Technical

Evaluation of Peanut and Cottonseed Oils for Deep Frying

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ABSTRACT

A comparative study of cottonseed and peanut oils for frying of potato chips was undertaken. Industrial scale frying was conducted for 5 days with cottonseed and 5 days with peanut oil and frying oils and chips were sampled twice a day. Frying oils and oils extracted from stored chips were analyzed for ultraviolet absorption (A_{232} and A_{268}), peroxide and acid values. Tocopherol and tertiary butylhydroquinone levels were determined by high performance liquid chromatography. Chips stored at room temperature for 12 weeks were organoleptically evaluated. During the first 20 hr frying the A_{232}, free acid and peroxide values of cottonseed oil increased rapidly, exceeding that of peanut oil, which increased moderately. For both oils, constant values were attained during the next 80 hr period, followed by moderate increases during the last 23 hr. Peanut frying oil lost 55% of its tocopherols and 54% of its tertiary butylhydroquinone during frying (103 hr), whereas cottonseed frying oil retained these compounds at the original levels. Tocopherols were also better retained in chips fried in cottonseed oil than in peanut oil. The fatty acid patterns of frying oils and oils extracted from chips did not show significant changes due to frying and storage, respectively. These results, therefore, suggest that cottonseed oil is sufficiently stable to be used as a substitute for peanut oil in deep frying.

INTRODUCTION

Various vegetable oils are used for deep frying of food products. Apart from chemical composition, the price and availability are major considerations when selecting an oil. Before switching from one oil to another, it is advisable to have some comparative data on the behavior of the oil during deep frying.

In this study, cottonseed and peanut oils were compared on the basis of industrial-scale frying of potato chips. The quality of the frying oils was measured by ultraviolet (UV) absorption, peroxide and free acid values. Simultaneously, the natural (tocopherol) and synthetic (tertiary butylhydroquinone) antioxidant levels of the frying oils were monitored. The quality of the fresh and stored products were finally compared by sensory evaluation.

EXPERIMENTAL PROCEDURES

Materials

Refined cottonseed and peanut oils were obtained commercially and contained ca. 0.01% tertiary butylhydroquinone (TBHQ), supplied by Eastman Products (Kingsport, TN). Glycerol tripalmitate and fatty acid methyl esters were obtained from Nu-Chek-Prep (Elysian, MN). Potatoes were all of the same variety, supplied by one farm.

Methods

Industrial scale frying of potato chips was conducted for 5 days with peanut and 5 days with cottonseed oils by means of a Ferry Model 15 Continuous Chip Fryer. The oil capacity of the fryer was 2,500 kg and product yield 205 kg/hr. The frying temperature was 160 C (direct gas heaters) and the oil level was adjusted at intervals of 15-30 min to compensate for the loss in oil caused by the absorption by the potato chips (average oil uptake of 75 kg/hr).

Chips were only fried during the day shift and the gas heaters were therefore turned off overnight and switched on in the morning 1 hr before frying was begun. Frying oils and fried chips were sampled twice daily at 0900 hr and 1400 hr. Oil samples were stored in sealed bottles at 5 C whereas fried chips were salted and stored in sealed packets at room temperature.

Peroxide and acid values of the frying oils were determined according to the AOAC method (1) and UV absorption at 232 and 268 nm were determined (2) on a Gilford SP 800 instrument. Oils were dissolved in spectroscopic grade iso-octane (0.2% solutions, m/v) and the carbonyl absorption was compensated by using a similar solution of glycerol tripalmitate.

TABLE I

A_{232}, A_{268}, Peroxide and Free Acid Values of Peanut and Cottonseed Frying Oils

Oil	A_{232}	A_{268}	Peroxide (meq/kg)	Free acid (mg KOH/g)
Peanut (frying time, hr)				
0	0.59	0.55	0.8	0.16
2	0.59	0.54	1.2	0.16
7	0.96	0.65	1.0	0.22
26	1.03	0.61	1.1	0.28
31	1.01	0.62	1.0	0.28
50	1.24	0.60	1.2	0.30
55	1.08	0.58	1.0	0.32
74	1.08	0.56	1.3	0.32
79	1.16	0.58	1.3	0.32
98	1.41	0.62	1.7	0.32
103	1.29	0.54	1.7	0.38
Cottonseed (frying time, hr)				
0	0.78	0.70	0.7	0.2
2	1.20	1.05	1.3	0.26
7	1.42	1.08	1.4	0.40
26	1.76	1.09	1.3	0.44
31	1.75	1.11	1.4	0.40
50	1.84	1.06	1.3	0.44
55	1.79	1.05	1.3	0.40
74	1.87	1.09	1.3	0.48
79	1.70	1.08	1.4	0.44
98	1.96	1.07	1.5	0.47
103	1.82	1.07	1.6	0.40

Methylation of oils were done according to Van Wijngaarden (3) and gas chromatography conducted with a Varian 3700 instrument. The glass column (2 m x 2 mm) was packed with 5% DEGS on Chromosorb G; peak areas were integrated with a Hewlett-Packard 3352B data system.

Liquid chromatographic analysis of the tocopherols (4) and TBHQ (5) was conducted with a Varian 5000 pump and Farrand Mk 1 fluorescence detector. A Lichrosorb SI 60 (5μ) column (25 cm x 4 mm) was used and peak areas integrated with an HP 3352 B data system. Dioxane in *n*-hexane (4 + 96, v/v for tocopherols and 24 + 76, v/v for TBHQ) was used as mobile phase at a rate of 3 ml/min and 13.9 μl oil samples were directly injected.

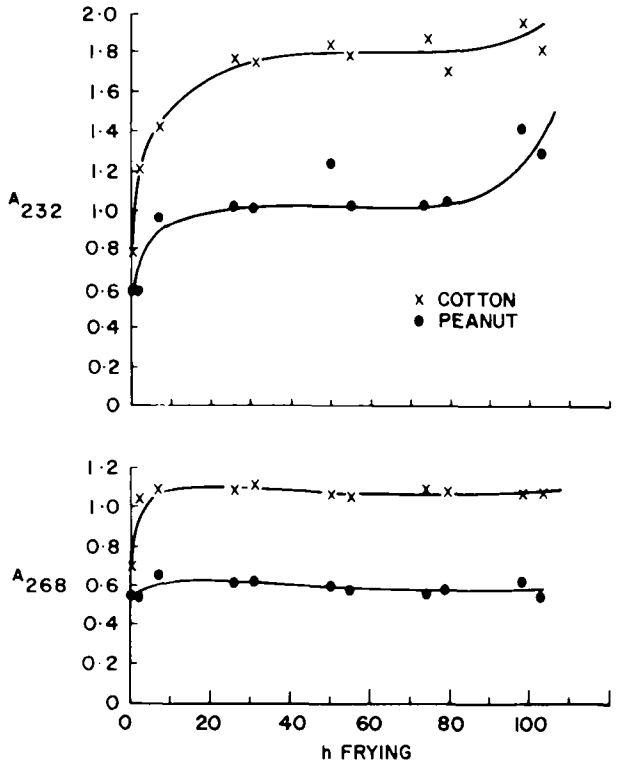

FIG. 1. A_{232} and A_{268} values of peanut and cottonseed oils during frying.

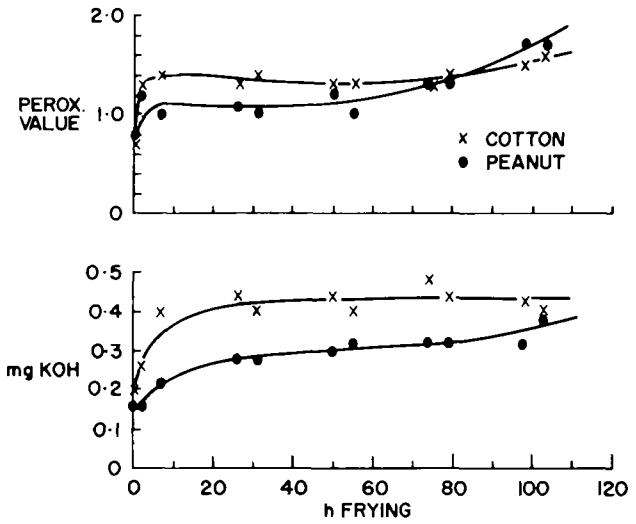

FIG. 2. Peroxide and free acid values of peanut and cottonseed oils as influenced by frying.

Taste and flavor of the stored chips were evaluated by a 10-member panel for a period of 12 weeks after frying.

RESULTS

UV absorption (A232 and A268 values), peroxide and free acid values of the frying oils are presented in Table I and Figures 1 and 2. Tocopherol and TBHQ results are given in Table II and Figure 3, whereas the tocopherol contents of the oil from fried chips, stored for several weeks, are presented in Table III. Table IV depicts the fatty acid patterns of both frying oils as well as that of oils from chips stored for several weeks.

TABLE II

α and γ-tocopherols and TBHQ Contents of Frying Oils (mg/100g oil)[a]

Frying time (hr)	Peanut Oil			Cottonseed Oil		
	α-Toc	γ-Toc	TBHQ	α-Toc	γ-Toc	TBHQ
0	38.9	27.4	8.9	50.7	48.2	8.8
2	38.3	27.3	7.8	42.3	37.1	7.2
26	30.7	20.3	5.7	37.7	34.2	6.8
50	23.3	16.9	5.2	38.6	34.4	7.6
74	18.6	14.8	4.7	40.0	36.2	7.4
103	15.6	14.0	4.1	50.0	43.1	7.8

[a]Peanut oil contains trace amounts of β- and δ-tocopherols and α-, β- and γ-tocotrienols. Cottonseed oil contains trace amounts of δ-tocopherol and α-, β- and γ-tocotrienols.

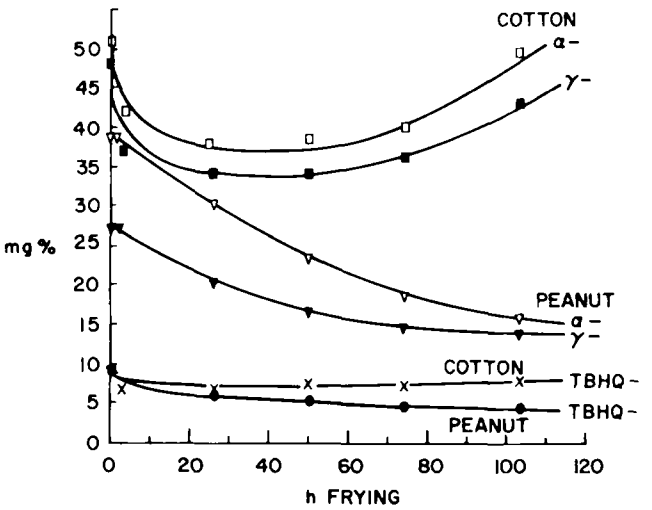

FIG. 3. α-, γ-Tocopherol and TBHQ contents of peanut and cottonseed oils as influenced by frying.

TABLE III

α- and γ-Tocopherol Contents of Oil Extracted from Chips

Storage time (wk)	α-Toc	γ-Toc
	Chips from peanut oil	
6	33.2	21.5
12	21.1	14.4
27	15.9	10.5
	Chips from cottonseed oil	
6	52.0	46.5
13	56.2	48.6
27	47.0	38.5

TABLE IV

Fatty Acid Patterns of Frying Oils and Oils Extracted from Chips (g/100 g)

Oil	Fatty Acid									
	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0
Peanut										
Unused	–	15.6	–	3.9	37.3	38.8	–	1.2	0.7	2.2
2 hr frying	–	13.0	–	4.2	37.6	38.7	–	1.5	0.9	3.1
50 ↓	–	12.9	–	4.3	39.3	37.9	–	1.5	0.8	3.3
98	–	12.5	–	4.3	39.7	36.8	–	1.8	1.0	3.8
6 wks stored	–	12.9	–	4.1	38.2	39.1	–	1.5	0.9	3.1
9 ↓	–	12.6	-	4.1	37.7	38.4	-	1.7	1.6	3.6
12	–	11.9	–	3.7	38.5	38.9	–	1.6	1.2	3.9
Cottonseed										
Unused	0.7	20.4	0.8	2.8	19.1	54.0	0.2	0.5	0.3	0.4
2 hr frying	0.7	20.8	0.7	2.8	19.8	53.2	0.2	0.7	0.6	0.3
50 ↓	0.7	20.5	0.7	2.8	19.9	53.6	0.3	0.4	0.2	0.4
98	0.7	21.1	0.7	2.5	19.9	53.9	0.2	0.4	–	–
7 wks stored	0.7	20.7	0.7	2.8	19.8	53.9	0.3	0.4	–	0.3
10 ↓	0.7	21.0	0.8	2.7	19.5	53.7	0.3	0.4	–	0.3
13	0.8	22.3	0.7	2.8	19.3	53.0	0.3	0.5	–	0.3

Organoleptic results for weeks 1, 4, 6, 8, 10 and 12 were analyzed with a computer program (6) to determine the significance (at 5% level) of the ratings. The mean panel scores for peanut- and cottonseed-oil chips are plotted against storage time and presented in Figure 4 and Table V.

DISCUSSION

It is possible to divide the frying period (5 days) into three phases. The first 20 hr resulted in a rapid increase in the A_{232} and A_{268} values (Table I and Fig. 1). It is evident that the rate of change for cottonseed oil was higher than that for peanut oil. Peroxide and free acid values (Table I and Fig. 2) showed a similar trend.

The next phase, which lasted from ca. 20 hr to 80 hr, was characterized by only moderate changes in the UV, peroxide and free acid values. These results indicate that peanut oil might be more stable than cottonseed oil.

However, the position was changed during the third phase after 80 hr. A_{232}, peroxide and free acid values of peanut oil increased at a higher rate than that of cottonseed oil (Figs. 1 and 2).

Of the three analytical methods it was apparent that the A_{232} determination was a very sensitive means to measure difference in oil stability. It is necessary, however, to interpret the A_{232} values very carefully, in combination with other analytical results (7). For comparison, the tocopherol analysis proved to be of great value. As indicated in Table II and Figure 3, peanut oil lost ca. 55% of its total tocopherols during the frying period. It is also of interest to note that the rate of loss for α-tocopherol was higher than that of γ-tocopherol. The graph for cottonseed oil, on the other hand, indicated a loss for the first 50 hr followed by an increase during the last 50 hr to attain values slightly lower than the original levels (Fig. 3). The initial decrease could be expected, but the gradual increase which took place after 50 hr was unexpected. Due to the uptake of oil by the chips, the total volume of fryer oil was replaced 1.2 times during the 5-day period. It therefore appears that the stability of cottonseed oil improved with time with the result that only minimal amounts of tocopherols were lost from the fresh oil. The good retention of tocopherols is in agreement with Dugan's observations (8).

For comparison, the TBHQ levels of the frying oils were determined. It was found that peanut oil lost ca. 54% of its TBHQ during frying (Fig. 3). The TBHQ levels, therefore, followed the same trend as those of the tocopherols. Cottonseed oil, on the other hand, lost very little TBHQ during the same period and this result was therefore in agreement with the tocopherol results.

The influence of chip storage on the tocopherol levels was determined by analyzing the oils extracted from stored chips. Peanut-oil chips were sampled on the first day and stored for 6, 12 and 27 weeks, and cottonseed-oil chips were sampled on the first day and stored for 6, 13 and 27 weeks. Tocopherol retention in peanut-oil chips was fair

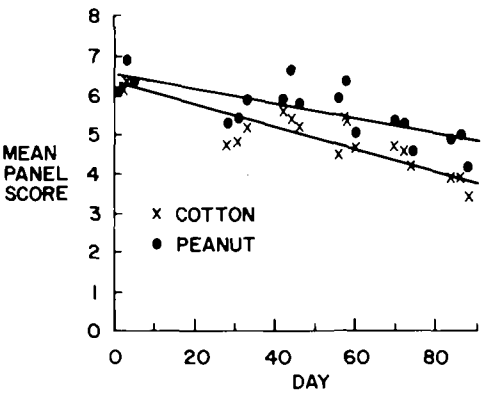

FIG. 4. Mean panel scores for peanut- and cottonseed-oil chips during storage.

TABLE V

Taste Panel Scores (Out of 10) for Peanut- and Cottonseed-Oil Chips (Mean Values of 10 Members)

Weeks stored	Peanut Sampling day			Cottonseed Sampling Day		
	1	3	5	1	3	5
1	6.1	6.9	6.3	6.1	6.4	6.2
4	5.3	5.4	5.9	4.7	4.8	5.2
6	5.9	6.7	5.8	5.6	5.4	5.2
8	5.9	6.4	5.1	4.5	5.4	4.7
10	5.4	5.3	4.6	4.7	4.6	4.2
12	4.9	5.0	4.2	3.9	3.9	3.4

and in cottonseed-oil chips only a slight decrease in 27 weeks was noticed (Table III).

The fatty acid patterns of cottonseed frying oil sampled at 2, 50 and 98 hr indicate very little change in composition. Chips were stored for 7, 10 and 13 weeks after which the oil was extracted and analyzed. With the exception of 20:1 (icocenoic acid) no change was observed. The patterns of peanut frying oils, sampled at 2, 50 and 98 hr were slightly changed in that the 16:0 (palmitic) and 18:2 (linoleic) acid percentages showed a small downward trend. Peanut-oil chips, stored for 6, 9 and 12 weeks showed no change in composition.

The organoleptic evaluation of the peanut- and cottonseed-oil chips indicated that both products were considered acceptable. It is important to note, however, that the mean panel scores for peanut-oil chips were significantly higher (at 5% level) than those for cottonseed-oil chips throughout the storage period. It must be remembered, however, that in practice, the majority of the chips is flavored. It is therefore doubtful whether differences would be observed between flavored chips.

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Effect of Enzyme Inactivation on the Extracted Soybean Meal and Oil

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ABSTRACT

The objective was prevention of lipoxygenase activity prior to oil extraction in order to obtain a meal of superior flavor quality and a crude oil of superior oxidative stability. Accordingly, experiments were performed in which soybeans were heated at various moisture contents and times to inactivate the enzyme system. Once the optimal conditions were determined, heat treated and raw beans were extracted in a laboratory system designed to simulate conditions in commercial solvent extraction and the component oil and meal were evaluated. Oxidative stability of the oil from heat-treated beans was increased as determined by the Swift stability test and an organoleptic evaluation. Similarly, organoleptic blandness ratings of the heat-treated meal were also superior to the meal produced from raw beans. It was concluded that steam heat treatment of soybeans prior to extraction was beneficial to quality of both oil and flake.

INTRODUCTION

The soybean has been recognized for many years as a rich source of the enzyme lipoxygenase. The enzyme itself has been recognized since the late 1920s. An extensive review of lipoxygenase in relation to food quality was published by Eskin (1). It has a high turnover number, 2×10^4 mol/mol enzyme/min (2). It is also well known for the variety and intensity of undesirable flavor it can produce from its normal substrate, linoleic acid (3,4). Investigators have identified a range of oxidation products of linoleic acid generated by lipoxygenase action (3,5-7). Examples are ethyl vinyl ketone, propionaldehyde and pentenal. In addition, many other volatile oxidation products have been identified from autoxidized linoleate, and at least in theory, these same compounds can be generated by lipoxygenase action. 3 *cis*-Hexenal, e.g., was identified as an oxidation product of linoleic acid by Hoffman (8) who concluded that its organoleptic threshold was less than 0.1 ppm. This compound has a "green bean" odor, and is one of the initial manifestations of reversion flavor in soy oil.

The specific effects of lipoxygenase activity on the flavor of aqueous suspensions of ground soybeans were investigated by Wilkens et al. (9). They found that the characteristic beany or painty flavor of such preparations was due to enzyme activity, and that the flavors could be improved by using hot water extraction. Mustakas et al. (10) similarly found that the heat treatment of whole beans prior to grinding produced full-fat soy flours which were much blander than flour made from raw soybeans. Nelson et al. (11,12) demonstrated that the off-flavors commonly associated with soybean products occur whenever damaged tissue is exposed to moisture. List et al. (13) noted that quality of both crude and hydrogenated oils was adversely affected by field and storage damage of the soybeans. Such damage clearly triggers enzyme activity. Gardner (14) also noted the importance of tissue rupture. Tissue rupture occurs during preparation of the soybeans for oil extraction. Specifically, the meats are "conditioned" for flaking by heating to 60-65 C with steam so that the moisture content is increased to 10.5-11.0%. It should be noted that this is an average moisture content after equilibration for 20-30 min, so the moisture content on the particle surface, where ruptured tissue is present, must be considerably greater. The meats show an equilibrium relative humidity of 60-70%, a moisture level suitable for enzyme activity (15). The next step, flaking, greatly exacerbates the problem by extensive rupture of the cells. Thus, the moisture content, temperature and time are suitable for at least some degree of enzyme activity in the flakes prior to extraction.

This enzyme activity could be detrimental to both oil and meal. Therefore, the objective of this work was to study the effect of moist heat enzyme inactivation prior to