Quality Assessment of Industrial Prefried French Fries

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An industrial production of prefried french fries using palm oil as a frying medium was studied over a period of 12 days. Samples of oils and french fries were withdrawn once a day. The quality of both the oil and the french fries was assessed using two types of tests. Some tests, such as the determination of free fatty acid (FFA) and the determination of thiobarbituric acid value (TBA), oxifritest and Food Oil Sensor correspond to what was used by a quality control laboratory. More elaborate techniques such as the determination of polar components, polymers and cyclic fatty acid monomers (CFAM) were also used. Only small increases of FFA, TBA, polar components and polymers were observed. However, in the case of palm oil, which contains a high percentage of diglycerides, it is more reliable to determine the quality of the oil using the amount of polymers instead of polar components which may include some diglycerides. Thus a high "polar components" value (up to 20–25%) would not necessarily reflect an altered sample.

The maximum amount of CFAM detected was 0.1% and they did not seem to be preferentially adsorbed on the french fries. These results, along with the sensory evaluations, showed that the french fries obtained in these production conditions were of good quality as far as the fat was concerned.

KEY WORDS: Cyclic fatty acid monomers, french fries, industrial frying, palm oil, polar components, polymers.

Many studies have been carried out on the effect of heat treatment of oils on the formation of oxidation products, polymers, cyclic fatty acid monomers (CFAM), as well as on geometrical fatty acid isomers (1–8). These studies usually have been carried out in laboratories either under severe conditions for structural work (6,9,10) or under simulated deep fat frying conditions (5,11,12). However, very little has been done on deep fat frying of food and on the study of the lipid exchanges during the process (12–18). This is also the case for food such as prefried french fries produced on an industrial scale.

The need for reliable information on commercial practice is well understood not only from the basis of scientific interest but also from the aspect of health implications of deep fried fats. In order to assess the quality of the products for human consumption we have withdrawn samples of oils and french fries during a twelve-day industrial production period of prefried frozen french fries. Palm oil was used as the frying medium and the quality of the oil samples and of the french fries were assessed using tests which are used in quality control laboratories and also by use of more elaborate techniques, such as the determination of polar components, polymers and cyclic fatty acid monomers.

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MATERIALS AND METHODS

Industrial process. The french fries were produced from the Bintje and Rekord varieties by a multi-step, continuous process including a two phase blanching of potato strips (9 × 9 mm) before a three phase drying operation to adjust the solids content and to add to the crispness of the final product. The prefried strips were flash-fried for 30 seconds in palm oil (176–181°C) and then cooled to be sold either chilled or frozen. At the beginning of the test period the production was started with fresh oil and oil was added to keep the oil level constant in the fryer. Records were kept on the quantities of raw materials used and the final product produced as well as the processing parameters.

Sampling procedure and lipid extraction. Oil samples were taken from the fryer every day of production at a set time. The samples (250 mL) were measured into pyrex bottles which were capped immediately with teflon lined caps. The bottles were then stored frozen until studied in the laboratories. French fry samples were taken simultaneously with the oil samples from the production line just after the ambient air cooler. The samples were frozen and stored at −25°C until studied in the laboratories. The lipids were extracted according to Folch *et al.* (19).

Laboratory tests for the quality control. In addition to the analyses to assess the regular production quality (strip length deviation, color, black spots, taste, etc.) a more detailed study was performed to follow the changes in oil during the test period.

The iodine value (IV) and the free fatty acids (FFA) were analyzed using the *Official and Tentative Methods of the American Oil Chemists' Society* (AOCS). The thiobarbituric acid (TBA) values were determined using the direct spectrophotometric micromethod of Ke and Woyewoda (20).

The rapid descriptive tests of oil quality, fritest (Merck, Darmstadt, Germany), and Food Oil Sensor value (Northern Instrument Corp., Lino Lake, MN) were carried out according to the analysis kit and instrument suppliers as described elsewhere (21,22). The total solids of french fries were determined as the weight difference before and after a ten-hour heat treatment in an oven at 105°C.

Determination of polar components. The amount of polar components was determined using the method described by Sébédio *et al.* (23), which is an alternative to the official IUPAC method (24). Briefly, about 90 mg of oil (dissolved in a mixture of petroleum ether and diethyl ether) were injected on top of a silica cartridge (Sep-Pak, Millipore, Milford, MA). The nonpolar fraction was eluted with 20 mL of a mixture of petroleum ether and diethyl ether and the polar fraction was eluted with 30 mL of pure methanol. The amount of polar fraction was calculated by difference from the total amount of sample injected and the amount of the nonpolar fraction as previously reported (23).

Determination of polymers. The amount of poly-

mers was determined by gel permeation chromatography using 2 Ultrastyragel columns (7.8 mm ID × 30 cm, Millipore), and THF at 1 mL/min and were quantified using a Varian CDS 401 system (Varian Associates, Palo Alto, CA).

Analysis of cyclic fatty acid monomers (CFAM). About 200 mg of the oil sample was weighed and the methyl esters were prepared using BF_3/MeOH as described by Morrison and Smith (25). 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. These were then submitted to high performance liquid chromatography on a C18 reverse phase column (7 mm ID × 25 cm, Merck) using a mixture of acetonitrile/acetone (90:10) at 4 mL/min. A fraction containing the hydrogenated cyclic fatty acid monomers and the internal standard was collected according to the procedure recently developed by Ribot *et al.* (Ribot, E., J.L. Sébédio and A. Grandgirard, submitted for publication). This fraction was submitted to a second hydrogenation in order to eliminate any traces of unhydrogenated 18:1 isomers. The mixture was then analyzed by GLC coupled with mass spectrometry (GC-MS) using a DBwax column (J&W Scientific, Folsom, CA) under the conditions described elsewhere (26).

RESULTS AND DISCUSSION

The deep fat frying experiment (Table 1) which took place over 12 days was stopped on days 6 and 7, which corresponded to the end of the week. The daily production of french fries during the experiment varied according to the customer orders and ranged from 6,500 kg on day 12 to 17,800 kg on day 10. A total of 121,000 kg of french fries were produced during the experimental period. Consequently, about 8,750 kg of fat was added during the process. The maximum level of fat added in one day was 1,175 kg.

Quality assessment of the frying oil. The IV during the experiment ranged from 51 to 54 (Table 2). The TBA value was very low with a maximum of 0.094 at day 5, which indicates the formation of only trace amounts of secondary oxidation products. The amount of FFA which in fresh oil is below 0.05%, ranged from 0.4% at day 1 to a maximum value of 0.45% at day 8 in the oil. When determining the oil quality by the fritest, the values from 1 to 2 are preferred, whereas the value 3 means that changes in the oil quality have already happened and number 4 indicates rancid oil. Respectively, the Food Oil Sensor has a scale from 0 through 6, four being the rejection limit. The highest values for the fritest (2.5) and food oil sensor (1.5) were also observed on day 8. These maximum values may be related to the production break during days 6 and 7, when the oil was stored in a closed storage tank at 120°C. In any case the amount of products arising from hydrolysis was low. However, the highest values of fritest seem to indicate that a problem of oxidation could take place even when using palm oil for frying medium when the industrial process is stopped for 2 days. On the other hand, a trained taste panel which was used to evaluate the organoleptic quality of the same french fry samples found all of them acceptable as far as their color, smell or taste was concerned.

Lipid exchanges between the oil bath and the french fries. Before frying, the potatoes contained about 0.2% lipids (Table 3). After frying, the fat content varied from 5.0 to 6.2% depending on the day the samples were collected. However, the percentage of lipids did not seem to be affected by the continuous production process (Table 3). If we calculate an average lipid content (~ 5.5%), and knowing the quantity of french fries produced (Table 1), the total amount of lipid present in the total french fry production would be 6,655 kg. This amount is quite different from the total amount of oil used (8,700 kg, Table 1). The difference arises from the quantity of oil needed in the frying unit before the start of operation and from the oil which was wasted from the strips between the fryer and cooler.

The amount of polar components in the starting oil was 13.5%. This value is not related to any alterations of the oil, as the amount of the polymers was low

TABLE 1

French Fry Production and Fat Added During an Industrial Operation

Day	Production (kg)	Fat added (kg)	Solids in french fries (%)
1	8,300	750	27.6-31.3
2	9,500	575	27.0-32.2
3	10,700	975	29.0-33.4
4	15,400	1,050	29.3-34.6
5	10,000	500	30.4-34.3
6[a]	—	—	—
7[a]	—	—	—
8	12,700	1,050	28.2-34.0
9	17,500	1,175	29.5-36.7
10	17,800	1,100	28.7-32.1
11	12,600	1,125	28.6-33.1
12	6,500	350	29.4-35.0
Σ	121,000	8,750	

[a]No production during days 6 and 7.

TABLE 2.

Iodine Value (IV), TBA, Free Fatty Acid, Fritest, and Food Oil Sensor Values of Oil Samples Collected During an Industrial Production of French Fries

Day	IV	TBA[a]	FFA[b]	Fritest	Food oil sensor
Fresh oil	—	-	-	<1	0
1	53	0.042	0.14	<1	0.6
2	53	0.078	0.27	1	1.3
3	54	0.059	0.24	1	1.1
4	53	0.077	0.39	1.5	1.3
5	53	0.094	0.41	1.5	1.4
8	51	0.077	0.45	2.5	1.5
9	53	0.047	0.39	1.5	0.8
10	52	0.045	0.41	1.5	1.4
11	52	0.039	0.33	1.5	1.0
12	52	0.040	0.40	2-	1.3

[a]In μmol/g of oil.
[b]In percentage.

TABLE 3

Polymer (wt%), Polar Components (wt%), Cyclic Fatty Acid (CFAM, wt%) and Lipid Content (wt%) of French Fries and the Corresponding Oil Samples as a Function of Number of Days of Production

	Oil			French fries			
Day	Polar	Polymers	CFAM	Lipids	Polar	Polymers	CFAM
Fresh oil	13.5	0.4	0.02	0.2	—	—	—
1	13.4	1.4	ND[a]	5.7	10.2	0.7	0.01
2	17.9	1.3	ND	6.0	16.0	5.1	ND
3	18.5	3.5	ND	5.0	16.6	3.0	ND
4	21.2	4.7	ND	5.0	14.2	4.9	ND
5	23.4	4.2	0.08	5.1	15.0	3.6	0.10
8	17.8	5.2	0.05	5.1	16.6	6.3	0.06
9	19.9	3.3	ND	5.6	14.6	1.2	ND
10	16.3	4.5	ND	5.6	15.8	4.4	ND
11	19.6	3.7	ND	6.2	19.1	3.8	ND
12	21.8	1.0	0.05	5.3	16.3	2.9	0.07

[a]ND, Not determined.

(0.4%), but rather to the amount of diglyceride usually found in palm oil (27). The amount of polar components in the oil increased up to day 5, reaching 23.4%. The amount of polymers also increased to a maximum value (5.2%) at day 8. A similar trend was observed for the french fries. In all cases, the amount of polar components in the oil extracted from french fries was lower than that in the frying oil, especially for the samples collected on days 4, 5 and 12. Gel permeation chromatography showed that a large amount of the polar components are diglycerides. However, considering the separation obtained between triglyceride and diglyceride, it is rather difficult to quantify them (28). This selective adsorption (polar components) was quite different to what was observed during frying operations carried out in the laboratory scale (18), where no differences in the amount of polar components were detected between the french fries and the oil bath.

However, this study was carried out on an industrial scale, and considering the large quantities of oil consumed and french fries produced, one could wonder if a sample of french fries and a sample of oil are really representative of what is happening at a given time. For further studies, it may then be necessary to collect more samples in shorter intervals to confirm the actual relationships between the respective oil and french fry samples. In all cases and in spite of the naturally high content of polar lipids in palm oil, the amount of the total polar components was lower than 25%, the critical value which indicates that an oil should be discarded (29).

In the case of palm oil, it is better to follow the quality of the products by looking at the amount of polymers. No special trend was observed if we compare the amount of polymers found in the oil and in the french fries. The value found was usually quite low (maximum of 5.2% in the oil and 6.3% in the french fries). Some studies have already shown a good correlation coefficient (0.98) between the amount of polymer and the amount of polar components. An equation ($y = 1.26\ \chi + 7.38$) where y represents the amount of polar components and χ the amount of polymers was established for 31 oil samples collected from restaurants and market vendors (30). Using this equation, 5.2% of polymer in the oil at day 8 would correspond to 13.9% of polar components, while 1.4% in the starting oil would correspond to 9.1% of polar components. Both these calculated values are smaller to what was observed (17.8 and 13.4%, respectively). This discrepancy could arise from the high content of diglyceride in palm oil. Moreover, the above equation was determined for different types of oils and it would be interesting to calculate the same type of correlation by taking palm oil samples at different states of degradation.

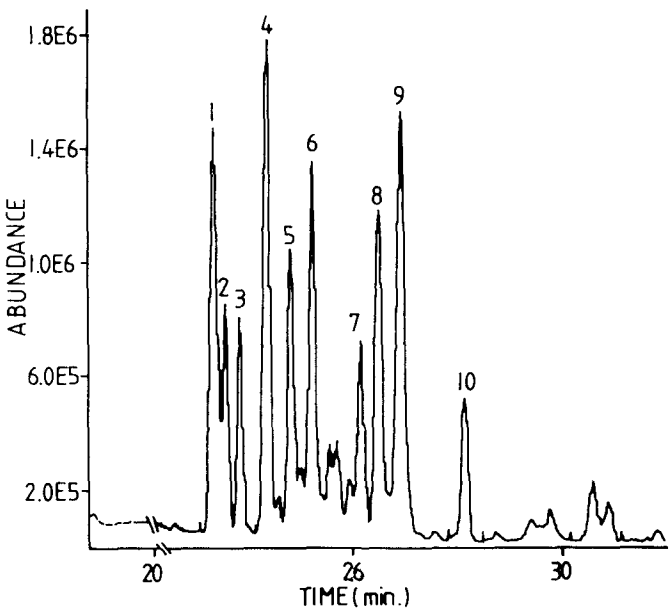

FIG. 1. Total ion chromatogram of the hydrogenated cyclic fatty acid isolated from the heated palm oil at day 12.

The amount of cyclic fatty acids (CFAM) is also a good criteria to determine the state of degradation of frying oil or fat in food products, as some of these components have shown a possible toxic effect (31,32). The amount of CFAM in the starting oil was 0.02%,

TABLE 4

Hydrogenated CFAM Identified by GC-MS in Heated Palm Oil, Day 12

Peak code	Component	Configuration
1	methyl 4-(2′-nonylcyclopentyl)-butanoate	*trans*
2	methyl 7-(2′-hexylcyclopentyl)-heptanoate	*trans*
4	methyl 9-(2′-butylcyclopentyl)-nonanoate	*trans*
6	methyl 4-(2′-nonylcyclopentyl)-butanoate	*cis*
8	methyl 9-(2′-butylcyclopentyl)-nonanoate	*cis*
9	methyl 9-(2′-propylcyclohexyl)-nonanoate	*trans*
10	methyl 9-(2′-propylcyclohexyl)-nonanoate	*cis*

an appropriate value for a good quality oil. After frying, the maximum values found in the oil and in the french fries were 0.08% and 0.10%, respectively (Table 3). The major identified CFAM (Fig. 1) found in the oil after day 12 of frying are listed in Table 4. These were identified using authentic standards (33) and data already published (26). It should be outlined that the majority of the cyclic fatty acids were those with a 5 carbon membered ring, as has already been found in oils containing nonappreciable amounts of linolenic acid (26). More studies still have to be carried out to identify components 3, 5 and 7.

The measurements of the quality of oil used in continuous industrial production of french fries as determined by conventional and rapid quality tests show no drastic changes during operation for 12 days. All the values observed stayed below the limits usually considered safe in industrial operation. Furthermore, small amounts of polar components, polymers as well as CFAM were formed during the process. Their health implications remain obscure, considering the complexity of the structures formed. It would be interesting to compare the behavior of different, commonly used oils having a higher degree of unsaturation than that of palm oil.

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