

Deep Fat Frying of Frozen Prefried French Fries: Influence of the Amount of Linolenic Acid in the Frying Medium

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Frozen prefried french fries containing about 2% lipids were fried in peanut and soybean oils. Thirty frying operations were effected at 180 °C for 5 min. The polymer content of both the oil and the french fries was studied as well as the amount of polar components. The cis and trans 18:1 isomers were isolated by using a combination of high-performance liquid chromatography (HPLC) and silver nitrate thin-layer chromatography (TLC). The position of the ethylenic bond was determined after ozonolysis in BF₃-MeOH. The study of the components formed after frying at 180 °C showed that soybean oil (containing close to 7% linolenic acid, 18:3 ω 3) does not behave differently from peanut oil and that one should not do more than 15 frying operations at this temperature to keep the amount of polar components below 25%. Similar quantities of polar components and polymers as well as similar 18:1 fatty acid profiles were found in the lipids extracted from the french fries after frying and in the frying oils.

INTRODUCTION

Deep fat frying in the past few years has become a common way of cooking food such as fish and french fries (Robertson, 1967; *Bull. Lab. Coop.*, 1983). Furthermore, prefried foods are now commonly used by fast-food restaurants and also by the consumer at home.

The purpose of this work was to study the lipid exchanges between the oil and the food as a function of the type of oil used and the number of frying operations. Because French legislation does not consider an oil a frying oil if it contains more than 2% linolenic acid, we selected two types of oil, one that contains only traces of linolenic acid (<0.2%) but a large amount of linoleic acid (peanut oil) and one that contains an appreciable quantity of linolenic acid (soybean oil). Furthermore, it is now known that the structure of some components which can present a certain toxicity [cyclic fatty acid monomers (CFAM)] are different when they are formed from linolenic acid if compared to those formed from linoleic acid (Sebedio et al., 1987b). Prefried frozen french fries which were prepared in a frying medium containing a partially hydrogenated oil were selected for the study as these contain trans 18:1 isomers that can be used as tracers to follow the lipid exchanges between the oil and the food. The other question raised was the possible preferential adsorption on the food of the newly formed components (polymers, oxidized components, etc.).

After frying, similar lipid compositions (polar components, polymers, fatty acid isomers) for the french fries and the oils used for the frying operations were observed. It should also be noted that at 180 °C soybean oil which contains close to 7% linolenic acid does not seem to behave differently compared to peanut oil for this type of food.

MATERIALS AND METHODS

Purification of Solvents. All the solvents were redistilled before used.

Heating Conditions. The deep fat frying operations were effected in a commercial electrical fryer (Nova, fritex 5) that

contained 2.6 L of peanut or soybean oil. These oils are refined but not hydrogenated and did not contain any detectable amount of trans 18:1 isomers by gas-liquid chromatography analysis. The oil was heated to 180 °C (20 min), and then 200 g of prefried frozen french fries (Beau Marais, France, 1 cm × 1 cm × 5.5 cm) were fried for 5 min; 180 °C was chosen as it is usually the temperature recommended for a good frying practice. These were then allowed to drain in a wire basket for 5 min. A total of 30 batches were cooked, over a period of 15 days, 1 in the morning and 1 in the afternoon. No oil was added at any time and at the end of the 30 frying operations, about 2.0 L and 1.96 L of peanut and soybean oils, respectively, were left in the fryer.

After each frying operation, 2 mL of oil was collected and all the samples (french fries and oils) were stored at -30 °C for further chemical analyses.

Lipid Extractions. The lipids of the french fries were extracted according to the method of Folch et al. (1957) using a mixture of chloroform/methanol (2:1).

Separation of Polar and Nonpolar Components. The quantity of polar components in the total lipid extracts was determined by using silica cartridges as previously described (Sebedio et al., 1986). The purity of each fraction was then checked by thin-layer chromatography (TLC) with Merck plates (5721, 0.25-mm thickness) using a mixture of hexane/diethyl ether/acetic acid (80:20:1) as solvent system (IUPAC, 1982).

Polymer Analyses. The amount of polymeric triglycerides in the lipid extract was determined by gel permeation chromatography (GPC) using tetrahydrofuran at 1 mL/min (Perrin et al., 1984). The components were detected by using a refractive index detector. All quantitative analyses were effected by using a Vista CDS 401 (Varian).

Gas-Liquid Chromatography (GLC). All the GLC analyses were carried out on a Becker-Packard 420 chromatograph fitted with a flame ionization detector (FID). The analyses were effected on capillary columns coated with CP Sil 88 (50 m long and 0.33 mm i.d.) and Carbowax 20 M (25 m long and 0.32 mm i.d.).

High-Performance Liquid Chromatography (HPLC). The semipreparative HPLC was carried out on a reverse-phase column (Merck, Lichrosorb, 7 μm, 7 mm i.d., 25 cm). The sample (~40 mg) was dissolved in acetone. Pure methanol was used at 4 mL/min.

Isolation and Identification of the C18:1 Isomers. Oil samples from french fries were saponified with KOH, and unsaponifiables were removed by AOCs procedure Ca-6a-40. The recovered fatty acids were converted to methyl esters by using

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Table I. Lipid Content (Grams per 100 g of Fries) of Frozen Prefried French Fries as a Function of Number of Frying Operations and the Type of Oil Used for the Final Frying Process

no. of frying operations	in peanut oil	in soybean oil
0	2.2	2.2
1	15.7	17.1
6	15.4	14.8
11	14.0	14.1
16	11.9	14.0
21	17.7	18.3
26	16.7	16.6
30	17.1	15.4

a solution of 7% BF₃-MeOH (Morrison and Smith, 1964). The total fatty acid methyl esters were fractionated by semipreparative HPLC as described above, and the C18:1 isomers were collected (Sebedio et al., 1982). This fraction also contained some 16:0. These were further fractionated by AgNO₃ TLC into cis and trans isomers (Sebedio et al., 1982). Three bands were obtained. The upper band contained 16:0 (*R_f* = 0.80), the middle band, the 18:1 trans (*R_f* = 0.60), while the lower band consisted of the 18:1 cis isomers (*R_f* = 0.50). The amounts of cis and trans 18:1 isomers were determined by GLC analyses of each band after addition of an internal standard (17:0). The position of the ethylenic bond on the carbon chain of the 18:1 isomers was determined by ozonolysis. The ozonolysis in BF₃-MeOH followed the method described by Ackman et al. (1981), slightly modified for the Supelco microozonizer (Grandgirard et al., 1984). The analyses of the resulting mono- and diester mixtures were carried out on a CP Sil 88 column.

RESULTS AND DISCUSSION

Many reactions take place during frying such as oxidation, polymerization, hydrolysis, cyclization, and isomerization, which lead to the formation of a complex mixture of volatile and nonvolatile products (Artman, 1969; Chang et al., 1978). Most of the work on heated fats has been carried out on oil heated without food fried in it in the laboratory, and extensive work on the structure of the components (cyclic fatty acids, geometrical fatty acids) formed after heat treatment has been accomplished (McInnes et al., 1961; Hutchison and Alexander, 1963; Saito and Kaneda, 1976; Potteau et al., 1978; Ottaviani et al., 1979; Rojo and Perkins, 1987; Sebedio et al., 1987a,b; Grandgirard et al., 1984). Some of this work indicated the possible toxicity of certain heated oils (Crampton et al., 1953; Nolen et al., 1967; Potteau et al., 1970a,b). However, only a few studies were carried out on oil with food fried in it and on the lipid exchange between the oil bath and the food during the frying operation (Meltzer et al., 1981; Peers and Swoboda, 1982; Aust and Thompson, 1981; Thompson and Aust, 1983; Stevenson et al., 1984; Greenfield et al., 1984; Poumeyrol, 1987).

The original frozen prefried french fries contained 2.2% lipids (Table I). After the first frying operation, the lipid content increased from 2.2% to 15.7% and 17.1% in peanut oil and in soybean oil, respectively. All the samples collected were not extracted, and we have reported in Table I only the lipid content of the french fries after the 1st, 6th, 11th, 16th, 21st, 26th, and 30th frying operations. No significant differences in the lipid content were observed between the 1st and the 30th frying operations in either peanut or soybean oil. However, the small differences observed in the lipid content from one operation to another could be due to the process used to eliminate the excess fat. In this study, the french fries were agitated in air in the fryer basket and then allowed to drain for 5 min. The nonutilization of an absorbent paper could possibly explain the differences observed in the lipid content. However, an earlier study (Greenfield et al., 1984) reported that

Table II. Percentage of Polar Components (Weight Percent) in Frozen Prefried Fries and the Corresponding Oil as a Function of Number of Frying Operations Effectuated and the Type of Oil Used

no. of frying operations	in peanut oil		in soybean oil	
	fries ^a	oil ^a	fries ^a	oil ^a
0	37.6	8.1	37.6	6.2
1	11.2	8.8	11.0	8.6
6	14.7	12.3	13.9	14.0
11	22.9	16.9	19.8	16.2
16	24.0	21.9	23.0	20.2
21	26.1	27.5	26.6	26.8
26	30.7	29.7	28.1	29.8
30	34.4	34.4	30.3	31.2

^a Average of two analyses.

Table III. Polymer (Weight Percent) and Free Fatty Acid Contents (Weight Percent) of Frozen Prefried French Fries and the Corresponding Oil as a Function of Number of Frying Operations Effectuated in Peanut Oil

no. of frying operations	fries		oil	
	polymers ^a	FFA ^{a,b}	polymer ^a	FFA ^{a,b}
0	12.6	2.0	1.3	0.7
1	1.7	0.7	1.7	0.8
6	3.1	0.3	3.5	0.6
11	7.1	1.0	6.6	0.8
16	9.3	0.5	10.1	0.7
21	13.6	0.7	13.7	0.6
26	16.7	0.5	17.2	0.7
30	18.7	0.7	20.2	0.6

^a Average of two GPC analyses. ^b FFA, free fatty acid, determined from GPC analyses.

Table IV. Polymer (Weight Percent) and Free Fatty Acid (Weight Percent) Contents of Frozen Prefried French Fries and the Corresponding Oil as a Function of Number of Frying Operations Effectuated in Soybean Oil

no. of frying operations	fries		oil	
	polymer ^a	FFA ^{a,b}	polymer ^a	FFA ^{a,b}
0	12.6	2.0	0.4	0.9
1	1.6	0.8	1.2	0.9
6	4.3	0.9	4.1	0.7
11	7.4	0.8	7.4	0.9
16	10.5	0.8	10.6	0.7
21	13.6	0.7	13.6	0.9
26	16.2	0.9	17.5	0.9
30	18.2	0.9	19.7	0.7

^a Average of two analyses. ^b FFA, free fatty acid.

excess fat was mainly removed during the initial agitation. Another possible explanation would be the size of the french fries. Each batch was not homogeneous (surface area/volume), and a decrease in size usually corresponds to an increase in fat uptake (Greenfield et al., 1984).

The transformation of the oils and the french fries was followed by two criteria—the amount of polar component (PC, Table II) and the amount of polymeric triglycerides (Tables III and IV). It was rather surprising to find about 37% polar components in the starting frozen prefried french fries; an oil or fat is considered unacceptable if it contains more than 25% polar components (Castang, 1981). However, this high value (37%) must be corrected since the lipids of the french fries also contained some diglycerides, which could arise from the utilization of some palm oil in the frying medium. These diglycerides are usually eluted with the polar components by column chromatography using the official standardized method (IUPAC, 1982), and whether or not they are oxidized cannot be determined in this step. The amount of diglycerides that can be estimated by GPC contributes to some extent to the high value for polar components.

Table V. Fatty Acid Composition (Weight Percent of Chromatographed Esters) of the Prefried Frozen French Fries and the Oil Bath as a Function of Number of Frying Operations in Peanut Oil

important fatty acids	french fries before frying	peanut oil	P1 ^a	FP1 ^b	P11	FP11	P21	FP21	P30	FP30
16:0	12.8	11.5	11.3	11.0	11.4	11.1	11.0	11.8	12.4	12.1
18:0	20.6	3.5	3.6	4.5	4.0	4.0	4.3	5.2	5.1	5.9
18:1	59.4	48.5	48.8	48.7	49.4	49.6	50.0	50.3	51.3	50.3
18:2	3.3	29.4	29.1	28.3	27.4	27.7	24.4	24.6	22.8	22.5
18:3	0.8	tr ^c	ND ^d	0.2	ND	ND	ND	0.2	ND	0.2
20:0	0.6	1.5	1.5	1.5	1.6	1.6	1.7	1.6	1.7	1.6
20:1		1.0	1.0	0.9	1.0	1.0	0.9	0.9	0.9	1.0
22:0	0.3	2.8	2.7	2.7	2.8	2.9	2.9	2.7	3.0	3.0
others ^e	2.2	1.8	2.0	2.2	2.4	2.1	3.8	2.7	2.8	3.4

^a P1, peanut oil after one frying treatment. ^b FP1, prefried frozen french fries after the first frying operation in peanut oil. ^c tr, trace <0.1%. ^d ND, not detected under analytical conditions. ^e Others, minor and unidentified fatty acids.

Table VI. Fatty Acid Composition (Weight Percent of Chromatographed Esters) of the Prefried Frozen French Fries and the Oil Bath as a Function of Number of Frying Operations in Soybean Oil

important fatty acids	french fries before frying	soybean oil	S1 ^a	FS1 ^b	S11	FS11	S21	FS21	S30	FS30
16:0	12.8	10.0	11.6	10.6	11.3	10.6	11.8	11.8	12.2	12.0
18:0	20.6	3.9	4.0	5.0	4.5	5.7	5.1	6.1	5.6	6.6
18:1	59.4	23.4	24.8	25.9	25.9	27.1	27.0	27.3	28.0	29.6
18:2	3.3	51.9	50.8	49.7	50.1	47.6	48.5	46.7	46.4	44.0
18:3	0.8	7.2	6.9	6.9	6.5	6.3	5.9	5.8	5.4	5.4
others ^c	3.1	3.6	1.9	1.9	1.7	2.7	1.7	2.3	2.4	2.4

^a S1, soybean oil after one frying treatment. ^b FS1, prefried frozen french fries after the first frying operation in soybean oil. ^c Others, minor and unidentified fatty acids.

Table VII. Trans 18:1 Isomer Content (of Total Cis plus Trans 18:1) Determined by GLC Analyses on CP Sil 88 for the Frozen Prefried Fries and the Corresponding Oil as a Function of Number of Frying Operations and the Type of Oil Used

no. of frying operations	in peanut oil		in soybean oil	
	fries ^a	oil ^a	fries ^a	oil ^a
0	42.2	ND ^b	42.2	ND
1	4.9	3.2	10.5	ND
6	5.7	1.4	7.8	ND
11	7.4	4.9	10.1	4.5
16	6.4	5.2	7.3	4.5
21	8.6	2.8	11.4	5.4
26	7.4	7.7	12.9	8.7
30	7.2	6.5	12.7	7.3

^a Average of two analyses. ^b ND, not detected under analytical conditions.

Table VIII. Trans 18:1 Isomer Content (of Total Cis plus Trans 18:1) Determined by a Combination of AgNO₃ TLC and GLC with Internal Standard for the Prefried Frozen Fries and the Corresponding Oil as a Function of Number of Frying Operations and the Type of Oil Used

no. of frying operations	in peanut oil		in soybean oil	
	fries	oil	fries	oil
0	64.4	ND ^a	64.4	ND
1	5.3	0.5	9.2	1.0
11	8.4	2.9	13.6	4.0
21	9.1	4.2	15.1	8.0
30	7.3	4.1	15.7	12.7

^a ND, not detected under analytical conditions.

This value first decreased after the 1st frying experiment (Table II) from 37% to 11% and then increased up to 30–35% after the 30th frying experiment. The first decrease corresponds to a dilution factor (accumulation of oil poor in polar components on the fries) and the increase to the release of polar components from the fries in the oil bath and also to the degradation of the oil. The amount of polar components in the oil increased from 6% and 8% to 31% and 34% in soybean oil and in peanut oil, respectively. It is interesting to note that at 180 °C soybean oil and peanut oil have similar behaviors, despite the difference in the 18:3 ω 3 content. It should also be noted that the level of 25%

PC was reached after the 16th frying operation. Therefore, after that point, the oil should be discarded.

The amount of polymers was also high in the starting prefried frozen french fries (12.6%) and low in the starting peanut oil (1.3%, Table III) and in the soybean oil (0.4%, Table IV). In both cases, the amount of polymers in the fries dropped after the 1st frying operation and then increased to reach a level of 19% after the 30th frying operation. These results are similar to what was observed for the PC and could be explained in a similar way, considering that a good correlation usually exists between the polymers and the PC (Sebedio et al., 1987c). The amount of free fatty acids (FFA), high in the starting french fries, decreased from 2.0% to 0.7–0.8% after the first frying operation while it stayed quite stable in the oil (0.6–0.8% in peanut compared to 0.7–0.9% in soybean). It was already noted (Ribot et al., 1989) in a large-scale study (600 samples) that the amount of FFA did not correlate with the amount of either polymers or PC and that the measurement of FFA was not the best criterion to test the state of degradation of an oil. These results seem to support the study of Ribot et al. (1989). Thus, the soybean oil containing 1.2% polymers and 8.6% PC and the soybean oil containing 17.5% polymers and 28.1% included the same amount of FFA (0.9%). These two oils could not be considered in any case as equally deteriorated. Similar values were observed by Ribot et al. (1989). However, different results were obtained by other authors (Stevenson et al., 1984).

As a consequence of the formation of PC and polymeric triglycerides, the amount of linolenic (18:3 ω 3) and linoleic (18:2 ω 6) acids decreased, while the amount of saturates and of 18:1 remained relatively unchanged. Similar fatty acid profiles were found for the oil and the potatoes fried in it (Tables V and VI), the french fries fried in peanut oil being rich in 18:1 (Table V), while those fried in soybean became richer in 18:2. These lipid exchanges had already been demonstrated (Thompson et al., 1983). We have focused our attention on the trans 18:1 fatty acids, as these could be used as tracers to follow the lipid exchanges between the french fries, which contained an appreciable amount of trans 18:1 isomers (Table VII), and the oil, which did not show any detectable trans 18:1. It

Table IX. Cis and Trans 18:1 Positional Isomers in the Prefried Frozen Fries as a Function of Number of Frying Operations in Soybean Oil

ethylenic bond position (Δ)	no. of frying operations									
	before frying		1		11		21		30	
	cis	trans	cis	trans	cis	trans	cis	trans	cis	trans
4	tr ^a	tr	ND ^b	ND	ND	tr	ND	tr	tr	tr
5	tr	0.1	ND	ND	ND	tr	ND	tr	tr	tr
6	0.3	1.2	tr	0.3	tr	0.7	tr	0.7	0.2	1.6
7	0.7	3.3	0.4	2.4	tr	2.0	tr	1.8	0.3	3.3
8	5.8	10.0	0.7	4.3	0.5	7.6	1.6	9.0	1.7	10.6
9	41.6	18.7	90.2	31.6	86.9	17.5	81.1	19.2	87.7	19.8
10	15.3	21.0	0.7	18.2	1.2	20.7	1.8	21.3	2.1	20.9
11	13.8	17.4	6.3	18.8	9.1	18.3	11.1	17.9	6.0	17.8
12	12.8	12.2	0.7	6.7	1.4	13.8	2.4	13.0	1.2	11.7
13	4.6	7.8	0.6	8.7	0.9	9.4	2.0	8.3	0.7	7.3
14	2.4	4.3	0.2	5.2	tr	5.4	tr	4.6	0.3	4.0
15	1.4	2.3	0.1	3.0	ND	2.7	ND	2.6	ND	2.1
16	1.0	1.7	ND	1.0	ND	1.9	ND	1.6	ND	1.1
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

^a tr, <0.1%. ^b ND, not detected under analytical conditions.

Table X. Cis and Trans 18:1 Positional Isomers in the Soybean Oil Samples Used for Frying the Prefried Frozen Fries (Table IX) as a Function of Number of Frying Operations

ethylenic bond position (Δ)	no. of frying operations									
	before frying, cis	1		11		21		30		
		cis	trans	cis	trans	cis	trans	cis	trans	
4	ND ^a	ND	ND	ND	ND	ND	ND	ND	tr ^b	
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	
6	ND	ND	ND	1.0	tr	0.8	0.8	tr	1.9	
7	ND	0.3	1.0	tr	0.8	0.3	0.5	1.7	2.2	
8	0.8	0.5	0.9	0.2	7.4	0.4	8.7	1.1	10.6	
9	91.7	92.8	34.8	89.9	20.6	92.8	20.7	89.0	23.4	
10	0.5	0.2	20.3	0.4	20.7	0.5	21.8	1.3	21.2	
11	6.2	6.0	14.5	8.7	20.2	5.3	25.3	5.7	16.4	
12	0.5	0.1	10.1	0.3	12.3	0.4	10.4	0.8	11.0	
13	0.4	0.2	8.2	0.5	8.6	0.3	6.1	0.4	7.0	
14	ND	ND	5.5	ND	4.6	ND	2.8	ND	3.7	
15	ND	ND	4.4	ND	2.3	ND	2.0	ND	1.7	
16	ND	ND	ND	ND	1.5	ND	0.9	ND	1.0	
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

^a ND, not detected under analytical conditions. ^b tr, <0.1%.

is possible to estimate the amount of trans 18:1 content by direct GLC analyses (Ackman et al., 1972; Ojanpera, 1978; Lanza and Slover, 1981). However, the results found are usually different from those determined by using a more sophisticated method which consists of AgNO₃ TLC and GLC with internal standard. This could be due to an overlap between the cis and the trans isomers for the direct GLC analysis. On polar columns such as CP Sil 88, most of the trans 18:1 isomers have retention times shorter than those of the cis isomers; however, some of the trans isomers could be eluted after the major cis- Δ -9 isomer of vegetable oils (Grandgirard et al., 1984). This overlap can depend on the degree of hydrogenation, and it is not surprising that the amount of trans isomers depends on the method which has been selected. For example, the direct GLC analysis gave 42.2% trans (Table VII) in the starting french fries, while the TLC/GLC method gave 64.4% (Table VIII). After the first frying operation (Table VIII), the amount of trans (determined as percent of total 18:1 isomers) in the fries decreased, then increased again to 8–9% for those fried in peanut oil and to 14–15% for those fried in soybean oil. This higher trans content found in the potatoes fried in soybean oil is only due to a dilution factor considering the higher quantity of cis 18:1 present in the original peanut oil (48.5%, Table V) compared to 23.4% for soybean oil (Table VI). This could not be due to a geometrical isomerization as it has already been observed that, even for polyunsaturated fatty acid, this

reaction could be considered negligible below 200 °C (Grandgirard and Julliard, 1987).

The major cis 18:1 positional isomers of the prefried frozen french fries were Δ 8, Δ 9, Δ 10, Δ 11, Δ 12, and Δ 13 (Table IX), with a maximum value for Δ 9 (41.6%). The major trans 18:1 isomers were also Δ 8, Δ 9, Δ 10, Δ 11, Δ 12, and Δ 13. However, the maximum value was for the Δ 10 isomer (Table IX). This isomer composition indicated that the french fries were already fried in a partially hydrogenated oil, the isomer distribution depending on the degree of hydrogenation (Dutton, 1979). The original soybean oil used for the frying experiments contained only cis 18:1 isomers, the major isomer being Δ 9 (91.7%), followed by Δ 11 (6.2%, Table X). This is usually the case for vegetable oils (Sebedio, 1979). For the french fries (Table IX), only small differences were observed for the distributions of the trans isomers, which reflected that of the starting prefried frozen french fries except for the first frying experiment, which showed a lower Δ 8 value and a higher Δ 9 value. The major changes were observed after the first frying operation for the cis isomers (Table IX), which reflected the isomer distribution of the original soybean oil (Table X). After the first frying operation, no major differences were observed as a function of the number of frying operations (11, 21, 30) either for the french fries or for the oil bath. For the oil bath, the trans isomer distributions reflected that of the original prefried frozen french fries (Tables IX and X).

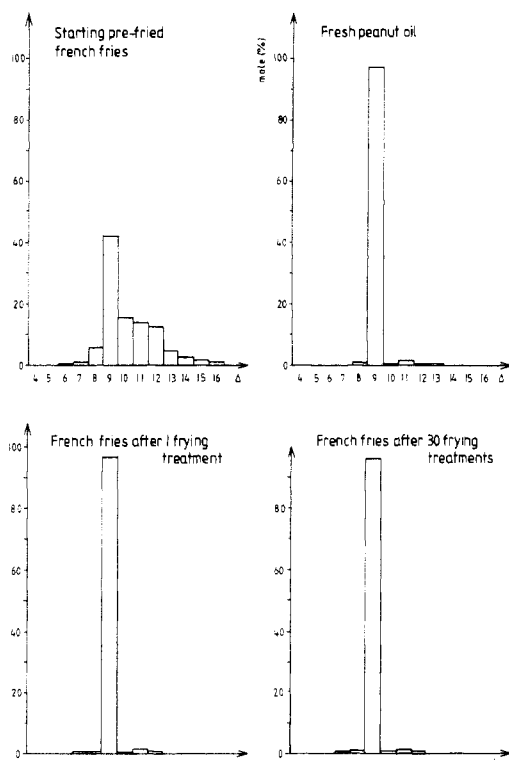


Figure 1. Isolated cis 18:1 isomers in the starting prefried french fries, in the fresh peanut oil, in the french fries after the 1st frying treatment, and in the french fries after the 30th frying treatment.

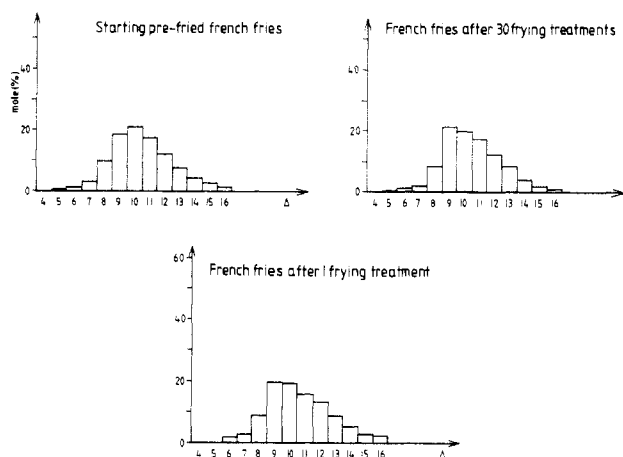


Figure 2. Isolated trans 18:1 isomers in the starting prefried french fries, in the french fries after the 1st frying treatment, and in the french fries after the 30th frying treatment in peanut oil.

Similar results were found for the french fries fried in peanut oil. The cis 18:1 isomer distribution of the prefried french fries changed drastically after the first frying operation (Figure 1) and remained unchanged even after 30 frying treatments, this composition reflecting that of the fresh peanut oil. For the trans 18:1 fatty acids of the prefried french fries, the isomer distribution remained quite stable during the 30 frying treatments (Figure 2). As for the french fries treated in soybean oil, the trans isomer distribution of the 18:1 fatty acids of the oil bath reflected that of the starting prefried frozen french fries. These results show that lipid exchanges are taking place both from the french fries to the oil and from the oil to the french fries, with no detectable preferential adsorption of any special positional isomers on the french fries.

This study has shown that trans 18:1 isomers could be good tracers to follow the lipid exchanges between the oil

bath and the food. No preferential adsorption of either polar components, polymers, or cis and trans 18:1 isomers was detected. During the first frying treatment, there is a release of oil from the french fries, and the cis 18:1 isomer profile of the fries reflects that of the oil bath. At 180 °C, soybean oil does not seem to behave differently from peanut oil. It should also be noted that in these conditions 15 frying operations correspond to the maximum amount of polar components which should be present in the frying oil according to French regulation.

Since these experiments were carried out at 180 °C, it would be interesting to continue this work at different temperatures and with different 18:2/18:3 ratios, especially to study the cyclic fatty acids formed during the transformation of the polyunsaturated fatty acids.

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Registry No. Linolenic acid, 463-40-1; linoleic acid, 60-33-3; *cis*-4-octadecenoic acid, 19308-06-6; *trans*-4-octadecenoic acid, 34450-19-6; *cis*-5-octadecenoic acid, 676-29-9; *trans*-5-octadecenoic acid, 7056-85-1; *trans*-6-octadecenoic acid, 593-40-8; *cis*-7-octadecenoic acid, 13126-31-3; *trans*-7-octadecenoic acid, 13126-32-4; *cis*-8-octadecenoic acid, 5684-71-9; *trans*-8-octadecenoic acid, 5684-81-1; *cis*-9-octadecenoic acid, 112-80-1; *trans*-9-octadecenoic acid, 112-79-8; *cis*-10-octadecenoic acid, 2442-70-8; *trans*-10-octadecenoic acid, 5684-82-2; *cis*-11-octadecenoic acid, 506-17-2; *trans*-11-octadecenoic acid, 693-72-1; *cis*-12-octadecenoic acid, 13126-37-9; *trans*-12-octadecenoic acid, 13126-38-0; *cis*-13-octadecenoic acid, 13126-39-1; *trans*-13-octadecenoic acid, 693-71-0; *cis*-14-octadecenoic acid, 13126-41-5; *trans*-14-octadecenoic acid, 13126-42-6; *cis*-15-octadecenoic acid, 13126-43-7; *trans*-15-octadecenoic acid, 13126-44-8; *cis*-16-octadecenoic acid, 13126-45-9; *trans*-16-octadecenoic acid, 10440-93-4.