GIDA (2012) 37 (4): 189-196 *Research* / Araştırma

EFFECTS OF DEODORIZATION ON THE QUALITY AND STABILITY OF THREE UNCONVENTIONAL SUDANESE OILS

Abdalbasit Mariod[1] , Bertrand Matthäus[2], K. Eichner[3], Ismail H. Hussein[4]

[1] Food Sci & Technology Department, College of Agricultural Studies, Sudan University of Science & Technology, P.O Box 71 Khartoum North, Sudan.
[2] Institute for Lipid Research of the Federal Center for Cereal, Potato and Lipid Research, Piusallee 68/76, 48147 Münster, Germany.
[3] Institute for Food Chemistry of the Westfälische-Wilhelms-University, Corrensstr. 45, 48149 Münster, Germany.
[4] National Oil Processing Research Institute, University of Gezira, P.O Box 20, Wad Madani Sudan.

Received / Geliş tarihi: 09.03.2012
Received in revised form / Düzeltilerek Geliş tarihi: 06.05.2012
Accepted / Kabul tarihi: 13.06.2012

Abstract

Crude oils have to be refined before the consumption, in order to remove undesirable accompanying substances; deodorization usually is the last step in the edible oil refining. In a laboratory all-glass deodorizer experiments, degummed, refined and bleached oils from *Sclerocarya birrea* (SCO), Sorghum bug (SBO), Melon bug oil water extracted ($MBOH_2O$) and Melon bug oil solvent extracted (MBOSOL) were deodorized for different periods of times (0.5, 1, and 2 hours) at different temperatures (190, 210, and 250 °C). Quality changes (free fatty acids, peroxide values, tocopherols, sterols and phosphatides) were determined, and also stability against oxidation (Rancimat test) beside the fatty acid composition. It is clear that there was no change in the phosphatides according to deodorization temperature and time, peroxides and free fatty acids content were significantly (P<0.05) reduced in all samples with the increase of deodorization temperature and nearly completely removed at 250°C. Tocopherols were decreased as a result of elevated temperature, and high decrease happened in high temperatures of 210 and 250 °C in all samples except $MBOH_2O$, where tocopherols completely removed during deodorization temperatures. The effect of deodorization on fatty acid composition indicates that, oils did not undergo any changes in the fatty acid compositions during deodorization. The oxidative stability was affected by temperature and time of deodorization, the stability increased as affected by elevated deodorization temperature in all studied samples.

Keywords: *Sclerocarya birrea* oil, Sorghum bug oil, Melon bug oil, deodorization, quality, stability

DEODORİZASYONUN GELENEKSEL OLARAK TÜKETİLMEYEN ÜÇ SUDAN YAĞININ KALİTE VE STABİLİTESİNE ETKİSİ

Özet

Ham yağlar istenmeyen maddelerin uzaklaştırılması için tüketimden önce rafine edilir ve deodorizasyon genellikle rafinasyonun son aşaması olarak kullanılır. Laboratuvar tipi cam deodorizatörde, yapışkan maddelerinden uzaklaştırılmış, asitliği alınmış ve ağartılmış *Sclerocarya birrea* (SCO), darı böceği (SBO), su ile ekstrakte edilmiş kavun böceği ($MBOH_2O$) ve solvent ile ekstrakte edilmiş kavun böceği yağları (MBOSOL) farklı sürelerde (0.5; 1 ve 2 saat) ve farklı sıcaklıklarda (190, 210, ve 250 °C) deodorize edilmiştir. Kalite değişimleri (serbest asitlik, peroksit değeri, tokoferoller, steroller ve fosfatidler) belirlenmiş, yağ asitleri dağılımının yanında, ransimat ile oksidatif stabilite tespit edilmiştir. Deodorizasyon sıcaklığı ve süresi fosfatidleri etkilemezken, peroksit ve serbest asitler bütün örneklerde deodorizasyon sıcaklığı arttıkça önemli düzeyde azalmış (P<0.05), 250 °C'de ise tamamı yağdan uzaklaşmıştır. Artan sıcaklık tokoferol kaybına da neden olmuş, $MBOH_2O$ hariç, diğer tüm örneklerde 210-250 °C sıcaklıklar arasında önemli kayıplar gözlenmiştir. Deodorizasyonun yağ asiti dağılımına herhangi bir etkisi olmamıştır. Yağların oksidatif stabilitesi ise, yükselen deodorizasyon sıcaklığı ile birlikte artmıştır.

Anahtar kelimeler: *Sclerocarya birrea* yağı, darı böceği yağı, kavun böceği yağı, deodorizasyon, kalite, stabilite

[1]*Corresponding author* / Yazışmalardan sorumlu yazar ;
basitmariod@yahoo.com, +249 (0) 185 311082, +249 (0) 185 311896

INTRODUCTION

Sclerocarya birrea subsp. caffera, family Anacardiaceae is a Savannah tree. The seed encloses 2 - 3 soft white edible kernels (nuts), which are rich in oil and protein (1, 2). In literature only few reports dealing with the seed oil of *Sclerocarya birrea* are available (3-6).

Melon bug (*Aspongubus viduatus*) is widely distributed in Western Sudan, where it is known locally as Um-buga and used in nutrition by collecting the oil from the bugs after hot water extraction. The oil is used in cooking (during famine and shortage of food) and some medicinal applications e.g. skin lesion remedy. The bug contain 45% oil which, contained 46.5, 3.4 and 44.2% oleic, linoleic and palmitic acids respectively, with low amount of tocopherol 0.3 mg/100g and high oxidative stability of 38 hour under Rancimat test (5). Tauscher *et al.* (7) reported that, in remote territories of Sudan oil from these bugs is used as sweet-oil. A poisonous effect of this oil is not described and the fatty acid composition corresponds with most animal oils.

In Western Sudan sorghum bug (*Agonoscelis pubescens*) adults are collected and eaten after frying, while in some areas of Sudan the collected bugs were extracted and the obtained oil was used for cooking and some medicinal uses. In Botana area of central Sudan, nomads use tar obtained from highly heated bugs for their camels against dermatological infections Sorghum bug oil content was 60% with 40.9, 34.5 and 12.1% of oleic, linoleic and palmitic respectively, the oil contains 34.0 mg/100 g tocopherols (5)

Crude oils are generally processed by degumming, alkali refining, bleaching, and deodorization to obtain odorless, bland, and oxidatively stable oil that is acceptable to consumers. The object of refining edible oils is to remove unacceptable materials with the least possible changes on desirable components and with least possible loss of oil (8). Deodorization removes volatiles compounds, carotenoids, free fatty acids and tocopherols and decomposes peroxides to improve flavor quality and stability of the oil (9). Deodorization is a vacuum-steam distillation at elevated temperature during which free fatty acids and volatile odoriferous components are removed in order to obtain bland and odorless oil (10). Deodorization improves the oils flavor and oxidative stability by nearly complete removal of free fatty acids and other volatile odor and flavor materials by thermal destruction of fat hydroperoxides. However, it has been shown that when deodorization is carried out at higher temperatures for longer times, some undesirable changes occur in the physical and chemical properties of deodorized oils (11). Crude vegetable oils are usually oxidatively more stable than the corresponding refined oils (12). Unfortunately, some of the refining processes have been reported to decrease the contents of natural antioxidants such as tocopherols and oryzanols (13). In general when a low temperature is used, more stable oils are obtained when the deodorization period is lengthened; when a high temperature is used, flavors and oxidative-stable oils are more likely when the deodorization period is short (14).

To our knowledge, no studies have been conducted or reviewed the effect of deodorization on quality and oxidative stability of SCO, SBO, and MBO oils. In this study, the effect of deodorization at different temperatures for different times on the composition and the oxidative stability of these three unconventional Sudanese oils was investigated.

MATERIAL AND METHODS

Materials

All solvents used were of analytical grade. n-hexane, n-heptane and methanol of HPLC grade, and betulin, tocopherol standards were supplied by Merck (Darmstadt, Germany)

Dried seeds of *Sclerocarya birrea* were collected manually from Western Sudan. Seeds were dehulled (decorticated) using a Vice model 2XFRONT (Heuer, Germany), crushed and ground by a grinding mill (Petra electric, Burgau, Germany). The oil was extracted from the ground material by extraction with n-hexane (b.p 50-60 °C) in a Soxhlet apparatus for 6 hr. following the AOCS method Aa 4-38 (15). The obtained oil was stored at 4 °C until further investigation.

A. viduatus bugs were collected from Ghibaish province in Western Sudan, and the oil was obtained by using a local hot water extraction method. In brief, the collected bugs were killed by a sudden hot water shock and crushed using a local woody mortar. The oil was extracted by using boiling water, and the top oily layer was collected. Then the oil was heated again to remove water drops and afterwards kept in a plastic container at 4 °C until further investigation.

A. pubescens bugs were collected from Rahad Agricultural scheme area in central Sudan. The bugs were stored in a tight polyethylene bag, killed by treatment with hot water for few minutes

and then sun dried. After crushing using a lab mortar the oil was extracted using diethylether following AOCS method Aa 4-38 (15). The oil obtained by the extraction was stored at 4 °C until further investigation.

Refining procedures

Degumming

The method of Tsaknis et al. (16) was used for degumming. In brief, crude oil (600 g) was taken from cold storage, heated at 75 °C, and 20% boiling water was added. The mixture was mixed for 10 min with the aid of a glass rod. After cooling, the oil was centrifuged for 10 min at 45006g in tubes of 200 mL (Heraeus sepateck, Dusseldorf, Germany).

Neutralization

Degummed oil was neutralized according to the method of Sathivel et al. (17): Sodium hydroxide (12.6 g 9.5% NaOH solution) was added to 100 g degummed oil, and the mixture was heated to 65 °C for 30 min with constant stirring using a magnetic stirrer. Then the sample was cooled to room temperature and kept undisturbed for 6 h. After centrifugation (Heraeus sepateck, Dusseldorf, Germany) at 45006g for 10 min, the oil was decanted from the precipitated soap. Demineralized water (50 mL) was added to wash out any remaining soap. The washing step was repeated three times. Water and impurities were removed from the oil by centrifugation at 45006g for 10 min.

Bleaching

The neutralized oil was bleached according to Dolesschall et al. (18), with some modifications: 500 g oil was weighed into a three-neck round-bottom flask and dried at 100 °C under vacuum. After 30 min of drying, the flask was aerated and a 0.5% bleaching earth (Tonsil 210 FF, Sudchemie, Munchen, Germany) was added to the oil. This bleaching earth is (FF, fast filtration) a very common and powerful acid activated bleaching clay made of bentonite/ montmorillonite. Immediately after addition of the earth, the sample was evacuated again and the temperature was quickly raised to 100 °C. The oil was intensively stirred at this temperature for 30 min; 10 min after starting the bleaching process, 0.05% (250 mL) of citric acid solution was added. In the next step, the oil was cooled down to 60 °C, nitrogen was led in, and the oil was vacuum-filtered on a filter aid in a Buchner funnel. The overall bleaching time lasted 30 min.

Deodorization procedure

Following the method of Pardun (19), where 50 g of degummed, neutralized and bleached oil was deodorized using a lab-scale all glass deodorizer (Karl Willers, Laborbedarf, Muenster, Germany) by heating under vacuum at 190, 210 and 250 °C and with steam as stripping gas at 10 mmHg pressure for 0.5, 1, and 2 hours and water temperature was 40 °C while water volume was 30, 40 and 50 mL according to increase of time. Deodorized oils were kept into brown glass bottles, covered with plastic caps, air remained in the headspace. Bottles were stored at 4 °C in the dark till analysis.

Methods

Fatty acid composition

The fatty acid composition of the deodorized oils was determined following the ISO draft standard (17). In brief, one drop of the oil was dissolved in 1 mL of n-heptane, 50 µl 2M sodium methanolate in methanol were added, and the closed tube was agitated vigorously for 1 min. After addition of 100 µL of water, the tube was centrifuged at 4500 g for 10 min. and the lower aqueous phase was removed. After that 50 µL 1 M HCl were added to the heptane phase, the two phases were shortly mixed and the lower aqueous phase was rejected. About 20 mg of sodium hydrogen sulphate (monohydrate, extra pure, Merck, Darmstadt, Germany) were added, and after centrifugation at 4500 g for 10 min the top n-heptane phase was transferred into a vial and injected in a Varian 5890 gas chromatograph with a capillary column, CP-Sil 88 (100 m long, 0.25 mm ID, film thickness 0.2 µm). The temperature programme was: from 155 °C heated to 220 °C (1.5 °C/min.), 10 min isotherm; injector 250 °C, detector 250 °C; carrier gas 1.07 mL/min hydrogen; split ratio 1:50; detector gas 30 mL/min hydrogen; 300 mL/min air and 30 mL/min nitrogen; manual injection volume less than 1 µL. The integration software computed the peak areas and percentages of fatty acid methyl esters (FAME) were obtained as weight percent by direct internal normalization.

Tocopherols

For determination of tocopherols a solution of 250 mg deodorized oil in 25 mL n-heptane was directly used for the 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 wavelengths for excitation 295 nm, for emission 330 nm) and a D-2500 integration system. 20 µL of the samples were injected by a Merck 655-A40 Autosampler

onto a Diol phase HPLC column 25 cm x 4.6 mm ID (Merck, Darmstadt, Germany) using a flow rate of 1.3 mL/min. The mobile phase used was n-heptane/tert-butyl methyl ether (99+1, v/v) (18).

Sterols

The sterol composition of the deodorized oils was determined following ISO\FIDS method (19). In brief, 250 mg of oil was saponified with a solution of ethanolic potassium hydroxide by boiling under reflux. The unsaponifiable matter was isolated by solid-phase extraction on an aluminium oxide column (Merck, Darmstadt, Germany) on which fatty acid anions were retained and sterols passed through. The sterol fraction from the unsaponifiable matter was separated by thin-layer chromatography on silica gel 20x20 cm, thickness of layer 0.25mm using hexane/diethyl ether (1/1 (v/v)) as developing solvent (Merck, Darmstadt, Germany), re-extracted from the TLC material and afterwards the composition of the sterol fraction was determined by GLC using betulin as internal standard. The compounds were separated on a SE 54 CB (Macherey-Nagel, Düren, Germany) (50 m long, 0.32 mm ID, 0.25 µm film thickness). Further parameters were: hydrogen as carrier gas, split ratio 1:20, injection and detection temperature adjusted to 320 °C, temperature programme: 245 °C to 260 °C at 5 °C/min.

Oxidative stability

The oxidative stability of the deodorized oils was determined by the Rancimat method (20). All experiments were carried out with a 743 Rancimat (Methrom AG, Herisau, Switzerland). In brief, 3.6 g oil was weighed into the reaction vessel, which was placed into the heating block kept at 120 °C. Air flow was set at 20 L/h for all determinations. Volatile compounds released during the degradation process were collected in a receiving flask filled with 60 mL distilled water. The conductivity of this solution was measured and recorded. The software of the rancimat evaluated the resulting curves automatically. All determinations were carried out in duplicate.

Phosphorus

The phosphorus content of the deodorized oils was determined after ashing spectophotometrically following DGF method (21).

Peroxide Value

The peroxide value was determined idometrically according to AOCS method (22). It consists in the reaction in darkness of a mixture of oil and chloroform/acetic acid 2:3 (v/v) with saturated potassium iodide and the results are expressed as milliequivalents of active oxygen in 1 kg oil.

Free Fatty acids

Free fatty acids of the deodorized oils were determined by titration according to AOCS official methods (23), and data are expressed as % oleic acid

Color

The color was determined spectrophotometrically, following method (24). The absorbance value at 400-800 nm of a sample solution (oil dissolved in heptane 1:10) in U-2000 Spectrophotometer (Hitachi, LTD.Tokyo, Japan) was measured.

Statistical analysis

The analyses were performed with three replicates. The mean values and standard deviation were calculated and tested using Duncan's test (P<0.05). Statistical analysis of variance (ANOVA) was performed on all values using the statistical program Statgrafics® Statistical Graphics System version 4.0 (25).

RESULTS AND DISCUSSION

Phosphatides

Phosphatides are the gummy, hydrated an unwanted constituent of refined oils, and are removed by adding 2% of water to hot oil followed by centrifugation. Tables 1, 2, 3, and 4 shows the phosphatide levels in the four oils after deodorization as indicated by phosphorus determination, no change in the content of phosphorus during deodorization

Peroxide value and free fatty acids.

Deodorization step was devised to reduce the peroxide value and free fatty acid of degummed neutralized bleached oils. The former values are a measure of the amount of oxidation, which has started to occur in the oil due to exposure to air. From tables 1, 2, 3 and 4, peroxide levels in all samples decreased significantly (P<0.05) with temperature and time of deodorization. This reduction was clear in oils deodorized at temperatures of 210 °C and 250 °C with increase of deodorization time. And that deodorization at 250 °C is quite sufficient to reduce peroxide to low levels, and peroxide destruction occurs rapidly at temperatures above 210 °C. Tables 2 and 4 show that deodorization for 1h at 250 °C reduced peroxides to their lower levels. From tables 1, 2, 3 and 4, free fatty acids (FFA) were reduced in all samples with temperature and time of deodorization and nearly completely removed at 250 °C. Free fatty acids are formed by the hydrolysis of triglycerides and removed simultaneously during deodorization (9).

Tocopherols

Tocopherols are important in vegetable oils, because of their vitamin activity and their antioxidant properties to protect vitamin A, ß-carotene, and essential fatty acids against oxidation. Tocopherols are sensitive to light, heat, alkali, and metal contaminants; and therefore are easily oxidized to tocoquinones, which no longer have antioxidant properties. Tocopherol retention/removal during odorization is mainly a result of distillation and as much a question of temperature and a mount of stripping steam.

In this study, the tocopherol contents of the bleached oils of SCO, SBO, MBO H_2O and MBO SOL were 10.2, 5.6, 0.1 and 0.2 mg/100g, respectively (Tables 1, 2, 3, 4). During deodorization the amounts of tocopherol were decreased significantly (P<0.05) as a result of elevated temperature, and less decrease happened in high temperatures of 210 °C and 250 °C in all samples except MBO H_2O. In all oils tocopherol loss is significantly dependent on deodorization temperature and time.

Under normal applied deodorization temperatures (220-260 °C), maximum 5% of tocopherols were thermally degraded (10). Tocopherols, which serve as natural antioxidants, show a marked loss at temperature of 190 °C depending on deodorization time. Minor losses in the tocopherol content during refining have been reported earlier in high-fatty acid rice bran oil, in soybean oil, and in coconut oil (12).

Effect of deodorization on fatty acids

Different authors have reported effects of refining, bleaching and deodorization on fatty acid composition of vegetable oils. Wilding *et al.* (26) processed soybean oil with laboratory-scale

Table 1. Effects of deodorization on composition and stability of SCO*

Oil sample	**Phosphorus [ppm]	**PV [meq/kg]	**FFA [%]	**Tocopherols [mg/100g]	**Sterols [mg/100g]	**IP [hours]
Degummed, neutralized, and bleached oil	4.8[a]	1.0[a]	2.5[a]	0.102[a]	3.283[a]	4.2[a]
Deod.190/0.5h	4.8[a]	0.3[b]	1.0[b]	0.097[b]	3.226[b]	5.0[b]
Deod. 190/1h	4.8[a]	0.2[b]	0.8[c]	0.096[c]	2.806[c]	5.2[c]
Deod. 190/2h	4.8[a]	0.2[b]	0.5[d]	0.096[c]	2.688[d]	5.4[d]
Deod. 210/0.5h	4.7[a]	0.1[c]	0.4[e]	0.094[d]	2.551[e]	5.5[e]
Deod. 210/1h	4.7[a]	0.1[c]	0.4[e]	0.091[d]	2.501[e]	5.5[e]
Deod. 210/2h	4.7[a]	0.1[c]	0.3[f]	0.092[e]	2.250[f]	5.6[f]
Deod. 250/0.5h	4.7[a]	0.1[c]	0.2[g]	0.090[f]	2.005[g]	5.7[g]
Deod. 250/1h	4.7[a]	0.1[c]	0.1[h]	0.090[f]	1.426[h]	5.5[e]
Deod. 250/2h	4.7[a]	0.1[c]	0.1[h]	0.090[f]	1.426[h]	5.5[e]

*The values shown are the average of three replicates except IP is in duplicate. **In all parameters means followed by different letters within a column are significantly (p<0.05) different.

Table 2. Effects of deodorization on composition and stability of SBO*

Oil sample	**Phosphorus [ppm]	**PV [meq/kg]	**FFA [%]	**Tocopherols [mg/100g]	**Sterols [mg/100g]	**IP [hours]
Degummed, neutralized, and bleached oil	4.5[a]	1.3[a]	1.5[a]	0.056[a]	3.500[a]	0.5[a]
Deod.190/0.5h	4.4[a]	1.2[b]	1.3[b]	0.054[b]	3.296[b]	0.9[b]
Deod. 190/1h	4.3[a]	1.1[c]	1.1[c]	0.054[b]	3.215[c]	0.9[b]
Deod. 190/2h	4.3[a]	0.8[d]	1.0[c]	0.053[a]	3.155[d]	2.0[c]
Deod. 210/0.5h	4.4[a]	0.7[d]	0.2[d]	0.052[c]	3.088[e]	2.2[d]
Deod. 210/1h	4.4[a]	0.7[d]	0.2[d]	0.052[c]	3.088[e]	2.2[d]
Deod. 210/2h	4.4[a]	0.5[e]	0.2[d]	0.052[c]	3.094[e]	2.2[d]
Deod. 250/0.5h	4.4[a]	0.5[e]	0.1[e]	0.048[d]	2.500[f]	2.4[e]
Deod. 250/1h	4.4[a]	0.2[f]	0.1[e]	0.046[e]	2.100[g]	2.5[e]
Deod. 250/2h	4.4[a]	0.2[f]	0.1[e]	0.046[e]	2.100[g]	2.5[e]

*The values shown are the average of three replicates except IP is in duplicate. **In all parameters means followed by different letters within a column are significantly (P<0.05) different.

Table 3. Effects of deodorization on composition and stability of $MBOH_2O$*

Oil sample	**Phosphorus [ppm]	**PV [meq/kg]	**FFA [%]	**Tocopherols [mg/100g]	**Sterols [mg/100g]	**IP [hours]
Degummed, neutralized, and bleached oil	4.8[a]	0.3[a]	0.2[a]	0.001[a]	2.02[a]	10.8[a]
Deod.190/0.5h	4.8[a]	0.2[b]	0.2[a]	0.00[b]	1.71[b]	12.4[b]
Deod. 190/1h	4.7[a]	0.2[b]	0.2[a]	0.00[b]	1.62[c]	12.8[c]
Deod. 190/2h	4.7[a]	0.2[b]	0.2[a]	0.00[b]	1.50[d]	12.8[c]
Deod. 210/0.5h	4.7[a]	0.1[c]	0.03[b]	0.00[b]	1.30[e]	15.2[d]
Deod. 210/1h	4.7[a]	0.1[c]	0.03[b]	0.00[b]	1.30[e]	15.2[d]
Deod. 210/2h	4.7[a]	0.1[c]	0.03[b]	0.00[b]	1.24[f]	15.6[e]
Deod. 250/0.5h	4.7[a]	0.1[c]	0.02[c]	0.00[b]	1.15[g]	15.6[e]
Deod. 250/1h	4.7[a]	0.1[c]	0.01[c]	0.00[b]	1.00[h]	15.8[f]
Deod. 250/2h	4.7[a]	0.1[c]	0.01[c]	0.00[b]	1.00[h]	15.8[f]

*The values shown are the average of three replicates except IP is in duplicate. **In all parameters means followed by different letters within a column are significantly (P<0.05) different.

Table 4. Effects of deodorization on composition and stability of MBOSOL

Oil sample	**Phosphorus [ppm]	**PV [meq/kg]	**FFA [%]	**Tocopherols [mg/100g]	**Sterols [mg/100g]	**IP [hours]
Degummed, neutralized, and bleached oil	5.3[a]	0.9[a]	0.2[a]	0.002[a]	0.695[a]	2.0[a]
Deod.190/0.5h	5.3[a]	0.9[a]	0.2[a]	0.002[a]	0.608[b]	2.3[b]
Deod. 190/1h	5.3[a]	0.8[b]	0.1[b]	0.001[b]	0.499[c]	2.4[c]
Deod. 190/2h	5.2[a]	0.7[c]	0.1[b]	0.001[b]	0.216[d]	2.5[d]
Deod. 210/0.5h	5.2[a]	0.6[d]	0.05[c]	0.001[b]	0.117[e]	2.7[e]
Deod. 210/1h	5.2[a]	0.6[d]	0.05[c]	0.001[b]	0.117[e]	2.7[e]
Deod. 210/2h	5.3[a]	0.6[d]	0.03[d]	0.001[b]	0.089[f]	3.2[f]
Deod. 250/0.5h	5.3[a]	0.5[e]	0.02[e]	0.001[b]	0.093[g]	3.2[f]
Deod. 250/1h	5.3[a]	0.4[f]	0.02[f]	0.001[b]	0.082[h]	3.2[f]
Deod. 250/2h	5.3[a]	0.4[f]	0.02[f]	0.001[b]	0.082[h]	3.2[f]

*The values shown are the average of three replicates except IP is in duplicate. **Means followed by different letters within a column are significantly (P<0.05) different.

equipment; they found no significant changes in fatty acid as result of processing, even at 238 °C the higher temperature of deodorization. While Sleeter (27) reported that, the polyunsaturated fatty acid content of soybean oil apparently was lowered during processing as a result from oxidation or conjugation.

The effect of deodorization on fatty acid composition of SCO, SBO and two MBO were studied. Results indicated that the oil did not undergo any changes in the fatty acid compositions during deodorization. Thus, no any changes in the fatty acid composition of these oils observed, and the fatty acid composition was nearly constant

Effect of deodorization on oils oxidative stability

Flavor and oxidative stability of vegetable oils is usually improved by deodorization, (14, 28). Deodorization increases the oils oxidative stability by nearly complete removal of free fatty acids and other volatile odor and flavor materials, by partial removal of tocopherols, and by thermal destruction of peroxides (29). The stability as determined in Rancimat apparatus, showed in Tables 1, 2, 3 and 4, where the stability of SCO deodorized at 190 °C was poor, this could be due to incomplete deodorization, while oil deodorized at 250 °C for 0.5 h was more stable (Table 1), in case of SBO (Table 2) there was a noticed increase in the stability as effect of deodorization and the stability increase with temperature increasing, all oils deodorized at temperatures higher than 190ºC were more stable even than the bleached ones, this could be explain as that, the stability towards oxidative rancidity of deodorized vegetable oils is usually greater than that of the oil prior to deodorization.

This increase in stability may arise from several factors: pro-oxidants other than peroxides may be deactivated or distilled from the oil, antioxidant may be formed or activated by the heat treatment, peroxides are decomposed and their destruction products are probably distilled from the oil (30). There seems to be no correlation between induction periods and the tocopherols and sterols content in all studied oils that might be due the low content of each component in these oils in comparison to other oils.

Effect of deodorization on oils color

Among the many tests that are required to be carried out on edible oils and fats along the refining process is the measurement of color. As most, if not all, refined oils are sold on the basis of their color, it is necessary to monitor each stage of the refining process to establish if the correct color has been attained. In general, the edible oil processor is concerned with bleaching to reduce the yellow red color of oils, and at the same time remove green pigments almost completely if they are present (31). Color bodies of edible oils and fats are primarily carotenoids and chlorophylls. Oxidation of these color bodies and phenolic compounds, or reaction of oxidized triglycerides with carotenoids or phenols lead to compounds, that explain why refined or partially refined oxidized oil has a dirty brown color.

The color change in oils of SCO, SBO, MBO H2O and MBO SOL during deodorization process was studied, the color decreased (more light) according to the decreasing of materials that responsible from color through out deodorization. During deodorization process the color darkened sharply, the degummed, neutralized, bleached oils were lighter than deodorized ones. The color substances were oxidized and the color degree (absorbance) increased through the deodorization process where the highest degree of coloration was obtained and the oil color darkened sharply.

Effect of deodorization on total sterols content

Sterols comprise a major component class of vegetable oils unsaponifiable matter. The most common phytosterols were b-sitosterol, campesterol, D-5-avenasterol, D-7-stigmasterol, D-7-avenasterol, cholesterol, and stigmasterol. The total sterols content was measured in bleached oils, and the changes during deodorization were determined in SCO, SBO, MBO H_2O and MBO SOL (Tables 1, 2, 3, 4). Sterols are physically removed substances during deodorization. From tables 1, 2, 3, 4 as expected, the deodorization treatment caused significant decreases in the total sterol contents (P<0.05). In SCO significant reductions in total sterol contents were observed and oil deodorized at 250 °C gave the highest reduction of total amount of sterols. In SBO and MBO oils deodorized at 250 °C for 1h gave the less total amount of sterols and that sterol loss is significantly dependent on deodorization temperature and time. The most significant reduction in the total sterol content can occur by distillation during deodorization (8). Changes in the contents of total amount of sterols of the deodorized oils could be particularly influenced by the deodorization conditions. In general, deodorization of oils can result in variable phytosterol losses (32). Deodorization is a high temperature, high vacuum, steam-distillation process that is necessary for the removal of volatile flavor and odor compounds to transform the oil into a bland-tasting clear liquid desirable to consumers (33).

ACKNOWLEDGEMENT

The first author thanks National Oilseed Processing Research Institute (NOPRI) University of Gezira, Sudan and German Academic Exchange Service (DAAD) for their financial support. We thank Dr. L. Brühl and Mrs. B. Bielefeld of the Institute for Lipid Research for their skilful carrying out of the GC and HPLC analysis.

REFERENCES

1. FAO: 1988. Food and Nutrition, Paper No. 42, Traditional Food Plants U.N Rome, Italy

2. Mizrahi Y. and Nerd A. 1996. New crops as a possible solution for the trouble Israeli export market. In: J. Janick (ed), Progress in new crops. ASHS press, Alexandria, 1996, pp. 37-45

3. Salama R. B.1973. The seed oil of *Sclerocarya birrea*. *Sudan J. Food. Sci. & Tech*, 5, 4-6.

4. Ogbobe O. 1992. Physico-chemical composition and characterization of the seed, and seed oil of *Sclerocarya birrea*. *Plant Foods Hum Nutr*, 42, 201-206.

5. Mariod AA, Matthaüs B, and Eichner, K. 2004. Fatty acid, tocopherol and sterol composition as well as oxidative stability of three unusual Sudanese oils. *J Food Lipids*, 11, 179-189.

6 . Mariod AA, Ali AO, Elhussein SA, and Hussien IH. 2005. A Re-investigation of physicochemical characteristics and fatty acid composition of *Sclerocarya birrea* (Homeid) kernel oil. *Sudan J Sci Technol*, 6, 178-183.

7. Tauscher B, Müller M, and Schildknecht H. 1981. Composition and toxicology of oil extracts (edible oil) from *Aspongopus viduatus*. *Chem. Mikrobiol. Technol. Lebensm*, 7, 87-92.

8. Ferrari R, Schulte E, Esteves W, Bruel L, and Mukherjee KD. 1996. Minor constituents of vegetable oils during industrial processing. *J. Am. Oil Chem. Soc*, 73, 587–592.

9. Jung MY, Yoon SH. and Min DB. 1989. Effects of processing steps on the contents of minor compounds and oxidation of soybean oil. *J. Am. Oil Chem. Soc*, 66, 118–120.

10. De Greyt WM, Kellens J, and Huyghebaert AD. 1999. Effect of physical refining on selected minor components in vegetable oils. *Fett/Lipid*, 101, 428-432.

11. Dudrow FA. 1983. Deodorization of edible oils. *J. Am. Oil Chem. Soc*, 60, 272-274.

12. Pekkarinen SA, Hopia NU, and Heinonen M. 1998. Effect of processing on the oxidative stability of low erucic acid turnip rapeseed (*Brassica rapa*) oil. *Fett/Lipid*, 100, 69–74.

13. Yoon SH. and Kim SK. 1994. Oxidative stability of high-fatty acid rice bran oil at different stages of refining, *J Am. Oil Chem. Soc*, 71, 227-229.

14. Moser HA, Partricia C, Cooney C, Evans D. and Cowan JC. 1966. The stability of soybean oil: effect of time and temperature on deodorization. *J. Am. Oil Chem. Soc*, 43, 632-634.

15. Official Methods and Recommended Practices of the American Oil Chemists Society. 4th edition by AOCS Press, Champaign. IL. 1993.

16. Tsakins J, Spiliotis V, Lalas S, Gergis V, Dourtoglou V, 1999. Quality changes of Moringa olifera, variety Mbololo of Kenya, seed oil during frying. *Grasas Aceites*, 50, 37–48.

17. Sathivel S, Prinyawiwatkul W, Negulescu II, King JM, Basnayake BFA. 2003. Effect of purification process on rheological properties of catfish oil. *J Am Oil Chem Soc*, 80, 829–832.

18. Doleschall F, Kemeny Z, Recseg K, Kovari K. 2002. A new analytical method to monitor lipid peroxidation during bleaching. *Eur J Lipid Sci Technol*, 104, 14–18.

19. Pardun, VH. 1988. Desodorierung von Speiseölen im laboratoriumsmaßstab. *Fat. SCi. Technol*, 90, 5-14.

20. ISO/FIDS 5509. 1997. International Standards 1st edn.

21. Balz M, Shulte E, and Their. HP. 1992. Trennung von Tocopherol und Tocotrienolen durch HPLC. *Fat Sci. Technol.* 94, 209-213.

22. ISO/FIDS 12228:1999 (E) International Standards 1st edn.

23. Metrohm, 1994. Oxidationsstabilität von Ölen und Fetten – Rancimatmethode. *Application Bulletin*, Nr. 204/1 d.

24. DGF (Deutsche Gesellschaft für Fettwissenschaft Wissenschaftliche Verlagsgesellschaft mbH Stuttgart, Germany) Standard Methods Section C- Fats Method C-VI 4 61- Part 1 (02) 1994.

25. Official Methods and Recommended Practices of the American Oil Chemists Society, Physical and Chemical Characteristics of Oils, Fats and Waxes section I by AOCS, Champaign, IL, 2001. method CD 8b-90.

26. Official Methods and Recommended Practices of the American Oil Chemists Society, Physical and Chemical Characteristics of Oils, Fats and Waxes section I by AOCS, Champaign, IL, 1997. method Ca 5a-40.

27. CT39 (IQA) NP-937,1987. Edible fats and oils. Determination of oils color and its chromatic characteristics.

28. STATGRAPHICS®. 1985–1989. *Statgraphics Statistical Graphics Systems, Version 4.0,* STSC Inc. & Statistical Graphics Cooperation, Rockville, MD.

29. Wilding MD, Rice EE, and Mattil, KF. 1963. The effect of processing conditions upon the nutritional quality of vegetable oils, *J Am Oil Chem Soc*, 140, 55-56.

30. Sleeter RT. 1981. Effects of processing on quality of soybean oil. *J Am Oil Chem Soc*, 58, 239-247.

31. Cmolik J, and Pokorny J. 2000. Physical refining of edible oils. *Eur J Lipid Sci Technol*, 102, 472–486

32. Dudrow FA. 1983. Deodorization of edible oils. *J Am Oil Chem Soc*, 60, 272-274

33. Baldwin AR. 1948. Effects of deodorization on the stability of vegetable oils. *J Am Oil Chem Soc*, 25, 33-35.

34. Belbin AA. 1993. Color in oils. Inform, 4, 648-649.

35. Kochhar SP. 1983. Influence of processing on sterols of edible vegetable oils, 22, 161–188

36. Erickson DR, Pryde EH, Brekke OL, Mounts, TL, and Falb RA. 1983. Handbook of Soy Oil Processing and Utilization. American Soybean Association and the American Oil Chemists Society. 1980, St. Louis, Missouri and Champaign, Illinois.