Enhancement the efficiency of some vegetable oils as frying oils

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Abstract: This study was conducted to identify the best blended oil in terms of physicochemical properties between cotton-seed, sunflower and palm olein oils and their blends. Blending sunflower with cotton-seed oils or by mixing palm olein with cotton-seed oils at the proportion of [25:75, 50:50 and 75:25 (%)] or blending palm olein with sunflower and cotton-seed oils at the proportion of [25:50:25 (%)]. The blended oils were heated at 180 ± 5°C for 32 hrs during four days. Some physico-chemical parameters for blended oils (refractive index, free fatty acids, peroxide value, polar, polymer, oxidized fatty acids contents and oxidative stability) were determined every 8 hrs. The data indicated that blending of 25% palm olein oil + 50% sunflower oil + 25% cotton-seed oil (F1) gave the best results where high oxidative stability after PO and blend oil (B3) (75% palm olein + 25% cotton-seed oil).
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1. Introduction

Sunflower oil is one of the most popular vegetable oils, extracted from sunflower seeds (*Helianthus annuus L.*) and widely used as a source of essential fatty acid linoleic (9-*cis*,12-*cis*-octadecadienoic) acid in nutrition **(Parveen *et al.*, 2011 and Poiana, 2012).** In some countries, it is preferred to soybean, cotton-seed and palm oils **(Gupta, 2002).** In season 2014, Egypt was produced 163816, 39872 and 22096 tonnes from cotton-seed, soybean and sunflower seeds, respectively **(FAO, 2014).**

Crude cotton-seed oil, extracted from the seeds (by-product) of *Gossypium hirsutum* (American) or *Gossypium barbadense* (Egyptian) varieties of cotton, has a typical of oleic and linoleic fatty acids (75% of total fatty acids). The nutty flavor of deodorized cotton-seed oil is more acceptable at high degrees of oxidation than other vegetable oils. Cotton-seed oil continues to be in demand by food processors due to its high flavor, stability and structure **(O'Brien, 2002).**

Palm olein, a liquid fraction obtained from the refining of palm oil, is rich in oleic acid (42.7% - 43.9%), β-carotene and vitamin E (toco-pherols and tocotrienols). It is rich in tocotrienol which has been reported to be natural inhibitors of cholesterol synthesis. Tocopherols are very important minor components of oils and fats because of their antioxidant properties **(Dauqan *et al.*, 2011).**

Palm olein was widely used in frying industry due to its excellent frying performance and oxidative stability **(Anon, 1991, Basiron, 1996).** The consumers always assumed the clouding appearance representing low quality attributes of oil although the clouding did not detrimentally influence the oil quality **(Swe *et al.*, 1994, Siew and Ng, 1996). Mostafa *et al.* (1996)** reported that blending palm olein with cotton-seed oil could decease the cloud point.

Mixing of two or more edible oils with different characteristics is the simplest procedures to make new specific oil. Oil blending was the most potent solution in producing vegetable oils with good storage stabilities and optimum fatty acids compositions. Blending different vegetable oils not only can change fatty acids profile, but also enhance the levels of bioactive lipids and natural antioxidants in the mixtures and give better quality oils, as well as improving nutritional value at affordable prices **(Marmesat *et al.*, 2012, Aladedunye and Przybylski, 2013).** Palm olein was occasionally blended with the other oils containing high unsaturated fatty acid such as soybean, sunflower oils, & etc. **(Nor Aini *et al.*, 2001). Basoglu *et al.* (1996)** revealed that addition of 20% palm olein with soft oils showed the desired clarity during shelf storage. Blending of oils can also reduce the risk of cloudy and partial crystallization in palm olein **(Siddique *et al.*, 2010).**

Oils and fats intended for commercial frying applications must be stabilized to prevent deterioration caused by oxidation, polymerization, and hydrolysis at high- temperature. Modifying the fatty acid composition of the oil, the most common method to stabilize frying oils can be conducted by several methods. For example, blending polyunsaturated oils with more saturated or monounsaturated oils is an option to adjust fatty acid to optimal levels **(Warner and Knowlton, 1997),** such as combining palm olein with sunflower and cotton-seed oils in our study. Blending technology was used by many authors to

improve oxidative stability **(Frankel and Huang, 1994 and Kleingarther and Warner 2001).**

Alireza *et al*. (2010) mentioned that product quality of deep frying depends on temperature, time, type and volume of frying oil. Reactions occurred during frying such as hydrolysis, oxidation and polymerization can affect the quality of oil**.** Usually many oils can be used for frying, e.g., palm, corn, cotton, soybean, canola, sesame, and sunflower oils. To get healthy oil, should be low content of $C_{18:2}$ and $C_{18:3}$ fatty acids**.**

The objective of this work was to study the frying performance for some oil blends to raise their efficiencies (high oxidative stability) as frying oils.

2. Materials and Methods

2.1. Materials

Sunflower and palm olein oils were obtained from Arma Oils Co. 10th of Ramadan, Egypt. Cotton-seed oil was obtained from Tanta Oils & Soap Company, Banha Factory, Egypt. Chemicals used in the study were obtained from Sigma Chemical Co, (ST. Louis, US) and El-Gomhoria Co. for Pharmaceutical, Cairo, Egypt.

2.2. Blending of oils

Blending cotton-seed oil with palm olein oil or sunflower oil were separately used or mixed them at different ratios as described in Table (1). The frying process was done at 180±5 ºC for 32 hours.

Table 1. Oil blending at different proportions (w/w%).

No. of samples	Type of sample	Palm olein oil (PO)	Sunflower oil (SU)	Cotton-seed oil (CS)
1	PO	100.00		
2	SU		100.00	
3	CS			100.00
4	B1	25.00		75.00
5	B2	50.00		50.00
6	B3	75.00		25.00
7	D1		25.00	75.00
8	D2		50.00	50.00
9	D3		75.00	25.00
10	F1	25.00	50.00	25.00

2.3. Methods

2.3.1. Fatty acids composition of blended oils:

Gas chromatography (Agilent 6890) was used for determination fatty acids of the oil samples. All GC measurements for each oil sample were made in triplicate and the average values were reported according to the methods of **(Cossignani *et al*., 2005).**

2.3.2. The Cox Value (Oxidizability)

The Cox value of oil blends was calculated according to **Fatemi and Hammond (1980)** as the following equation:

Cox Value = [1($C_{18:1}$%) + 10.3 ($C_{18:2}$%) + 21.6 ($C_{18:3}$%)]/100

2.3.3. Some parameters for non fried and fried oils

Refractive index at 25ºC, free fatty acids (FFA) (% as oleic acid) and peroxide value (meq. O_2 /kg oil) were estimated according to **A.O.A.C (2005).** Oxidized fatty acids and polymer contents were carried out using the methods of **Wu and Nawar (1986)**. Polar compounds were determined according to **Dobarganes *et al*. (1988)** method.

2.3.4. Oxidative stability

Oxidative stability of oil samples was carried out by Rancimat apparatus (Metrohm Ltd., Switzerland) at 100ºC with an air flow rate of 20 L/h according to the method described by **Gutierrez (1989).**

2.3.5. Statistical analysis

Statistical analyses were conducted using SPSS program version 16.0.

3. Results and Discussion

According to **Egyptian standard (2005),** the frying oil must be blended with two oils at least. Fatty acids composition of oil had major effect in stability and quality of fried products during frying **(Warner, 2003).** Table (2) indicates fatty acid composition of oils. The fatty acids were categorized into three groups, i.e., trace (less than 1%), minor (from 1% to less than 10 %) and major (from greater than or equal 10 %) contents. At zero time, fresh palm olein oil comprised fatty acids12:0, 14:0, 18:3 and 20:0 as trace contents. The fatty acid 18:0 presented as minor substances whereas, fatty acids 16:0, 18:1 and 18:2 found as major components. Also, results revealed that sunflower oil had 12:0, 14:0, 18:3 and 20:0 fatty acids in trace contents. The fatty acids 16:0 and 18:0 presented as minor substances whereas, 18:1 and 18:2 were as major constituents. Fresh cotton-seed oil contained fatty acids 12:0, 14:0, 18:3 and 20:0 as trace components and 18:0 was as minor fatty acid, whereas, 18:1,16:0 and 18:2 presented as major fatty acids. Generally, Palm olein oil contained 18:1 and 16:0 at remarkable levels. Sunflower oil was recognized by

high levels of 18:1 and 18:2 fatty acids. Whereas, cotton-seed oil was distinguished by the presence of 16:0 and 18:1 in higher and lower contents, respectively than in sunflower oil. The calculated oxidizability index (COX) for palm olein, sunflower and cotton-seed oils were 1.91, 5.96 and 5.64, respectively (Table 2). These values revealed that sunflower and cotton-seed oils may be much more susceptible to oxidation than palm olein oil.

Table 2: Fatty acids composition (%) and COX for palm olein, sunflower, cotton-seed oils and their blends.

No. of samples	Blended oils	Fatty acids (%)								TUSFA*	$C_{18:2}$ / $C_{16:0}$	COX
		$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:0}$			
1	Palm olein oil (PO)	0.28±0.10	0.94±0.10	38.82±3.55	4.28±0.90	41.50±5.10	12.73±1.02	0.87±0.10	0.38±0.10	55.10	0.33	1.91
2	Sunflower *oil* (SU)	0.10±0.0001	0.30±0.01	7.60±0.90	6.20±1.13	30.41±3.30	54.50±5.50	0.20±0.0001	0.60±0.15	85.11	7.17	5.96
3	Cotton-seed oil (CS)	0.10±0.0001	0.90±0.10	24.97±2.50	2.40±0.33	18.90±2.02	51.98±5.10	0.45±0.09	0.30±0.09	71.33	2.08	5.64
4	B1=PO+ CS	0.19±0.0001	0.91±0.11	29.20±2.01	3.20±0.66	21.30±0.90	44.50±4.13	0.40±0.11	0.33±0.10	66.20	1.57	4.88
5	B2=PO+ CS	0.20±0.01	0.92±0.12	31.51±2.81	3.50±0.63	26.44±1.88	38.48±3.11	0.06±0.0001	0.35±0.09	64.98	1.22	4.24
6	B3=PO+ CS	0.26±0.01	0.43±0.09	36.53±3.00	4.42±0.84	35.90±2.16	20.90±2.90	0.80±0.10	0.36±0.10	57.60	0.57	2.68
7	D1=SU + CS	0.10±0.0001	0.42±0.09	19.56±1.77	3.20±0.33	23.55±2.07	52.19±5.11	0.30±0.12	0.46±0.10	76.04	2.67	5.67
8	D2=SU + CS	0.20±0.01	0.61±0.13	16.42±1.33	4.21±0.67	25.30±1.98	52.81±5.33	0.25±0.01	0.43±0.10	78.36	3.22	5.75
9	D3=SU + CS	0.17±0.0001	0.75±0.15	10.22±0.90	5.27±0.98	28.50±2.08	53.70±4.92	0.23±0..01	0.30±0.07	82.43	5.25	5.86
10	F1=PO + SU + CS	0.16±0.0001	0.81±0.12	20.80±2.07	5.70±1.52	29.78±2.43	40.61±4.72	0.48±0.11	0.45±0.13	70.87	1.95	4.58

* TUSFA: Total unsaturated fatty acids.
Results are the means of three replications ± SD.

The ratio of linoleic to palmitic acids ($C_{18:2}/C_{16:0}$) has been suggested by **Normand *et al.* (2001)** as a valid indicator of the level of polyunsaturated fatty acid deterioration. The results showed that palm olein oil had the lowest ratio (0.33). On the other hand, sunflower oil had the highest ratio (7.17). Lower ratios were observed in blended samples of palm olein with cotton-seed oils than those in the blended samples of sunflower with cotton-seed oils. This ratio was decreased with increasing ratio of palm olein with cotton-seed oils. Data also showed that this ratio ($C_{18:2}/C_{16:0}$) of F1 blend was 1.95. This means that high stability against oxidation may be due to addition of palm olein (25%) to 25% cotton-seed oil and 50% sunflower oil.

Table (2) shows the fatty acid composition of blends of fresh cotton-seed oil mixed with various levels of either fresh palm olein or sunflower oils. Blending of cotton-seed with sunflower oils at different ratios led to increase its stability against oxidation and the extent of this phenomenon was basically depending on the blending ratios. The calculated COX values were 2.68, 4.24 and 4.88 for blended palm olein oil with cotton-seed oil at ratios of 75:25, 50:50 and 25:75%, respectively. COX values of F1 blend (25%palm olein + 50% sunflower + 25% cotton-seed oils) and B3 blend (75%palm olein + 25% cotton-seed oils) were at 4.58 and 2.68, respectively. It means that sample No.6 gave high stability due to their fatty acids composition.

Results in Table 3 revealed that palm olein oil had the lowest refractive index (1.4562), while sunflower and cotton-seed oils had 1.4739 and 1.4620, respectively. These results agree with the content of TUSFA of fatty acid composition which showed that sunflower oil had the highest percentage (85.11%), cotton-seed oil (71.33%) while palm olein oil had the lowest content of TUSFA (55.10%) (Table 2). Also, results showed that the value of refractive index of blended oil was between the values of the refractive indexes of pure oils previously used for preparing the blend. Also, Table (3) shows changes in the refractive index of unblended and blended oils under study during frying. Frying process caused gradually decrease in the refractive index values with frying time increase for all studied oils and their blends.

FFA is a significant index of oil deterioration. Data in Table (4) indicated that FFA content of palm olein oil was 0.02% as oleic acid followed by sunflower and cotton-seed oils (0.04 and 0.18% as oleic acid, respectively). Free fatty acid (FFA) was increased during frying time. The free fatty acids (FFA) content increased from 0.02% at zero time to 0.33% for palm olein oil, from 0.04 to 0.44% for sunflower oil and from 0.18 to 0.53% for cotton-seed oil after frying for 32 hrs. From the above results, it can be noticed that palm olein oil had the lowest value (0.33% as oleic acid) at the end of frying.

Data also in Table (4) elucidated that FFA contents of blending palm olein with cotton-seed oils decreased with increasing of PO content in the blends. These results may be due to the high content of oleic and palmitic acids. These fatty acids delay the hydrolysis of triglyceride **(Gopala *et al*., 2005).**

Primary lipid oxidation was measured by peroxide value (PV). So, the more of PV, means the more rate of oxidation of oil **(Atinafu and Bedemo, 2011).** Results in Table (5) revealed that the initial peroxide values were 1.00, 2.20, and 3.30 (meq. O_2 /kg oil) for palm olein, sunflower and cotton-seed oils, respectively. It can be observed that an increase in PV occurred with increment in the frying time. We noted that when increase palm olein oil percentage with cotton-seed oil blends, peroxide values were decreased. Data also showed that the lowest peroxide values were 1.00 and 10.57 (meq. O_2 /kg oil) for palm

olein oil followed by B3 blend (1.54 and 11.40 meq. O_2 /kg oil) and followed by F1 blend (2.00 and 12.05 meq. O_2 /kg oil) at zero time and after frying for 32hrs, respectively.

Table 3: Changes in the refractive index of unblended and blended oils under study during frying process.

No. of samples	Blended oils	Frying time (hr.)				
		Zero	8	16	24	32
1	Palm olein oil (PO)	1.4562±0.001	1.4560±0.001	1.4558±0.001	1.4551±0.001	1.4547±0.001
2	Sunflower oil (SU)	1.4739±0.001	1.4728±0.001	1.4723±0.001	1.4718±0.001	1.4715±0.001
3	Cotton-seed oil (CS)	1.4620±0.001	1.4618±0.001	1.4615±0.001	1.4613±0.001	1.4610±0.001
4	B1=PO + CS	1.4608±0.001	1.4600±0.001	1.4590±0.001	1.4582±0.001	1.4573±0.001
5	B2=PO + CS	1.4591±0.001	1.4582±0.001	1.4575±0.001	1.4570±0.001	1.4565±0.001
6	B3=PO + CS	1.4573±0.001	1.4570±0.001	1.4568±0.001	1.4567±0.001	1.4564±0.001
7	D1=SU + CS	1.4671±0.001	1.4707±0.001	1.4600±0.001	1.4792±0.001	1.4585±0.001
8	D2=SU + CS	1.4690±0.001	1.4687±0.001	1.4680±0.001	1.4675±0.001	1.4670±0.001
9	D3=SU + CS	1.4715±0.001	1.4695±0.001	1.4690±0.001	1.4688±0.001	1.4681±0.001
10	F1=PO+SU+CS	1.4667±0.001	1.4658±0.001	1.4658±0.001	1.4655±0.001	1.4648±0.001

Results are the means of three replications ± SD.

Table 4: Changes in free fatty acids (FFA%) of oils under study during frying process.

No. of samples	Blended oils	Frying time (hr.)				
		Zero	8	16	24	32
1	Palm olein oil (PO)	0.02±0.0001	0.09±0.0001	0.13±0.001	0.18±0.001	0.33±0.13
2	Sunflower oil (SU)	0.04±0.0001	0.14±0.001	0.17±0.001	0.23±0.01	0.44±0.15
3	Cotton-seed oil (CS)	0.18±0.01	0.18±0.001	0.37±0.01	0.40±0.15	0.53±0.20
4	B1=PO + CS	0.15±0.001	0.25±0.01	0.33±0.01	0.37±0.11	0.46±0.11
5	B2=PO + CS	0.13±0.001	0.20±0.01	0.26±0.01	0.32±0.07	0.43±0.10
6	B3=PO + CS	0.10±0.0001	0.13±0.001	0.17±0.001	0.24±0.03	0.38±0.09
7	D1=SU + CS	0.12±0.0001	0.18±0.01	0.20±0.01	0.28±0.09	0.46±0.14
8	D2=SU + CS	0.14±0.0001	0.21±0.01	0.27±0.01	0.34±0.13	0.49±0.16
9	D3=SU + CS	0.16±0.0001	0.28±0.03	0.35±0.01	0.38±0.15	0.52±0.20
10	F1=PO + SU + CS	0.03±0.0001	0.11±0.01	0.15±0.001	0.20±0.01	0.39±0.12

Results are the means of three replications ± SD.

Table 5: Changes in the peroxide value of oils under study during frying process.

No. of samples	Blended oils	Frying time (hr.)				
		Zero	8	16	24	32
1	Palm olein oil (PO)	1.00±0.10	2.85±0.20	4.35±0.39	6.24±0.61	10.57±0.94
2	Sunflower oil (SU)	2.20±0.19	5.96±0.55	6.94±0.55	10.62±0.82	12.89±1.00
3	Cotton-seed oil (CS)	3.30±0.25	4.04±0.44	6.06±0.49	9.85±0.79	13.78±1.12
4	B1=PO + CS	2.88±0.33	3.87±0.41	5.84±0.61	8.31±0.77	13.00±1.13
5	B2=PO + CS	2.18±0.20	3.71±0.29	5.33±0.54	7.66±0.68	12.28±1.22
6	B3=PO + CS	1.54±0.15	3.25±0.33	4.85±0.43	6.96±0.59	11.40±0.91
7	D1=SU + CS	3.00±0.47	5.00±0.45	6.10±0.54	9.81±0.83	13.00±1.02
8	D2=SU + CS	2.67±0.20	5.40±0.44	6.33±0.54	10.20±0.95	13.29±1.19
9	D3=SU + CS	2.35±0.17	5.61±0.49	6.68±0.63	10.43±0.96	13.62±1.13
10	F1=PO + SU + CS	2.00±0.17	3.35±0.39	5.20±0.47	8.63±0.79	12.05±0.89

Results are the means of three replications ± SD.

Total polar compounds (TPC) are defined as the sum of materials that are not triglycerids **(Blumenthal, 1991).** Therefore, TPC in fresh fried oil include tocopherols, mono and diglyceride, FFAs and other oil soluble components that are more polar than triglycerides. However, the TPC in the used fried oil are composed of the total breakdown products from the frying process **(Lake and Scoles, 1997). Stier, (2013)** mentioned that thermal oxidation was occurred during frying, so estimation of TPC is important indicator for oil degradation. Its maximum acceptable value was 25-27% in the most European countries

(Abdulkarim *et al*. 2007). Table (6) indicated that the initial polar content of cotton-seed oil was the highest content (0.13%), followed by sunflower and palm olein oils (0.09, 0.00%, respectively), reflecting the good quality of oil used, as TPC content of unused oils normally ranges between 0.4% and 6.4% **(Lumley, 1988).** Results revealed that frying time was increased, polar components were increased. The high values observed for sunflower oil could be attributed to the high content of PUSFA (85.11%). TPC values were not exceed 20% **(Sánchez-Muniz and Bastida, 2003)**, until 16 hrs. We notice that blends of palm olein oil with cotton-seed oil had lower values of polar content than blends of sunflower oil with cotton-seed oil. These may be related to the content of saturated fatty acids.

Table 6: Changes in the polar content (%) of oils under study during frying process.

No. of samples	Blended oils	Frying time (hr.)				
		Zero	8	16	24	32
1	Palm olein oil (PO)	0.00±0.00	1.25±0.23	6.11±0.54	13.89±1.13	22.80±2.22
2	Sunflower oil (SU)	0.09±0.001	6.49±0.56	14.76±1.11	25.08±2.54	35.16±3.33
3	Cotton-seed oil (CS)	0.13±0.001	7.43±0.64	16.73±1.25	29.70±2.79	29.46±2.19
4	B1=PO + CS	0.10±0.00	6.00±0.56	15.00±1.72	25.33±2.64	27.41±2.73
5	B2=PO + CS	0.06±0.10	4.22±0.40	13.13±1.33	20.70±2.00	25.00±2.15
6	B3=PO + CS	0.00±0.10	2.26±0.25	9.00±0.87	16.81±1.33	23.00±2.34
7	D1=SU + CS	0.11±0.00	7.00±0.67	15.31±2.00	26.50±2.79	31.11±3.19
8	D2=SU + CS	0.10±0.02	7.25±0.66	15.67±2.09	27.25±2.93	32.60±2.99
9	D3=SU + CS	0.10±0.13	7.41±0.59	16.15±2.71	28.60±3.01	33.50±3.33
10	F1=PO + SU + CS	0.01±0.001	3.01±0.29	9.00±0.88	16.90±1.41	24.10±2.18

Results are the means of three replications ± SD.

The initial polymer contents of palm olein, sunflower and cotton-seed oils were 0.00, 0.00, and 0.50%, respectively at zero time. These values were increased progressively with increase of the frying time (Table 7). **Sonia and Badereldeen (1983)** revealed that the amount of polymeric and oxidized glycerides increased by increasing the frying or heating time of cotton-seed oil through frying.

Table 7: Changes in the polymer content (%) of oils under study during frying process.

No. of samples	Blended oils	Frying time (hr.)				
		Zero	8	16	24	32
1	Palm olein oil (PO)	0.00±0.00	1.00±0.20	1.52±0.20	2.39±0.21	5.53±0.56
2	Sunflower oil (SU)	0.00±0.00	1.75±0.21	2.03±0.22	3.89±0.33	7.30±0.68
3	Cotton-seed oil (CS)	0.50±0.13	2.70±0.31	4.80±0.36	5.83±0.48	8.50±0.78
4	B1=PO + CS	0.30±0.11	1.67±0.17	1.89±0.15	3.25±0.33	7.00±0.69
5	B2=PO + CS	0.21±0.10	1.48±0.19	1.73±0.17	2.91±0.20	6.40±0.56
6	B3=PO + CS	0.07±0.001	1.04±0.22	1.60±0.16	2.50±0.28	5.60±0.67
7	D1=SU + CS	0.44±0.18	1.97±0.16	2.50±0.28	3.50±0.33	6.50±0.54
8	D2=SU + CS	0.29±0.10	2.49±0.19	3.60±0.34	4.91±0.48	7.93±0.85
9	D3=SU + CS	0.12±001	2.87±0.33	4.00±0.41	5.20±0.55	8.22±0.76
10	F1=PO + SU + CS	0.10±0.001	1.11±0.11	1.61±0.16	2.64±0.10	5.90±0.45

Results are the means of three replications ± SD.

Also, Table (7) shows the effect of blending at different ratios of palm olein oil or sunflower oil with cotton-seed oil during frying for 32 hrs. on polymer content. The increasing ratio of palm olein oil in the blending samples B1, B2 and B3 caused decreases of polymer content especially during frying process. **Lumley (1988)** reported that the more unsaturated, the greater tendency to form polymeric products. Data also indicated that the lowest polymer content (5.53%) for palm olein oil followed by B3 blend (5.60%) followed by F1 blend (5.90%) after frying for 32 hrs.

Yoon *et al*. (1988) mentioned that oxidized polymer compounds accelerated the oxidation of oil. Polymers accelerate further degradation of the oil, consequently, occurred increments in the oil viscosity **(Tseng *et al*., 1996)**. **Frega *et al*. (1999)** demonstrated that free fatty acids and their oxidized compounds produced off-flavor and make the oil less acceptable for deep-fat frying. The initial oxidized fatty acid

contents of palm olein, sunflower and cotton-seed oils were 0.01, 0.21 and 0.25%, respectively. In general, the results demonstrate a progressive increase in the amount of oxidized fatty acid contents with prolonging the frying time (Table 8). F1 blend had lower oxidized fatty acid after PO and B3 blend.

Table 8: Changes in the oxidized fatty acids content (%) of oils under study during frying process.

No. of samples	Blended oils	Frying time (hr.)				
		Zero	8	16	24	32
1	Palm olein oil (PO)	0.01±0.00	0.14±0.01	0.27±0.02	0.68±0.18	1.01±0.23
2	Sunflower oil (SU)	0.21±0.01	0.36±0.11	0.56±0.20	0.92±0.20	1.11±0.18
3	Cotton-seed oil (CS)	0.25±0.01	0.37±0.13	0.61±0.17	0.91±0.19	1.28±0.15
4	B1=PO + CS	0.19±0.01	0.33±0.09	0.53±0.15	0.90±0.16	1.19±0.21
5	B2=PO + CS	0.14±0.01	0.26±0.09	0.43±0.13	0.84±0.16	1.14±0.20
6	B3=PO + CS	0.09±0.01	0.18±0.11	0.34±0.10	0.78±0.15	1.08±0.14
7	D1=SU + CS	0.24±0.11	0.36±0.16	0.57±0.14	0.91±0.16	1.15±0.19
8	D2=SU + CS	0.23±0.12	0.36±0.17	0.59±0.11	0.91±0.18	1.18±0.28
9	D3=SU + CS	0.21±0.11	0.37±0.15	0.60±0.15	0.91±0.14	1.23±0.22
10	F1=PO + SU + CS	0.11±0.11	0.20±0.04	0.35±0.10	0.79±0.17	1.10±0.20

Results are the means of three replications ± SD.

The oxidative stability estimation by Rancimat is easy and commonly method used in the analytical laboratories. Table (9) indicates the oxidative stability of oils during frying. The initial oxidative stability of palm olein, sunflower and cotton-seed oils were (39.20, 7.20 and 9.30h, respectively). Results indicated that oil stability was gradually decreased during frying. The improvement of oxidative stability of was happened at adding palm olein oil with sunflower and cotton-seed oils at ratio 25, 50 and 25%, respectively. Therefore, results indicated that F1 blend was the best blend for maintaining the oxidative stability after PO and B3 blend.

Table 9: Changes in the oxidative stability (hr.) of oils under study during frying process.

No. of samples	Blended oils	Frying time (hr.)				
		Zero	8	16	24	32
1	Palm olein oil (PO)	39.20±3.09	30.30±3.01	22.60±2.16	15.40±1.12	7.20±0.79
2	Sunflower oil (SU)	7.20±1.06	5.08±0.56	2.03±2.11	1.25±0.24	0.00±0.00
3	Cotton-seed oil (CS)	9.30±1.33	7.65±0.94	4.80±0.49	1.56±0.40	0.70±0.17
4	B1=PO + CS	23.00±2.03	15.70±1.14	10.00±1.78	6.00±0.54	1.50±0.13
5	B2=PO + CS	29.60±2.18	22.50±2.33	16.20±1.66	10.00±1.00	3.40±0.23
6	B3=PO + CS	34.50±3.24	30.60±3.95	21.15±2.45	13.00±1.13	5.80±0.56
7	D1=SU + CS	8.80±0.91	7.00±0.75	3.90±3.09	1.55±0.26	0.65±0.11
8	D2=SU + CS	8.40±1.00	6.00±0.76	2.20±2.17	1.40±0.15	0.45±0.01
9	D3=SU + CS	8.00±1.18	5.60±0.58	2.60±2.28	1.30±0.14	0.20±0.001
10	F1=PO + SU + CS	29.70±2.22	25.80±2.06	17.30±1.76	11.00±1.09	4.90±0.45

Results are the means of three replications ± SD.

4. Conclusion

These findings led to deduce that blending sunflower oil with cotton-seed oil improved the oxidative stability more better than sunflower oil only during frying. Also, data indicated that using palm olein oil gave high frying performance with cotton-seed and sunflower oils at ratio of 25, 50 and 25%, respectively, which palm olein oil occurred decrease in the values of FFA, PV, polymer and oxidized fatty acids with high resistance for oxidative stability. So, from all the results, it can be recommended that palm olein can be used in the frying oil up to 25% with 50% sunflower oil and 25% cotton-seed oil to maintain the quality of frying oil in Egypt.

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