Suitability of Hydrogenated Soybean Oils for Prefrying of Deep-Frozen French Fries

M.J.H. KEIJBETS, G. EBBENHORST-SELLER and **J. RUISCH,** Institute for Storage and Processing of Agricultural Produce (IBVL), P.O. Box 18, 6700 AA Wageningen, The Netherlands

ABSTRACT

The suitability of hydrogenated soybean oils (fats) for prefrying of deep-frozen french fries has been investigated in a frying and storage experiment with five hydrogenated oils, of which four were commercially available and one was experimentally prepared. Three frying oils were hydrogenated soybean fats (0% C18:2 and C18:3), one was a partly hydrogenated soybean oil (25% C18:2; 0% C18:3) and one a hydrogenated palm fat (0% C18:2). An intermittent frying and heating procedure was used.

Prefried french fries were stored deep-frozen at −18 to −20 C for a period of one year. Although differences in hydrolysis and oxidation during frying were observed, the five hydrogenated frying oils were quite stable. During the storage period, hydrolytic and oxidative changes in the oil phase of prefried french fries were not detected, regardless of the frying oil used. Only slight changes in sensory quality could be detected in all french fry samples stored for one year at −18 to −20 C.

Some differences in odor and taste of finish-fried french fries observed initially were not observed after prolonged storage. Thus, it has been concluded that hydrogenated soybean oils, including a partly hydrogenated one, are suitable for prefrying french fries and for long-term storage of deep-frozen products.

INTRODUCTION

The french fry industry uses considerable amounts of hydrogenated oils (fats) for prefrying. In 1981, the potato processing industry in the Netherlands produced 312,500 metric tons of prefried french fries. It is estimated that the major french fry producing countries in the EEC produced about 830,000 metric tons, 74% of which were deep-frozen. With an average fat content of 5%, the amount of fat used in the EEC is estimated to be about 41,000 metric tons in 1981.

The choice of fat used for prefrying french fries depends on several factors such as frying characteristics, flavor, solidifying behavior, availability, whether it is animal or vegetable in origin, and price. In the European french fry industry, doubts exist about whether frying fats based on hydrogenated soybean oil are suitable for production of prefried french fries, in particular deep-frozen french fries. During prefrying and/or deep-frozen storage, typical off-flavors may develop which impair the quality and shelf-life of the product.

In the past, problems with the quality of french fries have been experienced when hydrogenated soybean oil was used. These may be ascribed to the unacceptable quality of some alkali-refined soybean oils (1) or a distinctive hydrogenation flavor (2). Generally, with adequate extraction and refining techniques, good quality soybean oils can be produced from good quality beans (1). Hydrogenation of soybean oil resulting in a lower level of polyunsaturation will reduce potential development of oxidation off-flavors (3).

Frying fats, based on palm oil, which are hardened to a melting point (mp) of about 45 C have been used often in the french fry industry. These frying fats have been hydrogenated to low or negligible levels of polyunsaturated fatty acids. The above-mentioned considerations have led to an investigation into the suitabiility of using hydrogenated soybean oil for prefrying and for storage of deep-frozen french fries. Preliminary results of this work already have been published (4).

EXPERIMENTAL PROCEDURES

Frying Oils

From 10 samples of commercial frying oils, obtained from companies in the Netherlands, Belgium and the Federal Republic of Germany, four oils were selected for a frying experiment.

One was a partly hydrogenated soybean oil, two were hydrogenated soybean fats (no. 1 and 2) and one a hydrogenated palm fat. The oils were selected on the basis of an investigation into oxidation and flavor stability by incubation at 60 C. The three fats selected were similar with regard to stability. A further sample of hydrogenated soybean fat (no. 3) was prepared on a small scale by Institute CIVO-Technology TNO (Zeist, The Netherlands). In the preparation of this fat, the soybeans were heated to about 110 C before oil extraction in order to inactivate enzymes, in particular phospholipases and lipoxygenases (1,2).

Prefrying and Storage of Deep-Frozen French Fries

The frying experiment was carried out in electrically heated laboratory minifriers using an intermittent frying procedure. Good quality potatoes (Bintje variety, size >50 mm) were steam-peeled, trimmed, cut into strips of 9.5 × 9.5 mm and washed with water to remove adhering starch. The minifriers each were filled with 10 l of one of the frying oils (fats).

Over a period of three days, 30 batches each of 500 g potato strips per day were prefried for one min at 160 C. After heating the frying oil in the morning to about 160-170 C, all 30 batches were prefried within a period of 90-105 min. Heating of the frying medium was continued for a total of eight hr at a temperature varying between 140 and 180 C. Each day after frying a 100-ml sample of oil was taken for analysis, the remaining oil was then filtered and 600 ml fresh oil added to compensate for losses through sampling and prefried french fries.

Immediately after being removed from the frying oil the prefried french fries were cooled with ambient air at a temperature of about 23 C until the fat solidified. After about 12 min the temperature of the french fries was 24 C. They were then frozen in an airstream which had a temperature of about −30 C; they reached a temperature of −20 C in 18 min and −30 C in 28 min.

The deep-frozen french fries, processed each day, were packed in 2 kg polyethylene bags obtained from a french fry factory and stored in a deep-freezer at −18 C to −20 C. After ¾, 3, 6, 9 and 12 months, 2-kg packs of french fries prefried in each of the oils were used for chemical analyses and sensory evaluation. Frozen french fries, obtained from a commercial production plant and packed in the same bags, also were stored and analyzed for comparison.

Analyses

For extraction of oil (fat), one kg of prefried french fries (from each 2 kg bag) was thawed and homogenized in a cutter. A 100 g subsample was homogenized (Ultraturrax) with 200 ml chloroform/methanol (1:1, v/v) for 30 sec. After addition of 100 ml chloroform, the sample was homogenized for a further 30 sec. The extract was filtered through filter paper and the residue homogenized again with 200 ml chloroform/methanol (2:1, v/v). After filtration, the extracts were pooled and shaken with 150 ml of aqueous $MgCl_2$ (0.05 mol/l). The chloroform phase was then dried with anhydrous Na_2SO_4 and filtered, and the solvent removed by evaporation in a rotary evaporator.

Free fatty acid content (FFA, acidity expressed as oleic acid), peroxide, iodine and p-anisidine value were determined according to standardized methods (5). The p-anisidine values were determined by CIVO-Institutes TNO.

Polar components (PC), which include polar substances present in fresh oil (mono- and diglycerides, free fatty acids) and polar products formed during frying and heating, were analyzed according to Guhr et al. (6), using silicic acid (Mallinckrodt, USA; 100 mesh).

The fatty acid composition (% peak area) was determined by gas liquid chromatography (GLC). Each sample was esterified by transesterification (7), and the methyl esters of the fatty acids were separated using a Hewlett-Packard 5700 gas chromatograph fitted with a flame ionization detector and a stainless steel column (6 ft, 1/8 inch) packed with 10% ethylene glycol adipate (EGA) on 80-100 mesh Chromosorb WAW DMCS. The temperature of the column was held at 175 C, detector 250 C, and injection port 240 C. Nitrogen was used as carrier gas at a flow rate of 30 ml/min.

The concentrations of copper, iron and nickel were determined by flameless atomic absorption spectrophotometry at CIVO-Institutes TNO. Oil samples were diluted with xylene (1:1, w/v) and, where necessary, diluted further with refined soybean oil. The metals were analyzed on a Perkin-Elmer Model 5000 atomic abosrption spectrophotometer, provided with a HGA-500 graphite furnace. Copper was measured at 324.7 nm (slit 0.7 nm), iron at 248.8 nm (slit 0.2 nm) and nickel at 232.0 nm (slit 0.2 nm). Standard curves were made with metal standards (Conostan, Ponka City, Oklahoma).

Volatile aldehydes in stored french fries were determined by headspace gas chromatography. A subsample of 30 g thawed french fries was placed in a 300-ml serum flask, 2 ml internal standard solution (ethylbutyrate, 5 µg/ml) was added and the volume made up to 150 ml with boiling tap water. The screw cap was closed and the flask thoroughly shaken for one min. Then 2.5 ml headspace gas was injected into a Perkin Elmer 3 B gas chromatograph fitted with a flame ionization detector and a glass column (10 ft, ¼ inch) packed with 10% Fluorad FC-431 on Chromosorb WHP (100-200 mesh). The temperature program used was: 7 min 75 C, 75 to 100 C at 10/min. Aldehydes were quantified with an external standard solution containing 2-methylpropanal, 2/3-methylbutanal and hexanal aldehydes (5 µg/ml).

Moisture and oil contents of prefried french fries were determined as described by the European Association for Potato Research (EAPR) (8). Moisture content was determined by drying of a ground, well-mixed sample of 3-5 g to constant weight at 105 C after previous pre-drying of a 1 kg french fry sample for 15 hr at 60 C.

Another sample of pre-dried french fries (100 g) was extracted with petroleum ether in a Soxhlett apparatus for 3 hr to determine oil content.

Sensory evaluation of prefried and finish-fried french fries was carried out by a small panel of 4 to 5 members, each with more than 10 yr experience in evaluating french fries, working in joint sessions. Odor, flavor and texture were scored on a 6-point scale on the basis of an evaluation scheme according to Paulus et al. (9). This 6-point scale contains the following scores and quality values: 6 = very good; 5 = good; 4 = fair; 3 = below fair (borderline); 2 = poor, and 1 = bad.

The color of prefried french fries was evaluated by description such as graying and bleaching. After finish-frying, the color was compared with the USDA color standards for frozen french fried potatoes (Munsell Color Company Inc., Baltimore, Maryland) according to the method of EAPR (8). The sampling and preparation for the sensory evaluation was as follows. From a 2-kg bag half was thawed and evaluated for color and odor and the remainder was used for chemical analysis. About 500 g were finish-fried for 2 min, at 180 C in hydrogenated soybean fat (mp about 45 C) and immediately evaluated for color, flavor and texture.

RESULTS AND DISCUSSION

Before the frying experiments, the characteristics of fresh samples of the five hydrogenated oils were determined. Acidity, peroxides and p-anisidine values were low for all samples (Table I). The palm fat had a high initial concentration of polar components (5.9%) which includes products of both hydrolysis, such as free fatty acids and mono- and diglycerides, and of oxidation, such as oxygenated triglycerides and polymers. The high initial concentration of polar components in the palm fat probably was due to mono- and diglycerides formed in the crude palm oil before refining. The concentrations of iron and nickel were quite high in hydrogenated soybean fat 2 (>1 mg/kg) (Table I), and also the concentration of nickel in hydrogenated soybean fat 1. The fatty acid composition of each fresh sample is given in Table II. Only the soybean oil sample contained linoleic acid (C18:2) and even a trace of linolenic acid (C18:3). The four fat samples were hydrogenated until linoleic acid was no longer detectable.

The frying experiment was characterized by discontinuous or batch frying of french fries, with intermittent heating periods. In this way, deterioration of the quality of the frying oil is likely to occur sooner than in continuous frying employed in the french fry industry.

For the same reason the frying temperature was raised to 160 C even though in the french fry industry temperatures in the range of 130-140 C usually are used.

TABLE I

Free Fatty Acids (FFA), Peroxides (PO), p-anisidine Value (AV), Polar Components (PC), Iodine Value (IV) and Metals in Fresh Frying Oils (Fats)

Oil/fat	FFA (%)	PO (µ mol/g)	AV	PC (%)	IV (g/100 g)	Cu (mg/kg)	Fe (mg/kg)	Ni (mg/kg)
Hydrogenated soybean oil	0	0.7	1.6	2.1	94	<0.01	0.03	0.1
Hydrogenated soybean fat 1	0.04	0.7	0.1	1.1	58	<0.01	0.05	0.6
Hydrogenated soybean fat 2	0.04	0.9	0.5	1.3	64	<0.01	0.4	1.5
Hydrogenated soybean fat 3	0.03	0.3	0.2	1.1	57	<0.01	0.03	0.03
Hydrogenated palm fat	0.07	0.7	1.1	5.9	41	<0.01	0.1	0.15

TABLE II

Fatty Acid Composition of Fresh Frying Oils (Fats)

Oil/fat	Fatty acids (%) C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3
Hydrogenated soybean oil		tr[a]	10.3	3.3	60.9	25.4	tr[a]
Hydrogenated soybean fat 1	0.1	0.1	11.2	19.2	69.4		
Hydrogenated soybean fat 2		tr[a]	11.5	12.8	76.3		
Hydrogenated soybean fat 3		0.5	10.4	17.6	71.5		
Hydrogenated palm fat	0.2	1.2	44.1	7.0	47.9		

[a]tr = trace < 0.05%.

TABLE III

Effect of Frying and Heating on Free Fatty Acids (FFA), Peroxides (PO) and Polar Components (PC) of Frying Oils (Fats) (Mean for 3 Frying Days)[a]

Oil/fat	FFA (%)	PO (μ mol/g)	PC (%)
Hydrogenated soybean oil	0.03[b]	3.0[b]	4.7[b]
Hydrogenated soybean fat 1	0.08[c]	7.0[c]	4.3[b]
Hydrogenated soybean fat 2	0.08[c]	3.7[b]	2.1[c]
Hydrogenated soybean fat 3	0.04[b]	4.7[bc]	2.2[c]
Hydrogenated palm fat	0.18[d]	3.1[b]	6.5[d]

[a]Figures with different letters differ significantly at the 5% level by the Least Significant Difference method.

Hydrolytic and oxidative changes which occurred in the frying oils during the frying experiment are given in Table III. For comparison, analyses of a fat sample from an industrial cooker for prefrying french fries were carried out. This fat sample was taken when the commercial deep-frozen french fries, which were included in the storage experiment, were being produced (see Experimental Procedures). This industrial frying fat sample was hydrogenated palm fat (C12:0, 1.0%; C14:0, 1.1%; C16:0, 40.2%; C18:0, 12.3%; C18:1, 44.5%; C18:2, 0.9%), with a FFA content of 0.16%, a peroxide value of 1.8 μmol/g and 8.1% polar components. The data presented in Table III show some differences between the five frying oils in the course of the frying experiment. The hydrogenated palm fat was most liable to hydrolysis, but this fat also had the highest initial FFA-concentration (Table I). The partly hydrogenated soybean oil, still containing 25% linoleic acid, and soybean fat 1 underwent more extensive oxidation than the other samples, as can be seen from the concentration of polar components (Tables I and III). The increase in polar components in the hydrogenated palm fat sample during frying was the lowest (0.7%). The high concentration of polar components in the palm fat from the industrial cooker may be explained as mentioned earlier by the high value in the fresh hydrogenated palm fat sample (Table I). The results of the frying experiment indicate that the five frying oils, both hydrogenated soybean and palm, were quite stable during three days of intermittent frying and heating. Hydrolytic and oxidative changes were of a comparable magnitude as during industrial frying. The significance of peroxide value, however, is doubtful, because of thermal breakdown of peroxides initially formed at the temperature of deep fat frying (10). The fat and moisture contents of prefried french fries produced in the laboratory frying experiment were similar to those of the commercial prefried product included in the one-year storage experiment. Fat contents were within a narrow range of 5.1-5.5% for laboratory fries and 5.1% for commercial fries; moisture contents were within the range 67.2-69.2% for laboratory fries and were 67.0% for commercial fries.

Chemical and sensory data, obtained during the storage of deep-frozen french fries, was pooled from each of the frying/heating days because an effect of the latter was negligible (Tables IV-VIII). Data of commercial industrial deep-frozen french fries is shown in Table IX for comparison. During the one-year storage period at −18 to −20 C, acidity and peroxide values of the oil/fat phase of deep-frozen prefried french fries remained low and constant (Tables IV, V and IX). Therefore, significant hydrolytic and oxidative changes during the storage period could not be observed. French fries prepared in partly hydrogenated soybean oil had a significantly lower FFA content than the other samples.

Those prepared in hydrogenated palm fat contained significantly more FFA (Table IV). The concentration of hexanal, the volatile oxidation product of linoleic acid and

TABLE IV

Changes in Free Fatty Acid Concentration (FFA) in the Oil (Fat) Phase of Deep-Frozen French Fries (Mean for 3 Frying Days)[a]

Oil/fat	FFA % Storage period (months) ¾	3	6	9	12
Hydrogenated soybean oil	0.13[bc]	0.15[bcd]	0.17[cde]	0.11[b]	0.18[def]
Hydrogenated soybean fat 1	0.23[ghi]	0.23[ghi]	0.25[i]	0.20[efgh]	0.23[ghi]
Hydrogenated soybean fat 2	0.23[ghi]	0.22[fghi]	0.24[hi]	0.19[defg]	0.22[fghi]
Hydrogenated soybean fat 3	0.23[ghi]	0.20[efgh]	0.18[def]	0.16[cde]	0.23[ghi]
Hydrogenated palm fat	0.34[kl]	0.33[kl]	0.37[l]	0.31[k]	0.34[kl]

[a]Figures with different letters vertically or horizontally, differ significantly at the 5% level by the Least Significant Difference method.

TABLE V

Changes in Peroxide Value in the Oil (Fat) Phase of Deep-Frozen French Fries (Mean for 3 Frying Days)[a]

Oil/fat	PO (μ mol/g) storage period (months) ¾	3	6	9	12
Hydrogenated soybean oil	1.0[bc]	1.5[bcdefg]	1.2[bcd]	1.3[bcde]	1.2[bcd]
Hydrogenated soybean fat 1	2.2[efgh]	2.5[h]	2.4[gh]	2.2[efgh]	2.3[fgh]
Hydrogenated soybean fat 2	1.6[bcdefgh]	2.0[defgh]	1.5[bcdefg]	1.1[bcd]	1.8[cdefgh]
Hydrogenated soybean fat 3	1.8[cdefgh]	2.0[defgh]	1.9[cdefgh]	2.0[defgh]	1.7[cdefgh]
Hydrogenated palm fat	1.0[bc]	1.3[bcde]	1.3[bcde]	1.3[bcde]	1.0[bc]

[a]See Table IV.

TABLE VI

Changes in Hexanal Concentration in Deep-Frozen French Fries (Mean for 3 Frying Days)[a]

Oil/fat used for prefrying of french fries	Hexanal (μ g/g) storage period (months) ¾	3	6	9	12
Hydrogenated soybean oil	0.07[bcd]	<0.01	0.02[b]	<0.01	0.02[b]
Hydrogenated soybean fat 1	0.02[b]	0.03[b]	0.03[b]	<0.01	0.01[b]
Hydrogenated soybean fat 2	0.06[bcd]	<0.01	0.02[b]	<0.01	0.05[bcd]
Hydrogenated soybean fat 3	0.05[bcd]	0.01[b]	0.09[bcde]	<0.01	0.04[bc]
Hydrogenated palm fat	0.17[e]	0.09[bcde]	0.13[de]	0.17[e]	0.12[cde]

[a]See Table IV.

TABLE VII

Mean Odor Score of Thawed Prefried French Fries (Mean for 3 Frying Days)[a]

Oil/fat used for prefrying french fries	Odor score Storage period (months) ¾	3	6	9	12
Hydrogenated soybean oil	6.0[h]	5.0[efg]	4.3[cd]	3.0[b]	3.0[b]
Hydrogenated soybean fat 1	5.0[efg]	6.0[h]	5.7[gh]	5.3[fgh]	3.7[bc]
Hydrogenated soybean fat 2	6.0[h]	6.0[h]	6.0[h]	5.7[gh]	5.0[efg]
Hydrogenated soybean fat 3	6.0[h]	6.0[h]	5.3[fgh]	4.7[def]	4.7[def]
Hydrogenated palm fat	6.0[h]	6.0[h]	5.0[efg]	5.7[gh]	5.3[fgh]

[a]See Table IV.

TABLE VIII

Mean Flavor Score of Finish-Fried French Fries (Mean for 3 Frying Days)[a]

Oil/fat used for prefrying french fries	Flavor score Storage period (months) ¾	3	6	9	12
Hydrogenated soybean oil	5.0[ef]	5.0[ef]	4.3[cde]	4.0[cd]	3.7[bc]
Hydrogenated soybean fat 1	3.0[b]	4.0[cd]	4.3[cde]	3.0[b]	4.0[cd]
Hydrogenated soybean fat 2	5.0[ef]	6.0[g]	4.0[cd]	3.7[bc]	4.3[cde]
Hydrogenated soybean fat 3	5.0[ef]	5.7[fg]	4.7[de]	4.3[cde]	4.3[cde]
Hydrogenated palm fat	4.3[cde]	4.0[cd]	4.0[cd]	4.7[de]	4.0[cd]

[a]See Table IV.

TABLE IX

Changes in Chemical and Sensory Characteristics During Storage of Commercial Deep-Frozen French Fries

Characteristic	Storage period (months)				
	¾	3	6	9	12
FFA (%)[a]	0.34	0.33	0.32	0.29	0.34
PO (μ mol/g)[a]	1.2	1.2	1.5	0.7	1.2
Hexanal (μg/g)	<0.01	0.07	0.18	0.14	0.08
Odor[b]	6.0	6.0	5.0	5.0	6.0
Flavor[c]	6.0	6.0	4.0	4.0	4.0

[a]Determined in fat phase.
[b]Odor of thawed prefried product.
[c]Flavor of finish-fried product.

a measure for rancidity (11), also remained low during storage (Tables VI and IX). The highest concentrations of hexanal were found in french fries prepared with hydrogenated palm fat. The presence of low levels of hexanal and the absence of detectable amounts of linoleic acid apart from that in partly hydrogenated soybean oil (Table II) seem contradictory. However, the sensitivity of hexanal analysis is about 1000 times higher than that of fatty acid analysis, and the potato itself contains polar lipids, which are very high in linoleic acid (12).

The fact that hexanal concentration was also low in french fries prefried in partly hydrogenated soybean oil particularly suggests oxidative stability during storage of all six products, regardless of whether they were laboratory or commercial fries and prefried in hydrogenated soybean or palm oil. The concentration of other aldehydres, methylpropanal and -butanal which are Strecker-degradation products, also was low and constant during storage.

As odor and flavor were more relevant to this study, color and texture scores are not presented. During one-year storage at −18 to −20 C, all prefried french fry samples underwent some degree of bleaching and gray discoloration, apart from the fries prefried in partly hydrogenates soybean oil which kept their yellow color after thawing. During prolonged storage, finish-fried french fries were perceived as being somewhat darker.

Texture of all the finish-fried french fries was considered to be constant and acceptable during the storage period. Odor changes in thawed, prefried deep-frozen french fries may especially indicate deterioration in the quality of the stored product. The reason is that at finish-frying the influence of this frying operation and the addition of frying fat may dominate quality changes in prefried products. There was a significant decrease of odor score for all french fries prefried in hydrogenated soybean oils (Table VII).

At the end of the one-yr storage period (12 mo), the odor scores for fries prepared with partly hydrogenated soybean oil and with soybean fat 1 were significantly lower. This result seems in line with the more extensive oxidation of these frying oils during frying and heating (Table III).

The low odor score for fries prepared with partly hydrogenated soybean oil was ascribed by the panel to an oily off-flavor, different from the more neutral flavor of french fries prefried in hydrogenated fats.

After finish-frying, the french fries prefried in hydrogenated soybean fat 1 and in hydrogenated palm fat were given quite low initial flavor scores (¾ and 3 months) (Table VIII), ascribed to an unspecified fat off-flavor. As a result of the decrease in scores with increasing staleness, that is loss of fresh flavor, all samples were given similar scores for the one-yr storage period (12 mo) (Tables VIII and IX).

Comparison of the results of odor and flavor tests makes clear that the changes of odor scores during the storage period express quality deterioration more obviously than the changes of flavor scores of the finish-fried product (Tables VII and VIII).

The odor (Tables VII and IX) and flavor scores for all french fries (Tables VIII and IX) never fell below the limit of acceptability (score 3) during the one-yr storage period. This means that all samples had a shelf-life of at least one year at −18 to −20 C, regardless of the frying medium used. The results of the sensory evaluation of stored prefried deep-frozen french fries support those of the chemical analyses that both hydrogenated soybean and palm oils are suitable for prefrying of deep-frozen french fries. This includes the partly hydrogenated soybean oil and the hydrogenated soybean fat 3 produced by CIVO-Technology TNO. Thus, it would seem that hydrogenated soybean oil (fat) is a suitable alternative for frying fats used until now in the french fry industry.

ACKNOWLEDGMENT

R. Leysen (American Soybean Association, Brussels) and J.T.L. Ong (Institute CIVO-Technology, Zeist) provided advice and cooperation.

REFERENCES

1. Ong, J.T.L., Voedingsmiddelentechnol. 15(24):18 (1982).
2. Ong, J.T.L., Proc. 2nd ASA Symp. on Soybean Processing, Brussels, 1981.
3. Erickson, D.R., JAOCS 60:303A (1983).
4. Keijbets, M.J.H., JAOCS 60:424A (1983).
5. IUPAC, 1979. Standard methods for the analysis of oils, fats and derivates. 6th Edition. Pergamon Press, Oxford.
6. Guhr, G., Ch. Gertz, J. Waibel and M. Arens, Fette, Seifen, Anstrichm. 83:373 (1981).
7. Peers, K.E., and P.A.T. Swoboda, J. Sci. Fd. Agric. 30:876 (1979).
8. EAPR, Methods of Assessment for Potatoes and Potato Products, Techn. Secretary: c/o IBVL, Wageningen, The Netherlands.
9. Paulus, K., R. Zacharias, L. Robinson and H. Geidel, Lebensm.-Wiss. u.-Technol. 12:52 (1979).
10. Peers, K.E., and P.A.T. Swoboda, J. Sci. Fd. Agric. 33:389 (1982).
11. Fritsch, C.W., and J.A. Gale, JAOCS 54:225 (1977).
12. Gaillard, T., J. Sci. Fd. Agric. 24:617 (1973).

[Received May 18, 1984]