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Chemical and Sensory Characteristics of Products Fried in High-Oleic, Low-Linolenic Rapeseed Oil

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Abstract The effects of frying Berlin doughnuts and potato crisps in high-oleic, low-linolenic (HOLL) rapeseed oil were compared to other commonly used oils (i.e., palm olein, high-oleic sunflower oil, or partially hydrogenated oils). The chemical parameters characterizing the oxidative state of the products fried in HOLL were comparable to products being fried in other commonly used oils. The sensory characteristics of potato crisps fried in HOLL rapeseed oil were satisfactory and comparable to products fried in the other oils. Potato crisps were stable under nitrogen atmosphere for 20 weeks as measured by sensory quality scores. However, a storage time of 16 weeks was achieved for products stored under normal atmosphere. The suitability of HOLL rapeseed oil to improve the storage stability of Berlin doughnuts was limited. The sensory quality decreased during storage due to the development of abnormal taste and smell. Changes in the sensory quality were comparable to the results of the partially hydrogenated oils but worse for products fried in palm olein. Nevertheless, HOLL was a good alternative to partially hydrogenated oils as a frying medium.

Keywords Berlin doughnuts · Deep-fat frying · Food quality · High-oleic, low-linolenic rapeseed oil · Potato crisps

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Introduction

Deep-fat frying is one of the most popular methods for the preparation of food in the world because it is fast and results in tasty products with a characteristic aroma appreciated by the consumer. Frying is used especially for the production of fast foods, e.g., for the preparation of French fries and snack foods such as potato crisps.

The choice of the frying medium for industrial production of snack food depends on several factors. From an economical point of view, availability and price are very important because the frying medium costs are an important factor for the calculation of the total production costs. Additionally, the frying medium should be stable against oxidation during processing and should not diminish the shelf life of the fried product. This is especially important for snacks and convenience foods such as potato crisps or Berlin doughnuts. Furthermore, an exchange of water and oil between the fried food and frying medium takes place resulting in aroma and flavor development of the fried food. If the frying oil has an off-flavor and aroma, the final product will also be of poor quality.

Recently, nutritional and physiological aspects of foods with undesirable lipids have been scrutinized, especially *trans*- and saturated fatty acids in commonly used frying media. A strong correlation between the intake of *trans*-fatty acids and the risk of coronary heart diseases has been identified [1, 2]. *Trans*-fatty acids increase the triacylglyceride and LDL levels and decrease HDL level. Thus, the FDA and other organizations recommend a maximum *trans*-fatty acid intake of 1% [3–5].

The main source for *trans*-fatty acids is partially hydrogenated fat. Stender et al. [6] reported that the content of *trans*-fatty acids differed widely in standardized meals from a well-known fast-food restaurant obtained from different countries all over the world. Although it was the same product, the content of *trans*-fatty acids was between 0.5% in Denmark and 11% in the U.S.A. The differences in *trans*-fatty acids are likely due to oil sources used during frying. A nearly complete exchange of the initial oil in the raw material occurs during frying. Thus, the product ultimately takes on the fatty acid composition of the frying oil.

There are several possibilities available to reduce the content of *trans*-fatty acids in products [7–12]. The first one is a combination of hydrogenation, interesterification, and fractionation, which allows the preparation of oils that have the required properties, but that are low in *trans*-fatty acids. Liquid oils may be fully hydrogenated before being further processed, resulting in *trans*-fatty acid contents below 1%. A disadvantage is that the content of saturated fatty acids in the resulting product is relatively high. Another alternative is the use of tropical oils (e.g., palm oils, palm kernel oil, and coconut oil) and fractionated tropical oils, but again a higher content of saturated fatty acids in the final product results.

The replacement of fats and oils high in *trans*- or saturated fatty acids with vegetable oils naturally high in monounsaturated fatty acids and low in saturated, polyunsaturated, and *trans*-fatty acids is a possible solution. This type of oil is characterized by a high nutritional value as well as by a high oxidative stability making it suitable for applications where high temperature is used. Today, oleic acid is of a certain importance from a nutritional point of view because this monounsaturated fatty acid lowers LDL, while increasing HDL [13, 14].

High amounts of α-linolenic acid in conventional rapeseed oil seem to be responsible for the unpleasant room-odor during deep-fat frying, characterized by a fishy and painty smell and evaluated during frying by a group of panelists [15]. The "room-odor test" allows an evaluation and a comparison in confined conditions of odors from two frying baths during cooking of potatoes. Odors are described through five characteristics with a scale from weak to strong: fruity, burnt, acrid, painty, and fishy. Carré et al. [15] reported that a content of more than 1.1% α-linolenic acid resulted in significantly higher intensity for fishy and painty odors in frying applications.

The frying performance of high-oleic, low-linolenic (HOLL) rapeseed oil was comparable or better than the frying performance of partially hydrogenated rapeseed oil or palm olein [16–18]. Both the chemical characteristic values and the sensory evaluation of the products fried in HOLL rapeseed oil were comparable to commonly used frying oils. The results of the frying studies showed that HOLL rapeseed oil is a good compromise between technological and nutritional demands. The oil is low in saturated fatty acids, contains no *trans*-fatty acids, has a high amount of oleic acid and a low amount of linolenic acid, has a high frying stability, and produces a product with good flavor.

Data are available about the effect of high-oleic sunflower oils on the quality of fried food during storage [19–22], but no data are available for HOLL rapeseed oil. It is known that potato crisps fried in conventional rapeseed oil had the best flavor directly after frying in comparison to other oils. However, product quality greatly diminished during storage while product quality remained stable for products fried in palm and peanut oil over a period of 16 weeks [23]. That means that frying in conventional rapeseed oil results in tasty food that consists of healthy oil, but during storage the product becomes inedible in a very short time.

Therefore, the aim of the present investigation was to compare the storage stability of potato crisps and Berlin doughnuts fried in HOLL rapeseed oil, high-oleic sunflower oil, palm olein, or partially hydrogenated fat by monitoring the degradation products and the sensory quality of the food during storage.

Materials and Methods

Samples

Six different oils were used for the investigation. HOLL rapeseed oil (Omega 9 Canola Oil—NATREON) (Dow AgroSciences, Indianapolis, IN, USA), partially hydrogenated fat [PHF (high-oleic, low-*trans* (HOLT); high-palmitic, low-*trans* (HPLT), high-*trans* (HT)] (composition see Table 3), palmolein (PO), and high-oleic sunflower oil (HOSO) were used for deep fat frying of potato crisps and Berlin doughnuts. Differences between the different partially hydrogenated fats are given in Table 3.

Reagents

n-Heptane, diethyl ether, ethanol, iso-octane, petroleum benzene, and tert.-butyl methyl ether were of analytical grade. The quality of tetrahydrofuran was puriss., absolute. All solvents were acquired from Merck (Darmstadt, Germany).

Frying Procedure

Potato Crisps

Potato crisps were produced on a laboratory scale with cultivar Lady Rosetta potatoes that were harvested in 2006 and stored at 8°C for 6 months including two applications of a sprout inhibitor (CIPC) (isopropyl-*N*-(3-chlorophenyl)-carbamate according to the manufacturer guideline.

Potato tubers were mechanically peeled (Flottwerk Type 16k, Rotenburg Fulda, Germany), sliced at 1.2 mm with an Urschel industrial slicer (model CC, modified; Urschel Laboratories, Valparaiso, IN, USA), rinsed with tap water to remove free starch, randomly divided into 150-g batches and fried for about 3 min at 175°C in a gastronomic-scale fryer to final moisture below 1.5%. HOLL, HOSO, PO, and PHF (HOLT) were used for frying.

All potato crisps were fried in the different oils within 4 h because the aim was to produce comparable product quality.

Fried crisps were packed in bags consisting of polyamide with a layer of polyethylene [PA/PEH 4/140 (Südpack Verpackungen, Ochsenhausen, Germany)] filled with normal atmosphere or pure nitrogen gas. The bags were stored at room temperature, and sensory testing was completed just after production and again at 4-week intervals over 24 weeks.

Berlin Doughnuts

Wheat dough for Berlin doughnuts was prepared according to the formula given in Table 1. The same fat was used in both the formulation and frying application. For example, when HOLL was used in the formula, it was also used during frying. After water addition, the dough was kneaded by a Diosna Spiral Mixer, Type SP 12 D (Osnabrück, Germany) for 1 min at the first speed and then for 7 min using the second speed. The temperature of the dough was 28 ± 1°C. Afterwards, the dough was proofed for 20 min at 32°C and 80% relative moisture in a climate-controlled test cabinet. About 1,500 g of the dough was separated into 30 dough pieces by a dough-dividing machine (Werner & Pfleiderer Lebensmitteltechnik, Type Rotamat F, Dinkelsbühl, Germany) and formed into round pieces. After 45 min at 32°C and 80% relative moisture, the surface of the dough pieces was dried by a ventilator for 2 min and then the pieces were fried for 8 min at 170 and 180°C, respectively, in the appropriate frying medium [HOLL, PO, PHF (HPLT), PHF (HT)]. Both temperatures are in use in industry. The frying medium was heated to frying temperature for 90 min before frying. After frying, excess frying medium was removed using a drip-off device. All Berlin doughnuts were from the same batch but were distributed into five different bags in portions of five pieces each. Then the portions were frozen by shock-cooling and stored at −18°C until further investigation at defined time intervals. By this procedure, it was possible to carry out the analytical investigation from different bags prepared and stored under comparable conditions.

Table 1 Composition of the dough for Berlin doughnuts

Consituents	Formula
Wheat flour, type 550	100 parts
Fat[a]	8 parts
Sugar	8 parts
Fresh bakers yeast	6 parts
Salt	1.5 parts
Fresh whole eggs	25 parts
Whole milk powder	6 parts
Water	35 parts

[a] Same fat as used for frying

Sensory Evaluation of the Products

Potato Crisps

The sensory profile was assessed by a panel of up to five trained panelists experienced in sensory assessment for the weighted characteristics: color (2×), texture (3×), taste and odor (5×) following the method of the German Agricultural Society, which is based on different DIN norms: DIN 10964:1996-02, DIN 10969:2001-05, and DIN 10975:2005-04 [24–26]. A quality score was calculated:

$$\text{Quality score} = \frac{(\text{Colour score} \times 2) + (\text{texture score} \times 3) + (\text{taste score} \times 5)}{10}.$$

Color of potato crisps was also measured by a Minolta Chromameter (CR 310) (Konica-Minolta, Langenhagen, Germany) using the CIE standard of lightness (L*) and coloration (a* and b*). A color score from 1 to 10 was derived from the data, with 1 = bad and 10 = very good.

Berlin Doughnuts

After frying, Berlin doughnuts were cooled for 2 h and sensory evaluation of a representative number of fresh Berlin doughnuts was performed by three trained panelists. The sensory profile of stored Berlin doughnuts was determined after a 3-h thawing at room temperature. The taste desciptors of the Berlin doughnuts were based on the criteria given in Table 2.

The method uses different DIN norms, DIN 10964:1996-02, DIN 10969:2001-05 and DIN 10975:2005-04 [24–26], and describes differences of the sample from the perfect doughnuts. Thus, the method considers only these differences in the assessment.

Table 2 Criteria for the assessment of the sensory quality of Berlin doughnuts

Criterion	Assessment
Appearance (surface)	Somewhat wrinkled, wrinkled, somewhat blistered, blistered, almost smooth, smooth
Curvature (surface)	Almost even, even, normal, somewhat concave, concave
Collar of the doughnut	Somewhat narrow, normal, somewhat broad
Brownness, color	Somewhat bright, bright, normal, somewhat dark, dark
Crumb color	Somewhat bright, bright, yellowish
Lift	Fluffy, slightly fluffy, somewhat dense, dense
Porosity (crumb)	Uneven, quite even, even
Bottom	Somewhat greasy, greasy, normal
Impact during chewing	Somewhat soft, soft, normal, somewhat hard, hard
Smell	Somewhat abnormal smell, abnormal smell, perfect
Taste	Somewhat abnormal taste, abnormal taste, perfect

Oligomer Triacylglycerides

The content of oligomer triacylglyerides was determined with gel-permeation chromatography using high-pressure liquid chromatography (HPLC) according to the AOCS method Cd 22-91 [27].

Peroxide Value (PV)

The peroxide value was determined following the DGF method C-VI 6a [28].

Anisidine Value

The anisidine value (AnV) was determined following the DGF method C-VI 6e [28].

Tocopherols

For the determination of vitamin E (tocopherols, tocotrienols, and plastochromanol-8), a solution of 250 mg oil in 25 mL *n*-heptane was measured by HPLC. The HPLC analysis was conducted using a Merck-Hitachi low-pressure gradient system, fitted with a L-6000 pump, a Merck-Hitachi F-1000 fluorescence spectrophotometer (detector wavelength for excitation 295 nm, for emission 330 nm), and a D-2500 integration system. Samples (20 µL) were injected by a Merck 655-A40 Autosampler onto a Diol phase HPLC column 25 cm × 4.6 mm ID (Merck, Darmstadt, Germany) using a flow rate of 1.3 mL/min. The mobile phase was heptane/tert. butyl methyl ether (99:1, v/v) [29]. The results were given as mg vitamin E/100 g oil.

Statistical Analysis

The required portions of potato crisps and Berlin doughnuts, respectively, were prepared within 4 h as one batch and stored. At the appropriate dates, each parameter was tested in triplicate with samples from different bags. This was not a complete replication of the experiment, but randomization of the selection of the raw material was a good compromise between expenditure with respect to time and raw material and reliability of the results.

Averages and standard deviations were calculated for the different parameters and frying media for each of the days tested. Student's *t*-test to evaluate the statistical significance for independent and variable interactions was performed with two-tailed *t*-tests at $P = 0.01$. The data were evaluated using a computer program (Statgraphics, Rockville, MD, USA).

Results and Discussion

Composition of the Fresh Oils

Table 3 shows the fatty acid and tocopherol composition of the fresh oils used in this frying experiment. HOLL rapeseed oil was characterized by a high amount of oleic acid, representing more than 70% of the total fatty acids, which is comparable to olive oil. The amount of saturated fatty acids and linoleic acid was comparable to conventional 00-rapeseed oil, which is low in glucosinolates and erucic acid, but the amount of α-linolenic acid has been drastically reduced as a result of appropriate conventional breeding programs.

Three different partially hydrogenated fats (PHF) were used. They differed in the fatty acid and tocopherol composition but also regarding different chemical and physical parameters. PHF (HOLT) was high in oleic acid (57.1%) and relatively low in *trans*-fatty acids (11.1%), PHF (HPLT) was high in palmitic acid (25.4%) and relatively low in *trans*-fatty acids (12.6%), and PHF (HT) was characterized by a high content of *trans*-fatty acids (24.8%).

Table 3 Physical and chemical data of fresh oils

	HOLL	PO	HOSO	PHF (HOLT)	PHF (HPLT)	PHF (HT)
Peroxide value (meq/kg)	2.2	2. 5	1.8	1.4	0.4	1.0
Anisidine value	1.2	0.5	1.5	4.6	0.8	3.6
Oxidative stability (h)	6.7	12.9	9.3	14.4	22.4	16.6
Oligom. trigly. (g/100 g)	0.4	0.2	0.2	0.6	0.3	0.6
Palmitic acid (%)	3.7	39.4	3.5	5.2	25.4	8.7
Stearic acid (%)	1.6	4.1	2.5	4.6	7.9	6.7
Oleic acid (%)	66.9	39.6	81.4	57.3	37.9	29.0
Linoleic acid (%)	16.1	10.8	7.1	4.6	0.1	0.1
Linolenic acid (%)	2.3	0.2	0.2	0.3	0.1	0.0
Trans-fatty acids (%)	0.7	0.4	0.6	11.1	12.6	24.8
Total content of tocoperols (mg/100 g)	44.4	59.7	42.0	38.9	33.6	19.3
α-Tocopherol (mg/100 g)	15.4	11.2	40.1	14.8	10.5	9.1
β-Tocopherol (mg/100 g)	0.2		1.1		0.1	0.4
γ-Tocopherol (mg/100 g)	24.2	0.1	0.4	18.8	10.9	8.9
δ-Tocopherol (mg/100 g)				0.5	0.3	0.4
Plastochromanol-8	3.9		0.3	4.3	2.5	0.4
α-Tocotrienol (mg/100 g)		19.6			3.3	0.1
β-Tocotrienol (mg/100 g)		1.4		0.2	0.7	
γ-Tocotrienol (mg/100 g)		21.5		0.4	3.9	0.1
δ-Tocotrienol (mg/100 g)		5.2			1.3	

HOLL High-oleic, low-linolenic rapeseed oil; *PHF* partially hydrogenated fat; *HOLT* high-oleic, low-*trans*; *HPLT* high-palmitic, low-*trans*; *HT* high-*trans*; *HOSO* high-oleic sunflower oil; *PO* palm olein

The composition of high-oleic sunflower oil (HOSO) had lower amounts of linoleic and α-linolenic acid compared to HOLL. Palmolein (PO) had a much higher amount of saturated fatty acids, with more than 30%, whereas the content of oleic acid was lower than the high oleic oils.

The oils had different total contents of tocopherols/tocotrienols and individual tocopherols/tocotrienols. HOLL rapeseed oil had the typical rapeseed oil tocopherol profile with α- and γ-tocopherol as main components. The main tocopherol/tocotrienol of HOSO was α-tocopherol, which accounted for 97% of the total. In the different PHFs, the content of tocopherols was lower in comparison to HOLL rapeseed oil, with α- and γ-tocopherol as the main components. PHF (HPLT) also contained tocotrienols. The main components of PO were tocotrienols, which accounted for about 80% of the total.

The chemical characteristics of the fresh oils were typical for refined edible oils. It can be assumed that PHF (HOLT) and PHF (HT) consisted of rapeseed oil while PHF (HPLT) also contained palm oil. The oils were low in peroxide and anisidine value as well as oligomer triacylglycerides. PHF had a high oxidative stability in the Rancimat test [(HOLT) 14.4 h, (HPLT) 22.4 h, (HT) 16.6 h], while the oxidative stability of HOLL rapeseed oil was only about 7 h.

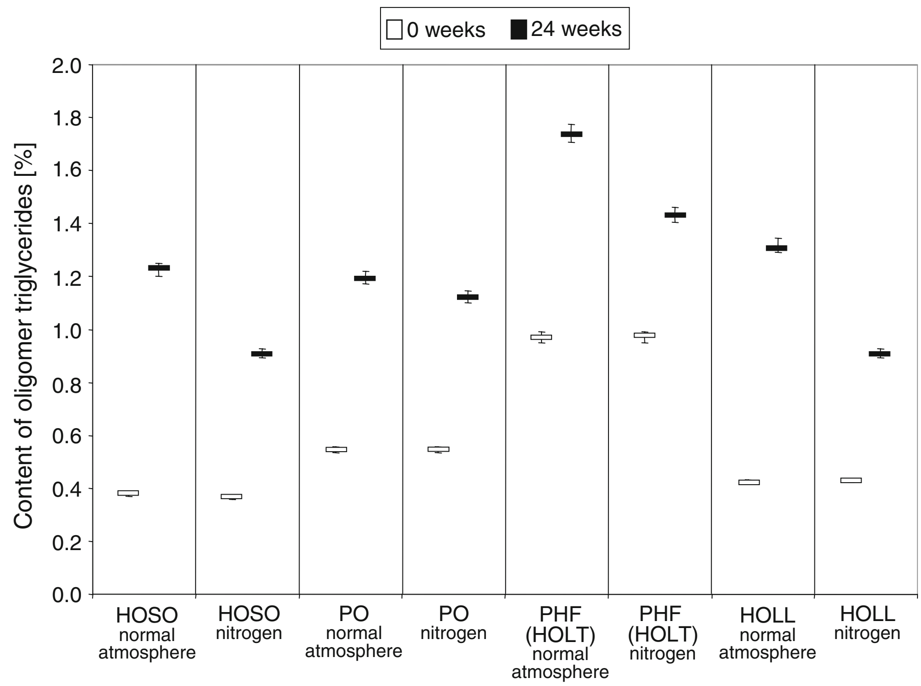
Oligomer Triacylglycerides

One chemical parameter used to verify the results of the sensory evaluation is the amount of oligomer triacylglycerides [30]. This is one of the most important methods for the assessment of frying oils. Therefore, in several European countries a maximum value of 12% is recommended for commercially used frying oils. The oils used in this study all had values less than 0.6% (Table 3).

The amount of oligomer triacylglycerides within 24 weeks of storage under nitrogen and normal atmosphere was very small (Fig. 1) for potato crisps. This increase ranged from 0.4 to 0.8% during storage under normal atmosphere and from 0.4 to 0.6% during storage under nitrogen. The highest amount of oligomer triacylglycerides was found for PHF (HOLT), with an amount of 1.8% after storage under normal atmosphere for 24 weeks due to the higher initial amount of oligomer triacylglycerides at the beginning of the storage experiment resulting from the processing. However the value was still far below the recommended limit.

This parameter can be used as an indicator of the history of the used frying medium, but during storage of the fried food only a small change was found. That means that the content of oligomer triacylglycerides is appropriate for the assessment of the oil quality after frying but not to evaluate

Fig. 1 Content of oligomer triacylglycerides in potato crisps during storage



the quality of potato crisps during storage. Although the products being fried in different frying media showed very low amounts of oligomer triacylglycerides, they were not suitable for human consumption after 24 weeks from a sensory point of view.

Comparing the results obtained for the different storage atmospheres shows that the content of oligomer triacylglycerides increased more slowly if samples were stored under nitrogen than for samples stored under normal atmosphere. For HOSO, HOLL, and PHF (HOLT), this result was statistically significant ($P = 0.01$), while for PO no difference ($P = 0.01$) was found for the oligomer triacylglycerides of potato crisps stored under normal atmosphere or nitrogen.

The oligomer triacylglycerides during storage of Berlin doughnuts were similar to potato crisps. For all products, only a slight increase in the content of oligomer triacylglycerides was found, and all samples remained far below the limit of 12% (results not shown). The highest content of oligomer triacylglycerides was found for PO and HOLL rapeseed oil with 1.7%. For samples being fried at 170°C, the absolute increase was only about 0.1% for HOLL rapeseed oil and 0.2% for PO; frying at 180°C resulted in an absolute increase of about 0.2 for PHF (HPLT) and 0.6% for HOLL rapeseed oil after storage for 12 weeks.

Totox Value

Often the peroxide value is useful to follow the oxidative deterioration of fats and oils. In the case of deep-fat frying, the use of this parameter is problematic because peroxides are destroyed by high temperature, and during cooling, new peroxides are formed [31]. Therefore, Fritsch [32] concluded that the determination of the peroxide value is not suitable for the assessment of frying oils. In contrast to the peroxide value, the anisidine value does not measure primary products of the oxidation process, but secondary decomposition products such as carbonyl compounds (aldehydes and ketones). The totox value is calculated as twice the peroxide value plus the anisidine value. Therefore the totox value describes the development of the primary and secondary degradation products during oxidation giving sufficient information about the oxidative state of a product.

A totox value of 30 has been suggested by industry and official authorities as a maximum limit. All samples of potato crisps stored under nitrogen came out below this value after 24 weeks of storage (Fig. 2). Samples stored under normal atmosphere had totox values that exceeded the limit during storage. For all samples stored under nitrogen, the totox value was comparable in the range between 26 (HOSO) and 30 (PO). Only the totox value of potato crisps fried in HOSO was significantly lower than the totox values of the other samples ($P = 0.01$). The differences between the different oils were a little higher for storage under normal atmosphere. These differences were statistically significant ($P = 0.01$) and ranged from 31 (HOSO) to 47 PHF (HOLT). The totox value for potato crisps fried in HOLL was the lowest just after preparation.

The situation was different for the storage of Berlin doughnuts. During storage for 12 weeks, only products fried in PHF (HT) at 170 and 180°C and HOLL rapeseed

Fig. 2 Totox value in potato crisps during storage

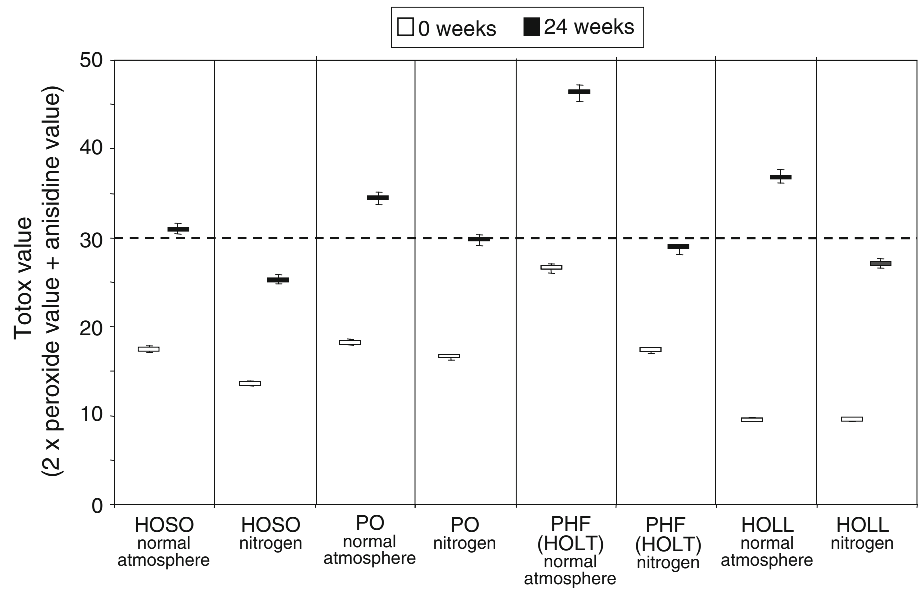
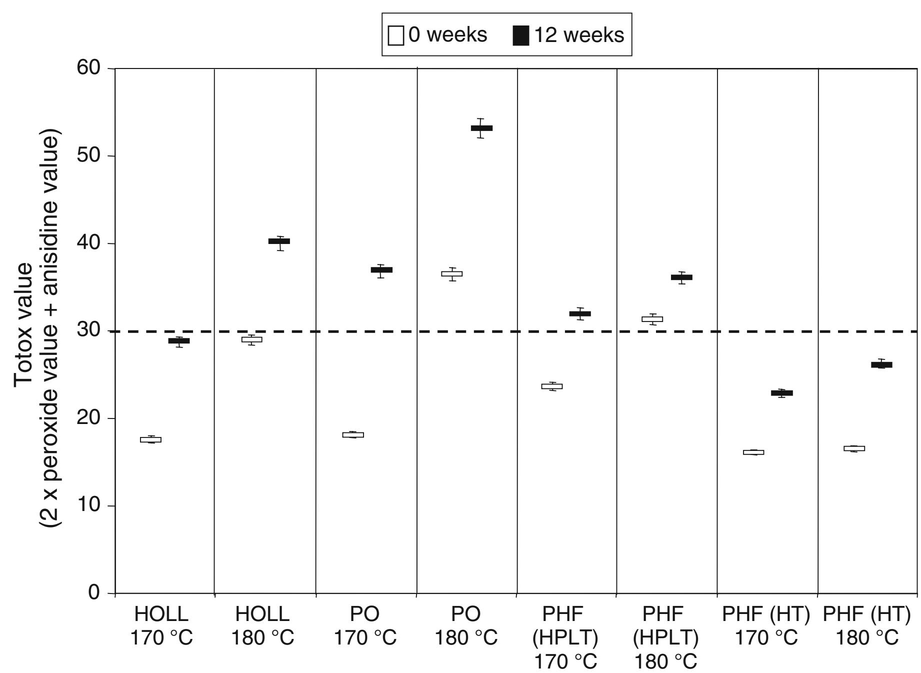


Fig. 3 Totox value in Berlin doughnuts during storage



oil at 170°C were below a limit of 30 for the totox value (Fig. 3). All other oils reached the limit in a very short time. In the case of PHF (HPLT) and PO used at 180°C, the limit was already exceeded directly after preparation of Berlin doughnuts. The result also shows the negative effect of a high frying temperature. While the increase of the totox value was moderate when using a temperature of 170°C, the increase was more pronounced at 180°C because of a higher initial formation of oxidation products during processing.

In contrast to the oligomer triacylglycerides, the totox value is a more suitable indicator of the deterioration of the products during storage. After heating the oil, the formation of deterioration products continues in the fried food depending on the storage conditions and the food.

Tocopherols/Tocotrienols

Tocopherols/tocotrienols are characterized by a high susceptibility to autoxidation at high temperatures. The highest amount of tocopherols/tocotrienols was in the potato crisps fried in PO, while the concentration in the products fried in other oils was significantly lower ($P = 0.01$), but quite similar to each other. After 24 weeks of storage of

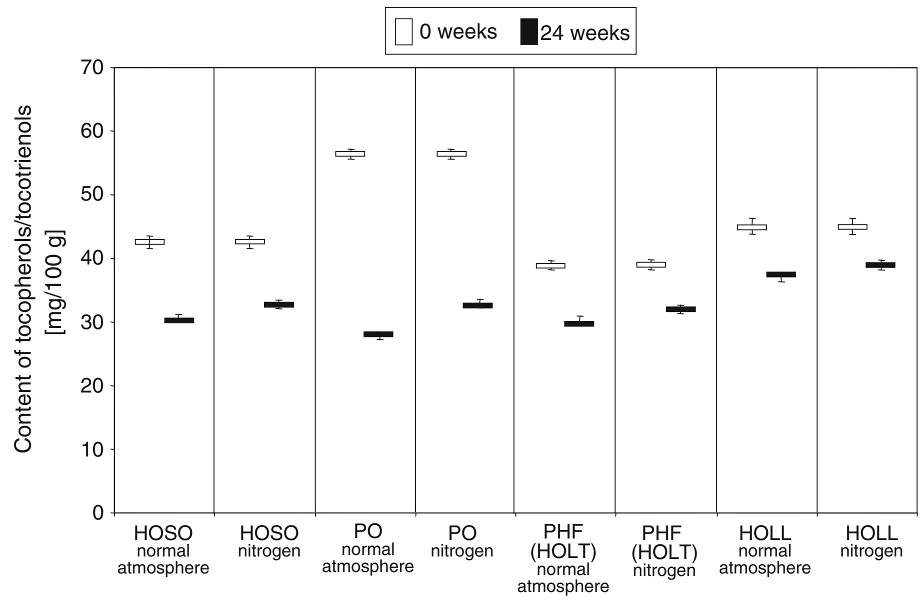


Fig. 4 Content of tocopherols/tocotrienols in potato crisps during storage

potato crisps, the highest degradation of tocopherols/tocotrienols was found for products being fried in PO. The reduction came to about 50%, while the rate of degradation in products being fried in the other oils came to about 25% (Fig. 4).

One reason for the faster degradation of tocopherols/tocotrienols in PO could be that this oil contained mainly tocotrienols. They have a higher antioxidant activity than tocopherols, resulting in a faster degradation during oxidation reactions [33].

Products stored over a period of 24 weeks after being fried in HOLL rapeseed oil still contained the highest amount of tocopherols/tocotrienols. Again, a positive effect of a nitrogen atmosphere was found. All samples stored under nitrogen contained slightly higher concentrations of tocopherols/tocotrienols, although the difference was only statistically significant ($P = 0.01$) for PO stored under normal atmosphere and nitrogen.

Depending on the composition, a certain degradation of the tocopherols/tocotrienols was found during storage of potato crisps. After 24 weeks of storage, however, about 30 mg/100 g tocopherols/tocotrienols were detectable in all the products.

No degradation of tocopherols/tocotrienols took place (results not shown) in Berlin doughnuts stored over 12 weeks at −18°C.

Sensory Assessment

The most important parameter for the consumer is the sensory evaluation of the product. The sensory evaluation of the potato crisps' appearance, consistency, smell, and taste were tested by a trained sensory panel and the results combined to give a weighted quality score in the range from 0 to 5. The results show that the sensory quality of potato crisps being fried in HOLL rapeseed oil was comparable to potato crisps being fried in PO and PHF (HOLT) with no significant difference between the different oils ($P = 0.01$) (Fig. 5a) when the samples were stored under normal atmosphere. Under normal atmosphere, the samples

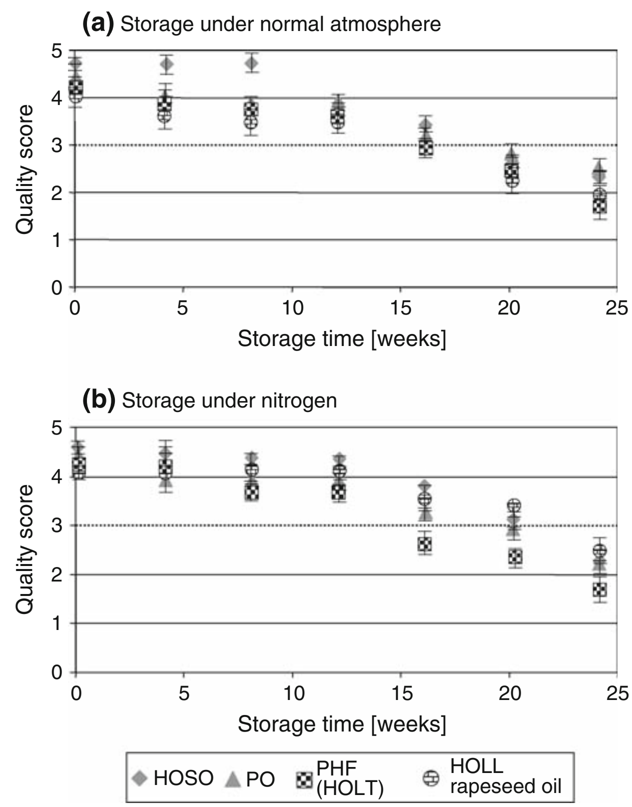


Fig. 5 Result of the sensory evaluation of potato crisps stored under normal (**a**) and nitrogen (**b**) atmospheres

Table 4 Result of the sensory evaluation of Berlin doughnuts

	Taste		Smell	
	Fresh	3 months	Fresh	3 months
Frying medium (frying temperture: 170°C)				
High-oleic, low-linolenic rapessed oil	Perfect	Slight oily, abnormal taste	Normal	Slight abnormal smell
Palm olein	Perfect	Slight oily	Neutral	Normal
Partially hydrogenated fat (HPLT)	Perfect	Abnormal taste	Neutral	Abnormal smell
Partially hydrogenated fat (HT)	Perfect	Sight abnormal taste	Neutral	Slight abnormal smell
Frying medium (frying temperture: 180°C)				
High-oleic, low linolenic rapeseed oil	Perfect	Abnormal taste	Slight abnormal smell	Abnormal smell
Palm olein	Perfect	Normal	Neutral	Normal
Partially hydrogenated fat (HPLT)	Perfect	Abnormal taste	Neutral	Abnormal smell
Partially hydrogenated fat (HT)	Perfect	Slight abnormal taste	Neutral	Slight abnormal smell

were storable for 16 weeks before the quality score fell below 3, which is the limit for product acceptability. The quality score of potato crisps fried in HOSO was significantly better than for products fried in the other oils in the first 8 weeks of storage. After 8 weeks of storage, there was no significant difference between the quality score of all the samples ($P = 0.01$). The storage time was extended up to 20 weeks for HOSO, HOLL rapeseed oil, and PO, for samples stored under nitrogen (Fig. 5b). However, sensory scores of samples fried in PHF (HOLT) fell below a score of 3 at the 16-week test. Again, no significant difference was found between samples fried in HOSO, HOLL, and PO after 20 weeks of storage ($P = 0.01$).

At the beginning of the storage experiment, the taste and smell of all fresh Berlin doughnuts was agreeable, independent of the oil used for frying and the frying temperature (Table 4). Only the use of HOLL rapeseed oil at 180°C resulted in a slight abnormal smell, which was different from high-quality Berlin doughnuts. At 170°C, this negative smell was not noticeable. During storage over a period of 12 weeks, the taste and smell of nearly all products changed significantly. While products being fried in PHF (HPLT) showed an abnormal taste and smell after 12 weeks of storage, products being fried in PHF (HT) only had a slight abnormal taste. The best results were obtained with palm olein. After 12 weeks of storage, no deterioration of the sensory characteristics was detected. HOLL rapeseed oil had a slight abnormal smell after 12 weeks for products fried at 170°C. The products fried at 180°C were inedible after 12 weeks.

Conclusions

It can be concluded that HOLL rapeseed oil is a good alternative to other commonly used oils for deep frying. The storage stability and suitability of HOLL rapeseed oil depends on the product being fried and stored, but in general the use of HOLL rapeseed oil resulted in comparable or better results than the commonly used oils. Additionally, the applicability of HOLL rapeseed oil has some advantages in terms of nutritional aspects, but also with regard to the sensory quality of the oil and the products. For nutritional reasons such as, a low amount of saturated and no *trans*-fatty acids, a high amount of oleic acid comparable to olive oil and also the almost optimal ratio of 18:2/18:3 of 7.5:1 the use of HOLL rapeseed oil in the preparation of deep-fried food is recommended.

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