Liver phospholipid content appeared to be unaltered by dietary treatment.

Histopathological Changes

Feeding for 12 weeks with refined, heated and partially hydrogenated *H. sabdariffa* seed oil at the 10% level did not alter the liver architecture of the experimental rats compared to that of rats fed peanut oil.

From the growth performance of the group of rats fed refined *H. sabdariffa* seed oil and also based on other observations in the study, it is concluded that refined oil is inferior to heated and partially hydrogenated oil. These observations indicate that *H. sabdariffa* seed oil may be considered an edible oil after suitable methods of processing such as refining, bleaching, deodorization and heating. Partial substitution or blending of this oil with other commonly used cooking oils will bring down the levels of unusual fatty acids and may make it suitable for human consumption.

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☘Lipid Content and Fatty Acid Profiles of Various Deep-Fat Fried Foods[1]

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ABSTRACT

Forty-one brands of nine different types of snack and convenience foods were purchased from food stores and fast service restaurants in the Sacramento area of California. All samples had been prepared by deep-fat frying. They included potato chips, corn chips, tortilla chips, cheese chips, cheese puffs, cake donuts, french fries, chicken pieces and fish pieces. These samples were analyzed in duplicate for total fat and fatty acid composition. The total lipid content of each type of food varied among different commercial sources; the average percentages were as follows: potato chips, 40; cheese puffs, 38; corn chips, 35; cheese chips, 25; tortilla chips, 24; cake donuts, 22; chicken thighs, 14; french fried potatoes, 14, and fish pieces, 10. The fatty acid profiles of the total lipids in several brands of potato chips were relatively constant. The fatty acid profiles of the total lipids in the corn and cheese snack foods varied widely. Fatty acid compositions of donuts, chicken and fish pieces and french fries were influenced by the amount and fatty acid profile of the lipids in each uncooked food, as well as by the composition of the cooking fat.

INTRODUCTION

Consumption of a wide variety of fast foods including convenience and snack foods continues to increase in the U.S.A. and other countries (1-3). Many of these foods, including french fried potatoes, chicken and fish pieces, potato chips, corn chips, tortilla chips, extruded snacks and donuts, are prepared by deep-fat frying. In this process, the cooking oil or fat often is kept hot for long periods of time at about 180 C and moisture and air are mixed into it. The fried foods absorb this heated fat and contribute substantially to the fat ingested by consumers. The lipid composition of deep-fat fried foods is of considerable interest to nutritionists concerned with nutrient intake of young people, who tend to consume large quantities of convenience and snack foods, and to individuals who wish to alter their fat intake for medical reasons. However, compositional data for these products are sparse and widely scattered in the scientific literature.

This paper provides information on the total lipid content, the fatty acid composition and the variability among selected deep-fat fried foods available in California.

EXPERIMENTAL

Samples

Forty-one samples of nine types of snack and convenience foods were obtained from food stores and fast service restaurants in the Davis and Sacramento areas of California. Potato chips, corn chips, tortilla chips, cheese chips and cheese puffs were sampled from brands including Albertson, Alpha Beta, Buffalo, Cheetos, Doritos, Granny Goose, Lady Lee, Laura Scudders, Lays, Party Pride and Tostidos. Plain cake donut brands included Fluffy, Hostess, Taylor's and Winchell's. French fries were collected from Carl's Junior, Fluffy Donut, Jack in the Box, Kentucky Fried Chicken, London Fish and Chips and McDonald's. Brands of chicken pieces (thighs) included Church's, Kentucky Fried, Pioneer and Swanson's. Fish pieces included samples from London Fish and Chips, H. Salt, Long John Silver's and Skipper's. All samples were stored under nitrogen at 4 C for 1-4 days before being analyzed at least in duplicate.

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Extraction of Lipids

Samples of the snack foods were broken into pieces 0.7 cm or less in size before extraction. Donuts, french fries and uncooked and cooked fish pieces were cut into 0.7 cm cubes with a razor blade. Thin cross-cut slices were taken from the middle regions of both fresh and cooked chicken thighs and were then diced.

The chloroform-methanol-water extraction procedure used to extract total lipids from each food was essentially that of Bligh and Dyer (4) scaled down to accommodate smaller samples. Briefly, this procedure uses a one-phase solvent system of chloroform-methanol-water which rapidly extracts the lipids; the food is further extracted with additional chloroform and water to form a two-phase system of chloroform and methanol-water. Any water-soluble contaminants are thus partitioned into the methanol-water phase, leaving the lipids, essentially free of contaminants, in the chloroform phase. The Bligh and Dyer procedure has been found to be quantitative, versatile and rapid (5,6).

Moisture percentages necessary for this procedure were estimated previously by drying portions of the samples to constant weight at 100 C. A representative 1-2 g sample of each undried food was weighed to the nearest 0.01 g into a 100-ml Virtis Homogenizer jar, then 0.88% KCl was added to bring the total water volume (food moisture plus added water) to 8.0 ml; 30 ml of chloroform-methanol (1:2, v/v) were blended with the sample at high speed for two min. Another 10 ml of chloroform was added to the jar and blended for one min, followed by an additional 10 ml of 0.88% KCl, and blended for 30 seconds. The blended material was centrifuged at 2000 rpm for 5 min. The upper phase was aspirated off and the lower phase (approximately 18 ml) was recovered. The percent fat of each food item was determined gravimetrically by drying a measured aliquot of the lower phase to constant weight.

Fatty Acid Analysis

Fatty acids were determined by gas-liquid chromatography (GC) of methyl esters prepared by the procedure of Metcalfe et al. (7). Instrumentation and conditions for GC included a Hewlett Packard Model 5711A gas chromatograph with a flame ionization detector and a 610 x 0.257 cm ID stainless steel column packed with 15% OV-275 (Supelco Inc., Bellefonte, Pennsylvania) on high performance Chromosorb W. The column was operated isothermally at 220 C, injector temperature at 225 C and detector temperature at 240 C. Nitrogen carrier gas flow rate was 12 ml/min. Standard mixtures of fatty acid methyl esters or of simple triglycerides were used to obtain relative retention times and response factors for calibration of the Hewlett Packard 3352E data system. Amounts of component fatty acid esters were converted to grams fatty acid per 100 grams lipid by multiplying by the factor 0.956 as used by Brignoli et al. (8).

Saturated fatty acids, as listed in Tables II and III, were the total of capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0) and stearic (C18:0) acids. Monounsaturated fatty acids included palmitoleic (C16:1 *cis*), oleic (C18:1 *cis*), eicosenoic (C20:1 *cis*) and docosenoic (C22:1 *cis*) acids. Major polyunsaturated fatty acids included linoleic (C18:2ω6), linolenic (C18:3ω3) and arachidonic (C20:4ω6) acids. *Trans*-unsaturated fatty acids included elaidic (C18:1 *trans*) and C18 *cis,trans* and *trans,trans* dienes.

RESULTS AND DISCUSSION

Total Lipid Content

Data in Table I show that the mean lipid content of the various food items varied from 40.4% (potato chips) to 10.1% (fish pieces). Potato chips, corn chips and cheese puffs were highest in fat, containing over 35% total lipids. There was appreciable variation in lipid content among the brands of potato chips (35.3-44.5%), corn chips (32.8-37.6%), tortilla chips (22.9-26.4%) and cheese chips (22.3-27.6%). Each of the other food items showed greater variability in total lipid content. These results clearly show that any one brand of snack or fast food cannot be considered representative of that type of food in general. Although the brands analyzed were representative of those in California outlets, similar variability in lipid content of these foods probably exists in other regions of the U.S.A. (9-12).

Deep-fat frying greatly increases the total lipid content of snack and fast foods compared to the unfried products. For example, raw potatoes contain only 0.17% total lipid on a fresh weight basis or 0.65% on a dry weight basis (13), compared to averages of 40.4% for potato chips and 13.5% for french fries (Table I). Uncooked chicken thighs of the present study had 6.8% total lipid which increased to as high as 21.7% after batter dipping and frying. Raw fish pieces (pollock) contained 1.4% lipid which increased to as high as 17.5% after deep-fat frying. The extent of the increase in total lipid content of various deep-fat fried foods is influenced by several factors including the original fat content, the original moisture content, the type of breading or batter used, surface area to volume ratio, cooking time and the extent of oil drainage following cooking.

TABLE I

Total Lipid Content of Selected Snack and Fast Foods

Food item	Number of brands	Lipid (g/100 g edible portion) Range	Mean	SD
Potato chips	9	35.3 - 44.5	40.4	3.2
Corn chips	4	32.8 - 37.6	34.8	2.3
Tortilla chips	3	22.9 - 26.4	24.1	2.0
Cheese chips	3	22.3 - 27.6	25.2	2.7
Cheese puffs	3	32.0 - 46.0	38.4	7.1
Donuts, cake	4	9.2 - 31.4	21.7	7.9
French fries	6	7.9 - 16.2	13.5	3.1
Chicken thighs	5	7.3 - 21.7	13.8	6.2
Fish pieces	4	6.6 - 17.5	10.1	5.0

TABLE II

Fatty Acid Composition of Lipids Extracted from Nine Brands of Potato Chips

Fatty acid	g/100 g of lipid Range	Mean	SD
C14:0	0.8 - 1.0	0.9	0.06
C16:0	20.0 - 25.9	24.5	1.86
C16:1*c*	0.6 - 0.8	0.7	0.05
C18:0	2.3 - 2.6	2.4	0.09
C18:1*t*	0.0 - 0.2	0.1	0.07
C18:1*c*	16.1 - 17.9	16.6	0.57
C18:2*tt*	—	—	—
C18:2*ct*	0.8 - 1.4	1.1	0.19
C18:2ω6	47.7 - 51.5	48.9	1.10
C18:3ω3	0.3 - 0.4	0.3	0.05
C20:1	0.1 - 0.2	0.1	0.05
C22:1	0.0 - 0.2	0.03	0.07
Total			
Saturated		27.8	
Monounsaturated		17.5	
Polyunsaturated		50.3	
trans-Unsaturated		1.3	

TABLE III

Fatty Acid Composition Ranges of Lipids Extracted from Various Deep-Fat Fried Foods

Fatty acids	g/100 g of lipid					
	Corn snacks (7)[a]	Cheese snacks (6)	Donuts (4)	French fries (6)	Chicken (5)	Fish (4)
C10:0	–	0.1 - 6.1	–	–	–	–
C12:0	–	0.1 - 46.6	–	–	–	–
C14:0	0.1 - 0.8	0.4 - 18.9	0.2 - 2.5	0.7 - 3.4	0.3 - 0.6	0.6 - 3.2
C16:0	9.0 - 24.8	9.4 - 21.9	11.5 - 20.9	13.6 - 24.8	15.9 - 20.0	13.3 - 24.7
C16:1*c*	0.2 - 0.7	0 - 0.7	0.3 - 3.2	1.1 - 4.3	3.2 - 6.2	1.1 - 4.1
C18:0	2.4 - 4.2	2.7 - 4.8	10.5 - 17.5	13.9 - 18.5	5.4 - 9.0	12.0 - 17.7
C18:1*t*	0 - 16.2	0.6 - 21.2	9.5 - 32.8	5.2 - 32.6	7.3 - 15.7	5.5 - 28.3
C18:1*c*	17.8 - 39.0	7.7 - 39.2	29.1 - 29.8	29.5 - 31.3	32.9 - 35.3	25.0 - 31.3
C18:2*tt*	0 - 1.8	0 - 2.1	–	–	–	–
C18:2*ct*	1.4 - 5.5	0 - 5.6	–	–	–	–
C18:2ω6	20.7 - 51.6	2.1 - 41.2	5.5 - 8.9	2.6 - 3.4	9.8 - 19.5	3.4 - 5.1
C18:3ω3	0.3 - 2.4	0 - 1.0	0.7 - 0.9	0.4 - 0.6	0.3 - 1.2	0.0 - 1.6
C20:1	0.2 - 0.8	0 - 0.6	–	–	–	–
C20:4	–	–	–	–	–	0.1 - 1.0
C22:6	–	–	–	–	–	0.1 - 1.5
Total						
Saturated	12.8 - 28.1	14.3 - 84.8	23.3 - 43.3	29.5 - 49.2	23.8 - 30.7	27.0 - 48.2
Monounsaturated	18.8 - 55.9	8.7 - 61.1	44.4 - 65.9	43.1 - 66.5	49.1 - 56.9	42.6 - 57.9
Polyunsaturated	26.3 - 55.4	2.1 - 42.4	6.6 - 10.3	3.1 - 4.0	10.9 - 21.9	4.5 - 6.2
trans-Unsaturated	0.8 - 22.0	1.0 - 28.1	10.1 - 34.3	6.3 - 34.1	7.7 - 16.4	5.8 - 29.9

[a]Number of examples analyzed.

Fatty Acid Profiles

The fatty acid composition of the lipids extracted from nine brands of potato chips is summarized in Table II. There was relatively little variation in either the type or amount of the individual fatty acids. The major components of the triglycerides analyzed were linoleic (48.9%), palmitic (24.5%), oleic (16.6%) and stearic (2.4%) acids. Only minor amounts (0-0.2%) of elaidic acid (C18:1 *trans*) were detected, and C18:2 *trans,trans* was not detected. These results demonstrate that the oil used to fry potato chips was only slightly hydrogenated. The data also show that cottonseed oil was the principal frying oil employed.

The amount of polyunsaturated fatty acids (average 50.3%) found in the potato chips was much greater than the values (2.5-22.3%) reported by Sheppard et al. (9).

Compared to potato chips, much greater variation in amounts of individual fatty acids was found among the other foods. Fatty acid composition ranges among seven brands of corn chips and tortilla chips are shown in Table III. Greatest variations were in the percentages of elaidic (0-16.2%), linoleic (20.7-51.6%) and oleic (17.8-39.0%) acids. These differences reflect the different types of frying oils used, such as palm and sunflower, and the extent of hydrogenation of these oils.

Types of fatty acids found in six brands of cheese chips and cheese puffs are given in Table III. Significant amounts of capric and lauric acids characterized this group. Greatest variations were in medium chain length fatty acids (C10:0 to C16:0) and in linoleic and oleic acids. These differences are related both to different frying oils and to the type and amount of cheese, which contained milk fat, used in the products.

Fatty acid composition ranges of lipids extracted from four brands of plain cake donuts are in Table III. Greatest variation was in the amounts of elaidic acid. Differences may be accounted for by the use of different types of hydrogenated vegetable shortenings for donut formulation and frying.

Data for the six brands of french fries show the influence of different types of frying shortenings. Some of the brands were fried in hydrogenated soybean shortenings that were much higher in elaidic acid and lower in palmitic acid than those brands fried in a mixed animal-vegetable (beef fats and cottonseed oil) shortening. French fries cooked in the former had higher amounts of elaidic acid.

Table III shows that differences were comparatively less in fatty acid profiles for the lipids extracted from different brands of fried chicken thighs. Hydrogenated soybean shortenings were used exclusively for deep-fat frying by the fast service restaurants sampled. Differences in the fatty acid profiles may be attributed to differences in the degree of hydrogenation of the frying oils, the amounts of chicken fat extracted into the frying oil and the amounts of unextracted fat in the cooked product.

Maximum differences in fatty acid profiles among four brands of fried fish pieces are shown in Table III. The raw fish used was low in fat, and most of the fatty acids were derived from the batter used to fry the fish pieces. Variations in the amounts of elaidic, palmitic and other acids are related primarily to the use of either mixed animal-vegetable or hydrogenated soybean shortenings for frying.

The principal groups of fatty acids in several types of foods are summarized in Tables II and III. Except for the potato chips, there was a wide range of values for each fatty acid group among the foods. The data for cheese snacks showed greatest variability. In general, potato chips (Table II) and corn snacks (Table III) had the highest amounts of polyunsaturated fatty acids. Appreciable amounts of *trans*-unsaturated acids (mostly *trans*-monounsaturated) were found in all samples of donuts, french fries, chicken and fish samples (Table III). The composition of the frying oil or shortening used exerted the major influence on the composition of the lipids in each deep-fat fried food. Composition of the frying oil used to cook french fries is known to be influenced by commercial frying practices (14). However, there is a need for additional information on the amounts of polyunsaturated and *trans*-unsaturated fatty acids in used frying oils because of the known or suspected nutritional and health effects of these acids.

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A Study of the Cause of Rapid Color Development of Heated Refined Palm Oil

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ABSTRACT

One of the most obvious changes when oils are heated is color darkening. Palm oil darkens very rapidly compared to other oils. The cause of this rapid color development was investigated. Various methods used to pretreat Lotox crude palm oil (CPO) to retard darkening during heating were by agitation with activated carbon S511, by water and water/isopropyl alcohol (95:5) washing of neutralized and unneutralized oil, and by liquid/liquid extraction of oil using water and water/isopropyl (95:5). Pretreatment of CPO did succeed in retarding color development. Retardation was especially evident in oils previously neutralized with sodium hydroxide before washing with water and water/isopropyl alcohol. The UV spectra of the liquid/liquid extracts showed strong absorption maxima at 256 nm. The addition of a base resulted in darkening of the extracts accompanied by shifts to longer wavelengths (288 nm). Reaction with freshly diluted 1-2% ferric chloride solution gave a brown color. The development of paper chromatography in butanol: acetic acid:water (6:1:2) revealed a blue fluorescence near the solvent front, with the same relative retention time as that of tannic acid. This evidence indicates that phenolic compounds were responsible for color darkening in palm oil.

INTRODUCTION

The color of refined oils is a good indication of their quality, inasmuch as bad quality oils are difficult to process into acceptable, light-colored products. While carotenoids are responsible for the dark orange-red color of crude palm oil, the final color of refined palm oil and its subsequent color on storing and/or heating is attributed to the process of oxidation and inherent color precursors in the oil itself. Although oxidation bleaches the carotenoid pigments, it also develops the color of other types of coloring materials and may even produce colored compounds of a quinoid nature (1). The partial oxidation of vegetable oils is known to increase this red and yellow color as a result of the formation of the chroman-5,6-quinones (2). In a study of the bleaching of cottonseed and soybean oils, there is evidence that oxidation develops new pigments and stabilizes existing pigments against adsorption, with the adsorbent itself strongly catalyzing the oxidation reaction (3). Traces of iron and some other metallic contaminants greatly favor color development in some fats, and certain pigments are very refractory to ordinary refining and bleaching treatment but may be removed effectively by liquid-liquid extraction.

When oils are heated as in the frying process, they rapidly change from a light yellow to an orange brown color. This is the combined results of oxidation, polymerization and other chemical changes. Darkening is considered a useful phenomenon in that it prevents the continual use of edible oils which have undergone excessive deterioration.

Palm oil darkens very rapidly on heating. While it has been reported that high molecular weight compounds are responsible for the color of refined palm oil (4) as well as for difficulties associated with decolorization of certain crude palm oils, the cause of rapid color development of heated refined palm oil is not fully understood.

Color changes on heating are primarily the result of oxidation but the responsible compounds formed in palm oil are not known. Red color development in soybean oil is attributed to α, β- and α, α'-unsaturated carbonyls (5). The appearance of a visible color in the oil is indicative of its ability to absorb visible light, and this is associated with the presence of certain unsaturated molecular groups (6). This report outlines the investigation into the cause of darkening in refined palm oil and the effort to isolate and identify the color causing compounds.

EXPERIMENTAL PROCEDURES

Apparatus

Ordinary laboratory apparatus were used. Instruments used included a Hewlett-Packard 8450A UV-visible spectrophotometer coupled to a H.P. 7225B plotter, a JOEL FX 100FT NMR and a Perkin Elmer Model 1330 IR spectrophotometer.

Reagents

All reagents were of analytical or spectroscopic grade.