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Physicochemical characteristics and fatty acid composition of three purple maize oil seeds consumed in Central-North of Côte d'Ivoire

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Abstract

In Ivory Coast, there are three different purple maize varieties whose culture is confined to Katiola (Central-North) area. These varieties locally called "Violet de Katiola" are the most widely grown and prized maize in this area because of its important socio-cultural character, its good organoleptic quality, its market value and its therapeutic virtues. The present paper aimed at evaluating physicochemical properties and fatty acid composition of these purple maize oilseeds in order to explore their nutritional and industrial potentialities. Physicochemical properties of the seed oils were: specific gravity, 0.90 to 0.91; refractive index (25 °C), 1.456 to 1.459; iodine value, 102.90 to 124.34 g I2 /100 g ; peroxide value, 4.23 to 4.99 meq.O2/kg ; free fatty acids, 0.74 to 0.86 %; acid value, 2.50 to 2.99 mg of KOH/g and; saponification value, 138.96 to 170.36 mg KOH/g. Results revealed that these oilseeds contained high amount of unsaturated fatty acids mainly consisting of linoleic (42.86 to 45.16 %) and oleic acids (33.27 to 34.98 %) which were desirable from the nutritional and health viewpoints. Palmitic acid was the major saturated fatty acid with contents ranged from 15.51 to 17.06 %. The oilseeds showed high PUFA/SFA ratios suggesting their ability to reduce cholesterol levels and coronary heart diseases in body. All these interesting characteristics confirm their usefulness for different nutritional and industrial applications.

Keywords: Purple maize varieties; Oil seeds; Physicochemical properties; Fatty acids; Côte d'Ivoire

1. Introduction

Maize or corn (*Zea mays* L.) is the largest crop in the world and the first cereal produced before wheat with approximately 989. 6 million tons in 2015 [1]. It is also the most important staple food in sub-Saharan Africa (SSA) and is critical to food security with more than 300 million Africans depending on it as main staple food. Of the 22 countries in the world where maize forms the highest percentage of energy in the national diet, 16 are in Africa [2].

The dominance of maize in Sub-Saharan Africa, particularly in West Africa has been favoured by its ability to adapt to agro-ecological conditions and by the strategic roles both as a cash crop and as a high-consumed product in many countries [3]. In West African countries as Côte d'Ivoire and Nigeria, maize kernels are consumed in several ways: sun dried, cooked, fermented, roasted, pounded or crushed [4]. It is used for food and feed (poultry, pigs, cattle) and as a raw material in some industries (brewing, soap and oil mill) [5]. Badu-Apraku and Fakorede [6] argue that the demand for maize as food, feed, and industrial raw material continues to increase in West and Central Africa. This increasing of demand would be fueled by expanding populations and rising incomes in all countries of the sub-region.

Maize kernels are the most energetic cereals [7], due to the high starch content and the most economical of the production point of view (simple culture to produce, harvest and store). Chemical composition of different maize kernels can be considered homogeneous, but it depends on cultivation conditions, temperature, variety and maize type

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(white, yellow, purple, black, etc). Cultivated varieties are often classified by referring to their form, vegetative cycle and colour of the grains [2]. In Côte d'Ivoire, the ordinary or classic yellow and white maize varieties are widely cultivated in all regions of the country. Contrary to these well-known varieties, the purple maize varieties are confined to Katiola (Central-North) and in surrounding areas justifying their name of "violet de Katiola" [8].

Maize kernel is mainly a basic source of starch (about 70 - 74%) which is responsible of the high nutritional value (either for human and/or animal consumption) [9]. Although maize is mainly cultivated for carbohydrate production, this crop has gained great significance as a source of edible oil [10]. This vegetable oil present in the embryo or germ (45 – 50 %), is used for cooking, seasoning and manufacture of soaps [11]. The amount and composition of oil in the kernel is under genetic control [12]. Fatty acids in corn oil are composed of 12% palmitic acid (16:0) and 2% stearic acid (18:0), for saturated fatty acid; 25% oleic acid (18:1), 60% linoleic acid (18:2) and 1% linolenic acid (18:3), for unsaturated fatty acid [13]. Maize oil is generally accepted as high quality, as determined by the high linoleic acid and low linolenic acid content [14]. Furthermore, the most important essential fatty acids (linoleic acid and linolenic acid) are important for human health as they are precursors for hormones as prostaglandins and they would regulate many biological parameters such as blood pressure and circulating triglycerides, HDL and LDL cholesterol [13]. Maize oil is amongst the richest sources of vitamin E in the form of γ-tocopherol with 94.1 mg/100 g as reported content, respectively [15]. However, these studies are usually conducted on the oil of ordinary corn varieties. To our knowledge, there is no report concerning the physicochemical and nutritive assessment of oils extracted from purple maize, especially the three varieties cultivated in Côte d'Ivoire. So, the aim of this work was to investigate the properties of these purple oilseeds in order to explore and discuss their nutritional and industrial potentialities.

2. Material and methods

2.1. Plants material

Dry kernels of three different varieties of Ivorian purple maize and the ordinary yellow maize (control) were used as raw material. Ordinary yellow maize kernels were purchased from local market in Abidjan. Purple maize seeds were grown during appropriate cropping season (raining season from May to July) in 2017 on experimental plots of the National Floristic Center of the University Felix Houphouet-Boigny and Bingerville (5°21′ N and 3°54′ W). After harvesting and drying, 30 kg of each sample were collected and transported to the Biotechnology Laboratory of Felix Houphouët-Boigny University for analysis. Maize crude flours were produced according to the process described by Moreira et al. [16], slightly modified. Dried kernel (5 kg) of each sample, free from any dirt, were ground using an electric crusher to obtain the crude flours.

2.2. Oil seeds extraction

Oils were extracted from 50 g of each crude flour with 300 mL of n-hexane (40 to 60 °C) in a Soxhlet extractor [17]. Then the solvent was removed (vacuum-packed) at 40 °C with a rotary evaporator (Heidolph, Hei-Vap, Germany). The extracted lipid was weighed to determine the oil content of the seed. Crude oils were stored at 4 °C in air tight brown sterile glass bottles [18] until further use for physicochemical and biochemical analysis.

2.3. Physico-chemical analysis

2.3.1. Specific gravity and refractive index

Specific gravity and refractive index of oilseeds were determined at 25 °C following [19] method by using a pycnometer and a refractometer (Abbe, Optic Ivymen, Spain), respectively.

2.3.2. pH, acid, peroxide, iodine and saponification values

pH value of oil samples was determined at 25 °C according to IUPAC [20] method by using a pH-meter (Hanna, Hi 8915 ATC, Spain). Oil sample (2 mL) was dissolved in 15 mL of n-hexane. The pH-meter electrode was standardized with buffer solutions (pH 4.0 and 7.0) and then immersed into the sample to record pH value. Acid, Peroxide, Iodine and Saponification values were determined following AOAC [21] methods.

2.4. Unsaponifiable matter

Unsaponifiable matter content of the studied oil was determined following IUPAC [19] method. Oil sample (5 g) was saponified with 50mL of 2N KOH methanolic solution for 1 h. To the resulted mixture, 100 mL of distilled water was added. The unsaponifiable matter was extracted three times with 100 mL of diethyl-ether. Organic fractions were collected, washed three times with 40mL of distilled water and then dried with sodium sulfate. Diethyl-ether was removed in a rotary evaporator (Heidolph, Hei-Vap, Germany) to recover the unsaponifiable matter, which was then weighed.

2.5. Fatty acids composition

The fatty acids were converted to their methyl esters (FAMEs) as described by the European Communities [22]. Approximately 0.1 g of oil sample was mixed with 2 mL of n-heptane and 0.2 ml of a methanolic solution of potassium hydroxide (2N). The whole mixture was shaken up for 30 s and allowed to settle for 5 min. The top layer containing the FAMEs was used for gas chromatography (GC) analysis.

FAMEs solution (1 µL) containing the internal standard (erucic acid) was injected into a gas chromatograph (Shimadzu, GC 14 A, Japan) equipped with a flame ionization detector (FID) and a capillary column TRD1 (60 m X 0.25 mm i.d. X 0.25 µm film thickness). The carrier gas was nitrogen and the flow rate was adjusted to 23 ml/min. Temperatures of detector and injector were 250 °C. The initial column temperature was fixed to 100 °C and programmed to increase by 5°C per min intervals until 220 °C and, kept for 10 min at this temperature. The fatty acid methyl esters peaks were identified by comparing their retention times with those of standards. After adjusting areas with the internal standard (erucic acid), the yield of each fatty acid was calculated as follow: area of the fatty acid/areas of total fatty acids in the oil sample × 100 (%).

2.6. Statistical analysis

Statistical analysis of data was done by the one way Analysis of Variance (ANOVA) using software IBM SPSS Statistics version 20.0. Differences between means were tested using the Duncan Multiple Range Test with 5% level of significant difference and figures were drawn on Excel 2013 Software.

3. Results and discussion

3.1. Extraction yield and physicochemical characteristics

The oil content of Yellow maize seeds (5.30 ± 0.00 %) was lower than those of purple seeds (6.21±0.05 for Dark Purple Corn (DPC), 6.14±0.08 for Light Purple Red Corn (LPRC) and 5.87±0.51 for Light Purple Corn (LPC).DPC and LPRC recording the highest contents (Table 1). Moreau et al. [23] found that the oil content of purple maize seeds is slightly upper than that (3-5%) of ordinary or classic maize. It seems that these variations between oil yields in maize seeds could be attributed to their cultivation climate, ripening stage, and harvesting time [24]. The knowledge of chemical and physical properties of oils is important having role in processing functionality, storage stability and nutritional behaviour. So, it is difficult to define single values for chemical and physical properties of edible oils since they exhibit considerable deviations in their composition [25]. Physicochemical properties of oil from studied purple maize are shown in Table 1. As regards the refractive index and specific gravities, no significant difference was observed ($p \leq 0.05$) between values obtained for the oilseed varieties. Refractive indexes were approximately of 1.456 while specific gravities were around 0.90. These values agreed with values reported for conventional edible oilseeds [26]. These values were higher than those (0.84 and 1.42) found for *Irvingia gabonensis* seed oil [27]. As reported by Falade et al. [28], refractive index of oils depends on several parameters such as molecular weight, fatty acid chain length, degree of unsaturation, and degree of conjugation. The relatively high refractive indexes suggest that studied seed oils have fatty acids with high number of carbon atoms and several double bonds. Values obtained for specific gravity corroborate the fluid state of these oils at ambient temperature as they are unsaturated. So, these physical characteristics would make the studied maize oils suitable in food industries to provide texture and softness to products [29].

Quality parameters such as acid value, peroxide value and free fatty acids were also highlighted in table 1. For these three parameters, purple maize oils showed lower values than those of yellow maize oil. Free fatty acid (FFA) obtained from the studied oilseeds ranged between 0.74 to 0.86 % for purple maize oils and 0.99% for yellow maize one. The free fatty acid contents were very low compared to the maximum limit of 5% for free fatty acids in high grade palm oil in Nigeria [30]. Likewise, peroxide values of the studied maize oilseeds ranging from 4.23 to 4.99 meq O_2/kg of oil were lesser than the maximum acceptable value of 10 meq O_2/kg set by the Codex Alimentarius Commission for groundnut seed oils. It is well known that the peroxide value is used as an indicator of deterioration of oils, thus low peroxide value indicates resistance of the oil to peroxidation during storage. The low free fatty acid and peroxide values recorded for the studied purple oilseeds indicate that they are less liable to oxidative rancidity at ambient temperature [31]. Thereby, these stable oils would not easily go rancid and could be stored for longer period without deterioration [32].

As concerned acid value which is an indicator for edibility and freshness of oil, results showed that values of purple oilseeds were significantly lower than the yellow maize samples. These values were ranged from 2.50 to 2.96 mg KOH/g.

These corn oilseeds could be suitable for cooking as their acid values fall within the maximum limit of 3.00 mg KOH/g recommended for cooking oils [33].

The iodine values of the various maize oilseeds varieties ranged between 102.90 g I_2/100 g (YC) and 124.34 g I_2/100 g (LPC). Purple varieties recorded higher iodine values than the yellow maize oil (classic corn oil)., All the samples have relatively high iodine values and these values are within the range of 95-125 g I_2/100 g of classic maize oil found by Defan et al. [34]. High iodine value is due to its high content of unsaturated fatty acids and indicates that the seed oil has the good qualities of edible oil and drying oil purposes [35]. The obtained iodine values agreed with values reported for conventional edible oils such as soybean (120 to143 g I_2/100 g) and sunflower (110 to 143 g I_2/100 g) oils [26].

As for the saponification value, purple oil maize recorded the highest value ranged between 138.96 (LPC) to 170.33 (LPRC) mg KOH/g compared to the yellow maize oil (Table I). High saponification value indicated the presence of greater number of ester bonds, suggesting that the fat molecules were intact. Thereby, these purple maize oilseeds, particularly LPRC, could also be recommended in soap making regarding its higher saponification value close than that (187-193 mg KOH/g) of palm oil extensively used in soapmaking [36].

Unsaponifiable matter includes substances frequently found dissolved in fats and oils which cannot be saponified by caustic alkali but are soluble in ordinary fat solvents [37]. With values ranged from 1.71 (LPC) to 1.87 g/100g (LPRC and DPC), purple maize oilseeds showed high unsaponifiable matter compared to classic yellow maize oil.

Table 1 Extraction yield and physicochemical composition of yellow and purple maize oilseeds

Physicochemical parameters	Oilseeds			
	YC	DPC	LPRC	LPC
Extraction yield (%)	5.30 ± 0.00^{c}	6.21± 0.05^{a}	6.14±0.08^{a}	5.87±0.51^{b}
Specific gravity	0.91 ± 0.01^{a}	0.90± 0.01^{a}	0.90 ± 0.00^{a}	0.90 ± 0.01^{a}
Refractive index at 50°C	1.456± 0.00^{b}	1.456±0.00^{b}	1.456 ± 0.00^{b}	1.459 ± 0.03^{b}
PH at 25°C	5.32 ± 0.39^{d}	5.77±0.02^{b}	5.89 ±0.10^{a}	5.64 ± 0.01^{c}
Acid value (mg KOH/g)	2.96 ± 0.39^{a}	2.52 ±0.07^{b}	2.50 ± 0.33^{b}	2.55 ± 0.50^{b}
Free fatty acid (% oleic acid)	0.99± 0.19^{a}	0.76±0.03^{c}	0.74 ± 0.16^{c}	0.86 ± 0.25^{b}
Peroxide value (meq O_2/kg)	4.99 ± 1.34^{a}	4.39±0.59^{c}	4.46 ± 0.02^{b}	4.23 ± 0.75^{c}
Iodine value (g I_2/100 g)	102.90± 0.50^{c}	120.97±4.2^{a}	109.29± 1,02^{b}	124.34± 3.06^{a}
Saponification value (mg KOH/g)	139.10± 3.92^{c}	154.63±2.8^{b}	170.36± 5.38^{a}	138.96± 8.38^{c}
unsaponifiable value (g/100g)	1.51 ±0.10^{b}	1.87 ±0.13^{a}	1.87 ± 0.22^{a}	1.71 ± 0.23^{a}

Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05). YC: Yellow Corn; DPC: Dark Purple Corn; LPRC: Light Purple Red Corn; LPC: Light Purple Corn

3.2. Fatty acids composition of maize oil samples

Fatty acids profile of the studied maize kernel oils is depicted in Figure 1. This profile indicates that the studied oilseeds consist mainly of palmitic acid (C16: 0), oleic acid (C18: 1), stearic acid (C18: 0), linoleic acid (C18: 2) and linolenic acid (C18:3).

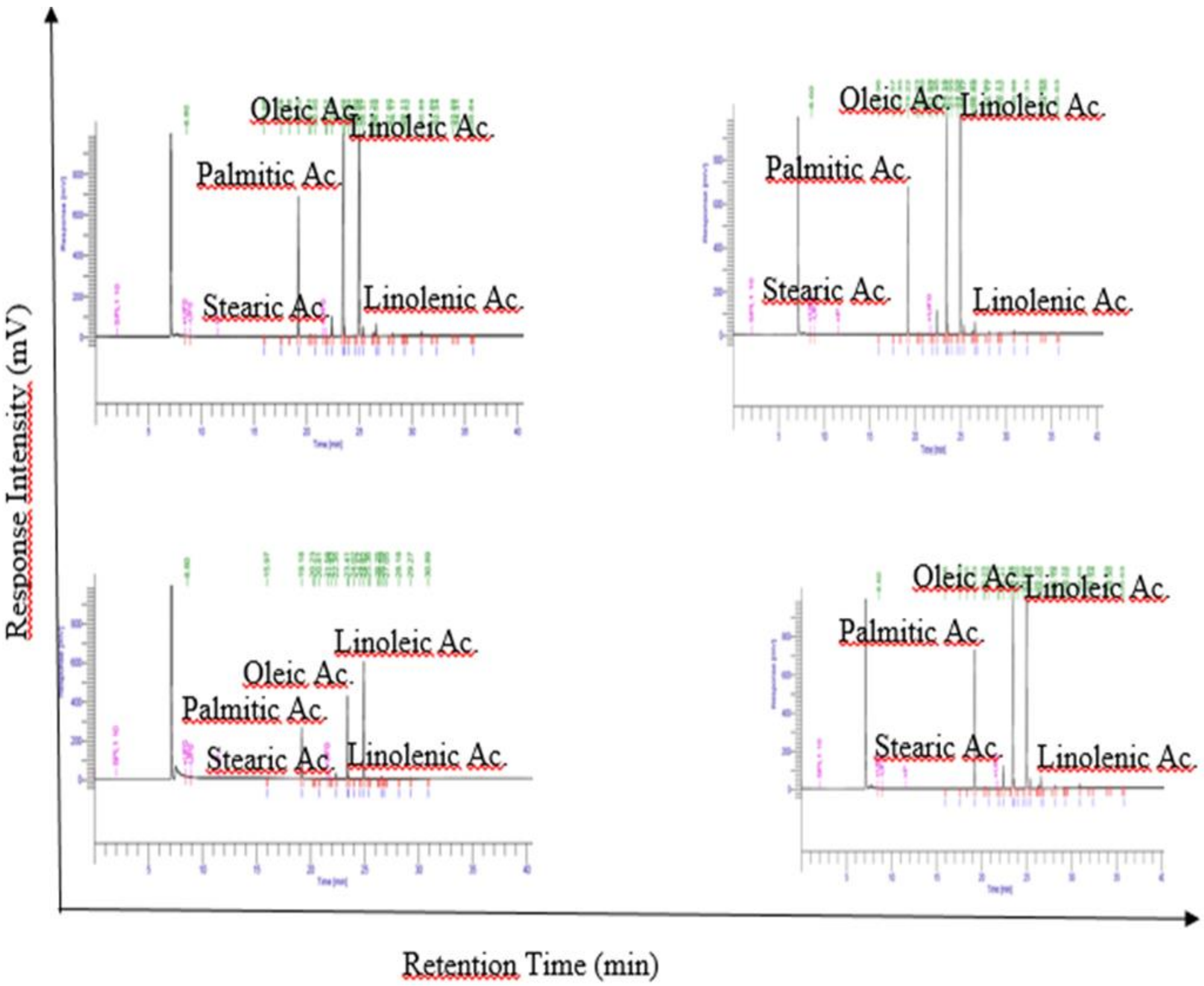

Figure 1 Gas chromatograms of fatty acids constituents of white and purple maize oilseeds.

Experiments were performed by gas chromatographic analysis (GC-FID) of fatty acids methyl esters derived from white and purple oilseeds. (A) Chromatogram of yellow corn (YC) oilseed, (B) Chromatogram of dark purple corn (DPC) oilseed, (C) Chromatogram of light purple red corn (LPRC) oilseeds and (D) Chromatogram of light purple corn (LPC).

Data given in the Table 2 showed that unsaturated fatty acids (UFA) ranged between 76.86% (LPRC) to 79.64% (DPC) were higher than saturated (19.18% for DPC to 19.64% for LPC oilseeds). All samples presented total saturated fatty acids (SFA) content less than one fifth of the total fatty acids content. The high unsaturated fatty acids content in the purple maize kernel oils could be explained by the high iodine values. The abundances of unsaturated fatty acids in the oil were desirable from nutritional and health points of view as unsaturated fatty acids consumption will not lead to heart related diseases [37]. The consumption of polyunsaturated and monounsaturated fatty acids has been recommended to improve the lipid profile. Unlike, excessive consumption of saturated fatty acids is implicated to the increase of the plasmatic cholesterol, the obesity and certain cardiovascular disorders like atherosclerosis [38]. The major unsaturated fatty acids in purple maize oils were linoleic acid (43.67% for DPC to 45.16% for LPRC) and oleic acid (33.27% for LPRC to 34.98 for DPC), while the major saturated fatty acids were palmitic acid (15.51% for DPC to 17.06% for LPRC oil sample). Linoleic acid is an important essential fatty acid required for growth, physiological functions and body maintenance [39]. Monounsaturated fatty acids (MUFA) as oleic acid was increasingly recommended for consumption since it seems not to affect the HDL levels, and it may reduce the LDL and triacylglycerols blood levels, that make it more effective in prevention of hearth diseases.

Ratio of polyunsaturated to saturated fatty acids (PUFA/SFA) calculated for studied maize oilseeds were ranged from 2.16 to 2.33. Purple maize oilseeds showed higher values than oil from yellow maize. PUFA/SFA ratio has been used to indicate the cholesterol lowering potential of a food. This ratio, expressing relationship between saturated and polyunsaturated fatty acid content, is an important parameter to determinate the nutritional value of edible oils. Several studies indicate that higher value of PUFA/SFA ratio means a smaller deposition of lipids in the body [37]. A PUFA/SFA ratio of 0.2 has been associated with high cholesterol level with high risk of coronary heart disorders while a ratio as high as 0.8 is associated with desirable levels of cholesterol and reduced coronary heart diseases [40]. Therefore, the studied maize kernel oils, especially the purple varieties could be used in the dietetic management of some coronary heart diseases.

Table 2 Fatty acid composition of yellow and purple maize oilseeds

Fatty acids	Oilseed samples			
	YC	**DPC**	**LPRC**	**LPC**
Essentials				
Linoleic acid	42.86±0.03^{d}	43.67±0.03^{c}	45.16±0.00^{a}	44.30±0.01^{b}
Linolenic acid	0.99±0.00^{a}	0.96±0.00^{b}	0.87±0.00^{d}	0.91±0.00^{c}
Non-essentials				
Palmitic acid	16.11±0.01^{b}	15.51±0.00^{b}	17.06±0.00^{a}	15.77±0.00^{b}
Stearic acid	2.89±0.00^{a}	2.39±0.00^{c}	1.93±0.03^{d}	2.70±0.00^{b}
Oleic acid	34.47±0.01^{b}	34.98±0.01^{a}	33.27±0.42^{d}	33.96±0.00^{c}
Arachidic acid	0.78±0.00^{a}	0.73±0.00^{b}	0.43±0.02^{d}	0.67±0.00^{c}
Behenic acid	0.23±0.00^{a}	0.23±0.00^{a}	0.10±0.00^{c}	0.20±0.00^{b}
Lignoceric acid	0.33±0.00^{a}	0.32±0.00^{b}	0.07±0.00^{d}	0.3±0.00^{c}
Ratios				
SFA	20.34±0.00^{a}	19.18±0.00^{c}	19.59±0.00^{b}	19.64±0.00^{b}
UFA	78.35±0.01^{c}	79.64±0.00^{a}	76.86±0.01^{d}	79.17±0.01^{b}
MUFA	34.5±0.01^{b}	34.98±0.01^{a}	33.13±0.01^{d}	33.98±0.01^{c}
PUFA	43.85±0.00^{c}	44.66±0.00^{b}	43.73±0.00^{d}	45.21±0.00^{a}
PUFA / SFA	2.16	2.33	2.23	2.30

Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05). YC: Yellow Corn; DPC: Dark Purple Corn; LPRC: Light Purple Red Corn; LPC: Light Purple Corn

4. Conclusion

The present study on the physicochemical properties and fatty acid composition of purple maize kernel oils suggests that these seeds could be considered as edible oil sources. These oilseeds contain high amount of unsaturated fatty acids (approximately four fifth of the total fatty acids content) mainly consisting of linoleic and oleic acids which were desirable from nutritional and health viewpoints. Moreover, the high PUFA/SFA ratios obtained for these oils suggest that their consumption could reduce cholesterol levels and coronary heart diseases in body. Also, these seed oils exhibited good physicochemical properties as saponification and stability confirming their usefulness for nutritional and industrial applications.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist.

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