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Characteristics and Oxidative Stability of Some Safflower (*Carthamus Tinctorius* L.)

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Abstract

The objective of this study was to evaluate the oil content, physicochemical properties, total lipid, fractionation, fatty acid composition ,unsaponifiable matter composition ,tocopherol content as well as the oxidative stability of safflower seed oils of two local Egyptian cultivars namely :Malawi and Giza 1 as well as one imported Ethiopian cultivar ,The fatty acid composition of the oils indicated that the predominant fatty acid was linoleic acid ((74.60-78.24%) followed by oleic (11.22 -14.19%), palmetic (6.03-6.66%) and stearic (2.01- 2.61%).The total lipids were fractionated to eight fractions with higher percent of triglyceride (81.70-85.34%). Total hydrocarbons constituted from 88.0 to94.7% while total sterols recorded from 5.32 to 12.00% of total unsaponifiable matters of oils. The tocopherols content was ranged from 1.36 to 56.96 mg/100 g oil .The oxidative stability of the studied oils was ranged from 6.20 to 6.45 h by using Rancimat at 100°C.The results indicated that safflower seeds contain a high content of edable oil which consider agood source of an essential linoleic fatty acid.

Keywords: *Carthamus tinctorius*; Safflower; Tocopherols, Fatty acid; Oxidative stability; Sterols

Introduction

Safflower (*Carthamus tinctorius L.*) - an oilseed crop - is a member of the family Compositae or Asteraceae. Carthamus is the latinized synonym of the Arabic word quartum, or gurtum, which refers to the color of the dye extracted from safflower flowers [1]. In Egypt, dye from safflower was used to colour cotton and silk as well as ceremonial ointment used in religious ceremonies and to anoint mummies prior to binding. Safflower seeds and packets and garlands of florets have been found with 4000-year-old mummies. The oil was used as an unguent and for lighting. By the 18th century, Egyptian safflower dye was used in Italy, France and Britain to color cheese and flavor sausage [2]. However, safflower is a minor crop with a world production of about 834,000 tons in 2013 [3]. For the last century the plant has been cultivated mainly for oil extraction from its seeds [4]. Seed oil content is between 35 and 50% [5]. Safflower oil is flavorless and colorless and similar in composition to sunflower oil [6,7]. In recent years, considerable attention has been generated in the consumption and development of safflower seed oil as an excellent health care product and health benefits derived from it include prevention and treatment of hyperlipidemia, arteriosclerosis, and coronary heart disease [8]. On other hand, safflower oil is stable and its consistency does not change at low temperature, making it particularly suitable for use in chilled foods. Safflower oil salad dressing have remained stable satisfactory to -12°C [2]. Moreover, high oleic safflower oils are very stable on heating, and do not give off smoker smell during frying [9]. Safflower oil is better suited to hydrogenation for margarine than soy or canola, which unstable in this process and it is sprayed on various edible products to prevent them absorbing or losing water, and thus extend their shelf live [10]. On other side, the oil is no allergenic, making it ideal for cosmetics [2]. Moreover, safflower is rich in premium grade high polyunsaturated essential fatty acid, linoleic, which makes the oil nutritionally and therapeutically valuable for human consumption [11]. However there is a lake in the information about safflower cultivars which found in Egyptian market and its oil characteristics thus, the objective of this work is to obtain information about the safflower seed oil characteristics as well as its oxidative stability for two Egyptian safflower cultivars as well as ne imported variety.

Materials and Methods

Materials

Safflower seeds of two Egyptian cultivars namely: Malawi and Giza 1as well as one imported cultivar from Ethiopian variety were obtained from the farm of Agricultural faculty; Cairo Univ. and local market of Cairo City during 2011/2012 season were used in this study.

The seeds were cleaned from forgien materials, hand dehulled and the obtained kernels were ground by using electrical grinder and used for analysis.

Methods

Determination oil content: The oil content of ground safflower seeds kernel was determined by extracting with petroleum ether for 6 hours in Soxhlet system according to the [12].

Lipid extraction: Total lipids of ground safflower seeds were extracted using chloroform and methanol mixture (2:1 v/v). The extraction lipids were filtrated over anhydrous sodium sulphate and stored in dark brown glass bottles at -20°C until further analysis [13].

Physicochemical properties of safflower seeds oil: Refractive index, specific gravity, acid value, iodine value, saponification number, and peroxide value and unsaponifiable matter of safflower seeds oil were determined by the method described in [14].

Fractionation of total lipid of safflower seeds oil: Total lipids

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were fractionated by thin layer chromatography technique. The total and neutral lipids were separated on silica gel G-coated thin layer plates using a solvent system of hexane: ether: acetic acid (80:20:1 v/v/v) as described by [15]. The lipid fractions were visualized by exposure to iodine vapor. All lipid fractions were identified on thin layer plates by comparing their RF values with those of known lipid standards [16]. For quantitatively analysis the TLC were scanned using the charring densitometry technique. The area under each peak was measured by computer software (TLSee 2v.) from LabHut.com, and the percentage of each fraction was computed with regard to the total area.

Fatty acid composition of safflower seeds oil: Preparation of methyl ester of fatty acids: The methyl esters of fatty acids were prepared from aliquots total lipids using 5 ml 3% H2SO4 in absolute methanol and 2 ml benzene as mentioned by [17]. The contents were heated for methanolysis at 90°C for 90 minute. After cooling, phase separation was performed by addition of 2 drops distilled water and methyl esters were extracted with 3 aliquots of 2 ml hexane each. The organic phase was removed, and filtered through anhydrous sodium sulfate.

Gas liquid chromatographic of methyl esters of fatty acids: The methyl esters of fatty acids were separated using HP 6890 GC capillary column gas liquid chromatography with a dual flame ionization were carried out on (30 m × 0.32 mm × 0.25 µm) DB-225 capillary column, stationary phase (50% cyanopropyl phenyl +50% dimethyl polysiloxane). Column temperature: initial temperature was 150°C, the temperature was programmed by increasing the temperature from 150-170°C at the rate of 10°C/minute, then increased from 170-192°C at the rate of 5°C/minute, holding for five minutes and then increased from 192-220°C during 10 minutes, holding three minutes. The injector and detector temperatures were 230°C and 250°C, respectively. Carrier gas: Hydrogen flow rate 40 ml/minute, nitrogen at the rate 3 ml/minute, and air flow rate was 450 ml/minute. Peak identifications were established by comparing the retention times obtained with standard methyl ester. The areas under the chromatographic peak were measured with electronic integrator. it was carried out in National Center of Research-Cairo.

Separation and identification of unsaponifiable matters of safflower seeds oil: The unsponifiable matters of safflower seeds oil were separated after saponification of oil samples according to the method outlined in [18]. The unsaponifiable matters were analysed using a PYE Unicam Pro-GC gas liquid chromatography with dual flame ionization in the presence of nitrogen as carrier gas. The separation was carried out at 70-290°C (temperature rate 10°C/min). The chromatography apparatus was fitted with 1.4 × 4 mm glass column, packed with diatomite C (100-120) mesh and coated with 3% OV 17. The injector and detector temperatures were 250 and 300°C, respectively. The nitrogen, hydrogen and air flow rates were 30, 33, 330 ml respectively. The chart speed was 0.50 cm/min. The peaks were identified by comparing their retention times with those of standard under same conditions.

Determination of tocopherol content of safflower seeds oil High performance liquid chromatography (HPLC) is used for the determination of tocopherols, using a solution of 250 mg of oil in 25 ml of n- heptane. 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.

The samples in the amount of 20 µl were injected with a Merck 655-A40 auto sampler onto a Diol phase of HPLC column; 25 cm × 4.6 mm ID (Merck, Darmstadt, Germany) using a flow rate of 1.3 ml/min. The mobile phase used was n-heptanes/tert-butyl methyl ether (99 + 1, v/v) along with pure standards of tocopherols for identification [19].

Determination of susceptibility to oxidative: Calculated oxidizability: The oxidizability of oil was calculated according to Fatemi et al. [20] as follows:

Oxidizability=[oleate % + 10.3 (linoleate%) + 21.6 (linolenate %)]/100

Determination of the susceptibility to oxidation with the rancimat method: Three grams of oil was accurately weighed into each of the six reaction vessels, and the following procedure was carried out according to the method described by [21]. The Metrohm Rancimat 679 (Metrohm Ltd., Herisau, Switzerland) was switched on until the temperature of the oil batch reached 120°C. Then 60 cm^3 of distilled water was placed into each of the six conductivity cells, and the air flow was set at 20 L/hr. The temperature was checked to ensure that it had a constant value. The air supply was connected to the tubes containing the oil samples, and the chart recorded was started. The determination continued automatically until the conductivity reached the maximal value and the induction period was recorded.

Result and Discussion

Oil content

Oil content of seeds is a very important economic trait of safflower cultivars and considered one of the most important factors affecting the successes of safflower introduction in new areas [22]. The data in Table 1 indicated the oil content of three safflower seed cultivars.

The data in Table 1 indicated that, the oil content was ranged from about 36 to 41% (on dry weight basis) in three studied cultivar .Among the local cultivars, Giza 1 variety contained more oil content (41.20%) compared with Malawi variety (35.89%). The imported safflower variety contained intermediate value (38.37). A mature seed of common types of safflower constitutes 27-32% oil and 5-8% moisture as reported by Gecgel et al. [23] while, Emongor et al. [24] found that, the seed contain 26-37% oil (on dry matter base). On other hand, the obtained oil content value was much less of 61.50% which reported by [25] for dehulled safflower seeds.

Physicochemical properties of safflower seeds oil

Some of the physical and chemical properties of safflower seeds oil are presented in Table 2. The physical and chemical characteristics of oils established its capability of application in either nutrition or industry. The specific gravity ranged from 0.919 to 0.921 and refractive index wad ranged from 1.468 to 1.471 were similar with the results obtained by Nagaraj [26] and Codex [27] for safflower seeds oil. The acid value of studied safflower seeds oil ranged from 0.31 to 0.90 (as % of oleic acid) with relatively high value for the imported Ethiopian variety. However, these results are agreed with those reported by Ortega-Garcia [28], Rafiquzzaman [29] and Ben moumen [30]. The data in Table 2 indicated that, the peroxide value (meq/Kg oil) ranged from 3.78 to

Safflower cultivar	Moisture (%)	Oil (%)
Malawi	6.60	35.98
Giza 1	6.79	41.20
Ethiopian	7.23	38.37

Table 1: Oil content (%) of safflower seeds kernel (% on dry weight basis).

Oil properties	Cultivar		
	Malawi	Giza1	Ethiopian
Specific gravity (25°C)	0.921	0.92	0.919
Refractive index (25°C)	1.471	1.469	1.468
Acid value (% oleic acid)	0.38	0.31	0.9
Saponification number(mg KOH/g)	211.5	215.7	218.35
Iodine value	147	144	143
Peroxide value (meq/k)	3.78	4.5	4.1
Unsaponifiable matter (%)	1.2	1.45	1.25
Thiobarbituric acid (TBA) (mg/kg)	1.3	0.96	1.24

Table 2: Physico-chemical properties of safflower seeds oil.

4.50 in the studied safflower seeds oil. On the other hand, the Codex Alimentarius Commission [31] permitted maximum peroxide levels of 10 meq peroxide/Kg oil for soy bean, cottonseed, rapeseed and coconut oils .The iodine value which used to indicate the degree of unsaturation of oils are presented in Table 2 for the studied safflower seeds oil. The iodine value was ranged from 143-147 (g I2/100 g oil).The obtained results were agree with the range of 130-150 which reported by Nagaraj [26] and the range of 136 -148 which reported by Codex Alimentarius standard [27].

The saponification number of the studied safflower seeds oil was ranged from 211.5 to 218.4 (mg KOH/g oil).The obtained results were higher than that reported by Codex Alimentarius [27] and Rafiquzzaman [29] who found the saponification values (86-198) and 190; respectively. The unsaponifiable matter of the studied oil samples was ranged from 1.20 to 1.45% as shown in Table 2. The results were in agreement with the results of Codex Alimentarius [27] and Rafiquzzaman [29].

Total lipid composition of safflower seeds oil

The qualitative and quantitative data of total lipids composition of safflower seeds oil are shown in Table 3.

The result revealed that, the total lipids of safflower seeds oil consisted of eight fractions for all the studied samples as shown in table 3.

The results indicated that, the major lipid component was the triglycerides which constituted from 81.70 to 85.34 % of the total lipids. The slight decrease of triglycerides percentage in Giza1 variety might had been some hydrolysis of triglycerides which had been appeared as increment of monoglycerides, diglycerides and free fatty acids compared with the other two cultivars as shown in Table 3. The polar lipid of safflower seeds oil was ranged from 1.43 to 1.84% of total lipids. However, Rafiquzzaman [29] indicated that, safflower seeds oil contained 90.5 and 1.2% of triglycerides and phospholipids of total lipids; respectively .On the other hand, monoglycerides was ranged from 1.86 to 2.18% of total lipids while diglycerides constituted from about 5.0 to 6.7% of total lipids. Moreover, the free fatty acids of the studied safflower seeds oil was relatively low and ranged from 0.38 to 1.01% of total lipids. The data in Table 3 revealed that, the free sterols content was ranged from 1.10 to 1.59% of total lipids composition. Beside, due to a correlation between sterols and health benefit, the content of them in foods has received much attention [8]. Sterol esters and hydrocarbons fraction of the studied safflower oils tanged from 4.31 to 5.30%of total lipids ,However , the obtained results of total lipids composition of safflower oil was slightly differ with the results of Ham and Hamilton [32] who found that , In crude safflower oils, triglycerides are the main constituents, making up to about 92-99%. Other constituents like phospholipids (0.4-0.6%), free fatty acids (1-2%), and unsaponifiable matter (0.6%) are present in minor amounts, and that may be due to the different of safflower cultivars, agricultural treatment or climate conditions.

Fatty acid s composition of safflower seeds oil

As known, the fatty acid composition of vegetable oil is a main factor affecting its commercial uses and it influenced by a lot of factors such as genotype of the variety, environmental conditions, etc., [23]. The fatty acid composition of total lipids extracted from the studied safflower seeds oil is presented in Table 4. As known, the fatty acid composition of vegetable oil is a main factor affecting its commercial uses and it influenced by a lot of factors such as genotype of the variety, environmental conditions, etc. [23]. The fatty acids composition of total lipids extracted from Ethiopian, Malawi and Giza1 safflower seeds are shown in Table 4, the results of analysis for fatty acid showed that the unsaturated fatty acids of linoleic (74.60, 78.24 and 77.90,%) and oleic (14.19, 11.22 and 11.39%) and the saturated fatty acids of palmitic (6.03, 6.57and6.66%) and stearic (2.61, 2.01 and 2.06%) were the most abundant fatty acids in respecting decreasing order, which together composed about 97.43, 98.04 and 98.01% of the total fatty acids for Malawi , Giza 1 and Ethiopian cultivars ; respectively. A negligible amount of linolenic acid was detected (0.07-0.08%) and minor amount of ecosenoic (C 20:1), palmitoleic (C16:1), arachidic (C 20:0) and behenic (C 22:0) were present and the values of them did not exceed 0.89% of the total fatty acids. These results are comparable to data previously reported in the literature by Sabzalian [33]. Besides

Lipid fraction	cultivar		
	Malawi	Giza 1	Ethiopian
Polar lipids	1.43	1.53	1.84
Monoglycerides	1.86	2.18	2.13
1,2 & 2,3 diglycerides	4.45	4.59	4.23
1,3 diglycerides	1.13	2.1	0.83
Free sterols	1.1	1.59	1.24
Free fatty acids	0.38	1.01	0.43
Triglycerides	85.34	81.7	84.63
Sterol esters & hydrocarbons	4.31	5.3	4.67

Table 3: Total lipids composition of safflower seeds oil.

Fatty acids	Carbon chain	Safflower seed cultivars		
		Malawi	Giza1	Ethiopian
Palmetic	C16:0	6.03	6.57	6.66
Palmetolic	C16:1	0.06	0.09	0.09
Margaric Acid	C17	0.02	0.03	0.02
Margaoliec acid	C17:1	0	0.01	0.01
Stearic	C18:0	2.61	2.01	2.06
Oleic	C18:1	14.19	11.22	11.39
Linoleic	C18:2	74.6	78.24	77.9
Linolenic	C18:3	0.07	0.08	0.08
Arachidic	C20:0	0.34	0.29	0.3
Ecosenoic	C20:1	0.19	0.17	0.17
Behenic	C22:0	0.24	0.24	0.25
Unknown	Unknown	1.51	0.91	0.93
Lignoceric Acid	C24:0	0.1	0.1	0.11
Total saturated fatty acid		**9.34**	**9.24**	**9.4**
Total unsaturated fatty acid		**89.11**	**89.8**	**89.64**
Nutritional quality index(linoleic/ saturated fatty acid)		**7.99**	**8.47**	**8.29**
Oil stability index(oleic/linoleic)		**0.19**	**0.15**	**0.15**

Table 4: Fatty acids composition of total lipids of safflower seed varieties (% of total fatty acids).

compared to most other common edible oils, safflower oil contains the highest level of the linoleic acid, an essential fatty acid, which is make it as premium edible oil, because of its nutritional advantages and potential therapeutically properties in the prevention of coronary heart disease and cancer but the presence of the large amounts of linoleic acid makes the oil quite sensitive to oxidation [34]. Moreover, the essential fatty acid is not easily synthesized in the human system and must be supplied externally through the diet [35]. Therefore, safflower seed oil with the highest w-6 essential fatty acid (linoleic acid) among all common edible oils can be a good nutritional supplement as a source of linoleic acid. Smith [36] indicated that, the importance of safflower seed oil is in its linoleic acid content, which is a required product with high poly unsaturated fatty acid clime. However , the total saturated fatty acid content of safflower oil was low (924-9.40%) of total fatty acids content while, the total unsaturated fatty acid was about 90% of total fatty acids content as shown in Table 4. Generally, high intakes of saturated fatty acids have been associated with raised blood cholesterol levels, one of the risk factors associated with heart diseases .In comparison mono unsaturated fatty acids decrease the bad cholesterol, (LDL-C) ,while polyunsaturated fatty acids also decrease LDL-C, intakes of n- 6 PUFA above 10% energy may have adverse effects on good cholesterol ,(HDL-C) as mentioned by Clarke et al. [37]. On other hand, the nutritional quality index (linoleic/saturated fatty acids) is very high and ranged from 7.99 to 8.47 compared with that of groundnut oil which ranged from 1.8 to 2.4 as reported by Nagaraj [26]. In opposite the ratio of oleic to linoleic acid being a measure of oil keeping quality (oil stability index) was low and ranged from 0.14 to 0.19 as presented in Table 4. Besides, the all studied safflower seed oils contained long-chain fatty acids (C20-C24) with minor mounts. The same observation was detected by Bozan and Temelli [38] when studied flax, safflower and poppy seed oils.

Unsaponifiable matter of safflower seeds oil

Data in Table 5 illustrated the analysis of unsaponifiable matters of safflower seeds oil using GLC. The hydrocarbons were fractionated to twenty component with (C11) to (C30) and constituted from 88.00 to 94.68% of total unsaponifiable matter of the studied safflower seeds oil .The sterols component were identified as Campsterol, Stegmasterol and β-sitosterol in the studied safflower seed oils and constituted from 5.32 to 12.00% of the total unaponifiable matters, However ,among the three studied safflower seed oils, Giza 1 cultivar contained the highest value of sterols (12%)followed by Ethiopian (5.94%)and finally Malawi cultivar with 5.32. However, plant sterols have a structure similar to cholesterol and hence reduce cholesterol absorption, there for reducing the circulating levels of total and low density lipoprotein (LDL) cholesterol [39] sterols are very important for human health and nutrition because of their biological properties related to reduce serum total and LDL cholesterol levels. Due to a correlation between sterols and health benefit, the content of them in foods has received much attention [8]. From this point , among the studied three oil , Giza 1 safflower seed oil consider superior than two other cultivar oils which contained more sterols content.

Tocopherols (Vitamin E) content of safflower seeds oil

Tocopherols, normally known as vitamin E, are a group of lipid soluble compounds which naturally occurring in oilseeds in four various forms (α-, β-, γ-and δ-tocopherol). Tocopherols are valued for their vitamin E activity and their antioxidant properties to protect polyunsaturated fatty acids against oxidation thus the level of tocopherol in seed oils are extremely important [11]. Tocopherols have widely been used for food, feed, pharmaceutical cosmetics and resins. In food, tocopherol is used as an antioxidant for frying oil, margarine, fried snakes, and so on. In addition, tocopherols, due to their capacity to quench free radical damage, play a positive role in prevention of Al zheimers disease and cancer [40]. Tocopherols (Vitamins E) content of the studied safflower seed oils are presented in Table 6 .The revealed data indicated that, the tocopherol content ranged from 1.36 to 56.96 mg/100 g oil. However, the local safflower cultivars contained less content of tocopherol as compared with the important one and that might be due to the genotype and environmental conditions .Beside among the local cultivars, Giza 1 cultivar contained more tocopherols than Malawi cultivar as shown in Table 6. Moreover, the tocopherols content of four varieties of Iranian safflower seed oil were ranged from 201 to 465 mg /kg oil .While, Nagaraj [26] mentioned that safflower oil contains about 270 mg/Kg .

Oxidative stability of safflower seeds oil

Oxidative stability is a paramount parameter in assessing the sensory and nutritive quality of the oils and fats which reflects their susceptibility to oxidative degeneration and it is influenced by the present of unsaturated fatty acids and bioactive constituents such as sterols and tocopherols [11]. Lipid oxidation causing reduction of the nutritive value and functional properties of food products [41-45].The results of Rancimat test are shown in Table 7. The oxidative stability of the analysis oils expressed as the oxidation induction time, was ranged from 6.20 to 6.45 hr at 100°C. The oil extracted from imported Ethiopian safflower was more stable for oxidation compared to the two Egyptian cultivars and that might be due to the higher content of tocopherols in the Ethiopian variety as indicated in table 6. However, among the two local cultivars the Giza 1 cultivar have more stability to oxidation than Malawi cultivar and that reflect its more of duplicate content of total

No	Component	Safflower seed cultivars		
		Malawi	Giza1	Ethiopian
1	Undecane(C11)	0	0.19	0
2	DodecaneC12)	0.82	0.76	1.22
3	Tridecane (C13)	0	0.53	0
4	Tetradecane (C14)	0	0.13	0
5	Pentadecane (C15)	0	0.21	0
6	Hexadecane (C16)	4.06	3.32	5.68
7	Hebtadecane(C17)	0	0.74	0.77
8	Octadecane (C18)	0	0.46	2.09
9	Nonadecane (C19)	2.4	1.08	2.68
10	Eicosane (C20)	2.98	2.28	0
11	Heneicosane(21)	5.46	8	15.47
12	Docosane (C22)	7.67	7.22	7.41
13	Tricosane(C23)	9.45	8.79	8.72
14	Tetracosane (C24)	7.2	6.53	5.72
15	pentacosane(C25)	10.46	9.97	9.48
16	Hexacosane (C26)	7.3	6.27	6.61
17	Hebtacosane(C27)	9.12	9.21	8.91
18	Octacosane(C28)	12.02	7.26	8.23
19	Nonacosane (29)	10.1	9.8	6.59
20	triacontane (30)	5.63	5.24	4.47
21	Campsterol	1.84	2.81	2.39
22	Stigmasterol	2.73	7.14	2.58
23	β-sitosterol	0.75	2.04	0.97
Total hydrocarbons		94.68	88	94.06
Total sterols		5.32	12	5.94

Table 5: Unsaponifiable matters content of safflower seed varieties (% of the total unsaponifiable matters).

Safflower oil cultivars	Malawi	Giza1	Ethiopian
Tocopherol (mg/100g of oil)	1.36	4.05	56.96

Table 6: Tocopherol (vitamin E) content in safflower seed oils (mg/100 g).

Characteristics	Safflower seed cultivars		
	Malawi	Giza1	Ethiopian
Rancimat value (at 100°C) (hours)	6.2	6.27	6.45
Calculated oxidizability	8.19	8.15	7.84

Table 7: Oxidative stability of Safflower seed oil varieties.

sterols and more twice content of tocopherols compared to Malawi cultivar as shown in tables 5 and 6; respectively. On other hand, the oxidative stability of safflower oil measured at 110°C was 2.87 h as reported by Bozan and Temelli [38] and was varied from 3.41 to 3.83 h at 110°C as found by Vosoughkia et al. [11]. Moreover, the calculated oxidizability depending on the fatty acid composition according to Fatemi and Hammoud, [20] was 8.19, 8.15 and 7.84 for Malawi , Giza 1and Ethiopian safflower; respectively and that agree with the oil stability index which shown in table 4 which depend on oleic/linoleic ratio [46,47].

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