

UTILIZATION OF DEODORIZER DISTILLATE UNSAPONIFIABLE MATTER OF COTTON SEED AND PALM OILS AS NATURAL ANTIOXIDANT FOR SUNFLOWER SEED OIL

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ABSTRACT

Deodorizer distillates of cottonseed oil (DODC) and palm oil (DODP) contained moisture 0.54, 0.46 unsaponifiable matter% 9.0, 14.9 tocopheral %0.14, 2.15 oxidized fatty acid %0.51, 0.84, acid value 10.35, 145.65, saponification value 182.4, 176.0 and peroxide value 3.74, 5.91 respectively. Using different concentrations (0.05, 0.1 and 0.3%) of unsaponifiable matter (USM) for each DOD increased the stability of sunflower seed oil. The results indicated that USM of DODP was more effective as natural antioxidant than that of DODC.

Keywords: Deodorizer distillate, Cotton seed oil. Palm oil, Sunflower seed oil, Unsaponifiable matter.

INTRODUCTION

Deodorization (Caustic or Physical refining) is the last major processing step in refining of edible oils. It is responsible for removing the undesirable ingredients present in natural fats and oils. Fraction produced from the deodorization process called, deodorizer distillate, contains the volatile organic material which is steam distilled during the deodorization of fats and oils. This distillate contains tocopherols, sterols, and hydrocarbons which are considered as valuable raw materials for production of natural antioxidant (tocopherol) Hui (1996) and Ó Brien (2004).

Antioxidants such as butylated hydroxy toluene (BHT), butylated hydroxy anisole (BHA) and propyle gallate (PG) are usually added at different concentrations ranged from 50 to 200 ppm to fats and oils to suppress the development of peroxide during food storage. Recently, there has been some discussions about the undesirable effect of synthetic antioxidants, as dietary administration of (BHT) to rats caused fatal hemorrhages in pleural and peritoneal cavities and in organs such as epididymis, tests and pancreas, (Verhagen, 1989). Also, BHT caused changes in rat thyroid stimulation of (DNA) synthesis and induction of enzyme BHA which had toxic effects, (Williams 1990). However, these antioxidants are approved for food use within limits. (Chen, et al., 1992) and Meza et al. (1999). However, over the past few years increase consumer demand for more natural "preservative free" products has led the food industry to consider the incorporation of natural antioxidants in a range of products. The use of natural antioxidants has the advantage of being more acceptable by the consumers as these are considered as "no. chemical". In addition , they do not require safety tests before being used.

This deodorizer distillate cause problems to the Egyptian problems since they discard it in the Nile water as it kills the fish and pollute the water, so that a trial for the utilization of its unsaponifiable matter, should be of a high value. Kamal – El. Din and Andersson (1997). compared the tocopherol levels in some oils, and found that the different oils contained various tocopherols with different concentrations. Parkhurst *et al.* (1968) studied the effect of various concentrations of tocopherols and tocopherol mixtures on the oxidative stability of lard sample at 97°C. The antioxidant effectiveness of the tocopherol was found to increase in the order α , γ , δ . The antioxidant and efficiency of all tocopherols decreased with increasing its concentrations of such that addition of any single tocopherol above a concentration of 250 $\mu\text{g/g}$ had little effect on oxidative stability. No antioxidant activity of a mixture equivalent to that of an average peanut oil sample, containing 150 $\mu\text{g/g}$ of α -tocopherol and 250 $\mu\text{g/g}$ γ -tocopherol and 15 $\mu\text{g/g}$ of- δ -tocopherol was found to be more stable than that containing 250 $\mu\text{g/g}$ of γ -tocopherol alone. Jung and Min (1990) studied the effect of 0, 100, 500 and 1000 ppm of α , γ , δ -tocopherol on the oxidative stability of purified soybean oil in the dark at 55°C. They found that the optimum concentrations of α , γ , δ - tocopherols requested to increase oxidative stability were 100, 200 and 500 ppm, respectively, as it had a significant prooxidant effect at higher concentrations. Satue *et al.* (1995) studied the effect of natural antioxidants (α - tocopherol at levels of 100 and 500 ppm) on the oxidative stability to olive oil, They found that the α -tocopherol at 100 ppm was effective antioxidant while it showed a prooxidant effect at higher concentration (500 ppm).

Hallabo (1977) found that the stability of refined cotton seed oil at 100°C increased from 8.5 hours to 31.5, 26.5 and 14 hours (equal to 3.7, 3.1 and 1.64 relative stability) when the unsaponifiable matter of soybean oil was added in concentrations of 0.1,0.2 and 0.3% respectively. Khalil *et al* (2001) reported that addition of unsaponifiable matter of crude olive pomace oil to sunflower increased its induction period from 6 days to 6.4, 6.8, 6.9 and 7.3 days by using concentration at 100, 200, 500 and 1000 ppm respectively. Malecka, (2002). reported that the addition of 0.3% form the USM isolated from tomato seed oil showed higher antioxidants activity than addition of 0.02% BHA and USM from oat grain or wheat germ oil. Δ_5 -avenasyerol and citrostadienol as well as tocopherol that were identified in USM of tomato seeds oil could be responsible for its potential antioxidants activity. Similar results were obtained by EL – Bastawesy *et al.* (2007 & 2008), who reported that peach, tomato, grape and mango seeds are considered rich sources of natural antioxidants. The methanolic extracts of these seeds had high antioxidants activity more than that of BHT.

Therefore, this work was carried out to evaluate the utilization of the by-products of deodorization process produced during refining of both cotton seed oil and palm oil as sources of unsaponifiable matters rich in tocopherols. and their utilization as natural antioxidants in sunflower oil that should be of quite high value for oil industry.

MATERIALS AND METHODS

Materials:

The following materials were used in the present investigation: Deodorizer distillate of palm oil (DODP) was obtained from Misr Gulf Oil Company, Attakah – Suez Egypt during physical refining process at 240°C and a pressure of 3 mm Hg. Deodorizer distillate of cotton seed oil (DODC) during deodorization process at 180°C and pressure of 10mm. Hg and refeined sunflower used obtained from Cairo Oil and Soap Company, El-Aiyat factory, Giza Egypt.

Standards: α , γ , & δ - tocopherols were obtained from Hoffmann – Laroche company L.td., Pasle, Switzerland. All organic solvents were purified according to the methods outlined by Vogel (1973). All chemicals used were analytical grade.

Methods:

Moisture was determined in DODP and DODC according the AOCS (1984) and acid, saponifacian, ester and peroxide values. Beside total fatty acids, free fatty acids, oxidized fatty acids, glycerides and unsaponifiable matters percentages were determined in DODP and DODC according to AOCS (1984) methods. Stability of sun flower seed oil was measured by using oven test at 63C° according to Cocks & Rede (1966).

Acid, peroxide, saponification, iodine values and unsaponifiable matter were determined in sunflower seed oil according to AOCS. (1984) methods.

Total tocopherols were determined in DODP, DODC unsaponifiable matters and sunflower seed oil according to the method of Wong *et al.* (1988) as follows: Two hundred \pm 10 mg of the sample were weighed accurately in a 10 ml volumetric flask. Five mls of toluene were added by pipette and the sample dissolved. Three and one half ml of 2,2 bipyridine (0,07 % W/V in 95% aqueous ethanol) and 0.5 ml of FeCl₃ 6H₂O (0.2 % w/v in 95% aqueous ethanol) were added in that order. The solution was made up to 10 ml with 95% aqueous ethanol after standing for one min. The absorption at 520 nm was measured using (Spectronic 20) against a reference of a blank solution that was prepared as above but omitting the sample. Solutions were protected from strong light during color development. The method was calibrated by preparing standard solutions, contains 0-100 μ g of pure α -tocopherol in 10 ml of toluene and then analyzed as above. The concentration of tocopherol in μ g in the samples was calculated from the standard curve.

Extraction of unsaponifiable matter of DODP and DODC:

The total unsaponifiable matters of DODP and DODC were extracted by using alkali solution according to AOAC (1990).

Efficiency of unsaponifiable matter as a natural occurring antioxidants:

The unsaponifiable matter extracted with alkali from DODP and DODC were added at 0.05%, 0.1% and 0.3% to the sunflower oil after evaporation of solvent. The oxidative stability was determined by the oven test method of Cocks and Rede (1966). An oil sample (100 gram) was placed in a 200 ml beaker covered with a watch glass and incubated at 63 \pm 0.5°C and peroxide

value measured every 24 hours for up to 1483 hours. Peroxide value reversed time was plotted and induction period determined according to Hallabo, (1977) to evaluate the unsaponifiables as natural occurring antioxidant. Also, concentration of 100, 200 ppm of α -tocopherol was used as antioxidant and its efficiency was compared with that of the unsaponifiable matter.

RESULTS AND DISCUSSION

Chemical composition of deodorizer distillates:

Chemical composition of deodorizer distillates of both palm and cotton seed oils (DODP and DODC) was determined. From the results shown in Table (1), it is noticed that moisture content in the DODP and DODC was 0.46 and 0.54% respectively. The results are in agreement with those obtained by Basiron (1996) and Ghosh & Bhattacharyya (1996). Also, it could be noticed that the free fatty acids content of the DODP and DODC were found to be 69.80% and 5.03%, respectively. Such difference might be due to the different conditions used during refining,. Deodorizer distillate of palm oil was essentially produced during physical refining process which was carried out at high temperature and low pressure (240°C and 3mmHg). These conditions decreased the FFA content of oil; being deodorized to quite low acid values than that obtained by the ordinary normal deodorization conditions and hence FFA content will increase in DODP. DODC was produced from oil that was alkali refined and subjected to only 180°C, and 10 mm Hg for its deodorization, hence FFA are not stripped in the DODC.

Schmidt (1989) reported that physical or steam refining might be able to lower the free fatty acid content in the oil to be between 0.02 and 1% down to be only 0.02-0.03%. However. Arnold (1977) found that the physical refining could produce refined oil containing only 0.03% FFA from crude palm oil containing 5% FFA. Meanwhile, during refining of cotton seed oil that was carried out with caustic refining, the FFA in caustic refining was mostly removed in soap stoke. The deodorization process was carried out at lower temperature and high pressure (180°C and 10 mm Hg). These results are in agreement with those reported by Abd El-Aziz (1985), who found that the FFA of DODC contained 18.56% FFA, while Jones (1996) reported that the FFA of DODP was 70%. Acid value of DODP and DODC was 145.56 and 10.35, respectively. The acid value of DODP was more than that of cotton seed oil, which is due to the higher content of FFA in the first one. Ramamurthi and McCurdy (1993) confirmed that the acid value of canola, mixed canola and soya, and soya deodorizer distillates was 157.6, 5, 64.8 and 44.8%. respectively. From the-same results mentioned in Table (1), it could be observed that the saponification values of DODP and DODC. were 176.00 and 182.40, respectively. Ghosh & Bhattacharyya. (1996) reported that the saponification value of sunflower oil deodorizer distillate was 138.1. Meanwhile, Ramamurthi, & McCurdy (1993) mentioned that the saponification value of canola and soya deodorizer distillate was 163 and 72.8, respectively. Bondioli *et al.* (1993) reported that the saponification value

of olive oil deodorizer distillate was 49.6. Also, from the results reported in Table (1), it could be observed that the ester value of DODP and DODC more 30.35 and 172.05 respectively. The ester value of DODC was more higher than that of the DODP, which is due to the higher percentage of esterified fatty acids in the first compared to the second. Also, it can be noticed that the peroxide value of DODP and DODC was 5.91 and 374 milliequivalent/kg DOD. respectively. These results confirmed with those obtained by Abd El-Aziz (1985) who reported that the peroxide value of DODC (on fresh weight basis) was 3.4%. El-Mallah *et al.* (1990) reported that the deodorizer distillate contained peroxides that are formed by mild oxidative of oils during processing. Basiron (1996) mentioned that the DODP contained more volatile odoriferous and oxidated products than the original oil. The total fatty acid percentage in the DODP and DODC was 84.64% and 90.27%, respectively while the esterified fatty acids (glycerides, mono, di and tri) were 14.84% and 85.24% respectively. The high glycerides content in DODC results from the method used for each production. The DODC was obtained after neutralization of the crude oil with alkali and hence, all FFA are esterified to soap. Oxidized fatty acids of DODP and DOPC were 0.84 and 0.51%, respectively. According to the results in Table (1), the total tocopherol in DODP was 2.15% (21500 ppm) [as α -tocopherol from standard curve], while total tocopherol of DODC was 0.14% (1400 ppm). The higher amount of total tocopherol of DODP than that of DODC, could be due to the different conditions of refining processing, since physical refining process causes a high reduction of tocopherol that resulted from the high temperature used during refining. Wong *et al.* (1988) mentioned that, during steam refining and deodorization processes, there was a substantial reduction in tocopherol content, from 907-920 ppm in the feed degummed and bleached olein to 636 ppm in the refined, bleached and deodorized oil. Cvengros (1995) reported that the physical refining of edible oil reduced phytosterol and mainly tocopherols. Also, conventional method (caustic refining) of cotton seed oil used basic solution in neutralization. The basic solution leads to degradation of tocopherol, so that the tocopherol content is lower than that in DODC. Rudy and Senkowski (1974) mentioned that the basic solutions in presence of oxygen leads to a rapid oxidization of tocopherol into quinine. Jones (1996) reported that the crude cotton seed oil contains about 1000 ppm tocopherols but up to one third could be lost during refining. The deodorization step removes tocopherols from the oil, but they may be recovered from the distillate and sometimes marketed as by-product. These amounts are more than that obtained by Abdul-Gapor (1984) who reported that total tocopherol in DODP was 0.4% (4000 ppm). El-Mallah *et al.* (1990), reported that the total tocopherol in deodorizer distillate of soybean oil reached up to 2%. Ramamurthi and McCurdy (1993) reported that the total tocopherol contents in deodorizer distillate of canola, mixed canola and soya were 1%, 4.15 % and 12.74%, respectively. Also, Brunner *et al* (1991) mentioned that the total tocopherol in deodorizer condensate of soybean oil was 11.6 % (2.2 α and 9.3 γ , β and δ -tocopherols). Ghosh & Bhattacharyya (1996) confirmed that the total tocopherol in sunflower oil deodorizer distillate was 4.8%. According to the results shown in Table(1), the unsaponifiable matter in the DODP and

DODC was 14.90% and 9.00% respectively. These results confirmed those obtained by Abd El- Aziz (1985) who reported that the unsaponifiable matter of deodorizer distillate of cotton seed oil was 10.6%, and also those obtained by Abdul Gapor *et al.* (1989) and Basiron (1996) who found that the unsaponifiable matter of DODP was 15.34%. Frank (1976) reported that deodorization reduced unsaponifiable matter content of soybean oil by about 60%. Meanwhile. Ramamurthi & McCurdy (1993) found that the unsaponifiable matter of canola and soya deodorizer distillates was 14.6% and 58.1%, respectively. On the other hand, Ghosh & Bhattacharyya (1996) reported that the unsaponifiable matter of sunflower oil deodorizer distillate was 24.9%.

Table (1): Chemical properties of DOD of palm and cotton seed oils.

Properties	DODP	DODC
Moisture (%)	0.46	0.54
Free fatty acids (%)	69.80	5.03
Acid value	145.65	10.35
Saponification value	176.00	182.40
Ester value	30.35	172.05
Peroxide value	5.91	3.74
Total fatty acids (%)	84.64	90.27
Glycerides % (mono, di and tri)	14.84	85.24
Oxidized fatty acids (%)	0.84	0.51
Total tocopherols (%)	2.15	0.14
Unsaponifiable matter (%)	14.90	9.00

Chemical composition of the unsaponifiable matters extracted from DODP and DODC.

Unsaponifiable matters extracted from DODP and DODC after saponification with alkali were analyzed for their contents of sterol, tocopherol and total hydrocarbon using TLC and Densitometer for quantitative identification percent of each component. From the results presented in Table (2), it is noticed that the unsaponifiable matter extracted from DODP after saponification with alkali contains 5.93% sterols, 22.53% total tocopherols and 43.00% hydrocarbons.

It is clear that the major component of the unsaponifiable matter of DODP was found to be hydrocarbon compounds and tocopherols; while the minor components were sterol and unknown compounds amounted to 28.54%. Also, from the results shown in Table (2), it is observed that the unsaponifiable matter of DODC contained 12.93% sterol, 17.88% total tocopherol and 51.89% hydrocarbon, while the unknown compounds amounted to 27.1%. These results indicate that the unsaponifiable matter extracted from DODP after alkali treatment contains more α , γ , δ -tocopherol and less sterol and total hydrocarbon than that extracted from DODC after the same treatment. These results are in agreement with those of Abd El-Aziz (1985), who reported that the major component in unsaponifiable matter extracted from DODC by alkali method was hydrocarbon, while minor component was sterol.

Table (2): Fractionation and identification of unsaponifiable matter from DODP and DODC after saponification with alkali

Component	USM of DODP%	USM of DODC%
Sterol	5.93	12.93
Unknown	6.95	6.02
δ – tocopherol	6.17	4.38
Unknown	9.72	--
γ -tocopherol	5.53	4.84
α -tocopherol	10.83	8.66
Unknown	--	2.20
Unknown	8.62	6.59
Unknown	3.25	12.29
Hydrocarbon	43.00	51.89

Chemical properties of sunflower oil used for estimation of its stability:

Acidity, acid value, peroxide value, saponification value, iodine value, unsaponifiable matter tocopherol (ppm) and stability at 63°C in hours were determined in the investigated refined sunflower oil. These properties will give an idea about the quality of oil under investigation and its freshness, and the obtained results are shown in Table (3). From the results shown in Table (3) it could be noticed that the acidity and acid value were 0.06% and 0.12, respectively. These results indicate that the oil was not subjected to hydrolytic rancidity in the seed before extraction. The peroxide value was found to be only 0.35 millequivalent/kg oil, which indicates also the freshness of the oil. Saponification value of sunflower oil was 189 and iodine value (Hunus) was 124.88 and both values are within limits for sunflower seed oil according to Egyptian Standard for Edible Oils (1993) and AOCS (1984). The unsaponifiable matter of sunflower oil was 1.28% and tocopherol content was 716 ppm. Such results are in agreement with those of Basiron (1996), who reported that the unsaponifiable matter of refined sunflower oil was 1.2% and tocopherol content was 700 ppm. Stability of sunflower oil by oven test at 63°C was 690 hours.

Table (3) Chemical properties of sunflower seed oil.

Properties	Value
Acidity (%)	0.06
Acid value	0.12
Peroxide value	0.35
Saponification value	189.0
Iodine value	124.88
Unsaponifiable matter %	1.28
Tocopherol (ppm)	716.00
Stability in hours at 63°C	690.00

Effect of addition of α -tocopherol standard on oxidative stability and relative stability of sunflower seed oil:

Addition of α -tocopherol with different concentrations (100 and 200 ppm) on the oxidative stability and relative stability of sunflower oil is shown in Table(4). From the results, it could be observed that the induction period of

sunflower oil alone (control sample) at 63°C was 690 hours; while addition of 100 and 200 ppm α -tocopherol caused a noticeable increase in the induction period of sunflower oil compared to that of control. Addition of 100 ppm α -tocopherol increased the stability by 230 hours (to 920 hr.); while addition of 200 ppm α -tocopherol increased the stability by 300 (to 990 hr). From the above mentioned results, it could be noticed that the stability of sunflower seed oil increased with increasing concentration of α -tocopherol. These results are in agreement with those of Soliman *et al.* (1990), who found that addition of DL - α -tocopherol between 250-500 ppm reduced the rate of oxidation in sheep and camel fats. Also Jung & Min (1990), found that the peroxide value of soybean oil containing 100 ppm α -tocopherol was lower than that of control sample at 63°C. From the results in Table (4), it could be noticed that the relative stability increased with increasing concentrations of α -tocopherol. The relative stability of control sample was 100%, while the relative stability after addition of 100 and 200 ppm tocopherol were 133.3% and 143.5%, respectively.

Table (4) Stability and relative stability of sunflower oil mixed with different concentrations of α - tocopherol.

	α-tocopherol concentrations (ppm)		
	Control	100	200
Stability in hours	690	920	990
Relative stability %	100	133.3	143.5

Effect addition of unsaponifiable matter separated from DODP and DODC by saponification method on the oxidative stability and relative stability of sunflower seed oil.

Effect of addition of different concentrations of unsaponifiable matter (0.05, 0.1, 0.3%) separated from DODP and DODC by saponification method on the oxidative stability and relative stability of sunflower oil is tabulated in Table (5). From the results it is clear that the induction period of sunflower oil without any addition at 63°C was 690 hours. On the other hand, the sunflower oil after addition of 0.05%, 0.1% and 0.3% unsaponifiable matter of DODP (containing 69.7, 139.9 and 418.2 ppm total tocopherols) caused an increase in the induction period of oil at 63°C from 690 hours for control sample to 890, 1000 and 1080 hours, respectively. From the above mentioned results, it could be observed that the stability increased with increasing the concentration of unsaponifiable matter. Hence, addition of 0.05% unsaponifiable matter (69.7 ppm tocopherols) increases the stability by 200 hours compared to control, while addition of 0.1% (139.9 ppm tocopherols) and 0.3% (418.2 ppm tocopherols) caused a noticeable increases in the stability by 310 and 390 hours, respectively.

Table (5): Stability and relative stability of sunflower oil in presence of unsaponifiable matter separated from DODP with saponification method.

	Unsaponifiable matter concentrations						
	Control	DODP	DODC	DODP	DODC	DODP	DODC
		0.05%	0.10%	0.30%			
Stability in hours	690	890	690	1000	700	1080	720
Relative stability	100	128.9	100	144.9	101.4	156.5	104.3

Also, from the same results it is clear that the relative stability of sunflower oil (control) was 100%, while addition of 0.05%, 0.1% and 0.3% unsaponifiable matter into the same oil led to an increase in the relative stability to 128.9%, 144.9% and 156.5%, respectively. Comparing these results with than obtained in Table (4), it is clear that addition of 200 ppm tocopherol increased the stability of sunflower oil by 43.5%, compared with control, while addition of 139.3 ppm tocopherol (0.1% unsaponifiable matter) increased the stability by 44.9%. This result indicate that tocopherol in the unsaponifiable matter increased stability more than the equivalent weight of tocopherol alone, this may be due the presence of other components besides tocopherols in the unsaponifiable matter that acted as antioxidant towards oxidation such as squalene and sterols. These results are in agreement with that obtained by Hallabo (1977) who found that the stability of refined cotton seed oil increased from 8.5 hours to 31.5, 26.5 and 14.0 hours (equal to 370, 310 and 164%, relative stability), respectively. Satue *et al.* (1995),, reported that the addition of 100, 500 and 1000 ppm of α -tocopherol to purified olive oil kept in the dark at 40°C, acted as powerful antioxidant was greater at 100 ppm than at higher concentrations.

On the other hand from the results in Table (5), it is observed that the stability of control sample was 690 hours, while the stability of other samples containing 0.05% (17.4 ppm tocopherol) 0.1% (34.8 ppm tocopherol) and 0.3% (104.4 ppm tocopherol) unsaponifiable matter of DODC was 690, 700 and 720 hours, respectively. These results indicate that the stability of control sample was found to be equivalent to that containing 0.05% unsaponifiable matter, while addition of 0.1% and 0.3% unsaponifiable matter led to only minor increase in the stability by 10 and 30 hours, respectively. Moreover, the relative stability of both control and 0.05% unsaponifiable matter led to minor increase with increasing the concentration since it reached to 101.4 and 104.3%.

Comparing with the results in Table (4), it could be observed that the relative stability of sunflower oil containing 0.3% unsaponifiable matter of DODC (104.4 ppm tocopherol) was 105.1%, while the relative stability of sunflower oil containing 100 ppm standard tocopherol was 133.3%.

Finally, one can conclude that the deodorizer distillate produced from chemically refined (DODC) could not be used as natural antioxidant because it has little antioxidant effect due to its low content of natural antioxidant. On the other hand, the deodorizer distillate produce from physical refining of palm oil (DODP) could be used as a good source of natural antioxidant due to its relatively high content of natural antioxidant.

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**الاستفادة من المواد غير القابلة للتصبن ناتج مرحلة إزالة الراحة لزيت القطن
والنخيل كمواد طبيعية مضادة للأكسدة باستخدام زيت دوار الشمس**
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وجد أن ناتج إزالة الراحة لزيت بذرة القطن وزيت النخيل يحتوي على ٤٪، ٤٪ مواد غير قابلة للتصبن، ٩٪ ١٤٪ توكو فيبرول، ١٤٪، ١٥٪، ٢٪، ١٥٪، أحماض دهنية مؤكسدة، ٣٥٪، ١٠٪، ٦٥٪، ١٤٥٪، ٤٪، ١٨٢٪، ٤٪، ١٧٦٪، ٠٪ رقم التصبن أما رقم البيروكسيد كان ٣,٧٤، ٥,٩١ على التوالي، وبإضافة المواد غير القابلة للتصبن إلى زيت دوار الشمس بتراكيمات (٥٪، ١٪، ٠٪، ٣٪) دلت النتائج على زيادة كفاءة المواد مضادة بزيادة التركيز المستخدم، وأيضاً أن المواد المفصولة من زيت النخيل ذات تأثير أقوى من زيت القطن كمضادات أكسدة طبيعية.

الكلمات الدالة: ناتج إزالة الراحة - زيت القطن - زيت النخيل - زيت دوار الشمس - المواد غير القابلة للتصبن.

قام بتحكيم البحث

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