ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 5, Issue, 04, pp. 4010-4020, April, 2015

International Journal of
DEVELOPMENT RESEARCH

Full Length Research Article

BIOCHEMICAL ASSESSMENT OF THE GENETIC DIVERSITY AMONG THIRTEEN MOROCCAN GENOTYPES OF SESAME (SESAMUM INDICUM)

[1,2]Meriem El Harfi, [2]Abdelghani Nabloussi, [1]Hajar Rizki, [2]Hassan Latrache, [3]Said Ennahli and [1]*Hafida Hanine

[1]Laboratory of Bioprocess and Bio-Interfaces, Faculty of Science and Technology, Beni Mellal, Morocco
[2]Plant Breeding and Plant Genetic Resources Conservation Research Unit, National Institute of Agricultural Research, Regional Centre of Meknes, Morocco
[3]Agriculture National High School of Meknes, Morocco

ARTICLE INFO

Article History:
Received 30th January, 2015
Received in revised form
06th February, 2015
Accepted 28th March, 2015
Published online 29th April, 2015

Key words:
Sesamum indicum L,
Cultivars,
Sesame oil,
Quality index,
Total phenolic content,
Carotenoid and chlorophyll.

ABSTRACT

The main goal of this paper is to assess the quality of sesame seeds (*Sesamum indicum* L) and their oils extracted from raw seeds of 13 cultivars collected in Tadla-Azilal region of Morocco. The results indicated that the physicochemical properties studied exhibited a biochemical diversity among the 13 cultivars, with significant differences ($p < 0.05$). Compositional analysis revealed that the sesame seeds contained considerable amounts of protein (27%) and high amounts of oil (45-55%). The characteristic of the seed oil revealed a high degree of unsaturation (79.50 -83.40% of UFA) and close values of Oleic and Linoleic acid (Oleic/ Linoleic ratio ranges between 0.80 to 0.97). Regarding quality index, there was a variation from 0.12 to 0.63 % of oleic acid for acidity, 82 to 179 mg $KOHg^{-1}$ oil for saponification index, 82.9 to156.85 g of I_2/100 g of oil for iodine index and 1.17 to 4.17 meq O2 kg^{-1} oil for peroxide value. Sesame seed oil was also found to be rich in total phenolic content (mg GAE/kg oil), chlorophyll (mg /kg oil) and carotenoid (mg/kg oil) with values ranged from 61.30 to 72.63; 0.53 to 7.57 and 0.59 to 3.34, respectively. The specific extinctions (K_{232}) and (K_{270}) ranged from 2.86 to 6.49 and from 0.62 to 2.13 respectively, while R-value (K_{232}/K_{270}) ranged from 1.66 to 8.71. These results could be beneficial and useful for sesame breeding programs in Morocco as well as in other areas of the world to develop improved cultivars with high contents of different major health-promoting compounds.

INTRODUCTION

As previously reported by Yu *et al*. (2013), the traditional analytical approach to study the genetic diversity was developed for many plants and it was based on the morphology of the fruiting body and cultivars. Other studies have used izoenzyme form to evaluate the genetic variability and systematic in Pleurotus species (Georgios *et al*., 2009). However, it was reported that the nutrient composition, which is relatively stable, accurate and independent of environmental influences, will be adopted in the case of genetic diversity of sesame seed. Sesame (*Sesamum indicum L.)* is an important and ancient oilseed crop belonging to the family Pedaliaceae (Bedigian, 2003).

Corresponding author: Hafida Hanine
Laboratory of Bioprocess and Bio-Interfaces, Faculty of Science and Technology, Beni Mellal, Morocco

It is cultivated in tropic and temperate zones of the world (Biabani and Pakniyat, 2008). It has been cultivated for centuries, particularly in Asia and Africa, for its high content of edible oil and protein. India and China are the largest producers of sesame in the world, followed by Myanmar. Nearly 70% of the world production is from Asia. Africa and Latin America grow around 26% and 4% of the world's sesame production, respectively (Abou-Gharbia *et al*., 2000). Sesame plant has received considerable attention around the world. Its seeds are used for oil extraction and food preparations (Elleuch *et al.,* 2007). It ranks second after olive oil with regard to nutritional value (Alpaslan *et al.*, 2001). Sesame seeds have the highest oil content compared to rapeseed, peanut, soybean, and other oil crops (Anilakumar, 2010). It is rich in oil (50-60%), protein (18-25%), carbohydrate, and ash (Alpaslan *et al.*, 2001). Sesame oil is highly unsaturated edible oil with abundant essential fatty

acids, such as linoleic acid. Sesame oil contains almost equal levels of oleic (35 to 54%) and linoleic (39 to 59%) acids, 10% of palmitic acid, and 5% of stearic acid (Hall *et al*., 2009). Sesame seed oil shows a remarkable stability to oxidation (Anilakumar *et al*., 2010) due to its high content of natural antioxidants, such as tocopherols, sesamol, sesamolin, and sesamin (Moazzami and Eldine, 2010; Philip *et al*., 2007). Among the primary edible oils, sesame oil has the highest antioxidant content (Cheung *et al*., 2007). Sesamin and sesaminol triglucoside in sesame seeds are major lignans that display an abundance of biological activities making sesame oil one of the best choices for healthy foods. From the medicinal point of view, sesame reduces plasma cholesterol and lowers blood pressure (Shankar *et al*., 2005), prevents various disorders, such as hypertension and hypercholesterolemia (Philip *et al*., 2007), reduces symptoms of osteoarthritis (Saddat *et al*., 2013), and decreases plasma triacylglycerol and arachidonic acid levels, imparting anti-inflammatory and estrogenic activities (Philip *et al*., 2007).

Sesame has been grown in Morocco for decades under a range of environmental and agronomic conditions. Therefore, oil content, fatty acid composition and the quality of oil vary greatly within Moroccan cultivars, offering possibilities of developing superior quality edible oils and particular industrial oils. Moreover, identification and use of local Moroccan cultivars with desirable genes has become more relevant today, because using biotechnological tools and transferring genes across species/genera is now feasible. It is, therefore, imperative to survey and investigate the quality of oil to identify Moroccan genotypes with superior quality of edible oil that can be used in breeding programs. Information on biochemical constituents in terms of quality indexes of sesame germplasm grown in Morocco is limited to nonexistent. Thus, the determination of phenol content, protein content, index quality of oil, chlorophyll and carotenoid in various genotypes could be beneficial and of a great interest for the selection of elite lines to be used in sesame breeding program to develop, in the future, improved cultivars with high seed quality. Therefore, this study aimed to determine the variability of quality of oil and content of oil, proteins chlorophyll and carotenoid in 13 genotypes grown in various locations of Tadla-Azilal region of Morocco.

MATERIALS AND METHODS

a. Plant material

Thirteen Moroccan sesame cultivars, including yellow and Brown seeds, have been used in this study. The cultivars were collected from different locations in Tadla-Azilal region (Fig. 1), in which they were grown during 2011.These were Bni Ayat (A), Tagzirt (B), Krakeb (C), Ouled Ziyane (E), Ouled Youssef (G), Ouled Yaïch (I), Had Boumoussa (J), Ouled Barakate (L), Krifate (S), El Bazaza (T), Ouled Ayad (B'),Ouled M'bark (H') and Ouled Slimane (M'). Tadla Azilal region is located in the center of the country, between the High Atlas, Middle Atlas and Trays phosphate, with an average altitude of 400-700 m. All the seed collected was increased. After collecting sesame seeds were immediately dried and stored at 4°C until analysis.

b. Chemical and Reagent

The solvents used, sodium bicarbonate, sodium thiosulfate, potassium iodide, potassium hydroxide, iodine monochloride, phenolphtaleine and gallic acid were of analytical grade (99% purity).

c. Seed analyses

Seeds from the populations collected in Tadla Azilal were analyzed for seed oil, proteins, polyphenol, carotenoid, chlorophyll content quality index and ratio C18 :1/C18 :2. All analyses were done on duplicated. They were performed every year shortly after seed collection or harvest. Weight of 1000 seeds was also measured. In some cases, the amount of seeds collected or increased were insufficient for analyses. We have considered in this study only those accessions for which data from different environments were available. This made a total of 13 accessions. Seed oil content was measured on intact seeds, previously desiccated at 103◦C for 17 h, using an Oxford 4000 nuclear magnetic resonance (NMR) analyzer (Oxford Analytical Instruments Ltd., Abingdon, OX, UK). The oil content was determined using NMR method (NF EN ISO 10565) and oil extraction from the ground seeds following the procedure described by Visavadiya *et al*, (1999). Twenty-five g of ground seeds were placed in paper cone cellulose in 250 ml of n-hexane for 8 hours using a Soxhlet extractor apparatus.

The n-hexane was selected as solvent extraction to improve oil extraction efficiency as compared to other polar solvents such as alcohol, ketone, aldehyde, ether, ester, etc. The oil was then recovered by evaporation of solvent using a rotary evaporator at 40°C. AFNOR NF methods and Regulation (EEC) N° 2568/91 were used for the determination of the following physical and chemical characteristics: peroxide index (AFNOR NFT 60-220), saponification (AFNOR NFT 60-206), iodine (Regulation (EEC) N° 2568/91 – 2008- Annex XVI) and acid values (AFNOR NFT60-204). Extinction coefficient (K_{232} and K_{270}) expressed as the specific extinction of a 1% (w/v) solution of oil in cyclohexane in 1 cm cell path length at wavelengths between 232 and 274 nm (232 nm, 266 nm, 270 nm and 274 nm), was measured using a Jasco spectraphysic 430 UV spectrometer the UV absorption following the analytical methods described in Regulation (EEC) N° 2568/91- 2008- Annex IX.

d. Biochemical analysis

Proteins were determined using Bradford reagent according to the method of Bradford, (1976). Analyses of chlorophyll and carotenoid contents were performed using a spectrophotometer (Spectraphysic Jasco V630 chroma_lab), according to the method previously described by Minguez-Mosquera *et al*, (1991). A quantity of 7.5 g of oil was dissolved in 25 mL of cyclohexane. The absorption at 470 and 670 nm was measured. The specific extinction wavelengths applied were E0 =2000 for lutein (a carotenoid component), and E0 = 613 for pheophytin (a chlorophyll component). The equations used for the pigment content calculation were:

Carotenoid content (mg/kg) = (A470× 106)/ (2000× 100×d)
Chlorophyll content (mg/kg) = (A670× 106)/ (613× 100×d)

Where A is the absorbance and d is the spectrophotometer cell thickness (1 cm). The data reported was based on sample oil weight. Total phenolic compounds were determined using Folin-Ciocalteu reagent according to Scalbert *et al*. (1989). One hundred µl of oil was diluted in 400 µl of methanol, mixed with 2.5 ml of folin Ciocalteu reagent (1/10). Two ml of sodium bicarbonate solution (75 g/l) were added to the mixture and allowed to stand at 50°C for 5 min. After cooling, the absorbance was measured at 760 nm using an UV visible spectrophotometer (Spectraphysic Jasco 430, Japan). The concentration was calculated using gallic acid as standard, and the results were expressed as mg gallic acid equivalents per Kg of oil.

The determination of oleic and linoleic acid was performed by preparing the methyl esters according to the method of Stefanoudaki *et al*, (1999). 0.25 g of sesame oil was transferred in to a test tube, and then 5 ml of n-hexane and 0.5 ml of methanolic solution of potassium hydroxide 2N was added. The mixture was centrifuged at 3500 rpm for 2 min. The supernatant was analyzed using a gas chromatograph. 0.2 µl of the methyl esterifies sample was injected into a gas chromatograph (Trace GC Ultra) coupled to a mass spectrometer (MS Polaris Q ion trap) instrument, fitted with a manual injector and fused silica capillary column VB-WAX (100% bonded polyethylene glycol) (30m x 0.25 mm x 0.25 µm). Eluents were detected on a flame ionization detector (FID). Conditions set for analysis included a split mode of injection (split ratio- 20). High- grade hydrogen was used as carrier gas with a column flow rate of 1.4 ml/min. The initial FID temperature of the column was set to 140 °C and then was increased at a rate of 10 °C/min to a terminal temperature of 250°C and the operating temperature was maintained at 22°C. Database used:NIST/EPA/NIH Mass Spectral Library version 2.0, build in January 2002. Individual FA composition was calculated using the peak areas of the FA species that appear in the chromatogram as a relative percentage of the total peak areas of all the FA in the oil sample.

e. Statistical Analysis

Data were analyzed using the SPSS (Version 20,SPSS Inc., Chicago, IL, USA) statistical software and p values <0.05 were considered statistically significant. In addition, Duncan's new multiple range test ($p < 0.05$) was applied to compare cultivars means.

RESULTS AND DISCUSSION

The sesame seeds upon Soxhlet extraction with n-hexane for 8 h have had a yellow white color. Thousand seed weight (TSW), protein content, oil content and ratio C18:1/C18:2 are given in Table 1. There were significant differences among cultivars ($p <0.05$) for oil content. It varied from 45%, for cultivars L and E, to 55%, for cultivar A with an average value was 48.24%. The observed variability of the seed oil content found in the present investigation, Table 1, could only be attributed to climatic factors, more probably to the differences in: temperature, humidity, soil nature and other climatic factors prevailing in the locality in which the sesame seeds are cultivated. These findings are similar to those reported in other studies (Asghar and Majeed 2013, Nzikou *et al*., 2009).

However, Abdullahi *et al*, (1991) reported that oil content of different sesame cultivars ranged from 50% to 69.03%, with an average of 59.5%. Baydar *et al*, (1999) reported significantly higher average oil content of 63.25% in Turkish cultivars. Variation in oil content can be attributed either to varietal factor, environmental factor, or interaction of both factors. Alpaslan *et al*, (2001), demonstrated that increased water availability during capsule development in sesame led to higher oil content. High oil content recorded in Moroccan cultivars (over 50%) is a desirable trait for breeding programs to improve sesame cultivars. Previously, Talha and Osman (1974) found that there was an effect of water stress timing on oil content. Early water stress resulted in a reduction in oil content while late water stress induced an increase in oil content. However a moderate stress after flowring period resulted always in an increase of oil content (El Asri *et al*., 2000; Flagella *et al*., 2000; Mekki *et al*., 1999). Temperature was also reported to influence oil content (Canvin, 1965; Trémolières *et al*., 1982; Harris *et al*., 1978; Rondanini *et al*., 2003).

Interaction between environmental condition and genotype effect on oil content was revealed. In our study, the cultivars H and A, having the lowest and the highest oil content, respectively, were planted at the same date and were subjected to the same cropping management. This indicates that the difference observed for oil content was mainly due to the genotype effect. Cultivars with higher fat content are generally selected for oil production and will be used for the breeding program. However, all the cultivars studied were comparable for protein content that have an average value around 27%. The ANOVA analysis of TSW shows that there is no significant different between the studied cultivars. Many results have revealed that sesame contains various beneficial nutritional components (Chen *et al*., 2005; Lazarou *et al*., 2007; Yokota *et al*., 2007). Especially, this crop is of great interest in the food industry due to high contents of primary metabolites, including protein, oil and fatty acids (Orrun˜ o & Morgan, 2007; Rangkadilok *et al*., 2010). Current work was to evaluate the contents of protein in sesame seeds for one crop years. As illustrated in Table 1, protein contents were observed only slight variations in cultivars demonstrating no remarkable differences between seed localities.

Moreover, this content was analyzed with a range of 27.1–27.7%. Our results were lesser than the average content of the earlier report (Orrun˜ o & Morgan, 2007) and those reported by Kimb *et al*. (2014) for black and white sesame, but there were not significant differences in the total average protein contents for the different genotype from different localities. According to Gharby *et al*. (2015), the values found in our cultivars are lower than those obtained for sesame from Sudan and higher than those from Congo, Nigeria, Turkey and Egypt genotypes (Soudan 34,4%, morocco 22%, Congo 20%, Nigeria 19%, Turkey 21% et Egypt 18,93/) (Elgharby, 2015). As reported in the previously works sesame protein may not depend on cultivars, genetics, and environmental conditions (year, temperature, moisture, and light). The value of TSW found in this investigation ranges from 2.72 to 3.27 g with a mean value of 3.05g. This result agrees with those obtained by El khier *et al*. (2008) for Sudanese sesame seed (2.33 to 3.70

g). In contrast, the TSW, values, are also comparable to those found for seeds of soybean.

Free acidity and peroxide value

Quality parameters used regularly to measure the physical and chemical properties of edible oils are content of free fatty acid (FFA), peroxide value, iodine value and saponification value. The quantity of free-fatty acids (FFAs), usually referred as ''the acid value'', is an important quality factor and has extensively been used as a traditional criterion for classifying olive and argan oil into various commercial grades (Gharby *et al*., 2012). FFA determination is particularly important for industrial purposes since FFA can modify the organoleptic or physicochemical properties of oil. The FFAs of the oils from varieties used in this study varied between 0.12 and 0.60 as oleic acid % for cultivars I and G, respectively (Table.2). The observed differences between the studied cultivars was significant ($p < 0.05$). which was below the limit for extra virgin oil (0.5-0.83%) lesser than those reported by Gharby *et al*, (2015). The oils from M' and G had higher acidity values when compared to other location oils, while the oils from I showed lowest free acidity values. Thus, the free acidity values were apparently affected by growing area as reported by Derya Arslan *et al*, (2013).

The recorded values were lower than those found by Ogbonna *et al*. (2013) (0.25-1.41 % of oleic acid), Borchani *et al*. (2010) (1.64 %of oleic acid), Paul E Dim (2013) (5.54 % of oleic acid), and Weiss (1983) (1.90 to 2.00 % of oleic acid). The maximum acceptable value for the sesame oil recommended by the Codex Alimentarius Commission for oils seeds is 4 % of oleic acid (Abayeh *et al*, 1998) and the maximum value as proposed by FAO is 6.0 mg KOH / g oil. Recorded values were very low, consistent with those found by Ogbonna *et al*, (2013) (0.25-1.41 as oleic acid %), and lower than those reported by Borchani *et al*, (2010) (1.64 % of oleic acid), Paul E Dim, 2013(5.54 as oleic acid %), and Weiss, (1983) (1.90 to 2.00 mg KOH / g oil). The minimum acceptable value for the sesame oil recommended by the Codex Alimentarius Commission for oils seeds is 4 mg KOH / g oil (Abayeh *et al*, 1998) and the maximum value as proposed by FAO is 6.0 mg KOH / g oil. Similarly low FFA values have already been reported for sesame seed oil from Sudan (0.49 Oleic acid %) (El Khier *et al*., 2008) or Nigeria (0.9 Oleic acid %) (Ogbonna and Ukaan, 2013).

The high acid value showed in sesame seed oil from Congo (1.8 Oleic acid %) (Nzikou *et al*., 2009). This high value is frequently an indication for a strong enzymatic hydrolysis of sesame seeds during harvesting, handling or oil processing (Gharby *et al*., 2014). The saponification index of sample oil sesames seeds from different locations varied significantly among the studied cultivars from 82,52 to 179,52mg KOH / g of oil, for cultivars S and T, respectively (Table 2). These values are slightly lower than those reported by Nzikou *et al*. (2009) (192 mg KOH/g of oil) and Paul E Dim (2013) (190.74 mg KOH/g of oil). Peroxide value is an indication of rancidity. It is the most important indicator of the stability of edible oils (Lee *et al*, 2008). Therefore, a high peroxide value (Table.2) indicates poor resistance of the oil to peroxidation during storage. The difference between Moroccan cultivars was significant ($p < 0.05$). The peroxide values derived from Moroccan cultivars ranged from 1.7 to 4.17 meq O2 / kg oil, which are below the maximum acceptable value of 10 meq O_2 / g set by the Codex Alimentarius Commission (Abayeh *et al*, 1998). These values are consistent with those reported by Ogbonna *et al*, (2013) and Paul E Dim, (2013), and higher than those found by Borchani *et al*, (2010). These value are higher than those reported for Morocco (2.7 ± 0.5), Soudan 6.9 ± 0.16, Congo 0.06 ± 0.1 and Nigeria (3.95 ± 2.1) (Gharby *et al*., 2015). This oxidative stability was due to the presence of lignin and tocopherols (natural antioxidant) in sesame seeds was indicted for resistance to oxidation.; These results suggested that sesame seed oil stability to oxidation is relatively good, which is due to the presence of antioxidants (sesamol, sesamolin and sesamin) together with tocopherols. The iodine value is a measure of the total number of double bonds present in fats and oils (Gharby *et al*., 2014). High iodine-value oil contains a greater number of double bonds than low iodine-value oil and has usually a reduced oxidative stability (Zine *et al*., 2014).

A higher degree of unsaturation in given oil led to a higher iodine value (Ronald and Ronald, 1989).Iodine values ranged from 82.9 to 156.85 g of I2 / 100g oil (Table.2). These results are consistent with those found by Ogbonna *et al*, 2013; Paul E Dim, 2013; Borchani *et al*, 2010; Nzikou *et al* 2009; Weiss in 1983. The iodine value recorded was higher in all cultivars, indicating a higher concentration of unsaturated fatty acid. Iodine values were reported to vary largely among cultivars, thus Seegeler in 1983 reported lower values ranging from117.2 g to 116.5 g of I2/100g of oil in many Indian and Ethiopian sesame varieties, while Weiss, (1983) reported higher values (163.0 and 161.0 g of I2/100g of oil). The formation of hydroperoxides is accompanied by the generation of conjugated diene measured by absorptivity at a wavelength of 232–234 nm (Guille´n and Ruiz, 2004). The hydroperoxide and the conjugated diene reflect the degree of formation of primary products of lipid oxidation (Guille´n & Ruiz, 2004). Both measurements have been used to determine the addition of oil to pure ones (Ogutcu *et al*., 2008). The higher concentration of conjugated dienes and trienes induce greater amounts of K232 and K270. Table 4 illustrates the values of extinction at 232nm and 270 nm for the sesame oils from Moroccan cultivars.

The extinction coefficient at 232 nm (K232), which measures the amount of conjugates dienes, varies between 2.03 and 3.54. The secondary oxidation compounds of oils evaluated by measuring the extinction coefficient at 270 nm (K270) recorded values ranging from 0.89 to 2.13. These reported values are consistent with those reported by Elleuch *et al*,(2007) and close to those found by Abdalla *et al*, (2014) for olive oil (232 nm range from 2.86 – 3.45 and 270 nm range from 0.32 – 0.62), and superior to those reported by Gharby *et al*, (2011) for argan oil (at 232nm from 1.02 -1.49 at 270nm from 0.18-0.25). At the same peroxide value, the K232 and K270 for sunflower, olive, and the pumpkin seed oils were reported to be 4.93 and 0.51, 3.32 and 0.65, and 8.88 and 1.99, respectively (Markovic and Bastic, 1975). This Value was higher than those reported (1.73) by Gharby *et al*., (2015). As reported in Table.4 the variations in saturated fatty acid (SFA), unsaturated fatty acid (UFA), monounsaturated fatty acid

Table 1. TSW, protein content, oil content of 13 Moroccan sesame cultivars of different sesame oils cultivars from Tadla's region: : Bni Ayat (A), Tagzirt (B), Krakeb (C), Ouled Ziyane (E), Ouled Youssef (G), Ouled Yaïch (I), Had Boumoussa (J), Ouled Barakate (L), Krifate (S), El Bazaza (T), Ouled Ayad (B'),Ouled M'bark (H') and Ouled Slimane (M')

	Sesame cultivars												
	A	B	C	E	G	I	J	L	S	T	B'	H'	M'
TSW(gper1000seeds)	3,20 ±0,26	3,07 ±0,20	3,04 ±0,09	3,02 ±0,19	2,72 ±0,18	2,89 ±0,19	3,11 ±0,23	3,27 ±0,08	2,96 ±0,23	3,14 ±0,23	3,03 ±0,29	3,04 ±0,29	3,16 ±0,23
Protein content (%)	27,15 ±0,15	27,03 ±0,06	27,70 ±0,26	27,15 ±0,06	27,52 ±0,15	27,47 ±0,03	27,68 ±0,06	27,69 ±0,08	27,12 ±0,02	27,66 ±0,10	27,66 ±0,28	27,48 ±0,03	27,52 ±0,04
Oil content (%) RMN	54,5	51,81	49,46	45,20	47,29	50,88	48,04	44,95	45,90	47,29	46,51	49,60	45,70

Table 2. Some physico-chemical characteristics of raw sesame seed oils from 13 Moroccan cultivars of different sesame oils cultivars from Tadla's region: : Bni Ayat (A), Tagzirt (B), Krakeb (C), Ouled Ziyane (E), Ouled Youssef (G), Ouled Yaïch (I), Had Boumoussa (J), Ouled Barakate (L), Krifate (S), El Bazaza (T), Ouled Ayad (B'),Ouled M'bark (H') and Ouled Slimane (M')

Sesame Cultivars	Acidity (as Oleic acid %)	Peroxide index (meq O_2 kg^{-1} oil)	Saponification Index (mg KOH g^{-1} oil)	Iodine Index of (g of I_2/100g of oil)
A	0.15±0.0162	3.5±0.5	119.68±0.81	102.50±4.88
B	0,16±0,0162	3,12±0,2	140,35±0,17	112,26±4,88
C	0,30±0,0326	2,33±0,58	148,85±2,62	131,78±4,88
E	0,21±0,0161	4,17±0,29	147,26±1,40	92,73±4,88
G	0,60±0,1303	2,25±0,25	149,17±0,71	82,97±4,88
I	0,12±0,0163	1,50±0,50	136,74±0,70	102,50±4,88
J	0,23±0,0002	1,17±0,29	139,55±0,70	102,50±4,88
L	0,25±0,0282	1,25±0,25	136,04±1,40	112,26±4,88
S	0,18±0,0163	2,17±0,29	82,75±1,40	102,50±4,88
T	0,26±0,0163	2,17±0,29	179,52±2,81	131,02±4,88
B'	0,25±0,0001	1,17±0,29	158,48±1,40	151,18±4,76
H'	0,17±0,0005	1,25±0,25	152,87±1,40	131,78±4,88
M'	0,57±0,0035	1,17±0,29	151,47±2,81	122,02±4,88

Table 3. Values of specific extinction in UV at 232 nm, 270 nm, Δk and R value of different sesame oils cultivars from Tadla's region: : Bni Ayat (A), Tagzirt (B), Krakeb (C), Ouled Ziyane (E), Ouled Youssef (G), Ouled Yaïch (I), Had Boumoussa (J), Ouled Barakate (L), Krifate (S), El Bazaza (T), Ouled Ayad (B'),Ouled M'bark (H') and Ouled Slimane (M')

	sesame seed Oil cultivars												
	A	B	C	E	G	I	J	L	S	T	B'	H'	M'
232 nm	6,49	6,49	6,49	6,49	6,49	6,49	4,03	6,49	3,41	3,45	3,54	2,86	3,31
270 nm	0,90	0,78	0,74	0,80	0,75	0,82	0,62	1,30	2,04	1,82	2,13	0,84	1,16
Δk	-0,031	-0,026	-0,016	-0,019	-0,010	-0,021	-0,022	0,036	-0,017	-0,017	-0,023	-0,028	-0,037
$R=K_{232}/K_{270}$	7,23	8,29	8,71	8,09	8,63	7,89	6,50	5,01	1,67	1,90	1,66	3,41	2,86

Table 4. SFA, UFA, MUFA, PUFA, ODR and LDR in seed oil of different Moroccan sesame cultivars from various locations of Tadla-Azilal region

Sesame Cultivars	SFA	UFA	MUFA	PUFA	ODR	LDR	C 18 :1/C18 :2
A	19.15	80.66	39.6	41.06	0.509	0.011	0.97
B	19.85	79.5	38.34	41.16	0.518	0.012	0.93
C	18.43	81.57	36.01	45.56	0.534	0.016	0.79
E	17.85	82.16	40.35	41.81	0.507	0.011	0.97
G	18.52	81.49	38.86	42.63	0.518	0.010	0.91
I	17.86	82.13	37.59	44.54	0.529	0.010	0.84
J	18.34	81.66	38.67	42.99	0.523	0.011	0.90
L	17.65	82.34	40.19	42.15	0.514	0.010	0.96
S	18.85	80.95	38.41	42.54	0.526	0.015	0.91
T	18.96	81.04	37.73	43.31	0.533	0.013	0.87
B'	19.58	79.98	37.57	42.41	0.535	0.013	0.89
H'	18.78	80.65	39.19	41.46	0.532	0.011	0.95
M'	19.48	80.3	38.99	41.31	0.539	0.011	0.95
Average	18.72	81.11	38.58	42.53	0.524	0.012	0.91

SFA: saturated fatty acid, UFA: unsaturated fatty acid, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid, ODR: oleic desaturation ratio, LDR: linoleic desaturation ratio, FFA: Free fatty acid

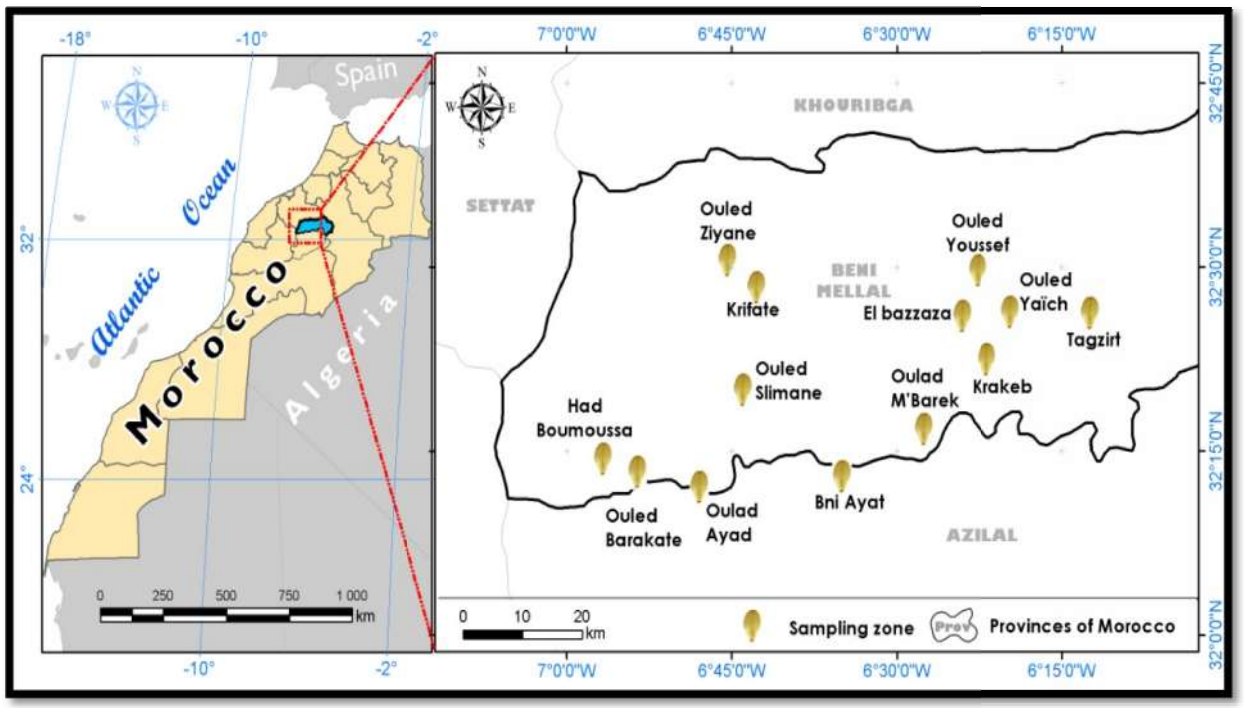
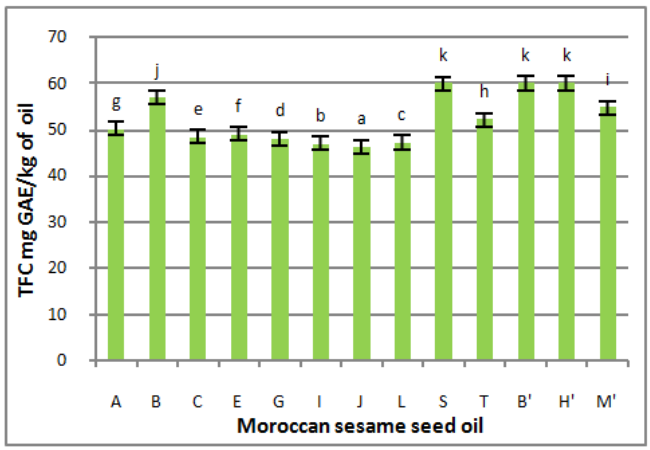
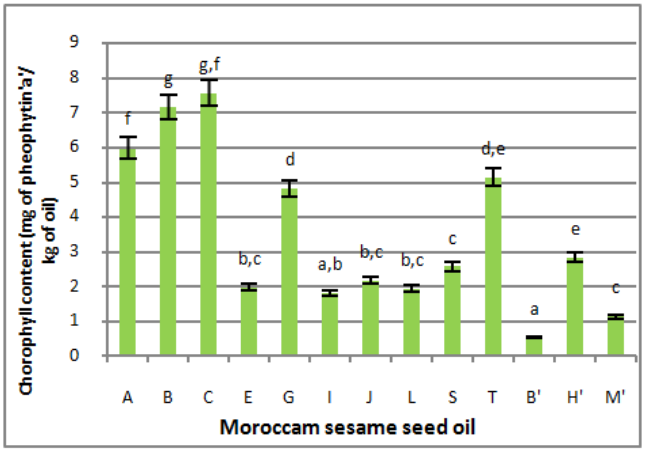


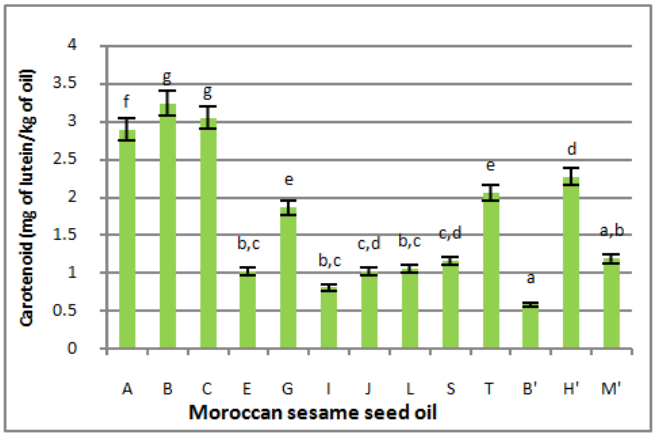
Figure 1. Map showing sesame collecting locations in Tadla-Azilal region in Morocco



(a)



(b)



(c)

Figure 2. Total phenolic content (a), Carotenoids contents (b) and Chlorophyll content(c) of 13 sesame seed oil cultivars from Moroccan region of Tadla-Azillal

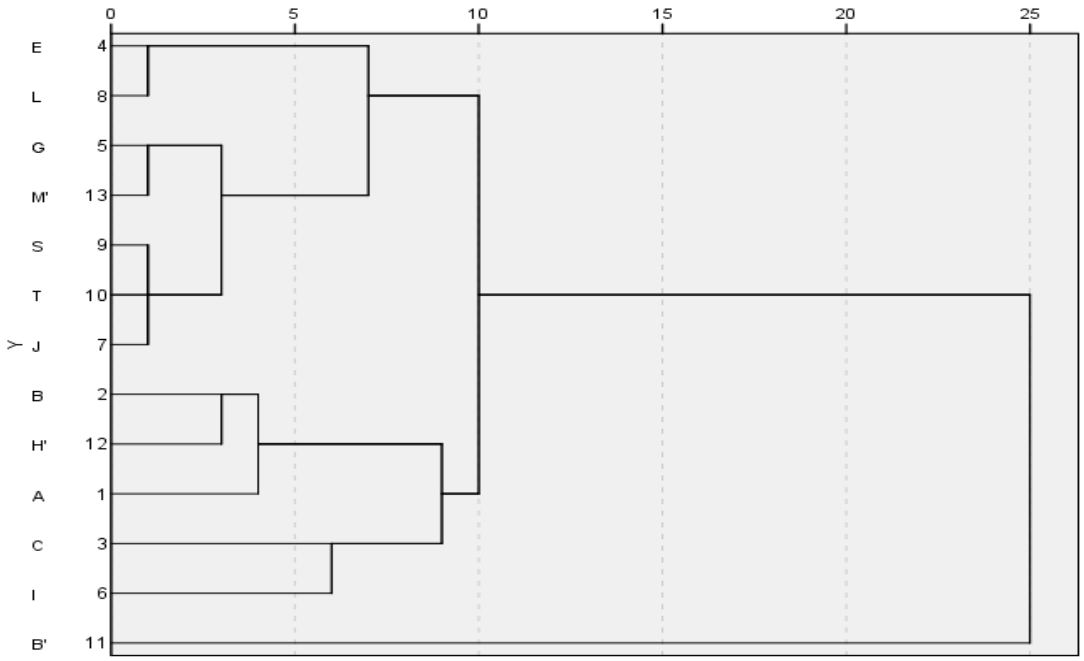


Figure 3. Dendrogram shown groups and under-groups of homogenous individuals on the base of physicochemical characteristics

(MUFA) and polyunsaturated fatty acid (PUFA) the cultivars (L) exhibited the highest UFA content (82.34%) and the lowest SFA (17.65%). High level of UFA increases the oil quality, allowing this oil to be suitable for human consumption. The highest PUFA content (45.56%) was recorded for the cultivars (C). PUFA are considered as essential and they must be brought in the quotidian diet to the human organism which can't synthesize them (Gunstone, 1992). Oils rich in PUFA are important for the market of drying oils (drying index >70), used in paint and coasting as well as in printing inks, which are industrial applications with a growing market (Van De Mark and Sandefur, 2005). Also, oils particularly rich in linoleic acid are used as a raw material in the manufacture of conjugated linoleic acid (Ma *et al*., 1999), a novel therapeutic nutrient with promising antioxidant and anti-tumor properties (Belury, 2002). This fatty acid has also important application as a component of skin care products (Darmstadt *et al*., 2002).

The values of Oleic desaturation ratio (ODR) and linoleic desaturation ratio (LDR) indicating, the efficiency of the desaturation systems from 18:1 to 18:2 and from 18:2 to 18:3, respectively, are shown in table 4. Mean value of ODR (0.52) was found to be quite high in comparison with that of LDR (0.012). These values explain the observed high content of 18:2 and the observed low content of 18:3 in the present research (Table 4. The highest value of LDR (0.016) is in cultivars (C) which exhibited the highest linolenic acid content in the collection (Table 4). Relatively higher average values of ODR and LDR explain the increase of C18:3 content (Velasco *et al*.. 1998). The high ODR values imply that the biosynthesis pathway was efficient in the formation of PUFA (18:2 and18:3) from desaturation of MUFA (18:1). Nevertheless, the low LDR values indicate that this pathway was not so efficient in the formation of 18: 3 from desaturation of 18:2. Consequently, 18:3 content was reduced and 18:2 content increased to reach a concentration higher than that of 18:1. Anyway, oleic and linoleic acids are the major components of Moroccan sesame seeds oil. On the other hand, the average ratio between PUFA and SFA was 2.27, which is lower than values found in previous studies in Iran: 3.03 (Tavakoli *et al*., 2013) and 3.18 (Sharif *et al*., 2009). SFA was higher in Moroccan collection due to the high stearic acid content. The ratio C18:1/C18:2 was 0,91 similar than those reported for the codex and for the sesame from Egypt, Turkey, Congo, sudan (Gharby *et al*., 2015) and Khier *et al*., 2008); Nzikou *et al*., 2009; Unal and Yalcın, 2008; Hassan, 2012). Therefore, a variability was observed between the differentes localities, the higher for A genotype, and the smaller for I genotype. The difference was due to edaphic conditions especially the effect of temperature (Champolivier et Merrien, 1996;) Lajara *et al*., 1990. Oleic acid is the main mono unsaturated fatty acid of sesame seed oil (Crews *et al*. 2006). The ratio Oleic/linoleic for sesame seeds oil varied from ;0,84 to 0,97 compared to Sanflower (0,26), Rapseed (2,89), Olive (0,03), Peanut (1,68), Soybean(0,43), Corn(0,5), Flax(1,21), Coprah(4) and Plam oil (3,8). (Harwood, 1988)

Biochemical Analysis

The total phenolic content (Figure2) of the methanolic sesame oil extracts ranged from 47 to 60 mg GAE/Kg of oil. The highest total phenolic content was recorded in cultivars from locations (I), (K) and (L) (60, 60 and 59 mg GAE/ Kg of oil). Oil extracted from cultivars in the location (G) recorded the lowest polyphenolic content (46.22 mg GAE/Kg of oil). These values are higher than those found by Elleuch *et al*, (2007) (23mgGAE/Kg,) and by Borchani *et al* 2010 (14.21mgCAE/Kg). Sesame oil extracts contained higher total phenolic content compared to other commonly available vegetable oils (Aleksander *et al*., 2008).This difference may be due to extraction techniques of oil, environmental and ecological characteristics of the particular growing area (Elleuch *et al*., 2007) and the effect of organic and bio-organic fertilization on total phenolics (TPC), total flavonoids as

reported by (Salama *et al*., 2015) on cultivars of fennel. It can be explained by the role of organic fertilizers in the biosynthesis which induces the acetate shikimate pathway, resulting in higher production of flavonoids and phenolics (Sousa *et al*., 2008) because a relationship between phenolic compounds, agronomical practices, and harvesting time exist.
In a previous paper (Boschin, D'Agostina, Annicchiarico & Arnoldi, 2007) we reported on the influence of the environment on the FA composition of O-acyl lipids of L. albus seeds. End users and plant breeders need to know whether the quality of lupin grain lots may also be affected by the genotype and, if sizeable genetic differences exist, whether they are consistent across environments or are subject to genotype environment (GE) interaction.

The main objective of this work was, therefore, to assess the extent of genotypic and GE interaction effects on the FA composition of L. albus cultivars grown in subcontinental or Mediterranean-climate conditions. Since it is not possible to differentiate between effects of soil and climatic conditions, environment is comprised of both soil and climatic conditions. Chlorophyll and carotenoids are important quality parameters because they correlate with color, which is a basic attribute for evaluating oil quality. Their magnitude depends on different factors, such as the fruit ripeness, cultivar, the climatic conditions and the type of soil, and the extraction procedures. Moroccan cultivars exhibited a notable amount of carotenoids ranging from 0.59 to 3.34 mg/kg of oil (Figure 2) and chlorophylls, ranging from 0.53 to 7.57 mg/kg of oil (Figure 3), which are responsible for the yellow color of the seed oil.

The obtained values are higher than those reported by Borchani *et al*, (2010) for raw sesame oil (0.04 mg/Kg of oil of chlorophyll and 2.62 mg/kg oil of carotenoids). The average chlorophyll content recorded in Moroccan sesame cultivars was found to be higher compared to other vegetable oils. The content of chlorophyll of sunflower, date palm and Moroccan Picholine are 0.99, 2.18 and 1.69 mg/kg of oil, respectively (Tamara *et al*, 2010, Herchi *et al*, 2014, Mansouri *et al*, 2013). Romero *et al*, (2003) reported that with respect to pigment content, the main effect was the minimum air temperature. Therefore, regardless of cultivars, observed variations are due in part to environmental effect. Local conditions reported to have significant effect on rapeseed (Marwede, *et al*., 2004), oats and barley (Peterson et Qureshi, 1993), soybean (Dolde, *et al*., 1999), and on sunflower (Nagao et Yamazaki, 1983; Velasco, *et al*., 2003).

The variability of oil content was due to the date of sowing (De la Vega and Hall, 2002a; De la Vega and Hall, 2002b) because they influence of thermic conditions during seeds maturation. The Figure 3 shows the results of the hierarchical analysis (CAH) by the average distance between classes (Pearson correlation). Two major distinct groups with a very large distance between classes are revealed. The first one consists of a single group and the other is subdivided into two homogeneous subgroups on the basis of all physicochemical characteristics studied. The first group consists of single homogeneous cultivars with distance between classes of 25; the second group consists of 12 cultivars with a distance class of 10.

Conclusion

The results of this study indicate that the region of Tadla-Azilal in Morocco is suitable to produce high quality sesame seed oil. The Moroccan sesame seed oil exhibited good physicochemical properties. The sesame produces high-quality oil, which can be used for health and industrial purposes. Compared to sesame oil obtained in other sesame producing areas in the world, Moroccan cultivars grown in the region of Tadla-Azilal exhibited an equally high quality of oil. However, seeds composition is largely influenced by genetic and environmental factors. Our study deals with the characterization of the accumulation of seed components useful for industrial transformations by the choice of cultural practices and genotypes. As a result, Moroccan cultivars can be used in breeding programs to develop varieties with desirable traits for better adaptation to local environmental conditions. This study of Moroccan sesame should compliment other molecular studies to better identify strong genotypes that suit the region's agronomical conditions with high potential to produce quality oil.

REFERENCES

Abayeh, O.J., Aina, E.A. and Okuonghae, C.O. 1998. Oil content and oil quality characteristics of some Nigerian oil seeds. *J. Pure Appl. Sci*. 1:17-23.

Abdalla I., khaddor, M., Boussab, A., El Garrouj, D., Souhial, B. 2014. Physical and Chemical Characteristics of Olive Oils from Cooperatives for Olive Growers in the North of Morocco. *International Journal of Basic & Applied Sciences*. 14(2):4-11

Abdullahi, Y., Adeniyi, M.O. and Ihekwuemere, C.A. 1991. Countdown to senior secondary certificate exams in Agric. Science. Evans Brothers, Nigeria. 150pp.

Abou-Gharbia, H.A., Shehata, A.A.Y. and Shahidi F.F. 2000. Effect of processing on oxidative stability and lipid classes of sesame oil. *Food Res. Intl*., 33: 331-340.

AFNOR NFT 60-204, 1985. Determination of acid value and acidity (titration methods), French Association for Standardization AFNOR, Paris.

AFNOR NFT 60-206, 1990. Determination of saponification value, French Association for Standardization AFNOR, Paris.

AFNOR NFT 60-220, 1995. Determination of peroxyde value, Association Française de Normalisation AFNOR. Paris.

Aleksander, S., Malgorzata, N. and Elenora, L. 2008. The content and antioxidant activity of phenoilc compounds in cold pressed plant oils. *Journal of Food Lipids*, 15, 137-149.

Alpaslan, M., Boydak, E. and Demircim, M. 2001. Protein and oil composition of soybean and sesame seed grown in the Harran (GAP) area of Turkey. Session 88B, Food Chemistry: Food Composition and Analysis. IFT Annual Meeting - New Orleans.

Anilakumar, K.R., Pal, A., Khanum, F. and Bawa A.S. 2010. Nutritional, medicinal and industrial uses of sesame (*Sesamumindicum* L.) seeds-an overview. Agriculturae Conspectus Scientificus (ACS), 75 (4):159-168

Annex IX- Regulation (CEE) No 2568/91 of the European Commission of 11 July 1991.

Annex XVI- Regulation (CEE) No 2568/91 of the European Commission of 11 July 1991.

Arslan, D., Karabekirb, Y. and Schreiner, M. 2013. Variations of phenolic compounds, fatty acids and some qualitative characteristics of Sarıulak olive oil as induced by growing area. *Food Research International.* 54: 2, 1897–1906

Asghar, A. and Majeed, M.N. 2013. Chemical characterization and fatty acid profile of different sesame verities in Pakistan. *American Journal of Scientific and Industrial Research*, ISSN: 4.6:540-545

Baydar, H. and Turgut, K. 1999. Variation of certain characters and line selection for yield, oleic and linoleic acid in the Turkish sesame (*sesamumindicum* L.) populations. *J. Agr. and Forest*. 23, 431-441.

Bedigian, D. 2003. Evolution of sesame revisited: domestication, diversity and prospects. *Genet Resour Crop Ev*, 50(7):779–787

Belury, M.A. 2002. Inhibition of Carcinogenesis by Conjugated Linoleic Acid: Potential Mechanisms of Action. Recent Advances in Nutritional Sciences. *American Society for Nutritional Sciences*. 02:0022-3166

Biabani, A.R. and Pakniyat, H. 2008. Evaluation of seed yield-related characters in sesame (*Sesamum indicum* L.) using factor and path analysis. *Pakistan Journal of Biological Sciences*. 11: 1157-1160.

Borchani, C., Besbes, S., Blecker, C., Attia, H. 2010. Chemical characteristics and oxidative stability of sesame seed, sesame paste and olive oils. *J. Agric. Sci. Tech*., 12:585-596.

Boschin, G., D'Agostina, A., Annicchiarico, P. and Arnoldi, A. 2007. The fatty acid composition of the oil from Lupinus albus cv. Luxe as affected by environmental and agricultural factors. *European Food Research and Technology*, 225, 769–776

Bradford, M. M. 1976. A rapid and sensitive method for the quantification of microgram quantities of protein utilizing the principe of protein- dye binding. *Anal. Biochem*. 72 : 248-254.

Canvin, D.T. 1965. The effect of temperature on the oil content and fatty acid composition of the oils from several oil seed crops. *Canadian Journal of Botany*, 43, 63-69.

Champolivier, L. and Merrien, A., 1996. Evolution de la teneur en huile et sa composition en acides gras chez deux variétés de tournesol (oléique ou non) sous l'effet de températures différentes pendant la maturation des graines. Oléagineux Corps Gras Lipides, 3, 140-144

Chen, P. R., Chien, K. L., Su, T. C., Chang, C. J., Liu, T. L., Cheng, H. and Tsai, C. 2005. Dietary sesame reduces serum cholesterol and enhances antioxidant capacity in hypercholesterolemia. *Nutritional Research*, 25, 559–567

Cheung, S.C., Szeto, Y.T. and Benzie, I.F. 2007. Antioxidant protection of edible oils. *Plant Foods for Hum Nutr* 62(1): 39-42.

Crews, C., Hough, P., Godward, J., Brereton, P., Lees, M., Guiet, S. and Winkelmann, W., 2006. Quantitation of the main constituents of some authentic grape-seed oils of different origin. *J. Agric. Food Chem*. 54, 6261–6265.

Darmstadt G.L., Mao Q.M., Chi E., Saha S.K., Ziboh V.A., Black R.E., Santosham M. and Elias P.M. 2002. Impact of tropical oils on the skin barrier: possible implications for neonatal health in developing countries. ActaPaed., 91: 546–554.

De la Vega, A.J. and Hall, A.J. 2002a. Effects of planting date, genotype, and their interactions on sunflower yield: II. Components of oil yield. *Crop Science*, 42, 1202-1210.

De la Vega, A.J., and Hall, A.J. 2002b. Effects of planting date, genotype, and their interactions on sunflower yield: I. Determinants of oil-corrected grain yield. *Crop Science*, 42, 1191-1201.

Dolde, D., Vlahakis, C. and Hazebroek, J. 1999. "Tocopherols in breeding lines and effects of planting location, fatty acid composition, and temperature during development". *Journal of the American Oil Chemists Society* 76 (3): 349-355

El Asri, M., Essahat, A., Bouniols, A. and Mondiès, M. 2000. Rendement et qualité des graines du tournesol cultivé sous contrainte hydrique. Résultats des essais en coopération au Maroc et dans le Sud-Ouest de la France. In: Proc. XV International Sunflower Conference, Toulouse, France, I C, 127-132.

El Khier, M.K.S., Ishag K.E.A. and Yagoub, A.E.A. 2008. Chemical composition and oil characteristics of sesame seed cultivars grown in Sudan. *Res. J. Agric. Biol. Sci*. 4(6):761-766

Elleuch, M., Besbes, S., Roiseux, O., Blecker, C. and Attia, H. 2007. Quality characteristics of sesame seeds and by-products. *Food Chemistry*, 103: 641-650.

Flagella, Z., Rotunno, T., Di Caterina, R., De Simone, G., Ciciretti, L. and et De Caro, A., 2000. Effect of supplementary irrigation on seed yield and oil quality of sunflower (*Helianthus annuus* L.) grown in a sub-arid environment. In: Proc. XV International Sunflower Conference, Toulouse, France, I C, 139-144.

Georgios, Z., John, S. and Constantinos, B., 2009. Genetic variability and systematic of eleven Pleurotus species based on izoenzyme analysis. *Mycol. Res*. 98, 329–341.

Gharby S., Harhar H., Guillaume, D., Haddad, A., Matthäus B. and Charrouf, Z. 2011. Oxidative stability of edible argan oil: A two year study. *Food Science and Technology*. 44(1):1-8.

Gharby, S., Harhar, H., Bouzoubaa, Z., Asdadi, A., El Yadini, A. and Charrouf, Z. 2015. Chemical characterization and oxidative stability of seeds and oil of sesame grown in Morocco. *Journal of the Saudi Society of Agricultural Sciences* (in press).

Gharby, S., Harhar, H., Guillaume, D., Haddad, A. and Charrouf, Z., 2012. The origin of virgin argan Oil's high oxidative stability unraveled. *Nat. Prod. Commun*. 7, 621–624.

Gharby, S., Harhar, H., Guillaume, D., Roudani, A., Boulbaroud, S., Ibrahimi, M., Ahmad, M., Sultana, S., Ben Hadda, T., Chafchaouni-Moussaoui, I. and Charrouf, Z., 2014. Chemical Investigation of Nigella sativa L. Seed Oil Produced in Morocco. *J. Saudi Soc. Agric. Sci*. (in press). http://dx.doi.org/10.1016/j.jssas. 2013.12.001.

Guille´n, M. D., and Ruiz, A. 2004. Formation of hydroperoxy- and hydroxyalkenals during thermal oxidative degradation of sesame oil monitored by proton NMR. *Journal of Lipid Science and Technology*, 106, 680–687.

Gunstone, F.D. 1992. γ-Linolenic acid- Occurrence and physical and chemical properties. *Prog. Lipid Res*., 31: 145-161.

Hall, C., Fitzpatrick, K.C. and Kamal-Eldin, A. 2009. Flax, perilla and camelina seed oils: α- linolenicacid-rich oils. In: Moreau, R.A. and Kamal-Eldin, A. (eds) Gourmet and health-promoting specialty oils. AOCS press, Urbana, IL, USA, pp 151-183.

Harris, H.C., McWilliam J.R. and et Mason W.K., 1978. Influence of temperature on oil content and composition of sunflower seed. Australian *Journal of Agricultural Research*, 29, 1203-1212.

Harwood, J.L., 1988. Fatty acids metabolism. *Annual Review of Plant Physiology and Plant Molecular Biology*, 39, 101-138.

Hassan, M.A.M., 2012. Studies on Egyptian sesame seeds (Sesamum indicum L.) and its products 1 – physicochemical analysis and phenolic acids of roasted Egyptian sesame seeds (*Sesamum indicum* L.). *World J. Dairy Food Sci*. 7 (2), 195–201.

Herchi, W, Kallel H. and Boukhchina, S. 2014. Physicochemical properties and antioxidant activity of Tunisian date palm (*Phoenix dactylifera* L.) oil as affected by different extraction methods. *Food Science and Technology*.

Kim, J.H, Seo, W. D., Lee, S. K., Lee, Y. B., Parka, C.H., Ryu, H.W. and Lee, J. H., 2014. Comparative assessment of compositional components, antioxidant effects, and lignan extractions from Korean white and black sesame (*Sesamum indicum* L.) seeds for different crop years, *Journal of Functional Foods*. 7. 495 – 505

Lajara, JR., Diaz, U. and Diaz Quidiello, R., 1990. Definitive influence of location and climatic conditions on the fatty acid composition of sunflower seed oil. *Journal of the American Oil Chemist's Society*, 67, 618-623

Lazarou, D., Grougnet, R. and Papadopoulos, A. 2007. Antimutagenic properties of a polyphenol-enriched extract derived from sesame seed perisperm. *Mutation Research*, 634, 163171

Lee, J., Lee, Y. and Choe, E. 2008. Effects of sesamol, sesamin and sesamolin extracted from roasted sesame oil on the thermal oxidation of methyl linoleate. *LWT Food Sci. Tech*., 41:1871-1875.

Ma, D., Wierzbicki, Field, C. and Clandinin, M. 1999. Conjugated linoleic acid in Canadian dairy and beef products. *Journal of Agricultural and Food Chemistry*, 47: 1956–1960

Mansouri, F., Ben moumen, A., Lopez, G., Fauconnier, M., Sindic, M., Serghini-Caid H. and Elamrani, A. 2013. Preliminary Characterization of monovarietal virgin olive oils produced in eastern area of Morocco. Inside Food Symposium, 9-12.

Markovic V. V. and Bastic L. V. 1975. Characteristics of Pumpkin Seed Oil. *J. Am. Oil Chem. Soc*. 53: 42–44.

Marwede, V., A. Schierholt, C. Mollers and H. C. Becker 2004. "Genotype X environment interactions and heritability of tocopherol contents in canola". *Crop Science* 44 (3): 728-731

Mekki, B.B., El-Kholy, M.A. and Mohammed, E.M., 1999. Yield, oil and fatty acids contents as affected by water deficit and potassium fertilization in two sunflower cultivars. *Egyptian Journal of Agronomy*, 21, 67-85.

Minguez-Mosquera, M.I., Rejano-Navarro, L., Gandul-Rojas, B., Sanchez- Gomez, A. H. and Garrido-Fernandez, J. 1991. Color-Pigment Correlation in Virgin Olive Oil. JAOCS, 68(5):332-336.

Moazzami, A.A. and Kamal-Eldin, A. 2006. Sesame seed is a rich source of dietary lignans. *J Am Oil Chem Soc*. 83(8):719–723.

Nagao A. and Yamazaki M., 1983. Lipid of sunflower seeds produced in Japan. Journal of the American Oil Chemist's Society, 60, 1654-1658.

NF EN ISO 10565 in November 1998 Oilseeds - Simultaneous determination of oil and moisture content - spectrometric method using pulsed nuclear magnetic resonance.

Nzikou, J.M., Matos, L., Bouanga-Kalou, G., Ndangui, C.B., Pambou-Tobi, N.P.G., Kimbonguila, A., Silou, Th., Linder, M. and Desobry, S., 2009. Chemical composition on the seeds and oil of sesame (*Sesamum indicum* L.) Grown in Congo Brazzaville. *Adv. J. Food Sci. Technol*. 1 (1), 6–11.

Ogbonna, P. E. and Ukaan, S. I. 2013. Chemical composition and oil quality of seeds of sesame accessions grown in the Nsukka plains of South Eastern Nigeria. *African Journal of Agricultural Research.* 8 (9): 797-803.

Ogutcu, M., Mendes, M. and Yilmaz E. 2008. Sensorial & Physico-Chemical Characterization of Virgin Olive Oils Produced in Çanakkale. *J. Am. Oil Chem.Soc*. 85: 441-456.

Orrun˜ o, E. and Morgan, M. R. A. 2007. Purification and characterization of the 7S globulin storage protein from sesame (*Sesamum indicum* L.). *Food Chemistry*, 100, 926934

Paul, E. Dim. 2013. Extraction and Characterization of Oil from Sesame Seed. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*. 4 (2): 752-757.

Peterson, D. M. and Qureshi, A. A. 1993. "Genotype and environment effects on tocols of barley and oats". *Cereal Chemistry* 70 (2): 157-162.

Philip, J.K., Kerui, Z., Jestina, B.K., Huiming, Z., Haifeng, Q. and Kexue, Z. 2007. Retraction - Biologically active components and nutraceuticals in sesame and related products: a review and prospect. *Trends Food Sci. Technol*., 19(4): 221.

Rangkadilok, N., Pholphana, N., Mahidol, C., Wongyai, W., Saengsooksree, K., Nookabkaew, S. and Satayavivad, J. 2010. Variation of sesamin, sesamolin, and tocopherols in sesame (*Sesamum indicum* L.) seeds and oil products in Thailand. *Food Chemistry*, 122, 724–730

Romero, M. P., Tovar, M. J., Ramo, T. and Motilva, M. J. 2003. Effect of crop season on the composition of virgin olive oil with protected designation of origin "Les garrigues". *Journal of the American Oil Chemists Society*. 80:5, pp 423-430

Ronald, S.K. and Ronald, S. 1989. Pearson's Composition and Analysis of Food (9th edition). Longman Publishers. London, UK 2:4-8.

Rondanini D., Savin R. and Hall A.J., 2003. Dynamics of fruit growth and oil quality of sunflower (Helianthus annuus L.) exposed to brief intervals of high temperature during grain filling. *Field Crops Research*, 83, 79-90.

Sadat, B., Haghighian K. M., Alipoor, B., Mahdavi, A., Jafarabadi, M. and Moghaddam, A. 2013. Effects of sesame seed supplementation on clinical signs and

symptoms in patients with knee osteoarthritis. *International Journal of Rheumatic Diseases* 16: 578–582.

Salama Z.A., El Baza F. K., Gaafara A. A. and Zaki, M. F., 2015. Antioxidant activities of phenolics, flavonoids and vitamin C in two cultivars of fennel (Foeniculum vulgare Mill.) in responses to organic and bio-organic fertilizers. *Journal of the Saudi Society of Agricultural Sciences* Volume 14, Issue 1, January, Pages 91–99

Scalbert, A., Monties, B. and Janin, G. 1989. Tannins in wood: comparison of different estimation methods. *Journal of Agricultural and Food Chemistry* 37(5):1324-1329.

Seegeler, C.J.P. 1983. Oil Plants in Ethiopia, their Taxonomy and Agricultural Significance. Pudoc, Wageningen

Shahidi, F., Amarowicz, R., Abou-Gharbia, H. A. and Shehata, A. Y. 1997. Endgenous Antioxidants and Stability of Sesame Oil as Affected by Processing and Storage. *J. Am. Oil Chem. Soc*., 74: 147-148.

Shankar, R. R., Eckert, G. J., Saha, C., Tu, W. and Pratt, J. H. 2005. The change in blood pressure during pubertal growth. *Journal of Clinical Endocrinology &Metabolism* 90 163–167.

Sharif, A., Farhoosh, R., Haddad Khodaparast, M. H. and Tavassoli Kafrani, M. H. 2009. Antioxidant Activity of Bene Hull Oil Compared with Sesame and Rice Bran Oils During the Frying Process of Sunflower Oil. *J. Food Lipids*, 16: 394-406

Sousa, C., D.M. Pereira, J.A. Pereira, A. Bento, M.A. Rodrigues, D.S. García, P. Valentão, G. Lopes, F. Ferreres and R.M. Seabra, P.B. 2008. Andrade Multivariate analysis of tronchuda cabbage (*Brassica oleracea* L. var. costata DC) phenolics: influence of fertilizers. *Journal of Agricultural and Food Chemistry*, 56, pp. 2231–2239

Stefanoudaki, E., Kotsifaki, F. and Koutsaftakis, A. 2009. Classification of virgin olive oils of the Two major cretan cultivars based on thier fatty acid composition. *Journal of American oils Chemists society*. 76: 623-626

Tamara, D. Premović, Etelka B. Dimić, Aleksandar A. Takači and Ranko S. Romanić. 2010. Influence of impurities and hull content in material for pressing on sensory quality cold –pressed sunflower oil. BIBLID: 1450-7188, 41: 69-76.

Tavakoli, J.; Khodaparast, M. H. H.; Kenari, R. E.; Lari, M. A. and Sharif, A. 2013. Evaluating antioxidant activity of kolkhung skin oil as a new edible source in Iran. *Iranian Food Science & Technology Research Journal* 2013 Vol. 9 No. 1 pp. Pe61-Pe67

Trémolières, A., Dubacq, J.P. and et Drapier, D., 1982. Unsaturated fatty acids in maturing seeds of sunflower and rape: regulation by temperature and light intensity. *Phytochemistry*, 21, 1, 41-45.

Van De Mark, M. R. and Sandefur, K. 2005. Vegetable oils in paint and coatings. AOCS, 478-481

Velasco, L. et Fernandez-Martinez J.M., 2003. Identification and genetic characterization of new sources of beta- and gamma-tocopherol in sunflower germplasm. Helia, 26, 17-24.

Visavadiya, N. P., Soni, B. and Dalwadi, N. 2009. Free radical scavenging and antiatherogenic activities of sesamum indicum seed extracts in chemical and biological model systems. *Food and Chemical Toxicology*, 47, 2507.

Weiss, E. A. 1983. Sesame. In: "Oilseed Crops". Longman Inc., New York. PP. 282- 340.

Yokota, T., Matsuzaki, Y., Koyama, M., Hitomi, T., Kawanaka, M., Enoki-Konishi, M., Okuyama, Y., Takayasu, J., Nishino, H., Nishikawa, A., Osawa, T. and Sakai, T. 2007. Sesamin, a lignan of sesame, down-regulates cyclin Dl protein expresson in human tumor cells. *Cancer Science*, 98, 14471453

Yu, L., Shouxian, W., Yonggang, Y. and Feng, X., 2013. Evaluation of genetic diversity of Chinese Pleurotus ostreatus cultivars using DNA sequencing technology. *Ann. Microbiol*. 63, 571–576.

Zine, S., Gharby, S. and El Hadek, M., 2013. Physicochemical characterization of opuntia ficus-indica seed oil from Morocco. *Biosci. Biotechnol. Res*. Asia 10 (1), 1–7

****