been used for analyzing products formed in heated oils. Animal feeding studies have been used for determining nutritional effects; results appear to indicate that deleterious effects on nutritive quality result only from drastic treatment of frying fat (Sims and Stahl, 1970).

The frying study reported herein consisted of two phases: 1) A laboratory study in which two frying fats were used repeatedly for frying two foods, potatoes and salmon. Fatty acid contents of the frying fats and of lipids extracted from the fried foods were determined. With salmon, phospholipid and neutral lipid fatty acids were to have been analyzed separately on the theory that the fractions might differ with respect to sensitivity to change. 2) A study in which cooperating food service establishments provided information concerning their frying practices and permitted the frying of a food in their fat at intervals, as well as collection of fat samples for analysis. Previously reported studies of commercially-fried foods involved collection of the foods used by the establishments rather than the frying of a single food at a number of establishments.

Laboratory Frying Studies

Procedure

Potatoes and salmon steaks were fried in cottonseed oil and in hydrogenated cottonseed oil. Idaho potatoes, purchased in one lot, were stored in the refrigerator until 24 hours before use, when they were removed and held at room temperature. After they had been pared and cut uniformly with a French-fry cutter, they were held in water for a few minutes; samples of about 150 grams were drained and fried 5 minutes in 2000 grams of each fat at 176°C. Identical aluminum electric fryers were used.

Frozen red salmon steaks, also purchased in one lot, were stored in a freezer until 24 hours prior to use, when they were transferred to a refrigerator to defrost. Although the salmon steaks were purchased in a single lot, there was no assurance of uniformity among the steaks; therefore, each steak was halved vertically at the backbone to provide paired samples for frying in the two fats. Each half,

about 1.5 centimeters thick, was fried 8 minutes in 2000 grams of fat at 170°C.

After each frying, heating of the fat was continued to complete one hour of heating, after which it was strained and refrigerated until the next use on the following day. This was repeated for a total of 12 fryings of each food in each fat. Reserve supplies of fat were heated at the same temperatures and for the same times in a similar fryer and used to replace the fat taken up by the food in each frying. Replacements were made on a weight basis.

The cooking fats were sampled before the first frying and after fryings 6 and 12. Potato and salmon samples analyzed after controlled draining on paper toweling were those from fryings 1, 3, 6, 9, and 12.

When it was found that changes in fatty acids were small during the 12 fryings, the frying fats were heated further for a total of 60 hours with no additional frying except one immediately after 60 hours. Heating was continuous for the last 48 hours and the fats were sampled for analysis after total heating times of 18, 24, 36, and 60 hours.

Lipids were extracted from the foods by the method of Bligh and Dyer (1959). Lipids extracted from raw and fried salmon were fractionated into neutral and phospholipid fractions according to the slurry method described by Murty **et al.** (1960). Methyl esters were prepared from extracted lipids and lipid fractions and from frying fats by the method of James (1960); methyl esters of the salmon lipid fractions were a casualty of a malfunctioning freezer before they could be analyzed. Unesterified fatty acids were removed prior to the methylation and were methylated and analyzed separately (Hornstein **et al.**, 1961). Procedures used for gas liquid chromatographic (GLC) analyses were those described previously by Campbell and Turkki (1967) except that a column temperature of 190°C was used for the salmon lipids. Two replications were completed.

Results and Discussion

For the potatoes, fatty acid contents of the extracted fats were nearly identical to those of the frying fats and the unesterified fatty acids were similar to those of the glycerol esters; therefore, the data are presented in Table 1 only for the frying fats. The rate of change in fatty acid concentrations during heating was quite uniform over the heating period and only the initial values and those after 60 hours of heating are included. The major change with re-use of fat was a decrease in linoleic acid concentration. Although the total decrease

Table1. Fatty acid concentrations of the frying fats initially and after a total of 60 hours of heating (including 13 fryings of potatoes)[a]

Fatty acid	Cottonseed oil		Hydrogenated cottonseed oil	
	Initially	After 60 hr.	Initially	After 60 hr.
		Percent		
14	0.4	0.5	tr	tr
16	24.9	35.3	12.4	16.8
16:1	0.5	0.7	0	0
18	1.0	1.6	5.2	8.9
18:1	10.0	16.4	70.7	69.2
18:2	63.7	45.4	11.7	4.9

[a] Each value is a mean from two chromatograms in each of two replications; expressed as percent of total fatty acids.

in linoleate concentration was considerable for the highly unsaturated cottonseed oil, the rate of decrease was slow for both frying fats under the conditions of this study. The care taken of the frying fats between uses during the first 12 hours of heating and the use of a relatively large amount of frying fat in relation to food fried probably can be considered to represent rather mild heat treatment.

The lipid extracted from fried salmon was less than 1% phospholipid, as compared with 5% in that from raw salmon. Fatty acid contents of the frying fats and lipid extracted from the salmon differed somewhat. Data are shown in Table 2 for the frying fats after

Table 2. Fatty acid concentrations of the frying fats after 60 hours and of the lipids extracted from raw salmon and from salmon fried in fats heated for 60 hours (including 13 fryings of salmon)[a]

Fatty acid	Cotton-seed oil	Hydrog. cotton-seed oil	Raw salmon	Fried salmon	
				In cotton-seed oil	In hydrog. cottonseed oil
			Percent		
14	1.1	tr	3.8	2.4	1.0
16	29.7	20.1	13.9	20.7	16.2
16:1	0.9	0.5	6.8	3.8	3.3
18	3.1	9.3	3.7	3.2	7.4
18:1	15.9	63.4	11.4	14.1	36.9
18:2	47.7	5.2	17.2	33.1	11.8
18:3	tr	tr	3.8	2.5	2.1
20:5?	tr	tr	15.7	7.0	6.9
22:4?	0	0	20.6	12.2	11.7

[a] Each value is a mean from two chromatograms in each of two replications; expressed as percent of total fatty acids.

60 hours and for the lipids extracted from raw salmon and from salmon fried in fats that had been heated 60 hours. The results with salmon were similar to those with potatoes in that the major effect of re-use of frying fat was a decrease in polyunsaturated fatty acids in the fried foods. They differed from the results with potatoes in that higher polyunsaturates were present.

Lipids of salmon fried in hydrogenated cottonseed oil differed from those of salmon fried in cottonseed oil in that their linoleate concentration decreased, whereas that of salmon fried in cottonseed oil increased. This reflects the inherent difference between the two frying fats with respect to their linoleate content. The frying fat influenced the fatty acid composition of the salmon lipid less than that of the potatoes because the salmon had a much higher concentration of fat initially than do potatoes.

Large Quantity Frying in a Variety Of Food Service Situations

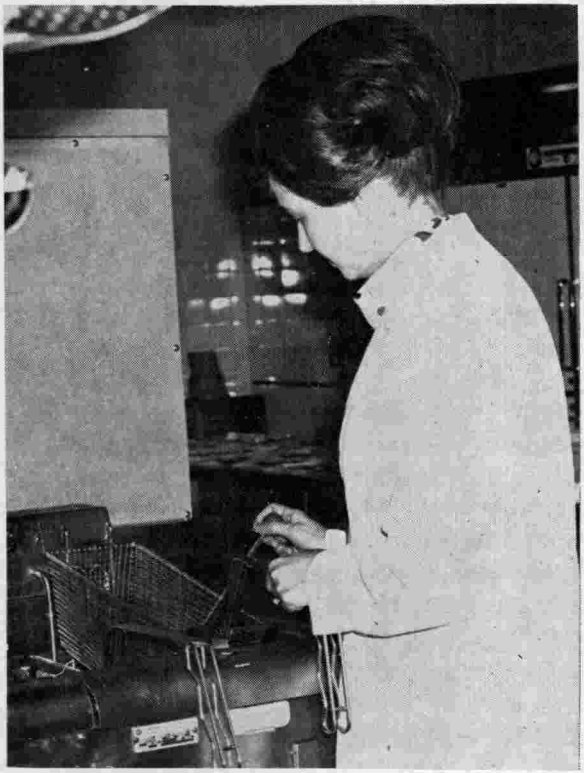
Procedure

Five establishments that serve fried foods cooperated: a chain drive-in restaurant, a private-owned restaurant, a privately-owned cafeteria, a university cafeteria, and a hospital. Information concerning frying practices was obtained through initial interviews with managers, later discussions with kitchen personnel, and observations at times of sample collection.

Frying fats used varied from a hydrogenated animal-vegetable fat mixture to cottonseed oil. Heating times ranged from 5 to 24 hours per day and median frying temperatures from 162 to 209°C. In one establishment the fat was heated continuously; in another, the fat was heated continuously for 16 hours out of 24; in the other three, fat was heated intermittently. Frying fat was refrigerated between uses in only one establishment and strained once or twice a day in all. Fresh fat was added at the rate of 2-50% (weight basis) of the fryer capacity per day. Total time of heating between complete changes ranged from 24 to 480 hours. This information concerning the food service establishments is presented as an indication of the large variability with respect to their frying practices. In presentation of the results, individual establishments will be mentioned only in instances where they differed considerably as to the observed effects.

Frying fat samples were collected immediately before use (after

complete change of fat), at the approximate midpoint of each use period (period between two complete changes of fat) and just prior to fat disposal. The collections were made during two complete use periods, that is six times at each establishment. Commercially-frozen breaded raw shrimps were obtained in quantity and a six-shrimp portion was fried immediately following each sampling of frying fat.



Removal of sample from deep fat fryer.

Viscosity of the oil samples was measured at 45°C with a Brookfield Viscometer, Model LVF. Lipids were extracted from raw and fried shrimp by Ostrander and Dugan's (1961) modification of the method of Bligh and Dyer (1959). Shrimp lipids from the first and last samples in each use period were separated into neutral lipid and phospholipid fractions by the column chromatographic method described by Hornstein **et al.** (1961). The neutral lipids from the shrimp fried at three of the establishments during one use period, as well as the corresponding frying fats, were separated further into subfractions differing as to saturation. The thin layer chromato-

graphic (TLC) procedure of Litchfield **et al.** (1964) was used for obtaining four fractions in which the lipids contained none, one, two, and three or more double bonds per molecule. Bands were eluted from the TLC plates by the method of Van Handel (1964) and the amount of triglyceride in each fraction was determined by the color reaction of Van Handel and Zilversmit (1957).

Methyl esters were prepared by the method of James (1960) for GLC analysis of fatty acids in the glyceride subfractions, the corresponding frying fat and the raw shrimp lipids. The GLC procedure was that used previously in this laboratory (Campbell and Turkki, 1967). Initial and final values for fatty acid concentrations were compared by use of the t-test for paired comparisons (Steele and Torrie, 1960).

Procedures were described in detail by Harvey (1965).

Results and Discussion

Frying fats from all five establishments increased somewhat in viscosity with heating. Over-all means for the unheated, midpoint, and final samples were 32, 34, and 42 centipoises, respectively. Apparently some polymerization of the frying fats occurred; no attempt was made to isolate polymers.

Lipid extracted from the fried shrimp averaged 11.7% of the original wet weight as compared with 1.2% in the raw shrimp. Concentrations did not change with re-use of fat, averaging 11.8%, 11.6%, and 11.7%, respectively for shrimp fried in oil heated just to frying temperature, in oil at the midpoint of the use period and in oil just prior to disposal. The means for lipid extracted from the fried shrimp for the five establishments varied from 10.8 to 12.7; the lowest and highest average fat absorptions occurred at the establishments where the heating temperatures used were highest and lowest respectively.

Phospholipids constituted 37% of the lipid extracted from the raw shrimp and an average of 3.7% of that from the cooked shrimp. This difference, as well as the difference in total fat content, reflects the great dilution of shrimp lipid with frying fat. Phospholipid concentration in cooked shrimp lipid did not differ among the establishments or among the three samples fried at each establishment during each use period.

Although the fatty acid contents of the frying fats differed among the establishments, they are averaged in Table 3, as are the values for the shrimp. Mean linoleic acid concentration in the frying fats decreased ($P < 0.01$) with re-use. The neutral shrimp lipids were

Table 3. Major fatty acids in the frying fats and in the neutral and phospholipid fractions of raw shrimp lipid and of lipid extracted from shrimp cooked in fresh fat (initial) and fat just prior to disposal (final)[a]

Fatty acid	Frying fat		Raw shrimp		Cooked Shrimp					
					Neutral lipid			Phospholipid		
	Initial[b]	Final	Neutral	p.l.[c]	Initial[b]		Final	Initial[b]		Final
				Percent						
16	28.3	30.2	18.9	47.2	25.1		29.2	43.6		41.6
18	6.3	5.5	0	9.1	4.1		3.8	11.3		9.4
18:1	47.0	51.7	13.4	13.4	48.0		55.6	15.1		16.4
18:2	16.9 **	11.6	67.1	23.0	21.5	**	11.2	25.7		28.4

[a] Each value is a mean for the five establishments, two periods of use, two chromatograms per sample; expressed as percent of total fatty acids.
[b] Initial samples of frying fat were taken when fat had been heated only to frying temperature; initial samples of the cooked shrimp lipid fractions represent lipid extracted from shrimp fried immediately following the fat collection.
[c] Phospholipid.
**$P < 0.01$.

much more highly polyunsaturated than were the phospholipids; the phospholipids contained correspondingly higher concentrations of the 16- and 18-carbon saturates. The neutral lipids of the cooked shrimp reflected the large contribution of the frying fat: the average concentration of linoleate was much lower in the cooked shrimp neutral lipids than in the raw and decreased considerably with re-use of the fat ($P < 0.01$). The greatest decrease in linoleic acid concentration was observed in the neutral lipids from the establishment that used the highly polyunsaturated oil. The phospholipid fraction was influenced little by the frying fat; most of the phospholipid present was that of the shrimp itself.

Frying fats and fried shrimp neutral lipids from three establishments for one use period were subfractionated by TLC because it was thought that changes not detected in study of the whole neutral lipid fractions might be found through study of subfractions. The subfractionation procedure used also supplemented GLC analysis in providing information as to the distribution of fatty acids among glyceride molecules in a given fat sample. Three establishments that differed considerably as to frying practices were selected. Separation of glycerides into subfractions on the basis of number of fatty acid double bonds per glyceride molecule resulted in seven distinct bands as indicated in Figure 1, a tracing of a typical thin-layer chromatogram.

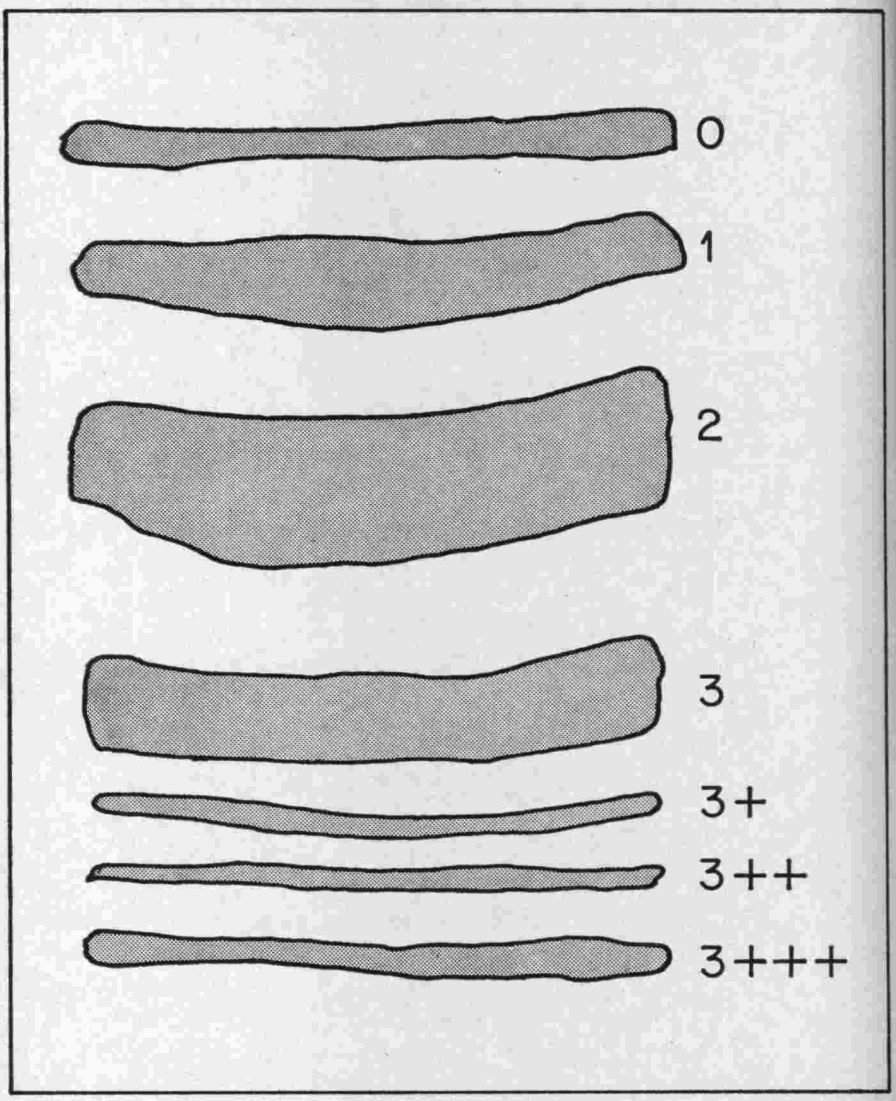


Figure 1. Tracing of a typical thin-layer chromatogram, showing glyceride subfractions separated on the basis of number of double bonds per molecule. (From top to bottom: 0, 1, 2, and 3 or more double bonds per glyceride molecule.)

The relative proportions of the various subfractions are shown in Table 4. Although the seven bands were eluted and analyzed separately, the values for fraction 3 represent a pooling of weighted

Table 4. Glyceride subfractions of frying fats and neutral lipids of fried shrimp, initial and final samples[a]

Subfraction[b]	Establishment:	Frying fat			Shrimp lipids		
		R	B	J	R	B	J
		Percent					
0							
Initial		14.4	3.2	15.7	10.6	1.6	12.5
Final		13.9	4.3	12.8	9.1	4.8	10.3
1							
Initial		21.2	5.9	29.7	28.2	1.4	8.7
Final		23.5	18.0	14.8	38.4	1.6	6.8
2							
Initial		35.2	14.2	30.7	30.7	19.4	32.2
Final		30.9	18.1	34.6	25.2	24.7	31.3
3 or more							
Initial		29.2	76.8	23.9	30.6	77.5	46.5
Final		31.8	59.6	37.9	27.3	68.9	51.6

[a] Each value is a mean calculated from six determinations; expressed as percent of recovered glyceride.
[b] Number of double bonds per molecule.

values for the four most unsaturated bands. Litchfield **et al.** (1964) analyzed these bands as a single fraction.

The amount of glyceride in each subfraction varied with the kind of fat that was used at the establishment. Lard from restaurant R and the hydrogenated compound from drive-in J had higher percentages of triglyceride in the subfractions containing zero and one double bond per molecule than did the fat from establishment B. The oil used in B had only 10.3% of saturated fatty acids originally as compared with 45.9% and 57.7% for the fats of R and J, respectively. Glycerides of the fried shrimp similarly were lower in subfractions **0** and **1** for establishment B than for the other two restaurants.

A decrease in the proportion of the most highly unsaturated subfraction, **3**, occurred in the frying fat used at establishment B between the first and last fryings. Although the oil was not highly polyunsaturated, it was the most unsaturated of the frying fats used at the three selected establishments and was used the longest.

The proportion of subfraction **3** in the frying fat and shrimp glycerides from establishment J increased with use of the fat, particularly in the frying fat itself. This could be an apparent rather than a real effect if hydrolysis of the fat occurred during use. With the solvent system used, the free glycerol then would contribute to the values for the most unsaturated subfraction. Occurrence of such

an effect at only the one establishment could be attributable to its having fried particularly large quantities of potatoes, which have a high moisture content. Establishment J also used higher frying temperatures than did the other restaurants.

The fatty acid compositions of the glyceride subfractions are shown in Table 5 for the frying fats and Table 6 for the fried shrimp neutral lipids. Values are averaged for the three establishments. The TLC procedure yielded fractions according to theory. The subfraction that supposedly consisted of glycerides having no double bonds indeed appeared to have only saturated fatty acids. The subfraction that theoretically contained glycerides having one double bond per molecule contained approximately one-third oleic acid and two-thirds saturated acids. The subfraction that presumably contained two double bonds per molecule had an average of 64% oleic acid and a small amount of linoleate in addition to saturated fatty acids. Subfraction 3 apparently was very complex, as indicated by its having separated into four bands, containing progressively higher proportions of unsaturated fatty acids. Values for the linoleate concentrations in the components of subfraction 3 are shown in Table 7. The greater the extent of unsaturation, the greater was the decrease in linoleic acid concentration with re-use of the frying fat.

The over-all effect of re-use of fat was not pronounced. Although

Table 5. Fatty acid composition of glyceride subfractions of the frying fats, initial and final samples[a]

	Fatty Acid						
Subfraction[b]	12	14	16	16:1	18	18:1	18:2
	Percent						
0							
Initial	6.2	5.9	46.1	0	41.5	0	0
Final	1.9	7.7	55.7	0	34.3	0	0
1							
Initial	0.9	3.7	51.3	0	13.7	29.9	0
Final	0.5	3.2	48.3	0	11.3	36.5	0
2							
Initial	0.4	2.4	26.5	tr	3.4	64.9	1.7
Final	0.2	2.1	21.5	tr	4.5	71.4	0
3 or more[c]							
Initial	0.4	1.7	14.8	1.0	1.6	59.0	20.9
Final	1.5	4.1	14.5	0.8	3.9	61.2	14.4

[a] Each value is a mean for three establishments, two chromatograms per sample; expressed as percent of total fatty acids in the subfraction.

[b] Number of double bonds per molecule.

[c] Values for the components were weighted by the relative proportions of the components and pooled.

Table 6. Fatty acid composition of the glyceride subfractions of the neutral lipids of fried shrimp, initial and final samples[a]

Subfraction[b]	Fatty acid						
	12	14	16	16:1	18	18:1	18:2
	Percent						
0							
Initial	0.2	6.8	48.0	0	44.8	0	0
Final	0	7.6	55.3	0	36.7	0	0
1							
Initial	0.4	5.7	48.3	tr	13.7	31.5	0
Final	0	5.7	50.0	tr	13.2	29.2	0
2							
Initial	0.2	2.2	27.5	0.2	5.3	60.0	4.6
Final	0.6	5.1	28.0	tr	7.4	58.3	0.3
3 or more[c]							
Initial	0.1	2.2	17.5	1.3	2.8	60.7	14.7
Final	0.7	3.9	23.6	1.6	3.5	60.5	5.7

[a] Each value is a mean for three establishments, two chromatograms per sample; expressed as percent of total fatty acids in the subfraction.

[b] Number of double bonds per molecule.

[c] Values for the components were weighted by the relative proportions of the components and pooled.

Table 7. Linoleic acid concentrations in the components of glyceride subfraction 3, for one period of use[a]

Component of Subfraction 3	Frying fat		Fried shrimp glyceride	
	Initial	Final	Initial	Final
	Percent			
3	2.1	2.5	3.1	0.2
3_{+}	9.4	10.6	tr	0.7
3_{++}	25.5	19.7	13.1	4.5
3_{+++}	59.6	30.6	35.1	14.8

[a] Each value is a mean from two chromatograms for each of three establishments; expressed as percent of total fatty acids.

some rather large decreases in percentage of linoleate were observed in the most polyunsaturated fractions, these fractions represented relatively small portions of the entire fat sample. To the extent that changes did occur, they varied with the kind of fat used and, to a limited extent, with the frying practices. If an establishment fries foods in a highly polyunsaturated oil, such as was used at one establishment in this study, and then re-uses that oil for as long a period as did another establishment, the effects on fatty acids of the fried foods could be drastic.

Probably the nature of the fat governs its use, however. There appears to be a trend toward commercial use of frying fats and oils of a relatively low degree of polyunsaturation, probably because of their greater stability. Neither the slight decrease in unsaturation of the fatty acids nor the slight increase in viscosity of fat found in this study seems sufficient to warrant consumer concern with respect to use of commercially-fried foods. Perhaps it is in the home situation, where highly unsaturated oils are commonly used for frying, that caution particularly needs to be exercised in the prolonged re-use of frying fat.

II. MICROWAVE VS. CONVENTIONAL BAKING OF PASTRY MADE FROM DIFFERENT SHORTENINGS

Procedure

Pastry was made from 82 grams of soft wheat all purpose flour, 36 grams of shortening, 16 milliliters of water, and 2 grams of sodium chloride. The dry ingredients were mixed together for 10 seconds at speed 2 in a Kitchenaid mixer, Model 3C. The shortening (room temperature) was added and mixing was continued at speed 2 for 35 seconds. The water was added all at once and mixed with the other ingredients 1 minute, again at speed 2. The dough was halved and rolled into two long strips, each 3 inches (7.6 centimeters) wide and 0.09 inch (2.3 millimeters) thick. The strips were cut into 1½-inch (3.8 -centimeter) wafers, which were placed on paper plates (three per plate), covered with foil, and frozen. Eighteen wafers were obtained from the dough. Before baking, the covered samples were thawed for 30 minutes at room temperature. Six wafers were baked in a rotary hearth oven for 4½ minutes at 425°F (218° C). Six were baked, three at a time, for 50 seconds in a microwave oven on "High" (2450 megaherz). The remaining six were analyzed raw.

The shortenings used were lard, hydrogenated cottonseed oil, and cottonseed oil. The order of preparation of doughs containing the three shortenings was randomized within each of four replications. Lipids were extracted from the raw dough and from the baked pastry by the Ostrander and Dugan (1961) modification of the method of Bligh and Dyer (1959). Methyl esters were prepared and analyzed by GLC under the conditions described by Campbell and Turkki (1967).

For each fatty acid the t-test for paired comparisons (Steele and Torrie, 1960) was applied to each pair of samples: raw and con-

ventionally baked, raw and microwave baked, conventionally and microwave baked.

Results and Discussion

Mean fatty acid values for the four replications are presented in Table 8. Although fatty acid contents of the pastry inevitably varied

Table 8. Fatty acid concentrations in lipid extracted from raw, conventionally baked and microwave baked pastry made from lard, hydrogenated cottonseed oil and cottonseed oil[a]

	Fatty acid				
	14:0	16:0	18:0	18:1	18:2
			Percent		
Effect of shortening[b]					
lard	1.2	38.1	6.0	50.9	3.7
hydrog. c.s.o.	tr	16.8	5.0	46.4	31.8
c.s. oil	0.3	22.5	0	7.6	69.6
Effect of baking[c]					
raw	0.5	26.0	4.0	35.4	34.0
conventional	0.6	26.1	3.5	34.4	35.3
microwave	0.4	25.3	3.4	35.2	35.8

[a] Each value is a mean from two chromatograms for each of three treatments in four replications; expressed as percent of total fatty acids.
[b] Values are averaged for the three types of samples analyzed.
[c] Values are averaged for the three shortenings.

considerably with the shortening used, differences among the raw, conventionally-baked, and microwave-baked samples with respect to fatty acid content did not occur. Other types of analyses on foods cooked in the microwave oven also have shown little or no change. Because of the high temperature reached on the surface of conventionally-baked pastry, the combination of conventional baking and polyunsaturated oil might be expected to show an effect, but such was not the case.

III. EFFECT OF COOKING ON BEEF PHOSPHOLIPIDS

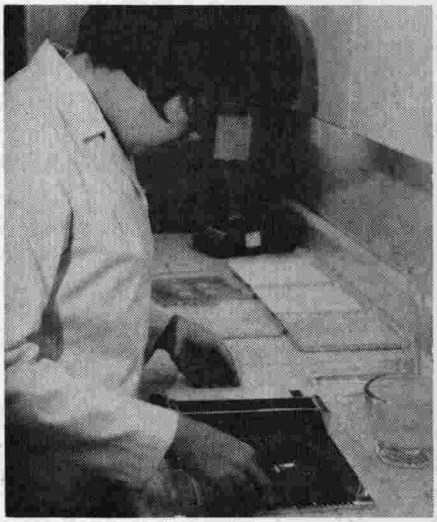
In a previous study reported from this laboratory (Campbell and Turkki, 1967), phospholipid concentration was higher in cooked ground beef than in the raw meat, whether expressed on the wet or dry weight basis or as percent of total lipid. The meat used had a high concentration of total lipid, 12-16% of the wet tissue weight.

The present investigation involved the effect of cooking on the phospholipid concentration of very lean ground beef. Relative concentrations of the three major phospholipid classes as well as concentration of total phospholipid were determined.

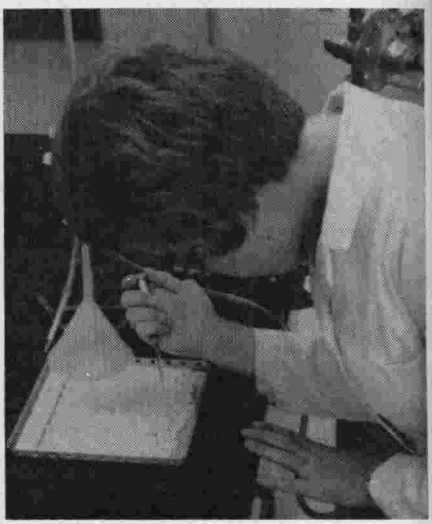
Procedure

Eight boneless roasts of beef chuck, consisting of the triceps brachii muscles and graded **U. S. Good,** were procured from a local market. Each roast was trimmed and ground and the ground meat was cooked by the procedure described by Campbell and Turkki (1967). Lipids were extracted from raw and cooked meat and from drip by the method of Bligh and Dyer, as modified by Ostrander and Dugan (1961). Lipid fractionation by the thin layer chromatographic procedure of Wood and Kinsell (1963) and quantitation of the major phospholipid classes by phosphorus analysis (Marinetti, 1962) were carried out as described by Turkki and Campbell (1967). The equipment and conditions previously used in this laboratory (Campbell and Turkki, 1967) for gas liquid chromatography were employed in fatty acid analysis of a pooled sample of each fraction. The t-test for paired comparisons (Steele and Torrie, 1960) was used for comparison of means for raw and cooked meat lipids and of those for cooked meat and drip lipids.

Procedures were described in detail by Roberts (1966).



Preparation of thin-layer plates.



Spotting of thin-layer plates.

Results and Discussion

Mean lipid values are presented in Table 9. Both the lipid and the phospholipid concentrations were higher in the cooked than in the raw meat, on the wet weight basis. On the dry weight basis neither the lipid nor the phospholipid concentration in the meat changed with cooking, indicating that the apparent increases on the wet weight basis primarily reflected evaporation of water. Under such conditions phospholipid concentration expressed as percent of total lipid should not, and did not, differ for raw and cooked samples.

The effect of cooking on the phospholipid content of beef apparently depends on the meat used as well as on the method of expressing values. The proportion of phospholipid in the muscle lipid decreases as the percentage of lipid in raw beef muscle increases (Callow, 1962; Campbell and Harrill, 1971). In the cooking of lean beef, such as was used in this study, a relatively small amount of lipid is lost into the drip and the proportions of neutral and phospholipids remaining are essentially unchanged.

On the other hand, meat with a higher fat content, and thus a larger proportion of neutral lipid, loses a relatively large amount of neutral lipid during cooking. In such a case (Campbell and Turkki, 1967), the proportion of phospholipid increased, whether expressed as percent of the cooked meat or as percent of total lipid. Results reported here in relation to those of the previous study (Campbell and Turkki, 1967) suggest that apparent differences between raw and cooked beef with respect to phospholipid concentration reflect changes in water and neutral lipid content more than the actual quantitative change in phospholipid.

A small qualitative difference in phospholipids of raw and cooked beef is noted from the distribution of phospholipids among the three major classes (Table 9). The cephalin concentration of the cooked meat phospholipid was slightly but consistently lower than that of the raw meat phospholipid and considerably lower than that of the drip phospholipid. If the cephalins are lost into the drip more readily than are other phospholipids, the reason is not yet apparent.

Fatty acid data are from two chromatograms for a pooled sample of each phospholipid fraction. Saturated fatty acid and monoene values are grouped in Table 10. Linoleate was the only polyunsaturate detected. The cephalin fraction was the least saturated of the raw meat phospholipid fractions. The primary effect of cooking on fatty acids of the phospholipid classes apparently was the loss of linoleate in the cephalin fraction, with a correspondingly higher

Table 9. Lipid composition of raw and cooked ground beef and of drip[a]

Component	Raw meat		Cooked meat		Drip
			Percent		
Lipid (% of wet weight)	3.1±0.44	***	4.1±0.66		0.8±0.4
Lipid (% of dry weight)	12.2±1.5		12.1±1.4		
Phospholipid					
% of meat, wet weight	0.6±0.1	*	0.9±0.1		
% of meat, dry weight	2.6±0.2		2.5±0.2		
% of total lipid	21.4±3.0		20.6±3.8		9.4±3.6
Phospholipid class (% of total phospholipid)					
lecithin	60.1±4.8		60.6±4.3	***	41.5±2.5
cephalins	32.7±4.2	*	28.5±3.5	***	48.4±2.0
sphingomyelin	7.2±1.0		10.9±4.4		10.1±1.0

[a] Means for eight samples ± standard deviations.
* $P < 0.05$.
*** $P < 0.001$.

Table 10. Saturated, monounsaturated and polyunsaturated fatty acids in phospholipid classes[a]

Phospholipid class and fatty acid grouping	Raw beef	Cooked beef	Drip
		Percent	
Lecithin			
saturates	71	61	67
monoenes	23	25	23
polyunsat.[b]	6	14	10
Cephalin			
saturates	47	56	70
monoenes	27	26	26
polyunsat.[b]	26	18	4
Sphingomyelin			
saturates	100	100	100

[a] Each value is a mean from two chromatograms of a pooled sample from eight lots of beef, expressed as percent of total fatty acids.
[b] Linoleate.

concentration of saturates in the cooked than in the raw meat. Drip phospholipids had even lower linoleate and higher saturate concentrations than did the cooked meat phospholipid.

IV. GRASS VS. GRAIN FINISHING OF BEEF

Meyer **et al.** (1960, 1966) studied the effects of grass and grain finishing of beef on the concentrations of several vitamins of the B-complex. The vitamins studied differed in their response to type of

finish. Muscles in different parts of the carcass are known to differ in their content of specific lipid components and it is not clear to what extent lipid constituents of muscle tissue are subject to dietary effects.

Procedure

Muscle samples were obtained from a pair of Hereford steers that were closely matched with respect to age, grade, and genetic background and were finished, one on pasture and one on a mixture containing 75% concentrate and 25% hay. Samples of psoas major, gastrocnemius, semitendinosus, and extensor muscles were removed from the carcasses after 29 days of aging; the samples were trimmed of external fat and loose connective tissue and ground three times in an electric grinder with plates of increasing fineness. The ground samples were mixed thoroughly under nitrogen, wrapped tightly in a double layer of aluminum foil, and frozen. At the time of analysis the samples were defrosted in the refrigerator and re-mixed in order to redistribute drip. Analyses in addition to moisture determinations included: 1) lipid extraction (Ostrander and Dugan, 1961); 2) silicic acid column chromatographic separation of lipid into neutral lipids and phospholipids (Hornstein **et al.**, 1961); 3) GLC analysis of fatty acids in the neutral lipid and phospholipid fractions.

Gas-liquid chromatographic analysis.

Results and Discussion

The four muscles differed considerably in their lipid concentrations and in phospholipid concentration expressed as percent of total lipid (Table 11). Variability was greater among muscles than between finishes. Two points are of special interest: 1) In agreement with previous findings in this laboratory (Campbell and Harrill, 1971), phospholipid concentration expressed as percent of total lipid varied inversely with lipid expressed as percent of wet weight; 2) Expression of phospholipid concentration as percent of tissue weight greatly reduced the differences among muscles and between finishes.

Fatty acid concentrations in the neutral lipid and phospholipid fractions also varied more among muscles than between finishes (Table 12). The lipid fractions were different in their fatty acid distributions; the phospholipids were lower in total saturates and in monoenoic fatty acid and much higher in linoleate than were the neutral lipids. On the basis of the samples studied, from a single pair of animals, type of finish does not seem to be a factor that influences concentrations of lipid components in muscle tissue.

Table 11. Lipid and phospholipid concentrations in four muscles of grass and grain finished beef.[a]

Muscle	Lipid wet wt. basis	Phospholipid percentage		
		Of total lipid	Of wet wt.	Of dry wt.
	Pct.		Percent	
psoas major				
grass	6.7	7.8	0.52	1.76
grain	7.8	7.5	0.58	2.02
gastrocnemius				
grass	5.2	11.7	0.61	2.18
grain	3.0	21.7	0.66	2.38
semitendinosus				
grass	3.4	16.0	0.54	2.10
grain	4.7	12.4	0.58	2.09
extensor				
grass	1.6	43.9	0.69	2.87
grain	2.4	27.7	0.65	2.57
Means				
grass	4.2	19.8	0.59	2.23
grain	4.5	17.3	0.62	2.26

[a] Means for duplicate determinations on single muscle samples and means for the four muscles.

Table 12. Major fatty acid concentrations in lipid fractions from muscles of grass and grain finished beef[a]

	Neutral lipids						Phospholipids					
Muscle	14	16	16:1	18	18:1	18:2	14	16	16:2?	18	18:1	18:2
						Percent						
psoas major												
grass	2.9	34.4	3.0	31.6	28.1	tr	1.2	20.0	4.4	17.0	24.2	17.2
grain	4.2	32.2	3.9	20.3	39.4	tr	1.1	26.3	6.4	16.3	22.2	20.6
gastrocnemius												
grass	3.5	29.6	5.1	20.2	39.8	1.8	1.2	25.7	3.8	17.4	23.7	16.9
grain	3.6	27.6	5.8	14.8	45.3	2.9	2.8	24.1	4.2	17.1	29.4	13.2
semitendinosus												
grass	2.9	27.2	7.1	17.2	44.4	1.2	0.8	26.0	3.2	17.0	26.8	15.0
grain	3.7	30.0	6.8	13.0	46.4	tr	1.0	29.6	4.2	16.8	24.0	18.1
extensor												
grass	3.0	29.2	5.4	14.0	45.0	3.4	1.4	22 6	5.4	15.6	23.6	18.1
grain	3.0	29.4	4.7	14.4	45.4	3.0	1.0	20.2	5.2	19.2	22.4	17.9

[a] Means for two chromatograms per sample.

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