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Industrial production of crisps and prefried french fries using sunflower oils

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SUMMARY

Industrial production of crisps and prefried french fries using sunflower oils

Crisps and prefried french fries were prepared during industrial operations in order to study the possibility of using sunflower oils («normal» and high oleic) instead of palm olein and mixtures of partially hydrogenated vegetable oils and palm oil in industrial frying. The quality of the food items was evaluated by determining the total amount of polar components, the amount of the different components in the polar fraction (dimers, oxidized triglycerides, diglycerides), the quantity of cyclic fatty acid monomers (CFAM), as well as the 18:2 geometrical fatty acid isomers.

For both the production of crisps and french fries, very small increase in the polar components was observed. Frying of crisps did not result in any changes in the fatty acid composition and in the amount of 18:2 geometrical isomers. However the amount of CFAM increased in samples fried in SO. An increase of CFAM was observed also for french fries independently of the nature of the frying medium. No modifications of the *cis* and *trans* isomer distributions were observed for the french fries prepared in the mixture of palm oil and partially hydrogenated canola.

These results show that sunflower oils could be used for the industrial production of french fries and crisps. However, storage studies are being carried out in order to determine if both types of sunflower oils give products which are as stable as those prepared in a solid frying medium.

KEY-WORDS: Crisps – French fries – High oleic sunflower oil – Industrial frying – Mixtures of vegetable oils – Palm olein –Sunflower oil.

1. INTRODUCTION

Many studies have been carried out on the effect of heat treatment of fats and oils on the formation of oxidation products, polymers, cyclic fatty acid monomers (CFAM) and geometrical fatty acid isomers (Artman, 1969; Ottaviani et al., 1979; Grandgirard and Julliard, 1987; Dobarganes and Perez-Camino, 1988; Mossoba et al., 1994, Dobson et al., 1995; Marquez-Ruiz et al., 1995). Most of the studies so far carried out were on oils heated in the laboratory under severe conditions, but also on oils heated under simulated deep fat frying conditions (Peers and Swoboda, 1982), on oils after frying food items (Sébédio et al., 1990; Perez-Camino et al., 1991, Warner and Mounts, 1993; Sanchez-Muniz et al., 1993) and also on samples collected in restaurants (Thompson and Aust, 1983; Zhang et al., 1991).

Deep fat frying has become a common way of cooking food such as french fries, and frozen prefried foods are now used by the consumer at home and by fast food restaurant (Pravisani and Calvelo, 1986). However, little information is available on the industrial products such as frozen prefried foods (Perez-Camino et al., 1991; Sébédio et al., 1991; Sébédio et al., 1994). The choice of the fat depends on such factors as the availability and price (Orthoefer, 1987), frying performances, flavor and stability of the product during storage. Frying fats based on palm oil and partially hydrogenated oils are used mainly by the potato industry (Sébédio et al., 1991; Sébédio et al., 1994; Keijbets et al., 1985). Consequently, prefried frozen french fries usually contain saturated and *trans* monounsaturated fatty acids. Considering some of the latest results published on *trans* fatty acids (Mensink and Katan, 1993; Kris-Etherton, 1995), one could wonder if it would not be desirable to replace partially hydrogenated oils by other oils in industrial frying.

We have tested the possibility of using liquid oils such as sunflower oils both high in linoleic acid (SO) and in oleic acid (HOSO) for the industrial preparation of crisps, and prefried frozen french fries. The products made in sunflower oils were compared to those made in palm olein and in a mixture of partially hydrogenated rapeseed oil and palm oil. The effects of adding dimethylpolysiloxane (DMPS) to the sunflower oils for continuous industrial frying were studied also.

2. MATERIAL AND METHODS

Industrial process

The french fries were produced as described by Niemelä et al. (1996) by a multi-step, continuous process including a two-phase blanching of potato

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strips before a three-phase drying operation. The strips were fried for 30 seconds in either a mixture of partially hydrogenated rapeseed oil-palm oil, or a normal (SO) and high oleic (HOSO) sunflower oils. The volume of the fryer (2.5 m x 0.8 m width) was 400 L and the depth of the oil layer was 0.17-0.20 m. The production rate of the french fries was 1500 Kg/h, with a fat consumption of 100 Kg/h and a total turnover rate of 3.4 h.

The crisps were produced as described by Niemelä et al. (1996) using a fryer of a total volume of 700 L (5.5 m in length and 0.5 m width). The depth of the oil layer was 0.22-0.26 m and the frying temperature was 180°C. The production rate of crisps during the trials was 140 Kg/h. The total oil consumption was 48 Kg/h and the turnover rate was 13 hours. The crisps were prepared in SO, HOSO, SO + DMPS (with dimethyl polysiloxane added), HOSO + DMPS and palm olein (PO).

Quantitation and distribution of polar compounds

The amount of polar compound was determined by silica column chromatography following the method proposed by the IUPAC (1987) with two slight modifications: a mixture of hexane:diethyl ether (90:10) was used to elute the non polar fraction while a final elution of the column with methanol improved the recovery of the sample. The polar fractions were further submitted to a fractionation by high-performance size exclusion chromatography (Dobarganes et al, 1988). Briefly, the samples were analysed in a Konik 500 A chromatograph with a 10 µl sample loop. A Hewlett Packard 1037 A refractive index detector was used with two 100 Å and 500 Å Ultrastyragel columns (Waters Associates, Mildford, MA) connected in series operated at 45°C. The columns were 25 cm x 0.77 cm I.D., packed with porous, highly cross-linked styrene divinylbenzene copolymer. HPLC-grade tetrahydrofuran was used as the mobile phase at a flow rate of 0.5 mL/min. Samples were injected in tetrahydrofuran (15-20 mg/mL).

Determination of total fatty acid composition by gas-liquid chromatography (GLC)

GLC of fatty acid methyl esters prepared following the method of Morrison and Smith (1964) were performed on Hewlett-Packard 5890 Series II chromatographs equipped with split/splitless injectors (250°C) and flame ionization detectors (250°C). Two fused silica columns of different polarity were used: a 50 m x 0.25 mm i.d. and 0.2 µm of film thickness (DB-Wax, EW Scientific, Folsom, CA, USA) and a 50 m x 0.33 mm i.d; x 0.4 µm of film thickness (BPX-70, SGE, Melbourne, Australia). Helium was used as carrier gas. For the DB-Wax column, the oven temperature was programmed from 60 to 190°C at 20°C/min. For the BPX column, the oven temperature was programmed from 60 to 170°C at 20°C/min. Quantitative analyses were performed using a chromjet integrator (Spectra Physics, Les Ulis, France), coupled to a PC equipped with Labne-Software (Spectra Physics).

GLC analysis of the 18:2 geometrical isomers

The total fatty acid methyl esters were submitted to a semi-preparative HPLC fractionation on a C18 reversed phase column (Merck, Lichrosorb, 7 µm, 7 mm i.d., 25 cm), using a mixture of acetonitrile: acetone (90:10) at 4 mL/min. The fraction containing the 18:2 isomers was collected and further injected on a BPX column as described above.

Analysis of cyclic fatty acid monomers (CFAM)

About 100 mg of the oil samples was weighed and the methyl esters were prepared using BF_3-MeOH as described by Morrison and Smith (1964). The resulting methyl esters were weighed and a known amount of internal standard was added (C16:0 ethyl ester). The total sample was hydrogenated using PtO_2 as a catalyst (Potteau et al., 1978). These were then submitted to high performance liquid chromatography on a C18 reversed phase column (7 mm ID, 25 cm in length, 7 µm, Merck), using a mixture of acetonitrile: acetone (90:10) at 4 mL/min. A fraction containing the internal standard and the CFAM was collected according to the procedure recently published by Sebedio et al. (1994). This fraction was further analysed by GLC on a BPX column in the same conditions as described previously.

Isolation and identification of 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 a solution of 7% BF_3-MeOH (Morrison and Smith, 1964). The total fatty acid methyl esters were fractionated by semi-preparative HPLC and the C18:1 isomers were collected (Sébédio et al., 1994). The semi- preparative HPLC analyses were performed on a reversed phase column (Merck, Lichrosorb, 7 µM, 7 mm ID, 25 cm). The sample was injected in acetone and fractionated by using a mixture of acetonitrile: acetone (90:10) at 4 mL/min. The 18:1 fraction also contained some 16:0. These were further fractionated by $AgNO_3$-TLC into *cis* and *trans* isomers. Three bands were obtained. The upper band contained 16:0 (Rf = 0.80), the middle band, the 18:1 *trans* (Rf = 0.60), while the lower band consisted of the 18:1 *cis* isomers (Rf = 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 BF_3-MeOH followed the method described by Ackman et al (1981) slightly modified for the Supelco microozonizer (Grandgirard et al., 1984). The analysis of the resulting mono- and diester mixtures were carried out on a BPX-70 column.

3. RESULTS AND DISCUSSION

Four types of oils (Table I) were used as frying medium. While the crisps were prepared in sunflower (SO), high oleic sunflower (HOSO) and palm olein (PO), the french fries were fried in SO, HOSO and in a partially hydrogenated rapeseed oil, palm oil mixture (RP). Palm olein and mixtures of partially hydrogenated oil and palm oil are typical oils used for industrial frying (Keijbets et al., 1985; Sébédio et al., 1994), so that, in this work, the crisps and french fries made in these oils are considered as reference samples. SO was rich is linoleic acid (65%) and HOSO and the RP mixture rich in oleic acid, 73% and 61% respectively. Palm olein was rich both in 16:0 (34%) and in 18:1 (47%). However, due to the hydrogenation process (Dutton, 1979), the RP mixture contained both *cis* and *trans* 18:1 positional isomers. The *cis* isomer fraction (Figure 1) was composed mainly of the 9- (73%), 10- (6.7%) and 11-isomers (7.0%). These were accompanied by smaller quantities of the other isomers. For the *trans* isomers, the double bond was more delocalized along the carbon chain, 8, 9, 10 and 11 being the major isomers with respectively 15, 25, 23 and 14%.

Table I
Fatt acid composition (wt%) of the starting oils

Fatty Acid	SO[a]	HOSO	RP	PO
16:0	7.0	4.3	17.4	33.7
18:0	5.0	4.5	11.7	4.3
18:1	21.5	73.0	61.4[c]	46.9
18:2	65.1	16.4	4.5	12.2
Others[b]	1.4	1.8	5.0	2.9

[a] SO: sunflower oil; HOSO: high oleic sunflower oil; RP: hydrogenated rapeseed/palm oil mixture; PO: Palm olein.
[b] include minor fatty acids such as 14:0, 16:1, 18:3, 20:0 and 22:0.
[c] contained 44.5% of *trans* isomers and 55.5% of *cis* isomers.

The profile of polar compounds, determined by a combination of silica column and high-performance size-exclusion chromatographies, is shown in figure 2, for used frying oils and the corresponding oils extracted from crisps. Five groups of compounds could be quantified, i.e. triglyceride polymers (TGP), triglyceride dimers (TGD), oxidized triglyceride monomers (oxTGM), diglycerides (DG) and free fatty acids (FA). While TGP, TGD and oxTGM are compounds formed through oxidation and polymerization reactions, DG and FA are components arising from hydrolysis (Dobarganes and Pérez-Camino, 1988). As can be observed, chromatograms were practically identical for each frying oil and its counterpart extracted oil, thus indicating no significant differences between oils extracted from crisps and their corresponding oils collected from the fryer, as reported previously (Sébédio et al., 1990, Dobarganes et al, 1993).

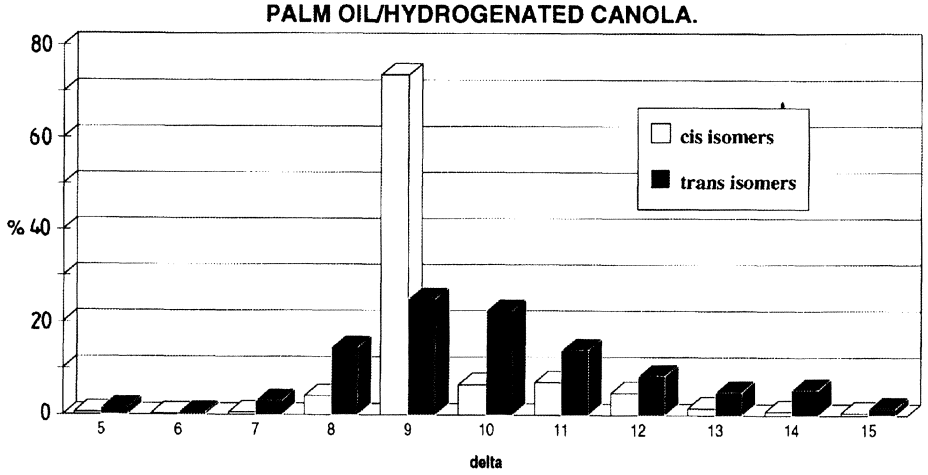

Figure 1
Distribution of *cis* and *trans* $C_{18:1}$ isomers in the starting partially hydrogenated rapedseed-palm oil mixture

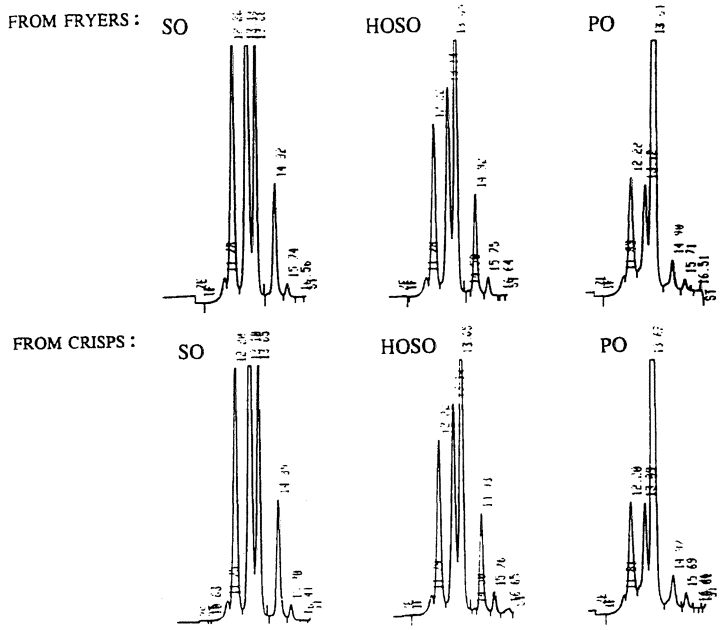

Figure 2
HPSEC chromatograms of polar compounds in oils from fryers and oils extracted from crisps. Retention times (min): 11.7, triglyceride polymers; 12.2, triglyceride dimers; 13.1, oxidized triglyceride monomers; 13.6, diglycerides, 14.9, fatty acids

Table II shows evolution of polar compounds, including total level and their distribution, from the starting oils to the samples obtained after the first and second days of frying of crisps. Only a small increase was observed for all samples, independently of the nature of the frying medium. No significant differences were found between samples of the same oil, with or without DMPS, which seemed to indicate that DMPS had no effect in continuous frying. In fact, later studies (Jorge et al., 1996) demonstrated that DMPS had only a positive action in discontinuous frying, when oils were not protected by the steam blanket produced by food moisture. Initial levels of polar compounds were rather high in PO because of the considerable content of DG, characteristic of this type of oil (Goh and Timms, 1985) and hence higher amounts of polar compounds were obtained after the second day of frying, as compared to the other oils. Apart from this, it was clear that increases in alteration compounds from the starting oils depended on the unsaturation degree, the highest level found for SO. In general, a larger increase in TGD was observed for SO samples compared to HOSO or PO samples, while values of oxTGM were similar, although slightly lower for PO samples. Values of DG and FA did not change in any of the oils, and this indicates that hydrolytic alteration was not significant in spite of the high moisture content of potatoes.

Table II
Industrial preparation of crisps: Evolution of total polar compounds (wt% on oil) and polar compound distribution (mg/g oil) in frying oils

		Distribution[a]				
Samples	**Total**	**TGP**	**TGD**	**oxTGM**	**DG**	**FA**
SO-0	2.8	0.4	3.6	8.3	10.6	5.1
SO-1	4.9	1.1	14.9	14.4	12.8	5.8
SO-2	5.2	1.7	16.8	14.8	13.0	5.7
SO DMPS-1	5.3	1.2	15.3	16.3	13.8	6.4
SO DMPS-2	5.7	1.7	17.9	17.6	13.7	6.1
HOSO-0	3.1	0.5	2.6	6.9	16.3	4.7
HOSO-1	4.3	0.7	8.0	11.0	18.2	5.1
HOSO-2	4.9	1.1	10.4	12.9	19.4	5.2
HOSO DMPS-1	4.2	0.7	7.3	10.7	17.6	5.7
HOSO DMPS-2	4.6	1.2	9.9	11.5	17.9	5.5
PO-0	7.7	0.8	3.8	6.1	65.2	1.1
PO-1	8.7	1.8	10.4	9.9	62.8	2.1
PO-2	8.9	1.9	10.9	10.2	63.5	2.5

For abbreviations see Table I
Further description of oils indicate:
DMPS: oils containing 2 ppm of dimethylpolysiloxane
O: starting oil; 1: after the first day of frying; 2: after the second day of frying
[a] TGP: triglyceride polymers; TGD: triglyceride dimers; oxTGM: oxidized triglyceride monomers; DG: diglycerides; FA: fatty acids + polar unsaponifiable fraction.

Similar observations can be made for the samples corresponding to french fries (Table III), which only showed, in general, small increases in polar compounds, and particularly similar increases in oxTGM, which did not seem to depend upon the nature of the frying medium. However, as found in crisps, TGD showed again the highest value for the most unsaturated oil (SO) while the lowest value corresponded to RP, which contained the smallest quantity of linoleic acid. In this case, because of the high turnover period (3.4 hours) and given that a constant alteration level is reached in continuous frying for periods of frying higher than 4 times the turnover period (Pérez-Camino et al., 1988), it can be assumed that values for the first and second days of frying correspond to the maximum alteration level. Therefore, these levels are also expected to be found in the long term.

Table III
Industrial preparation of french fries: Evolution of total polar compounds (wt% on oil) and polar compound distribution (mg/g oil) in frying oils.

		Distribution				
Samples	**Total**	**TGP**	**TGD**	**oxTGM**	**DG**	**FA**
SO-0	3.1	0.3	4.2	9.3	12.3	4.9
SO-1	7.7	5.5	30.9	22.6	13.0	5.0
SO-2	7.4	4.8	29.8	22.0	12.3	5.1
HOSO-0	3.3	0.6	3.2	8.7	15.6	4.9
HOSO-1	7.3	5.3	23.9	22.4	16.8	4.6
HOSO-2	7.4	5.6	24.7	22.5	16.5	4.7
RP-0	4.1	0.5	3.2	8.2	25.5	3.6
RP-1	7.2	3.5	17.1	19.7	27.6	4.1
RP-2	7.5	3.2	16.9	21.5	29.3	4.1

For abbreviations, see Tables I and II

In general, values of polar compounds obtained for both frying of crisps and of french fries were very low and far below the 25% established in recommendations and official regulations for discarding used frying oils (Firestone, 1993). Thus, both sunflower oils (SO and HOSO) can be regarded as excellent alternatives for industrial frying under conditions similar to those applied in these trials.

The fatty acid composition of the starting oils and of the oil extracted from the crips fried in SO, HOSO and in PO are listed in Table IV. No major changes in the fatty acid composition of the crips fried in SO, HOSO and PO were observed. Furthermore, the utilization of DMPS did not seem to have any effect on the fatty acid composition of the final product. These results are in good agreement with those of the polar components previously discussed.

Table IV
Major fatty acids (wt%) of the starting oils and oils extracted from crisps

	16:0	**18:0**	**18:1**	**18:2**
SO-0	7.0	5.0	21.5	65.1
SO-2	7.7	4.9	21.6	64.3
SODMPS-2	7.0	5.2	22.1	64.2
HOSO-0	4.3	4.5	73.0	16.4
HOSO-2	4.8	4.4	73.0	16.2
HOSO DMPS-2	4.7	4.3	70.6	18.2
PO-0	33.7	4.3	46.9	12.2
PO-2	33.8	4.4	44.8	13.6

For abbreviations see Tables I and II

Gas-liquid chromatographic analyses of the fatty acid composition of the french fries showed the presence of *trans* 18:1 fatty acids in some samples prepared in normal and high oleic sunflower oils especially for the sample collected after 1 day of frying. Detailed analysis of samples made in SO and HOSO collected after 4, 8, and 12 hours of frying (Dobarganes, unpublished results) showed maximum values of 2.6% and of 1.5% 18:1 *trans* isomers for samples prepared in SO and HOSO respectively. The amount of *trans* 18:1 then decreased so that no *trans* monounsaturated fatty acids could be detected in the samples collected after two days of frying (SO-2 and HOSO-2). Except for the presence of these *trans* 18:1 isomers, the fatty acid profile of the french fries (prepared in SO and HOSO) was not modified as a result of the number of frying hours. This was probably due to a small carry over from one experiment to the next one as there was only a slight increase in polar components during the process (Table III). This problem then dissapeared due to the high turnover rate. The same phenomenon was observed also for the french fries prepared in the RP mixture. We have represented the fatty acid composition of two RP mixtures in Table V, RP-OA being an oil used before HOSO and SO and RP-OB being the same oil used for frying operations which took place after frying in HOSO and in SO. From the different fatty acid compositions, it is obvious that the higher content of 18:2 (9.7%) in the RP-OB (which was collected in the fryer before the beginning of the process) could be explained by a carry over from a previous frying treatment in SO. Consequently, after two days of frying, the quantity of 18:2 decreased and the fatty acid composition of the final sample (RP-2) is close to what was found for sample RP-OA. It is obvious, that it is very difficult, to avoid these contaminations in industrial frying from a carry over considering the large volume of the frying equipment (400 L).

Table V
Major fatty acids (wt%) of the starting oils and oils extracted from french fries

	16:0	18:0	18:1	18:2
SO-0[a]	7.0	5.0	21.5	65.1
SO-1	7.3	5.2	23.3[b]	63.1
SO-2	6.7	4.9	22.0	66.3
HOSO-0	4.3	4.5	73.0	16.4
HOSO-1	4.7	4.0	76.3[c]	15.0
HOSO-2	4.5	4.1	76.2	15.2
RP-OA	17.4	11.7	61.4[d]	4.5
RP-OB	16.8	11.5	60.4[d]	9.7
RP-1	16.8	11.5	60.5[d]	9.3
RP-2	17.7	11.2	63.5[d]	5.4

a For abbreviations see Tables I and II.
b including 2.6% *trans* isomers.
c including 1.5% *trans* isomers.
d 44.5% *trans* and 55.5% *cis* isomers.

Special attention was given to the analyses of *trans* polyunsaturated fatty acids and of cyclic fatty acid monomers (CFAM) as the 18:2 geometrical fatty acid isomers are known to be converted into geometrical isomers of arachidonic acid (Berdeaux et al., 1996), which may have some potential biological effects (Berdeaux, 1996). Furthermore, the CFAM have shown in certain cases some toxic properties (Sebedio and Grandgirard, 1989). Frying of crisps in HOSO and in PO (Table VI) did not result in any increase in CFAM. However, frying of crisps in SO resulted in an increase in CFAM (90 ppm in the starting oil compared to 270 ppm after two days of frying). However, all the CFAM values observed stayed quite low. These are comparable to the values observed in refined vegetable oils sold on the French market (Sebedio, unpublished results). Slightly different CFAM profiles (after total hydrogenation) were obtained when frying the crisps in HOSO and in SO (Figure 3). While the major CFAM isolated from SO were monunsaturated fatty acids (Christie et al., 1993), some saturated CFAM were formed when frying in HOSO (Dobson et al., 1996). Frying of the french fries (Table VII) resulted in an increase of CFAM (two to three folds) for the three frying oils tested. Again a smaller increase was observed for HOSO and RP compared to SO. CFAM contents of french fries and of crisps were similar and comparable to the data published for another industrial frying operation (Sebedio et al., 1991).

Smaller quantities of 18:2 geometrical isomers were found in HOSO and SO compared to PO and RP in the starting oils (Tables VI and VII). Furthermore, only mono-*trans* isomers of 18:2, the 18:2 9c, 12t and 18:2 9t, 12c were detected. Geometrical isomers of polyunsaturated fatty acids, as 18:2 n-6 and 18:2 n-3 are known to be formed during refining in the deodorization step (Ackman et al., 1974; Wolff, 1993) and in general during heat treatment of fats and oils (Grandgirard et al., 1984; Sebedio et al., 1988; O'Keefe et al., 1993). While mono-*trans* isomers are formed at lower temperature, di-*trans* isomers are also observed when the heating temperature is higher than 220°C (Grandgirard et Julliard, 1987). These results indicate that SO and HOSO were deodorized at a lower temperature. Frying the crisps in either SO, HOSO or PO did not result in any increase in *trans* 18:2 isomers (Table VI). For frying of french fries (Table VII), SO and HOSO and RP seem to behave similarly showing higher values of *trans* 18:2 after 2 days of frying compared to the original oil, especially for RP if compared with the original oil (RP-OB). Much smaller differences were observed if we compare sample RP-2 (2 days frying) with RP-OA (the same original oil but collected before frying SO and HOSO). This again indicates that the higher *trans* 18:2 content in the sample after 2 days of frying is not due to a loss of 18:2 through thermal or oxidation reactions, but most likely to a carry-over from one frying operation to the next one as described earlier for the data presented in Table V.

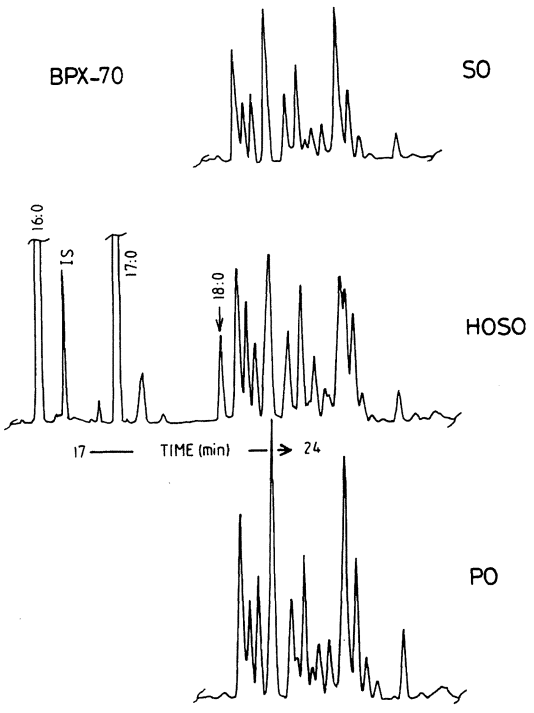

Figure 3
Parts of the GLC chromatograms of the hydrogenated cyclic fatty acid monomers fraction isolated from the lipids of crisps prepared in sunflower oils and in palm olein

Table VI
Percentage of the cyclic fatty acid monomers (CFAM) and of the 18:2 geometrical isomers in the original oils and in the crisps samples after 1 and 2 days of frying.

	18:2[a]	CFAM[b]
SO-0[c]	0.5	90
SO-1	0.6	170
SO-2	0.6	270
SODMPS-1	0.5	120
SODMPS-2	0.5	200
HOSO-0	0.5	150
HOSO-1	0.6	120
HOSO-2	0.4	160
HOSO DMPS-1	0.3	130
HOSO DMPS-2	0.4	140
PO-0	3.5	140
PO-1	3.4	170
PO-2	2.8	140

[a] as % of the total 18:2 isomers
[b] ppm in the oil
[c] for abbreviations, see Tables I and II

Table VII
Percentages of cyclic fatty acid monomers (CFAM) and of geometrical 18:2 isomers in original oils and in samples of french fries after 1 and 2 days of frying.

	18:2[a]	CFAM[b]
SO-0[c]	0.4	100
SO-1	0.5	280
SO-2	0.6	270
HOSO-0	0.8	120
HOSO-1	1.1	240
HOSO-2	1.3	230
RP-OA	12.5	100
RP-OB	6.2	110
RP-1	6.0	130
RP-2	10.3	200

[a] as % of the total 18:2 isomers
[b] ppm in the oil
[c] for abbreviations, see Tables I and II

Only minor changes were observed in the 18:1 *cis* and *trans* isomer distributions before and after frying when using the palm oil/partially hydrogenated rapeseed oil mixture (Table VIII) for preparation of french fries during frying. This indicates that there is no preferential adsorption of any isomers on the french fries. The *cis* isomers were mainly the 9 isomer (73%) accompanied by smaller quantities of 5, 6, 7, 8, 10, 11, 12, 13, 14 and 15 isomers. The *trans* double bond was more evenly distributed along the carbon chain, the 9 position being the major isomer. However, higher quantities of 8, 10, 11 and 12 were observed. No major differences were detected also for the distribution of the 18:1 isomers in the two RP samples before frying (RP-OA and RP-OB), so that we have only reported the results of RP-OA for reasons of clarity. These 18:1 isomer distributions are similar to those described for industrial samples bought on the French market (Sebedio et al., 1994).

Table VIII
Distribution of cis and trans 18:1 isomers in the starting partially hydrogenated rapessed, palm oil mixture and in the oils extracted from french fries

	RP-OA		RP-1		RP-2	
Isomers (β)	cis[a]	trans[b]	cis	trans	cis	trans
5	0.4	2.1	0.7	2.9	0.7	2.4
6	0.3	0.6	0.3	1.1	0.5	1.2
7	0.5	3.2	0.5	3.5	0.7	0.8
8	4.0	14.6	4.0	14.5	4.1	14.5
9	73.4	25.0	68.5	24.1	72.5	25.4
10	6.7	22.8	7.9	22.2	6.3	23.6
11	7.0	13.8	8.3	13.6	6.4	13.9
12	4.7	8.3	5.8	8.4	4.6	8.5
13	1.5	5.1	1.9	5.1	2.5	5.2
14	0.8	2.9	1.1	2.9	0.8	2.9
15	0.7	1.6	1.0	1.7	0.9	1.6
	100	100	100	100	100	100

[a] % on total *cis* 18:1 isomer
[b] % on total *trans* 18:1 isomer

Only minor changes in most of the parameters studied were observed (total polar components, minor glyceridic components, cyclic fatty acid monomers, *trans* polyunsaturated fatty acids). This seems to indicate that in good industrial frying practice, there is little loss of unsaturated fatty acids through oxidation, polymerisation, cyclisation and isomerisation reactions. In that case, the quality of the final products will depend to a great extent of the nature of the initial oils and to the conditions used for refining. All these data show that sunflower oils (normal or high oleic) are good alternatives to fats as palm oil or partially hydrogenated oils for industrial frying of crisps and french fries. Stability studies carried out using sensory evaluations (Raoux et al, 1996, Van Gemert, 1996) and chemical analyses (Martín et al., 1996, Lahtinen et al., 1996) also showed that «normal» sunflower oil should only be used to produce french fries while high oleic sunflower oil would be the ideal oil to fry both crisps and french fries.

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