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Fatty Acid Composition and Quality Characteristic of Some Vegetable Oils Used in Making Commercial Imitation Cheese in Egypt

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Abstract

Fatty acid composition and quality of vegetable oil are very important factors for improving its stability and applicability. Quality characteristics of the four available vegetable oils in the Egyptian market for imitation cheese making were evaluated. The fatty acids composition, trans fatty acids (TFA), as well as oxidative stability were examined. Both coconut oil (CO) and palm oil (PO) samples showed a significant elevation in peroxide values (by about 71%, $p<0.05$) compared to cocoa butter substitute oil (CBSO) and shortening oil (SHO) samples. The CBSO showed significant resistance to oxidation as indicated from results of oxidative stability (about 100% more stability, $p<0.05$). CBSO were characterized with extremely high lauric, myristic and stearic fatty acids content, but the SHO were characterized with a high content of palmitic and stearic fatty acids. The highest quantity of unsaturated fatty acids was recorded for oleic acid (C18:1) in SHO (35.23 ± 0.005 g/100 g) compared to 3.6 ± 0.1 g/100 g in CBSO. Also, TFA were detected in CBSO and SHO samples (4.22 ± 0.007 (C18:1) and 0.324 ± 0.006 (C18:2) g/100 g, respectively). All samples were not in agreement with Codex standards for moisture and volatile matter content (except PO) and they showed higher insoluble impurities content than the maximum limit stated by standards.

Keywords: Vegetable oils; Shortening oil; Fatty acids; Trans fatty acids; Oxidative stability

Introduction

Cheese was considered as one of the most popular dairy products in Egypt. The average cheese consumption in Egypt is about 7.1 per capita per year [1]. This average was higher in developed countries like USA which account for 12.7 per capita per year [2]. Due to the fact that more than 60% of milk fat is saturated, cheese and other milk products can be considered as major sources of dietary saturated fats.

There is a correlation between saturated fats in diet and levels of blood cholesterol which consequently correlated with risk of atherosclerosis [3]. It was found that replacing saturated fats by unsaturated fats will help in controlling blood cholesterol levels.

The increased consumer demand for healthy products has encouraged substitution of milk fat by vegetable oils in dairy products. New verities of cheese have been made by using vegetable oils which so called imitation cheese or vegetable oil-based cheese [4]. There are different vegetable oils that can be used to substitute milk fat. In the Egyptian market, shortening, cocoa butter substitute, palm oil and coconut oil are the main commercial oils that are used for manufacture of vegetable oil-based cheeses. Beside its high content of saturated fatty acids, partially hydrogenated vegetable oils also contain trans fatty acids [5].

Previously, trans fatty acids showed an increase in cholesterol levels in blood. It was regarded as a risk factor for increasing coronary heart disease and atherosclerosis [6]. Therefore, it is very important to search for foods that have lower content of trans fatty acids.

The aim of this work was to evaluate quality characteristics of some commercial vegetable oils that were available for manufacturing of imitation cheeses in the Egyptian market. The fatty acids composition, trans fatty acids, as well as oxidative stability of vegetable oils were examined.

Materials and Methods

Materials

Vegetable oil samples of four different variants : Shortening (un hydrogenated refined palm oil), Cocoa butter substitutes (hydrogenated palm kernel oil), Palm oil and Coconut oil were obtained from local markets in Cairo, Egypt.

All the chemicals used were of analytical grade. Pure standards of fatty acids methyl esters (FAMES) were purchased from (Sigma Chemical Company, St. Louis, MO, USA).

Methods

Samples were transferred to lab and kept at 4°C until analysis. Samples of oils were analyzed in triplicate.

Quality parameters: Moisture, insoluble impurities, acid value, peroxide value, unsaponifiable matter and saponification values were determined according to Dieffenbacher [7].

Fatty acids composition: Preparation of fatty acids methyl esters (FAMEs) Fatty acids were converted into their methyl esters according to ISO standard method [8].

Gas chromatography analyses (GC): Gas chromatography of the

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FAMEs was performed according to ISO standard [9]. Conditions were as follows: apparatus HP 6890 GC System with auto sampler; column: SGE Capillary BPX 70, highly polar column, 60 m length, 0.22 mm internal diameter with 70% Cyanopropyl (equiv.) polysilphenylene-siloxane; temperature program from 160 to 190°C, heating rate: 2.5°C/min; carrier gas: helium, flow rate 0.6 mL/min; injector: split-splitless 240°C; detector: a flame ionization detector (FID); flame gas: H2; software: HP Chemstation v. 3.11; sample: 1 micro liter in iso-octane. FAMEs were identified by comparing their relative and absolute retention times to those of authentic standards of FAMEs obtained from Sigma Chemical Co. All quantifications were done by a built-in data-handling program provided by the manufacturer of the gas chromatograph. The FA composition was reported as a relative percentage of the total peak area.

Oxidative stability by rancimat measurements: The induction times for oxidation were measured using a Metrohm Rancimat apparatus model 679 (Herisau, Switzerland). The oxidation process is monitored by measuring the change in conductivity of distilled water resulting from the formation of volatile oxidation products. Purified air is passed through a heated fat sample. The effluent air contains volatile organic acids which increase the conductivity. The fat stability index (induction period) is defined as the point of maximum change of the rate of oxidation [10]. The tests were carried out at 110°C with 2.5 g ± 0.02 of fat. Air flow rates were set at 20 L/h. Determinations were conducted following standard ISO procedures [11]. The average induction time was given in hours.

Conjugated dienes and trienes: Samples were diluted in iso-octane and oxidation products in the form of conjugated dienes and trienes were determined by measuring specific extinction at 232 and 268 nm in UV region using the method of Paquot et al. [12].

Statistical analysis: Data were analyzed using Statistical Package for Social Sciences (SPSS) version 16. Quantitative Data were presented as means ±SD. The independent sample- ANOVA with Post-hoc (LSD) test was used to analyze mean difference. Probability values (P) of less than 0.05 were regarded as statistically significant.

Results and Discussion

The physical and chemical quality characteristics of vegetable oil samples are given in Table 1.

Moisture and volatile matter content and insoluble impurities

According to Codex standard [13], the moisture and volatile matter content of vegetable oils must be lower than 0.2%. It can be noted from this results that PO samples showed an agreement with Codex standards [13], all other vegetable oil samples were not in agreement with Codex standards (Table 1). The highest value of moisture and volatile matter content was observed in CO sample (0.6 ± 0.1%) which was significantly ($p<0.05$) higher than all other samples. It has been stated that the moisture and volatile matter content is depend directly on the efficiency of extraction and clarification steps. The less moisture content of oil will increase its stability during storage [14-16].

According to Codex Alimentarios Commission [13], insoluble impurities must be lower than (0.05%). The results in Table 1 showed that all oil samples have insoluble impurities between 0.5 ± 0.3 to 0.85 ± 0.1% which are higher than the maximum limit stated by Codex Alimentarios Commission [13]. In fact, the amount of insoluble impurities is reflecting the efficiency of clarification during extraction of oil [16]. It was found that different processing methods resulted in a variation in purity of the resulted oil [15].

Acid value (AV)

According to Codex Alimentarius Commission [13], the AV must be lower than (0.6 mg/g fat). The results in Table 1 showed that, all vegetable oil samples were in agreement with [13]. As shown from the results in Table 1, there were no significant differences ($p>0.05$) among all vegetable oil samples. The highest value of AV was observed in PO sample (0.3 ± 0.1 mg/g), while the lowest value was recorded in CBSO sample (0.05 ± 0.04 mg/g).

Saponification value (SV) and unsaponifiable matter (USM)

The highest saponification value was observed in coconut oil (270 ± 2 mg KOH/g fat), while the lowest value was observed in shortening oil (181.4 ± 2.5 mg KOH/g fat). According to Codex Alimentarius Commission [13] saponification value of palm oil is (190-209 mg KOH/g fat), palm kernel oil (230-254 mg KOH/g fat) and coconut oil (248-265 mg KOH/g fat). The saponification value in shortening oil was slightly low (181.4 ± 2.5 KOH/g fat), whereas cocoa butter substitute oil was very low (195 ± 3 KOH/g fat) when compared with Codex standards.

As shown in Table 1, the highest value of unsaponifiable matter was observed in palm oil samples (0.87 ± 0.1%), while the lowest value was recorded in CBSO (0.5 ± 0.2%). There were no significant differences ($P>0.05$) among all vegetable oil samples. These results are in agreement with those obtained by Udensi [14], Agbaire [16].

Oxidative stability

Peroxide values (PV), Rancimat values (RV) and Conjugated dienes (CD) and conjugated triens (CT) of oil samples are presented in Table 2. Both PV and RV were used to give an indication about early stage of oil oxidation where hydroperoxides are formed [17]. The data presented in Table 2 revealed that both cocoa butter substitute (CBSO)

Quality Parameters	Samples			
	Cocoa butter substitute	Shortening Oil	Coconut Oil	Palm Oil
Moisture and volatile matter content (%)	0.4 ± 0.08^{ab}	0.3 ± 0.1^{a}	0.6 ± 0.1^{b}	0.2 ± 0.1^{a}
Insoluble impurities (%)	0.5 ± 0.3^{a}	0.85 ± 0.1^{a}	0.6 ± 0.2^{a}	0.8 ± 0.1^{a}
Acid value (mg KOH/g fat)	0.05 ± 0.04^{a}	0.26 ± 0.21^{a}	0.1 ± 0.01^{a}	0.3 ± 0.1^{a}
Saponification value (mg KOH/g fat)	195 ± 3^{b}	181.4 ± 2.5^{a}	270 ± 2^{d}	209 ± 3^{c}
Unsaponifiable matter (%)	0.5 ± 0.2^{a}	0.61 ± 0.21^{a}	0.6 ± 0.1^{a}	0.87 ± 0.1^{a}

[a]Values are means ± S.D (n=3)
[b]Means in each row followed by different letters are significantly different ($p<0.05$).

Table 1: Physical and chemical characteristics of vegetable oils samples.

Quality Parameters	Samples			
	Cocoa butter substitute	Shortening Oil	Coconut Oil	Palm Oil
Peroxide value (meq/kg fat)	0.62 ± 0.01^{a}	0.61 ± 0.008^{a}	1.03 ± 0.08^{b}	1.03 ± 0.04^{b}
Oxidative stability (h at 100°C)	69.04 ± 5.69^{b}	33.46 ± 4.06^{a}	33.05 ± 2.29^{a}	36.98 ± 2.06^{a}
Conjugated diens at 232 nm	1.042 ± 0.05^{a}	2.15 ± 0.08^{b}	2.911 ± 0.04^{c}	2.246 ± 0.01^{b}
conjugated triens at 270 nm	0.064 ± 0.01^{a}	0.677 ± 0.07^{b}	0.776 ± 0.05^{b}	0.777 ± 0.03^{b}

[a]Values are means ± S.D (n=3)
[b]Means in each row followed by different letters are significantly different ($p<0.05$).

Table 2: Oxidative stability of vegetable oil samples.

and shortening oil (SHO) have similar values of PV. The coconut oil (CO) and palm oil (PO) samples showed a significant ($p<0.05$) elevation in PV (by about 71%) compared to CBSO and SHO samples.

A low PV represents either early or advanced oxidation. It was observed earlier that PV values were decreased after initial increase due to the high rate of peroxides degradation after its formation at late stage of lipid oxidation [18]. Therefore, the high values of PV expressed by CO and PO could indicate early stage of lipid oxidation. Besides, low PV could be due to both early and advanced stage of lipid oxidation in CBSO and SHO samples, respectively.

The results in Table 2 indicated also that the highest values in oxidative stability by rancimat measurements were (69.04 ± 5.69 h) for CBSO, while the lowest value were (33.05 ± 2.29 h) for coconut oil. There were no significant difference ($p>0.05$) among shortening oil (SHO), palm oil (PO) and coconut oil (CO). The significant differences were observed in cocoa butter substitute (CBSO) compared with other vegetable oils samples. The high oxidative stability of (CBSO) is due to the process of hydrogenation which leads to the increase of saturated fatty acids. These results are in agreement with those obtained by Al-Abbad [19-23]. It could be observed that CBSO samples showed significant ($p<0.05$) resistance to oxidation as indicated from results of oxidative stability (about 100% more stability) compared to both SHO and CO samples. Another parameter for lipid oxidation is the presence of CD and CT. The term CD means two double bonds separated by one single bond which can absorb UV light at 232 nm. When CD extended to include one more single bond, this is called CT which can absorb UV light at 268 nm. Measurement of either CD or CT is a good indicator for early stage of oxidation of fat or oil as they are increased proportionally to the formation of peroxides during the early stages of oxidation [24].

As presented in Table 2, the highest value of CD (2.911 ± 0.04) was observed in CO, while the lowest value (1.042 ± 0.05) was recorded for CBSO. On the other hand, the highest values of CT (0.776 ± 0.05 and 0.777 ± 0.03) were recorded for CO and PO, respectively, while the lowest value (0.064 ± 0.01) was observed in CBSO samples. These values of CBSO confirmed the lowest PV and the higher oxidative stability of these samples (Table 2) These results are in agreement with those obtained by Al-Abbad [19,25].

Fatty acid composition

Fatty acid composition of SHO and CBSO samples is presented in Table 3 and Figures 1a and b. While short chain fatty acids were detected in CBSO (caproic, caprlyic and capric with a level of 0.068 ± 0.018, 3.719 ± 0.005 and 3.291 ± 0.004 g/100 g, respectively), they were not detected in SHO (Table 3). Also, butyric acid (C4) was not detected in both oil samples. CBSO was characterized with extremely high lauric, myristic

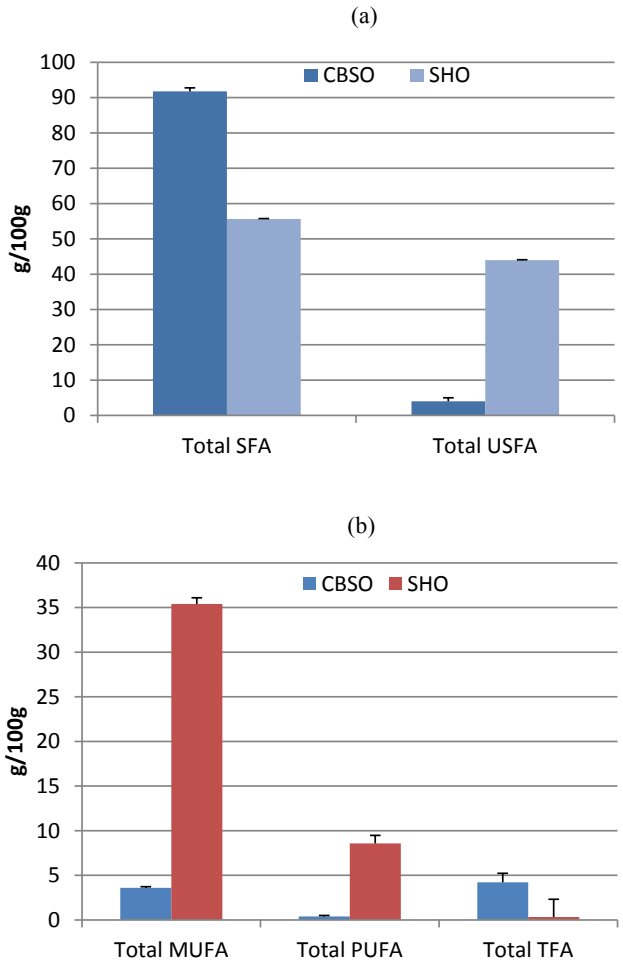

Figure (1a and 1b): Total fatty acids composition of Coca butter substitute (CBSO) Shortening (SHO) samples. a) Total saturated (SFA) and unsaturated (USFA) fatty acids composition. B) Total monounsaturated (MUSFA), polyunsaturated (PUSFA) and trans (TFA) fatty acid composition. Values are means ± S.D (n =3). Mean value was significantly different between CSBO and SHO samples ($P<0.05$).

A: Saturated fatty acids, %

Samples	C4:0	C6:0	C8:0	C10:0	C12:0	C14:0	C16:0	C17:0	C18:0	C20:0	C22:0
CBS	nd	0.068 ± 0.015	3.719 ± 0.005	3.291 ± 0.004	44.95 ± 0.02	14.07 ± 0.03	9.188 ± 0.002	0.03 ± 0.01	16.36 ± 0.04	0.059 ± 0.022	0.043 ± 0.002
SHO	nd	nd	nd	nd	0.318 ± 0.002	1.156 ± 0.002	49.09 ± 0.02	0.111 ± 0.006	4.648 ± 0.004	0.331 ± 0.004	nd

B: Unsaturated fatty acids, %

Samples	C16:1	C17:1	C18:1	C18:2	C18:3	C20:1	C18:1 Trans	C18:2 Trans
CBS	nd	nd	3.6 ± 0.08	0.211 ± 0.003	0.19 ± 0.008	nd	4.22 ± 0.007	nd
SHO	0.177 ± 0.002	nd	35.23 ± 0.005	8.58 ± 0.009	nd	nd	nd	0.324 ± 0.006

Values are means ± S.D
Means in each row followed by different letters are significantly different ($p<0.05$).
CBS: cocoa butter substitute oil, SHO: shortening oil.
LSD: least significant difference
nd: No difference

Table 3: Fatty acid composition of vegetable oil samples.

and stearic fatty acids content (44.95 ± 0.02, 14.07 ± 0.03 and 16.36 ± 0.04 g/100 g, respectively), but the SHO was characterized with a high content of palmitic and stearic fatty acids (49.09 ± 0.02 and 4.648 ± 0.004 g/100 g, respectively). Margaric fatty acid was detectable with a close ratio in both SHO and CBSO (0.107 ± 0.006 and 0.03 ± 0.01 g/100 g), respectively (Table 3). It is thought that the higher content of stearic and palmitic acids may be due to the presence of hydrogenated oils or interesterified fats during manufacturing of margarines or shortenings [5]. These results are in agreement with those obtained by Bakeet [26].

The highest quantity of unsaturated fatty acids was recorded for oleic acid (C18:1) in SHO sample (35.23 ± 0.005 g/100 g) compared to 3.6 ± 0.1 g/100g in CBSO sample. While heptadecanoic (C17:1) and gadoleic (C20:1) fatty acids were not detected in both CBSO and SHO samples, hexadecanoic (C16:1) fatty acids detected in SHO but not in CBSO samples (Table 3). Also, trans fatty acids (C18:1) and (C18:2) were detected in CBSO and SHO samples (4.22 ± 0.007 and 0.324 ± 0.006 g /100 g, respectively) The CBSO samples were higher in the trans fatty acids (4.22 ± 0.007 g/100 g) compared to the SHO samples (0.324 ± 0.006 g/100 g). The low value of trans fatty acids (TFA) in SHO could be resulted from the increased awareness of the negative effects of TFA which encourage the margarine manufacturers to lower the quantity of TFA in their products [27].

As shown in (Figure 1a), CBSO samples were significantly ($p<0.05$) higher (91.77 ± 0.1 g/100 g) in total saturated fatty acids (SFA), while SHO samples were significantly ($p<0.05$) higher (43.99 ± 0.16 g/100 g) in total unsaturated fatty acids (USFA). Because SHO were higher in the USFA, they were also higher in both total monounsaturated (35.40 ± 0.007 g/100g) and total polyunsaturated (8.58 ± 0.009 g/100 g) fatty acid contents (Figure 1b) these results are in agreement with those obtained by Ritvanen [28], Babalola [29].

Conclusion

All samples were not in agreement with Codex standards for moisture and volatile matter content (except PO) and they showed higher insoluble impurities content than the maximum limit stated by standards. CBSO samples showed low peroxide values as well as a significant oxidative stability. Also, they were characterized with extremely high lauric, myristic and stearic fatty acids content. The SHO samples were characterized with a high content of palmitic and stearic fatty acids. The highest quantity of unsaturated fatty acids was recorded in SHO samples. Tran's fatty acids were higher in CBSO than SHO samples. The importance of the above vegetable oils characteristic from the nutritional point of view requires further study.

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