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Long-term storage of three unconventional oils

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RESUMEN

Conservación a largo plazo de tres aceites no convencionales

Tres muestras de aceite, *Sclerocarya birrea* oil (SCO), Melon bug oil (*Aspongubus viduatus)* (MBO), and Sorghum bug oil (*Agonoscelis pubescens*) (SBO), fueron almacenadas en la oscuridad a 30 ± 2 °C durante 24 meses. Cada 2-4 meses se toman alícuotas para analizar los cambios de calidad. Se determinaron la composición en ácidos grasos, el contenido en tocoferol, el índice de peróxidos y la estabilidad oxidativa mediante el aparato Rancimat. Después de 24 meses de almacenamiento, la composición en ácidos grasos no experimentó variación mientras que el contenido en tocoferol disminuyó en los tres aceites. SCO y MBO mostraron cambios minoritarios como se comprobó por los indices de peroxides y estabilidad a los 24 meses. SBO fue el menos estable de los tres aceites.

PALABRAS-CLAVE: *Agonoscelis pubescens – Almacenamiento – Aspongubus viduatus – Composición en ácidos grasos – Estabilidad oxidativa – Índice de peróxidos – Sclerocarya birrea – Tocoferol.*

SUMMARY

Long -Term storage of three unconventional oils

Three samples, *Sclerocarya birrea* oil (SCO), Melon bug oil (*Aspongubus viduatus)* (MBO), and Sorghum bug oil (*Agonoscelis pubescens*) (SBO), were stored (autoxidized) in the dark at 30 ± 2 °C for 24 months. Oil aliquots were withdrawn every 2-4 month for analyses of changes in four quality indexes, namely fatty acid composition, tocopherol content, peroxide value and oxidative stability index by Rancimat. After 24 months of storage the fatty acid composition of the three oils showed no change while tocopherol contents were decreased. SCO and MBO showed only slight changes in their oxidative stability as indicated by the peroxide value and induction period during the 24 months of storage. Sorghum bug oil showed a periodical increase in the peroxide value and had less stability as measured by the Rancimat in comparison to other oils.

KEY-WORDS: *Agonoscelis pubescens – Aspongubus viduatus – Fatty acid composition – Long-term storage – Oxidative stability – Peroxide value – Sclerocarya birrea - Tocopherol composition.*

1. INTRODUCTION

Sclerocarya birrea subsp. caffera is a Savannah tree, belonging to the family Anacardiaceae. The plant develops pale yellow fruits, which are plum-like, 3 - 4 cm in diameter with a plain tough skin and a juicy mucilaginous flesh (FAO, 1988). The fruit is edible and contains a hard brown seed. The seed encloses 2-3 soft white edible kernels (nuts), which are rich in oil and protein (Mizrahi and Nerd, 1996). The kernels contain 53.0, 28.0 and 8.0% oil, protein and carbohydrate on a dry basis respectively. In Western Sudan, the dry seeds are crushed, and the kernels obtained are an item of the local trade for edible purposes. Although, the tree represents a potential new oil source, it has never been commercially exploited for the production of oil or protein, (Mariod *et al*., 2005). The oil contains 67.2, 5.9 and 14.1% of oleic, linoleic and palmitic acid, respectively; 13.7 mg/100 g of tocopherols and has high oxidative stability, 43 hours at 120 °C in the Rancimat test (Mariod *et al*., 2004). Ogbobe (1992) who studied Nigerian Sclerocarya reported that it contained 50.7 % stearic, 22.6 % palmitic, 8.4 % arachidonic acid, with an iodine value of 102 and 3.1% unsaponifiable matter.

Glew *et al*. (2004) reported that the pit (kernel) of *Sclerocarya birrea* seed contained relatively large amounts of copper, magnesium, zinc and protein (36.4 % of dry wt); however, fatty acids accounted for 47% of the pit, two-thirds of which was due to oleic acid.

Aspongubus viduatus (melon bug) is a bug of 20 mm height, belonging to the order Hemiptera. The bugs are considered to be the main pest of watermelons. The adult nymphs pierce leaves, stems and young fruits and suck the sap, resulting in wilting, fruit drop and death of the plant. Melon bugs are considered edible in Namibia, where the last nymph stage is called “nakapunda”. In this soft stage the bug is cooked and eaten (http//www.science.mcmaster.ca). Melon bugs are widely distributed in Sudan, mainly in the western areas

(Kordofan and Darfor states) where field watermelons are considered as one of the most important crops for the traditional rainfed agriculture. In the western Kordofan state of Sudan the bug 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. a skin lesion remedy. The bugs contain 45% oil on a dry basis, which consisted of 46.5, 3.4 and 44.2% oleic, linoleic and palmitic acids, respectively, with low amounts of tocopherols, 0.3 mg/100g, and high oxidative stability of 38 hours in the Rancimat test (Mariod *et al.*, 2004).

Tauscher *et al.* (1981) 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 that of most animal oils.

Agonoscelis pubescens (Sorghum bug) belongs to the order Hemiptera (family Pentatomidae), commonly known in Sudan as Dura andat where it is one of the main pests of sorghum (Dura) in both rain fed and irrigated areas. The bugs have piercing-sucking mouthparts at all stages. They injure host plants by sucking the plant juices resulting in a characteristic musty flavor, which is detectable when a large number of the bugs is present or when the bugs are crushed.

In Western Sudan sorghum bug 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 the Botana area of Central Sudan, nomads use tar obtained from highly heated bugs for their camels against dermatological infections. The oil content of sorghum bug was 60% on a dry basis with 40.9, 34.5 and 12.1% of oleic, linoleic and palmitic acid, respectively, as main fatty acids. The oil contains 34.0 mg/100 g tocopherols (Mariod *et al.*, 2004).

The oxidative stability of vegetable oils depends on the fatty acid composition and the presence of minor components such as tocopherols, carotenoids, chlorophylls metal ions, phosphorus and initial amounts of hydroperoxides (Pekkarinen *et al.*, 1998). The storage stability of salad and cooking oils for long periods concerns a number of governmental agencies, commercial users and producers, as well as the individual consumer. Public reaction usually occurs only when rancid or oily flavors lower the quality of food purchased. Different authors studied the changes in fatty acid and tocopherol composition, stability, effect of packaging materials and chemical quality indexes of oils during storage (Fourie and Basson, 1989; Gómez-Alonso *et al.*, 2004; Evans *et al.,* 1973; Okogeri and Margari, 2002; Van der Merwe *et al.,* 2003; Budin and Breene, 1993; Gutierrez and Fernanz, 2002)

Especially in countries with high temperatures and limited facilities for cool storage the oxidative deterioration of fats and oils is a great problem. In this case the availability of fats and oils with a high oxidative stability during long term storage under the extreme climatic conditions of these countries is important.

The present study was aimed to investigate the changes that occurred in the fatty acid and tocopherol composition, peroxide value and oxidative stability during 24 months of storage of three unconventional Sudanese oils.

2. MATERIALS AND METHODS

2.1. Materials

All solvents used were of analytical grade, n-hexane, n-heptane, diethyl ether, ethanol and methanol were acquired from Merck, Darmstadt, Germany.

Dry seeds of *Sclerocarya birrea* were collected manually from the Ghibaish and Abu Gibaiha provinces of Western Sudan. Seeds were dehulled (decorticated) using a Vice model 2XFRONT (Heuer, Germany), crushed and ground by a grinding mill (Petra electric, Burga, 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 (1993). The obtained oil (SCO) was stored at 4 °C until storage experiment.

Aspongubus viduatus was collected from the Ghibaish province of western Sudan, and the oil was obtained by using a local hot water extraction method according to Mariod *et al,* (2004). In brief, the collected bugs were killed by a sudden hot water shock and crushed using a local woody mortar. The oil was extracted with boiling water, and the top oily layer was collected. Then the oil was heated again to remove water drops and afterwards melon bug oil (MBO) was kept in a plastic container at 4 °C until storage experiment.

Agonoscelis pubescens was collected from the Rahad Agricultural area of central Sudan. The bugs prepared for oil extraction following Mariod et al., (2004). In brief, the collected bugs were stored in a tight polyethylene bag, killed by treatment with hot water for a few minutes and then sun dried. After crushing using a lab mortar the oil was extracted using diethyl ether followed by AOCS (1993). The sorghum bug oil (SBO) obtained from the extraction was stored at 4 °C until storage experiment.

2.2. Oxidation experiments

Three samples of SCO, MBO and SBO (300 g each) were stored in 500-ml Erlenmeyer flasks, nearly full, tightly closed with aluminum foil and stored in darkness in an oven (Memment, Germany) at 30° ± 2 °C.

Oil aliquots were withdrawn for analyses periodically, every two months (for the first eight months) and every four months (for the next 16 month), to carry out analyses of fatty acid and tocopherol composition, peroxide value and oxidative stability by Rancimat

2.3. Fatty acid composition (FAC)

The fatty acid composition (FAC) of the three oils was determined following the ISO draft standard (ISO/FIDS 5509, 1997). 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 the 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 n-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 to a vial and injected into a Hewlett Packard 6890 gas chromatograph (Agilent, Waldbronn, Germany) with a capillary column, CP-Sil 88 (100 m long, 0.25 mm ID, film thickness 0.2 µm) (Varian GmbH, Darmstadt, Germany). 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 peak areas were computed by the integration software and percentages of fatty acid methyl esters (FAME) were obtained as weight percent by direct internal normalization. All determinations were carried out in triplicate.

2.4. Tocopherols (TOC)

For the determination of tocopherols a solution of 250 mg 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. Twenty 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) (Balz, *et al.,* 1992). All determinations were carried out in triplicate.

2.5. Oxidative Stability

The oxidative stability of the oils was determined by the Rancimat method. All experiments were carried out with a 743 Rancimat (Metrohm, Filderstadt, Germany) (Metrohm, 1994). 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.

2.6. Peroxide value (PV)

The peroxide value was determined following the German Society for Fat Science method (DGF C-VI 6a, 2002). In brief, 5 g sample were dissolved in 50 mL of a mixture of glacial acetic acid/isooctane (3:2 v/v) and 0.5 mL of saturated potassium iodide solution were added. Then the liberated iodine was titrated with a solution of 0.01 N sodium thiosulfate.

2.7. Statistical analysis

The analyses were performed with three replicates. The mean values and SD were calculated and tested using the Student-t-test ($p < 0.05$). A statistical analysis of variance (ANOVA) was performed at the end point of oxidation on all values using the statistical program Statgrafics® (Statistical Graphics System version 4.0, 1989).

3. RESULTS AND DISCUSSION

3.1. Changes in fatty acid composition

The fatty acid composition of the three oils before storage is shown in Table 1. No change in the fatty acid composition of the three oils studied was observed during storage for 24 months at 30 °C (Data not shown). These results agree with results found for other stable edible oils. Gutierrez and Fernanz (2002), who determined the fatty acids of virgin olive oil stored for 6 months at 30 °C in the dark, found no effect of storage time on fatty acid composition.

3.2. Changes in tocopherol content

Tocopherols are considered as one group of minor components responsible for the stability of oils. Changes in the content of these components during storage for 24 months at 30 °C are shown in Tables 2 to 4. In this study, α, γ, and δ-tocopherols were detected in the oils of SCO and SBO, while only α- and γ-tocopherol were found in MBO in very small amounts. The most predominant member of these compounds in the oils was γ-tocopherol.

After storage for 24 months at 30 °C, the level of total tocopherols fell by 25.0 %, 100.0%, and 86.5% in SCO, MBO, and SBO, respectively. Already after the first two months of storage the beginnings of tocopherol degradation were observed in all the oils. The most drastic decrease in total tocopherols was found for SBO, where the amount fell from nearly 35 mg/100 g to 4 mg/100 g after 24 months of storage.

Table 1
Fatty acid composition [%] of the starting unconventional oils*

Fatty acid	SCO Mean ± SD	MBO Mean ± SD	SBO Mean ± SD
Lauric acid (12:0)	0.31 ± 0.02	0.02 ± 0.01	0.0 ± 0.01
Myristic acid (14:0)	0.33 ± 0.09	0.33 ± 0.02	0.21 ± 0.02
Palmitic acid (16:0)	14.16 ± 0.2	30.95 ± 0.3	12.22 ± 0.1
Palmitoleic acid (16:1n-7)	0.15 ± 0.1	10.71 ± 0.1	1.04 ± 0.02
Margaric acid (17:0)	0.11 ± 0.01	2.43 ± 0.1	0.14 ± 0.01
Stearic acid (18:0)	8.84 ± 0.2	3.47 ± 0.1	7.27 ± 0.2
Oleic acid (18:1 n-9)	67.25 ± 0.3	46.63 ± 0.3	40.97 ± 0.2
Vaccenic acid (18:1 n-11)	0.84 ± 0.03	0.46 ± 0.02	0.73 ± 0.04
Linoleic acid (18:2 n-6)	5.93 ± 0.1	3.90 ± 0.02	34.53 ± 0.22
Linolenic acid (18:3 n-3)	0.12 ± 0.04	0.09 ± 0.01	1.14 ± 0.08
Eicosanoic acid (20:0)	0.91 ± 0.04	0.23 ± 0.03	0.77 ± 0.08
Gadoleic acid (20:1 n-9)	0.36 ± 0.01	0.17 ± 0.03	0.23 ± 0.05
Behenic acid (22:0)	0.22 ± 0.01	0.0 ± 0.02	0.23 ± 0.02
Lignoceric acid (24:0)	0.31 ± 0.02	0.0 ± 0.02	0.0 ± 0.01
SAFA	25.19 ± 0.6	37.43 ± 0.6	20.84 ± 0.5
MUFA	67.76 ± 0.4	57.51 ± 0.4	42.24 ± 0.3
PUFA	6.05 ± 0.1	3.99 ± 0.1	35.67 ± 0.3
Ratio UFA/SAFA	29.0	1.60	3.70

All determinations were carried out in triplicate and mean value ± standard deviation (SD) reported. SCO (*Sclerocarya birrea* oil), MBO (Melon bug oil), and SBO (Sorghum bug oil) are codes for the different oils. SAFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

In all oils a-tocopherol was exhausted first, but it must be taken into consideration that in all oils the amount of α-tocopherol was significantly less than (SCO and SBO) or equal (MBO) to the amount of γ-tocopherol. In MBO the total amount anyway was very low, so that the deterioration within the storage period was almost complete. Especially in SCO a remarkably high amount of γ-tocopherol remained in the oil after 24 months of storage (10.1 mg/100 g).

3.3. Changes in peroxide value

Changes in the peroxide value (PV) as a measure of primary oxidation in the three oils during storage are shown in Figure 1. The initial PVs of SCO, MBO and SBO were 0.2, 2.8 and 12.7 meq O2/kg; respectively and at the end of the investigation the oils reached PVs of 1.0, 6.4 and 71.5 meq O_2/kg. The mean values of the PVs of the oils were significantly different ($p < 0.05$) at the end of the experiment.

In SCO PV remained constant throughout the first year, then there was a very small increase with progressive storage time from 0.2 to 1.0 meq O2/kg oil in the last 12 months. In the case of MBO there was slight increase with storage time from 2.8 to 6.4 meq O2/kg oil during the whole storage period. Both values were significantly below the limit of 10 meq O_2/kg oil, used for the assessment of edible oil in different countries.

In contrast, SBO showed a fast increase of the peroxide value with storage time from 12.7- 71.5 meq O2/kg oil, which can be explained by the fatty acid composition with low oleic and high linoleic acid and the high initial peroxide value.

This indicates that SCO and MBO were highly stable against oxidative deterioration during long-term storage, while SBO showed a remarkable increase of the primary oxidation products.

The peroxide value of SCO remained constant up to the first 12 months of storage then increased slightly, which can be explained by the fact that this is a long-term oxidation study on monounsaturated oil which contains some natural antioxidants that prevent oxidation at first then by laps of time these antioxidants decreased and the peroxide value increased.

3.4. Changes in oxidative stability

The oxidative stability of oils can be evaluated experimentally in different ways, e.g., by measuring the amount of oxygen absorbed, by changes of conductivity of solutions containing secondary oxidation products or by time required to attain a predetermined peroxide value. The time period, which elapses until the oxidation process accelerates is a measure for the resistance of an oil against oxidation and is expressed as induction period (IP) or induction time (Wagner and Elmadfa, 1999).

The effect of storage on oxidative stability, measured as induction period (IP) of the three oils is shown in Figure 2. The initial values of the three oils were different. While for SCO and MBO a stability of more than 40 h was found, the oxidative stability of SBO was about 5 h. The high stability to oxidation of melon bug oil might be correlated with the high content of saturated fatty acids and to the high total amount of phenolic components (20.66 mg/100g oil) as well as to selected simple phenol components which were t-cinnamic and syringic acid, quercetin and pelargonin (Mariod, 2005).

During the storage experiment SCO showed an almost constant stability, with only a very slight

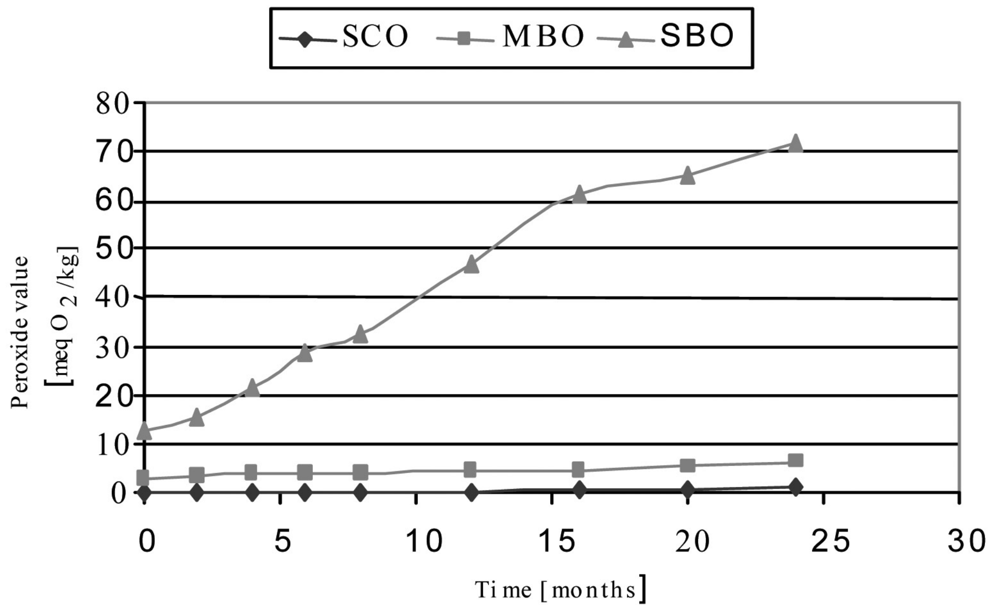

Figure 1
Peroxide values (meq O_2/kg) of the samples in the dark at 30 ± 2 °C.
(Mean values of oils are significantly different ($p < 0.05$) at the end of oxidation)

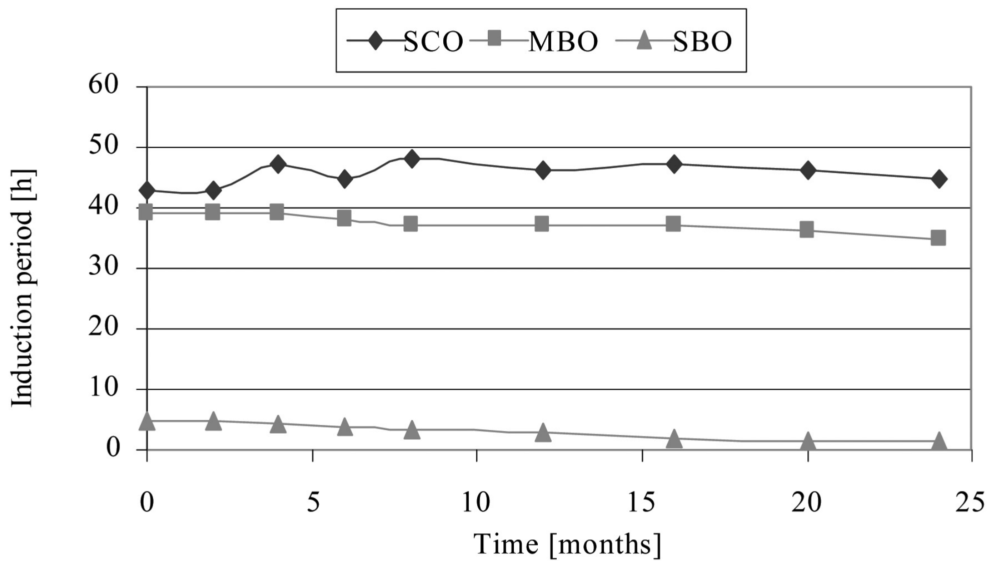

Figure 2
Induction periods [h] of oils stored in the dark at 30 ± 2 °C for 24 months.

decrease within 24 months, which was not significant ($p < 0.05$). Also for MBO only a very slight decrease of the oxidative stability was found. On the other hand, SBO showed a significant decrease of the stability during storage with a loss of 73%, indicating the higher susceptibility of this oil against oxidative deterioration during two years of storage at 30 °C.

The results show the high oxidative stability of SCO and MBO, which presented no significant changes.

In contrast, for other oils such as olive oil, previous studies (Pereira *et al.,* 2002; Gutierrez and Fernanz, 2002; Wagner and Elmadfa, 1999) reported a decrease in stability during storage by 30-41% and 40-70%, respectively, in the Rancimat test at 110 °C.

4. CONCLUSIONS

The three oils show significant differences in their behavior during long-term storage over a period of 24 months. While the fatty acid composition of the oils remained almost unaltered, a remarkable decrease in the amount of total tocopherols was found. While SCO showed a reduction of the tocopherols of about 23 %, in MBO

Table 2
Tocopherol [mg /100g] analysis of SCO during storage*

Time [month]	α-tocopherol Mean ± SD	γ-tocopherol Mean ± SD	δ-tocopherol Mean ± SD	total amount Mean ± SD
0	0.36 ± 0.02	13.05 ± 0.14	0.32 ± 0.17	13.73 ± 0.13
2	0.21 ± 0.02	13.02 ± 0.10	0.31 ± 0.11	13.54 ± 0.10
4	0.21 ± 0.01	12.14 ± 0.11	0.25 ± 0.12	12.60 ± 0.10
6	0.15 ± 0.01	12.09 ± 0.12	0.31 ± 0.10	12.55 ± 0.11
8	0.15 ± 0.01	12.08 ± 0.13	0.31 ± 0.13	12.55 ± 0.12
12	0.14 ± 0.01	11.13 ± 0.14	0.14 ± 0.14	11.41 ± 0.13
16	0.14 ± 0.01	11.05 ± 0.10	0.13 ± 0.12	11.32 ± 0.10
20	0.13 ± 0.01	10.17 ± 0.10	0.12 ± 0.11	10.42 ± 0.10
24	0.13 ± 0.01	10.06 ± 0.13	0.11 ± 0.16	10.30 ± 0.13

*All determinations were carried out in triplicate and mean value ± standard deviation (SD) reported.

Table 3
Tocopherol [mg /100g] analysis of MBO during storage*

Time [months]	α-tocopherol Mean ± SD	γ-tocopherol Mean ± SD	total amount Mean ± SD
0	0.17 ± 0.12	0.14 ± 0.15	0.30 ± 0.15
2	0.17 ± 0.10	0.12 ± 0.13	0.29 ± 0.11
4	0.15 ± 0.10	0.12 ± 0.14	0.27 ± 0.12
6	0.15 ± 0.12	0.08 ± 0.13	0.23 ± 0.13
8	0.12 ± 0.11	0.10 ± 0.12	0.22 ± 0.14
12	0.11 ± 0.13	0.02 ± 0.15	0.13 ± 0.10
16	0.08 ± 0.14	0.02 ± 0.13	0.10 ± 0.10
20	0.08 ± 0.11	0.01 ± 0.10	0.09 ± 0.08
24	0.00 ± 0.13	0.00 ± 0.10	0.00 ± 0.09

* All determinations were carried out in triplicate and mean value ± standard deviation (SD) reported.

Table 4
Tocopherol [mg /100g] analysis of SBO during storage*

Time [months]	α-tocopherol Mean ± SD	γ-tocopherol Mean ± SD	Plastochromanol-8 Mean ± SD	δ-tocopherol Mean ± SD	Total amount Mean ± SD
0	0.89 ± 0.12	32.16 ± 0.02	0.21 ± 0.11	0.78 ± 0.11	34.03 ± 0.15
2	0.80 ± 0.11	31.21 ± 0.02	0.19 ± 0.10	0.76 ± 0.10	32.96 ± 0.13
4	0.68 ± 0.10	31.17 ± 0.01	0.18 ± 0.10	0.75 ± 0.12	32.78 ± 0.12
6	0.42 ± 0.10	23.23 ± 0.01	0.16 ± 0a.11	0.56 ± 0.12	24.37 ± 0.16
8	0.35 ± 0.10	16.58 ± 0.01	0.00 ± 0.06	0.31 ± 0.10	17.24 ± 0.10
12	0.36 ± 0.11	15.97 ± 0.02	0.00 ± 0.06	0.30 ± 0.11	16.63 ± 0.11
16	0.31 ± 0.10	13.55 ± 0.02	0.00 ± 0.06	0.48 ± 0.10	14.34 ± 0.10
20	0.09 ± 0.09	5.26 ± 0.01	0.00 ± 0.06	0.38 ± 0.09	5.73 ± 0.09
24	0.00 ± 0.08	4.08 ± 0.01	0.00 ± 0.06	0.50 ± 0.09	4.58 ± 0.08

* All determinations were carried out in triplicate and mean value ± standard deviation (SD) reported.

and SBO tocopherols were reduced by 73 and 83%, respectively.

Remarkably stable was SCO during storage at 30 °C ± 2 °C, showing neither a decrease of the oxidative stability measured by Rancimat test nor an increase in the peroxide value. Also MBO showed only a slight decrease in oxidative stability with losses of 10% of the initial IP, while for SBO a gradual increase in the PV and a low stability as measured by IP was found.

The results show that especially SCO, but also MBO seem to be favorable for storage under extreme climatic conditions prevailing in African countries like Sudan. Both oils show only very slight changes in composition and in parameters describing the oxidative state of the oils after a period of 24 months at 30 °C ± 2 °C.

5. ACKNOWLEDGEMENT

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