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Characterization and Composition of Untraditional Seed Oils as a Potential New Source of Healthy Edible Oil

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Abstract: Mango seed kernel, apricot seed kernel, papaya seed and roselle seeds are the most important wastes remaining after the processing of fruits. Due to the shortage of edible oils particularly in developing countries, it has become necessary to search for new sources of oils. Therefore, the aim of this study was to evaluate the possibility of utilization these wastes as untraditional sources of edible oils. The results showed that all seeds samples had high amounts of oils and considered to be a good source of crude oils. Physicochemical properties of the oils extracted were iodine value, 54.25-112.30 g I_2/100 g oil; saponification value, 189.36-195.45 mg of KOH/g of oil; acid value, 0.88 - 2.56 mg of KOH/g of oil, free fatty acid, 0.83 - 2.29 g/100 g of oil, and peroxide value 1.29-2.89 meq of O_2/kg of oil. Oil samples had high amounts of unsaturated fatty acids with oleic and linoleic acids being the major ones. The major fatty acids in mango seed kernel oil were stearic and palmitic acids which recorded 49.33 and 8.06%, respectively. It is worthy to mention that the percentage of unsaturated fatty acids in apricot seed oil was the highest (93.59%), followed by papaya seed oil (79.81%) and roselle seed oil (73.19%), respectively, which reflect the nutritional importance of these oils.

Key words: Mango Seed Kernel · Apricot Seed Kernel · Papaya Seed · Roselle Seed · Oils · Fatty Acids Composition · Lipid Class · Physicochemical Properties

INTRODUCTION

Thousands of tons of fruit seeds are discarded every year worldwide as agro-industrial byproducts. For example, watermelon, citrus, parika, papaya, muskmelon, pumpkin and apricot seeds, which remain in large quantity as waste products after the removal of pulp and peel, could be utilized both for both the production of oil and other important by-products [1, 2]. In recent years, the production of available oils from agricultural by-products has attracted attention due to the widespread demand for oil for human consumption and industrial application. Inedible seeds cause considerable waste in the processing of fruit and vegetable in many countries, while resulting in environmental pollution [3]. If these seeds can be used as a partial alternative for conventional oils, it will bring additional values to these by-products, making resources utilization more rational and efficient. These seeds constitute new sources of edible oils, tested especially from under exploited such as mango kernel, apricot kernel, papaya seed and roselle seed (food industry by-products).

Fruit seeds have a high oil content, are rich in monounsaturated fatty acids (FA) and in n-6 and n-3 polyunsaturated essential FA. Sterols, phospholipids, glycolipids, carotenoids, tocopherols and polyphenols are other seed phytochemicals that make them interesting from a commercial viewpoint. Fruit seeds have high potential as raw material for several industries, but their lipid profile remains poorly studied [4]. The by-products of the selected fruits are an excellence source of oils with interesting composition and biological properties. Previous studies carried out on some of these oils confirmed the interest in use them as a possible functional ingredient [5-7].

Mango (*Mangifera indica* L.) is a common and one of the most important tropical fruits in the world, which is characterized by its sweet tasty pulp. In mango about 40-50% of total fruit is wasted of which peel is 12-15%, pulper waste is 5-10% and the kernel is 15-20% [8].

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Mango seed kernel (MSK) is an important source of nutrients and oil [9]. It has mainly been on the lipid component of the kernel, and of its potential application in the confectionery industry as a source of cocoa-butter substitute [10], and could potentially be used in the formulations of food products such as chocolate and biscuits as a natural nutritional additive [11]. Mango seed kernel oil is suitable for blending with other vegetable oils rich in unsaturated fatty acids since its more stable and it can also serve as cheap alternative source of vegetable oil that has similar chemical and physical properties to cocoa butter for use in confectionery industry [12].

MSKO is a promising edible oil, safe and natural source of edible fat, it is not contain trans FA [13]. MSKO is a promising and a safe source of edible oil and was founded to be nutritious and non-toxic, so that it could be substitute for any solid fat without adverse effects [14]. Toxicity was not noticed in rats fed with diets containing 100g/kg crude of MSKO [15]. The lipids were extracted from several varieties of mangoes, free of toxic materials such as hydrocyanic acid [16]. The oil of mango seed kernel consist of about 44-48% saturated fatty acids (majority stearic) and 52-56% unsaturated. Mango seed kernels have a low content of protein but they contain the most of the essential amino acids, with highest values of leucine, valine and lysine. Mango seed kernels were shown to be a good source of polyphenols, phytosterols as campesterol, sitosterol and tocopherols.

Apricot (*Prunus armeniaca*) is important fruit tree mostly grown in Mediterranean countries. The plant is well known for its great medicinal and economical importance. The high production of apricot fruits generates a huge quantity of apricot seeds, which could be potentially utilized for the production of oil rich in oleic acid and γ?tocopherol [17]. Apricot kernels contain oil 53% in the seed and crude protein content 20-25% [18]. Apricot kernel oil is edible and can be used for salad and frying oil compared to the oil yield of some commercial seed oils such as soybean (15-20%), cottonseed (30-36%) and sunflower (36-55%) [19]. The apricot oils because of the fatty acid composition indicates that they may be suitable as edible oils and vitamin E rich contents make these oils suitable for use in preparation of cosmetic and moisturizing creams for dry skins, massaging oils and for industrial use [20].

Papaya (*Carica papaya*) is a principal horticultural crop of tropical and subtropical regions. It is commonly known for its nutritional, medicinal and nutraceutical properties worldwide. Large quantities of waste generated from papaya fruit processing can be recovered and combined in order to obtain added value products [21, 22]. Papaya seed oil utilized in high amount such oils could lead to reduced risk of coronary heart disease. In addition, high oleic oil has sufficiently stability be used in demanding application such as frying. Area of spray oil for snacks, crackers, cereal dried fruit, bakery products where the oil is used to maintain product quality and to increase palatability. Papaya seed oil can be considered as high oleic oil and hence viewed as a healthy alternative to many other vegetable oils [23].

Roselle (*Hibiscus sabdariffa*; Malvaceae) is a tropical herb employed in traditional medicine with various therapeutic uses. Additionally, the roselle seed is an excellent source of dietary fiber [24]. Roselle seeds are often discarded during processing, while they can be used as a source of nutritional and functional compounds, especially bioactive compounds, oils and dietary fiber, whereas, protein and oil content were about 25.20% and 21.10%, respectively [25, 26].

Roselle seed oil is classified as semidry oil, the most fatty acids are linoleic, oleic, palmitic, and stearic. Roselle seeds are a good source of lipid-soluble antioxidants, particularly tocopherols and phytosterols. The characteristics of Roselle seed oil suggested its use in various important industrial processing, such as in cooking, mayonnaise [27]. Roselle seed oil to belong to linoleic/oleic acid category indicating its usefulness to be utilized as a nutritional oil [28].

Mango, apricot, papaya and roselle seeds are by-products that present a novel potential source of excellent oil and protein that might be used for food and other industrial applications. The main aims of this study were to evaluate the possibility of utilization mango, apricot, papaya and roselle seeds as a untraditional source of edible oil, detection and quantitation of unsaturated and saturated fatty acid content and study chemical and physical of the crude oils.

MATERIALS AND METHODS

Materials: Mango (*Mangifera indica*) and apricot (*Prunus armeniaca*) seeds as by-products (waste) were obtained from Edfina Company for Food Preservation, Alexandria, Egypt. Papaya (*Carica papaya*) were brought from farm in Al Hayatem village, Tanta, Gharbia Governorate. Roselle seed (*Hibiscus sabdariffa* L.) from Agriculture Research Center, Giza, Cairo. All solvents and reagents were purchased from various suppliers of the highest purity needed for each application.

Methods:

Preparation of Seeds Samples: Mango kernel was removed manually from the seeds. The kernels were chopped and dried at 50°C over night [29]. Apricot kernel was washed, dried at 50°C and splitted from the shell. Papaya and roselle seeds cleaned, washed and dried at 50°C. The dried materials were ground using an electrical grinder (National Model MX-915C, Japan) at speed 6 for 2 min. into powders to pass through 35 mm (42 mesh) sieve.

Oil Extraction: The crude oils were extracted by n-hexane, which added to seeds powders at ratio 2:1 (v/w) and kept overnight in dark with shaking at 20°C. The miscella separated from the cake by filtration with Whatman filter paper. The filtrate miscella, were combined and n-hexane was evaporated in a rotary evaporator at 30°C. The extracted oils were kept at -18°C until analysis.

Determination of Physicochemical Properties of Selected Seeds Oils: Physical properties of oil included, yield (%), refractive index (at 25°C), specific gravity (at 25°C), viscosity, pH, density, melting point, smoking point. Color values of tested oils were evaluated using the Lovibond tintometer (Tintometer® Model F., Greece) by achieving the best possible match with a standard color slide [30]. Chemical characteristics including acidity (as % oleic acid), free fatty acid (FFA), saponification value (mg KOH/g), iodine value (gI_2/100g oil), peroxide value (meq. O_2/kg oil), unsaponifiable matter (%), tocopherol, total phenolic compounds (mg GAE/100g), total flavonoids (mg QE/100g), and were determined according to AOCS [31]. All determinations were performed in triplicates and the means were reported. Oxidative stability of different oils was determined as induction period (hr) using Rancimat 679 apparatus (Metrohm Co., Switzerland) at 100°C with air flow rate 20L/hr until the time taken reach to fixed level of conductivity according to the method reported by Taskins *et al*. [32].

Fatty Acid Composition of Oil Samples: The methyl esters of crude oils were prepared according to Chalvardjian [33] using a 1% of H_2SO_4 in absolute methyl alcohol. The fatty acid methyl esters obtained were separated by Shimadzu gas chromatography (GC-4CM, PFE) with a flame ionization detector in the presence of nitrogen as a carrier gas. A glass column (2.5 m x 3 mm), packed with Chrom Q 80/100 mesh at a temperature of 270°C. Standard fatty acid methyl esters were used for identification. The area under each peak was measured and the percentage expressed in regard to the total area as mentioned by El-Adawy *et al*. [34].

Lipid Classes: Lipid classes of the crude oils samples were separated by thin layer chromatography (TLC) using pre-coated plastic sheets (POLYGYRAM SiL G, 0.25 mm silica gel, Germany) according to the method of Mangold and Malins, [35].

Statistical Analysis: The analytical data were analyzed using SPSS 16.0 software. Means and standard deviations were determined using descriptive statistics. Comparisons between samples were determined using analysis of one-way variance (ANOVA) and multiple range tests. Statistical significance was defined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Physical Properties of Tested Seeds Oils Samples: The physicochemical properties of crude oils extracted from some seeds are shown in Table 1. The results showed that ASK had the highest oil yield, which recorded 42.65% followed by papaya seed (29.16%). On the other hand, the oil yields from mango and roselle seeds oils were 12.53 and 22.38%, respectively. Roselle seed oil was reported previously to be 21.85% and 17.35% from the seed [36,37], while oil yield extracted from papaya seeds recorded so far varies from 13%-38% [38-41]. The result of the oil yields indicates that the selected seeds exhibited high oil content suitable for consideration in the edible oil production.

The refractive index is used to check the purity of substance and also reflects the degree of unsaturation and chain length of oil. The refractive index of MSKO, ASO, PSO and RSO at 25°C is about 1.4653, 1.4685, 1.4634 and 1.4593. The specific gravity of the studied seed oils were 0.8962 for mango seed oil, 0.9153 for apricot, 0.9242 for papaya seed oil and 0.9558 for roselle seed oil. These results are in agreement with those reported by Mustafa *et al.* [42] who reported that the specific gravity of the some oils were as follows: 0.9136 for apricot, 0.9153 for peach and 0.8969 for mango oil.

Relative viscosity is an adequate indicator of the resistance of the oil towards flow, and generally, it proportional correlated with the polymeric material of the oil. From the tabulated data, it could be noticed that MSKO had the highest value of viscosity which recorded 117.33 cp followed by ASKO (99.65 cp). The viscosity value of 117.33cp as determined reflects the resistance of the oil to shear stress. Mabrouk *et al*. [43] reported that

Table 1: Physical and chemical properties of seeds oils samples

Properties	MSKO	ASKO	PSO	RSO
Physical properties				
Oil yield (%)	12.53±0.12^{d}	42.65±0.19^{a}	29.16±0.16^{b}	22.38±0.14^{c}
Refractive index (25°C)	1.4653±0.23^{a}	1.4685±0.20^{a}	1.4634±0.19^{a}	1.4593±0.21^{ab}
Specific gravity (25°C)	0.8962±0.15^{b}	0.9153±0.19^{ab}	0.9242±0.14^{a}	0.9558±0.18^{a}
Viscosity (cp)	117.33±0.22^{a}	99.65±0.24^{b}	49.73±0.17^{c}	56.57±0.19^{cd}
pH	6.07±0.09^{a}	7.66±0.11^{b}	5.58±0.08^{b}	5.39±0.12^{b}
Density at 25°C (g/ml)	0.9106±0.12	0.9313± 0.16	0.9116±0.13	0.9171±0.10
Melting point (°C)	32.81±26.20	30.11±0.15b^{c}	43.26±0.12^{a}	26.43±0.09^{c}
Smoking point (°C)	250.66±0.05^{a}	254.41±0.09^{a}	213.17±0.10^{c}	221.17±0.13^{b}
Color	30Y+10R	25Y+0.8R	20Y+6.6R	30Y+2.07R
Chemical properties				
Acid value (mg KOH/g oil)	0.88±0.13^{c}	2.56±0.16^{a}	1.83±0.17^{b}	1.99±0.11^{b}
Free fatty acids (as % oleic acid)	1.69±0.17	2.29±0.12	1.39±0.16	0.83±0.13
Saponification value (mg KOH/g oil)	189.36± 0.32^{bc}	191.80±0.28^{b}	195.45±0.28 ^{a}	194.83±0.25^{ab}
Iodine value (g I_2/100g oil)	54.25±0.13^{cd}	112.34±0.21^{a}	103.56±0.19^{b}	64.50± 0.23^{c}
Peroxide value (mEq O_2/kg oil)	1.29±0.21^{c}	2.89±0.19^{b}	3.34±0.17^{a}	2.48±0.20^{c}
Unsaponifiable matter (%)	3.65±0.14^{a}	0.89±0.12^{c}	1.38±0.09^{b}	1.55±0.11^{b}
Tocopherol (mg/100g oil)	98.34±0.23^{c}	59.77±0.20^{d}	118.54±0.19^{b}	235±0.12^{a}
Total flavonoids	23.78±0.17^{d}	36.19±0.15^{c}	109.56±0.17^{a}	53.43±0.18^{b}
Total phenolic (mg GAE/g)	6.19±0.08^{c}	8.22±0.11^{b}	9.36±0.09^{a}	6.24±0.06^{c}
Oxidative stability (hours)	141.37±0.22^{a}	22.45±0.06^{cd}	29.60±0.14^{c}	34.86±0.12^{b}

(ASK) Apricot seed kernels, * (MSK) Mango seed kernels, PS (Papaya seed); RS (Roselle seed)

Values are the mean of triplicate determinations with standard division.

** Calculated by difference. The different letters at the row means significant differences at ($p<0.05$) and the same letters means no significant differences.

the viscosity value of roselle seed oil was 30 cp at 40°C. The pH value of papaya seed oil (5.58) is slightly low indicating the slightly acidic nature of the oil. These results are agreement with Afolabi and Ofobrukweta [44] who found that pH of papaya seed oil was 5.556. Also, Seshamamba *et al*. [45] reported that the pH value of papaya seed oil was slightly low indicating the slightly acidic nature of the pH value is 5.6.

The density values recorded in this study were 0.9106, 0.8813, 0.9116, and 0.9171 for MSKO, ASKO, PSO, and RSO, respectively. These results are accordance with Manzoor *et al*. [46] who reported that the density value of ASO was ranges between 0.87 and 0.93 mg/mL. The density of MSKO ranged between 0.83 and 0.085 g/ml [47].

From the same table, it could be noticed that melting points of tested seeds oils were ranged from 43.26°C (in PSO) to 26.43°C (in RSO). Melting point is dependent on the degree of unsaturation of the fatty acids present in the oil and on the chains of fatty acids. The low melting point of the papaya seed oil (42.30±3.0°C) can be attributed to their unsaturation [48]. Nadeem *et al*. [49] revealed that, MSK oil is solid at ambient temperature and pressure (melting point 32 to 36°C), hydrogenation is not necessary for its utilization in the food industry. Smoke point is the temperature at which heated oil begins to smoke and produces toxic fumes and harmful radicals while flash point is the temperature at which vapor coming from oil will catch fire from an ignition source [38]. ASKO recorded the highest value of smoking point (254.41°C) followed by MSKO (250.66°C) and RSO (221.17°C), while PSO scored 213.17°C.

The obtained data showed that MSKO, ASKO, PSO and RSO colors were 30Y+10R, 25Y+0.8R, 20Y+6.6R and 30Y+2.07R, respectively. Similar results were obtained by Yanty *et al*. [50] who reported that the oil color of the samples were 35Y 1.56R, 30.3Y 2.07R and 25.2Y, 2.1R for marula seeds oil, roselle seeds oil and Christ's thorn seeds oil, respectively. The papaya seed oil had a Lovibond color index of 15.2Y + 5.2B.

Chemical Properties of Tested Seeds Oils Samples: Referring to Table 1, ASO had high value of acidity (2.56 mg KOH/g oil) followed by the RSO (1.99 mg/g oil) and PSO (1.83 mg KOH/g oil) while MSO recorded the lowest value (0.88 mg/g oil). These results are agreement with Brahmi *et al*. [51] reported that ASO had high value of acidity (4.40 mg/g oil) followed by the WSO (1.10 mg/g oil) and, MSO (0.80 mg/g oil). Also, Abdel-Razik *et al*. [52] who found that acidity of MSO was 0.76 mg KOH/g oil). Free fatty acid (FFA) contents of mango, apricot, papaya and roselle seeds oils were 1.69, 2.29, 1.39 and 0.83%, respectively. In this respect, Mustafa *et al*. [53] found that free fatty acid (FFA) contents of apricot, peach and

Table 2: Fatty acids composition (%) of mango kernel, apricot kernel, papaya seed and roselle seeds oils

Fatty acids	Symbol	Mango	Apricot	Papaya	Roselle
Saturated Fatty Acids					
Myristic	C14:0	0.03	0.02	0.20	0.22
Palmitic	C16:0	8.06	4.85	13.79	20.10
Margaric	C17:0	0.12	0.04	0.13	0.10
Stearic	C18:0	49.33	1.33	4.94	5.29
Archidic	C20:0	2.83	0.13	0.37	0.88
Behenic	C22:0	0.55	0.03	0.23	0.30
TSFA	-	60.93	6.40	20.18	26.80
Unsaturated Fatty Acids					
Palmitolic	C16:1	0.05	0.67	0.35	0.38
Ginkgolic	C17:1	0.02	0.13	0.10	0.10
Oleic	C18:1	33.54	67.93	70.69	32.51
Linoleic	C18:2	4.93	24.64	5.89	38.43
Linolenic	C18:3	0.43	0.09	0.37	1.73
Gadeolic	C20:1	0.10	0.34	0.12	0.04
TUSFA	-	39.06	93.59	79.81	73.19
U/S ratio	-	0.64	14.62	3.95	2.73

TSFA = Total saturated fatty acids; TUSFSA= Total unsaturated fatty acids; U/S Unsaturated/saturated ratio

mango kernel oils were 1.35, 0.97 and 1.59%, respectively. The saponification value (SV) used to know theamount of free fatty acid present in the oil, and amount of free fatty acid estimated by determining the quantity of alkali that should be added to the fat to make it neutral [54]. As shown in Table 1, the saponification value of the oil samples were 189.36, 191.80, 195.45 and 194.83 mg KOH/g oil for mango, apricot, papaya and roselle seeds oils, respectively. Saponification number of all wild ASKO ranged from 183.3 mg KOH/g to 195.5 mg KOH/g [55] .

All oil samples had relatively high iodine values (expect for mango seed oil which recorded 54.26), thus reflecting a high degree of unsaturation. Apricot and papaya seed oils had the highest iodine values which recorded 112.34 and 103.56 g I_2/100g oil), respectively. Mohamed and Girgis [56] found that iodine number of mango seed oil ranged from 49 to 53, which is in agreement with our results.

The peroxide value of MSKO in the present study was 1.29 meq O_2/kg oil, which was lower than 2.89, 2.34 and 2.48 meq O_2/kg oil for apricot, papaya and roselle seeds oils, respectively (Table 2). PV of different apricot varieties from Pakistan ranged from 1.0 to 2.32 meqO_2/kg [17]. The peroxide value of the MSO, ASO, PSO and RSO oils are outside the range of 0-10mEq/kg stipulated for freshly prepared oil [57]. The term "Unsaponifiable Matter" in oils or fats, refers to those substances that are not saponifiable by alkali hydroxides but are soluble in the ordinary fat solvents, and to products of saponification that are soluble in such solvents [58]. MSKO recorded the highest value of unsaponifiable matter (3.65%), followed by RSO (1.55) while the lowest value scored in PSO (0.89%).

RSO had the highest value of total tocopherol which recorded 235.26 mg/100g oil followed by PSO (118.54 mg/100g oil) while the lowest value was in ASKO (59.66 mg/100g oil). Total tocopherols were detected at an average concentration of 247 mg/100 g oil in roselle seed oil.

The phenolic content of oils assessing the quality of oil as it is correlated with color and the shelf-life of oil, in particularly its resistance to oxidation [59]. From the tabulated data, total phenolic and total flavonoids contents recorded higher level in PSO (109.56 mg GAE/100g and 9.36 mg QE/100g, respectively) than other studied seed oils. Total phenolic and total flavonoids contents of MSKO, ASKO and RSO were 23.78, 36.19, 53.43 mg GAE/100g and 6.19, 8.22 and 6.24 mg QE/100g, respectively. The total phenolic content (TPC) and DPPH radical scavenging (IC50) capacity of MKOs varied from 7.03 to 11.00 mg GAE/g and 4.33 to 8.32 mg/mL, respectively [60]. Total phenolic and flavonoids contents in RSO were 56.31mg GAE and 4.99 mg catechin g/ oil, respectively [61]. In addition, El-Deab and Ghamry [62] reported that total phenols in roselle seed oil was18.37 mg/ g oil as gallic acid equivalents. The total phenolic content of papaya seed oil was 109.56 mg GAE/100g oil. This value is higher than the content obtained by Siger *et al*. [63] in cold-pressing oilseeds from soya (1.48 mg/100 g), sunflower (1.20 mg/100 g), corn (1.26 mg/100 g), rapeseed (1.31 mg/100 g), and rice bran (1.44 mg/100 g). Oxidative stability is an important parameter for the quality assessment of oils. The oxidative stability index, defined as the time required for the oil sample to develop a measurable rancidity during the Rancimat test [64]. From the obtained data, it could be clear that the MSKO had the highest oxidative stability reached to 141.36 hr at 100°C. This may be due to its fatty acids pattern which is rich in saturated fatty acids (60.93% as shown in Table 2).

The results obtained are in a good agreement with Abdel-Razik *et al*. [52] who reported that the oxidative stability of mango seed kernel butter was 148.4 hr. at 100°C. El-Deab and Ghamry [62] reported that percentage of free fatty acid and oxidative stability in roselle seed oil was 2.10% and 21.30 hr, this may be due to the nature of roselle seeds. The high oxidative stability of roselle seed oil could be at least partially attributed to its high tocopherol content, particularly γ-tocopherol.

Table 3: Lipid classes of crude oils extracted from different seeds

Lipid classes	MKSO	AKSO	PSO	RSO
Hydrocarbon	0.64	0.33	0.54	2.53
Triglycerides	88.41	95.13	96.06	71.87
Free fatty acid	0.54	0.23	0.16	5.41
Sterols	1.33	1.09	1.17	3.29
Diglycerides	3.22	1.89	2.36	7.24
Monoglycerides	0.82	1.43	0.89	2.95
Phospholipids	3.49	1.56	1.03	1.48

The oxidative stability of RSO and PSO was 3486 and 29.60 hr, while, ASKO recorded the lowest value of oxidative stability (22.45 hr). Abdel-Hameed *et al*. [64] reported that oxidative stability of PSO was found to be 29.60 h at 100°C. Also, Sahar *et al.* [61] reported that induction period of oxidative stability of RSO was 24.88 h.

Fatty Acid Composition of MSO, ASO, PSO and RSO: Table 2 shows the fatty acids composition (%) of mango, apricot, papaya and roselle seeds oils. Apricot seed oil had the highest content of total unsaturated fatty acids (93.59%) followed by papaya seed oil (79.81%), roselle seed oil (73.19%) and mango seed oil (39.06%). From the obtained data, it could be noticed that MKO contained a considerable amount of total saturated fatty acid 60.93%. This means that MKO can be to be resistant to oxidation and can be stored for a prolonged period without affecting its physicochemical and functional properties. Oleic acid (C18:1) was the predominant fatty acid which was 70.69% in papaya seed oil and 67.93% in apricot seed oil. Roselle seed oil had the highest content of linoleic acid (38.43%). The presence of high amounts of linoleic acid suggests that these oils are highly nutritious, due to their ability to reduce serum cholesterol and these fatty acids play a natural preventive role in cardiovascular disease and in the alleviation of some other health problems [65]. From the same table, it could be observed that predominate fatty acid of crude AKO was oleic acid (67.93%) followed by linoleic acid (24.64%) and palmitic acid (4.85%), respectively. These findings agree well with those obtained by Shariatifar *et al.* [66] who reported that oleic acid (60.01-70.56 %) is the key fatty acid found in wild apricot kernel oil, followed by linoleic acid (19.74-23.52 %) and palmitic acid (2.35-5.97 %).

The major fatty acids in the extracted oil from papaya seeds were oleic (70.69%), followed by palmitic (13.79%), linoleic (5.89%) and stearic (4.94%) acid. These results are in harmony with those that Malacrida *et al*. [67] who found that oleic (71.30%), followed by palmitic (16.16%), linoleic (6.06%) and stearic (4.73%) acid in papaya seed oil. The high-oleic acid content of papaya seed oil is also similar to commercially available high-oleic vegetable oils such as canola (75%) and safflower (77%). These oils have sufficient stability to be used for food frying applications [67].

Lipids Classes of Tested Seeds Oils: Fractionation of lipid classes by fat extraction could be very important to study functional properties of each seeds oils fraction such as emulsifying properties of phospholipids and monoglycerids. The quantitative data of the individual lipid classes of crude oils of mango seed kernel, apricot seed kernel, papaya seed and roselle seed are shown in Table 3. Triglycerides fraction is considered as the major fraction of lipid classes in all tested oil samples. Papaya seed oil recoded the highest value of trigleceride (96.06%) followed by apricot seed oil (95.13%) and mango seed oil (88.41%). On the other hand, free fatty acids represent a very small portion of the total lipids of tested seeds oils. In this concern, Kiralan *et al*. [68] reported that AKO is composed from 98% triacylglycerols, 1.1% phospholipids, 0.2% free fatty acids, and 0.7% unsaponifiable matters of the oil weight. In AKO triglyceride composition differences are due to incompletely separation of some triglycerides. Also, Samia El-Safy *et al*. [69] found that prickly pear, grape, cantaloupe, mango kernel, paprika, pumpkin, husk tomato and guava seeds oils samples could be fractionated into seven classes including triglycerides as the major lipid class.

CONCLUSION

The results showed that the mango, apricot, papaya and roselle seeds as by-product could be economic and new source of edible oils helping for covering a part of lack in edible oils. MSKO is rich in oleic and stearic acid indicating that oil was stable and tolerant to rancidity. This oil may be considered as an important source of UFA and has the potential to be used as nutrient rich food oil. It could be concluded that the MSKO, ASKO, PSO and RSO could be become valuable resource to produce high value of vegetable oil.

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