Acta Physiol Plant (2009) 31:455–461
DOI 10.1007/s11738-008-0253-4

ORIGINAL PAPER

Roots volatiles and fatty acids of coriander (*Coriandrum sativum* L.) grown in saline medium

Manel Neffati · Brahim Marzouk

Received: 25 April 2008 / Revised: 1 November 2008 / Accepted: 26 November 2008 / Published online: 24 December 2008

Abstract An hydroponic culture was conducted to investigate the effect of saline stress on the essential oil and fatty acid composition of Tunisian coriander (*Coriandrum sativum* L.) roots. Ten days old coriander seedlings were treated during 3 weeks with different NaCl concentrations (0, 25, 50 and 75 mM). Roots volatile components and fatty acids were analyzed. The essential oil yield was 0.06% in the control, on the basis of dry matter weight, and did not changed at low concentration (25 mM), while it increased significantly with increasing NaCl concentrations to reach 0.12 and 0.21% at 50 and 75 mM NaCl, respectively. The major volatile component was (*E*)-2-dodecenal with 52% of total essential oil constituents, followed by decanal, dodecanal, (*E*)-2-tridecenal and (*E*)-2-dodecenal. Further, the amount of these compounds was affected differently by the NaCl level. Total fatty acid amount of coriander roots increased significantly only with 50 and 75 mM NaCl. Three major fatty acids: linoleic (43%), oleic (25.5%) and palmitic (21.6%) were identified. Linoleic acid amount remains unchanged at 25 mM, while it increased with raising NaCl concentrations. However, oleic acid amount decreased only at 25 mM and no effect was observed at 50 and 75 mM. Fatty acid percentages were differently affected by salt. The oleic/linoleic ratio was reduced with raising NaCl concentrations.

Keywords Essential oil · (*E*)-2-dodecenal · *Coriandrum sativum* · Linoleic acid · NaCl

Communicated by A. Puppo.

M. Neffati (✉) · B. Marzouk
Aromatic and Medicinal Plants Unit, Biotechnologic Center Borj-Cedria Technopark, B.P. 901, 2050 Hammam-Lif, Tunisia
e-mail: neffatimanel@yahoo.fr

Introduction

Salinity is one of the most important environmental stresses which affected nearly half of the irrigated surface (Flagella et al. 2002). It limits crop productivity by decreasing the water potential of the root medium, the ion toxicity due to excessive sodium and chloride uptake, and the nutrient ion imbalance by the disturbance of essential intracellular ion concentrations (Greenway and Munns 1980). These effects on plant growth include a modification of different, morphological, physiological and biochemical processes and anatomical changes (Tester and Davenport 2003). Salinity is known to affect several aspects of plant metabolism, including lipid metabolism in many species (Erdei et al. 1980). Salinity impact on the yield and the fatty acid composition of oil has been previously reported in different plant species, such as safflower (*Carthamus tinctorius* L.) (Bassil and Kaffka 2002), chia (*Salvia hispanica*), stock (*Matthiola tricuspidata*) and evening primrose (*Oenothera biennis*) (Heuer et al. 2002), mustard (*Brassica juncea* L.) seeds (Parti et al. 2003) and sunflower (*Helianthus annuus* L.) (Flagella et al. 2004). Neffati and marzouk (2008) indicated a significant reduction of the total fatty acid amount from coriander leaf under saline conditions. Even, salt stress may affect the biosynthesis of secondary metabolites in plants such as essential oil compounds (Dow et al. 1981) and no much reports has been done on essential oil content and composition of plants subjected to salinity. Coriander (*Coriandrum sativum* L.) is an annual herb belonging to the Apiaceae (Umbelliferae) family and indigenous to the Mediterranean basin areas and the Near East (Purseglove et al. 1981). This plant is widely distributed and mainly cultivated for its seeds which are used for different purposes such as food, drugs, cosmetics, phytotherapy and perfumery. Coriander seed oil is rich in an unusual fatty acid, the

petroselinic acid (C18:1n-12), which composes as much as 85% of the total fatty acids, but is virtually absent from the leaf (Dutta and Appelqvist 1991). Coriander fresh green leaves, commonly known as cilantro or Chinese parsley (Potter 1996), are widely featured in the cuisines of China, Mexico, South America, India and Southeast Asia. Concerning roots, to our knowledge, one study has been undertaken on their essential oil content (Msaada et al. 2007) with 1.21 μg g^{-1} fresh weight.

In a previous work, Neffati and Marzouk (2008) examined for the first time the effect of salinity on coriander leaves essential oils and fatty acid composition. However, at our best knowledge no information is available about the fatty acid profile of coriander roots and the effect of salinity on its composition.

In the present work, we project first to evaluate the essential oil yield and amounts of coriander (*C. sativum* L.) roots subjected to different NaCl concentrations. The second aim was to identify for the first time the fatty acid profile of coriander roots and the changes in fatty acid amounts of roots submitted to different salinity levels.

Materials and methods

Plant material and culture conditions

Coriander (*C. sativum* L.) fruits were collected on April 2006 from cultivated plants in the region of Korba (North Tunisia) reputed for its spices culture. Seeds were puted to germinate at 25°C. Ten days old coriander seedlings were grown in quarter-strength Hoagland's solution laced with 0, 25, 50 and 75 mM of NaCl. An hydroponic culture was carried out in a greenhouse with 25°C day maximum and 18°C night minimum, under artificial light of 141 μmol m^{-2} s^{-1} (6,000 lux) with 16 h photoperiod and 60–80% air humidity. Nutrient solution was continuously aerated.

Essential oil isolation

Roots (50 g) were subjected to hydrodistillation during 90 min fixed after a kinetic survey during 30, 60, 90 and 120 min (Msaada et al. 2007). The distillate was extracted using diethyl-ether as solvent (v/v) and dried over anhydrous sodium sulphate. The organic layer was then concentrated at 35°C using a Vigreux column and the essential oil were stored at 20°C prior to analysis.

Extraction of total lipids

Roots were fixed by boiling water during 5 min to inactivate the tissue phospholipases (Benson and Strickland 1960). Total lipids were extracted by pouring the samples into a mixture of chloroform/methanol (2:1 v/v). Finally, the fixation water was added to collect the lipids extracted during fixation. After resting for 24 h at +4°C, two phases were obtained and the chloroformic one (lower phase) containing the foliar lipids was dried under N_2; then, the residue was dissolved in a known volume of toluol–EtOH (4:1 v/v) at −20°C for further analyses.

Fatty acid methyl esters preparation

Fatty acid from total lipids was transformed into their corresponding methyl esters as described by Cecchi et al. (1985). Transmethylation was made by the addition of 2 ml of hexane, 0.5 ml of 3% sodium methylate, a known amount of nonadecanoic methyl ester (C19:0) used as an internal standard, 0.2 ml of 1 N H_2SO_4 and 1.5 mL of 10% sodium chloride. The hexanic phase that contains fatty acid methyl esters (FAMEs) was aspired and the solvent volume reduced in a stream of nitrogen, prior to analysis.

Gas chromatography

GC analysis were performed using a Hewlett-Packard 6890 gas chromatograph equipped with a flame ionization detector (FID) and an electronic pressure control (EPC) injector. A polar HP Innowax (PEG) column and an apolar HP-5 column (30 m × 0.25 mm, 0.25 μm film thickness) were used. The carrier gas was N_2 (U) with a flow rate of 1.6 ml min^{-1}. The split ratio was 60:1. The analysis was performed using the following temperature program: oven temps isotherm at 35°C for 10 min, from 35 to 205°C at the rate of 3°C min^{-1} and isotherm at 205°C during 10 min. Injector and detector temperature were held, respectively, at 250 and 300°C. Quantitative data were obtained from the electronic integration of the FID peak areas.

Fatty acid methyl esters were analyzed by GC using the same apparatus previously described. The initial oven temperature was held at 150°C for 1 min, increased at a rate of 15°C min^{-1} to 200°C, and then held there for 3 min and finally ramped at 2°C min^{-1} to 242°C. Injector and detector temperatures were set at 275 and 250°C, respectively. The identification of FAMEs was achieved by comparing the peak retention times with those of authentic standards.

Gas chromatography–mass spectrometry

GC–MS analyses were carried out on a gas chromatograph HP 5890 (II) coupled to a HP 5972 mass spectrometer with electron impact ionization (70 eV). A HP-5MS capillary column (30 m × 0.25 mm, 0.25 μm film thickness) was used. The column temperature was programmed to rise from 50 to 240°C at a rate of 5°C min^{-1}. The carrier gas was

helium with a flow rate of 1.2 ml min^{-1}; split ratio was 60:1. Scan time and mass range were 1 s and 40–300 *m/z*, respectively.

Compound identification

Essential oil components were identified by comparison of their retention indices (RI) relative to (C8–C22) *n*-alkanes with those of authentic compounds under the same conditions (Davies 1990). Further identification was made by matching their recorded mass spectra with those stored in the Wiley/NBS mass spectral library and other published mass spectra (Adams 2001). Fatty acids were identified by comparison of their retention times with those of pure reference standards. Essential oil and fatty acids standards were obtained from Fluka and Sigma Aldrich.

Statistical analysis

Data were subjected to statistical analysis using statistical program package STATISTICA (Statsoft 1998). The one-way analysis of variance (ANOVA) followed by Duncan multiple range test were employed and the differences between individual means were deemed to be significant at $P < 0.05$.

Results and discussion

Essential oil yield and compound amounts

As shown in Fig. 1, roots essential oil yield at vegetative stage was 0.06% in the control, based on their dry weight and did not changed by 25 mM NaCl. However, this yield was 2 and 3.4 times higher under 50 and 75 mM NaCl, respectively. Such increase of essential oil yield by salinity has been reported earlier in other plant species, such as *Salvia officinalis* (Hendawy and Khalid 2005), *Mentha piperita* (Abou El-Fadl et al. 1990) and *C. sativum* leaf at low and moderate NaCl levels (Neffati and Marzouk 2008). The stimulation of essential oil production under moderate salinity could be due to a higher oil gland density and an increase in the absolute number of glands produced (Charles et al. 1990). Salt may also affect the essential oil accumulation indirectly through its effects on either net assimilation or the partitioning of assimilate among growth and differentiation processes (Charles et al. 1990). In contrast to our result, Ansari et al. (1998) having studied three *Cymbopogon* species indicated a reduction in essential oil yield and content with increasing water salinity.

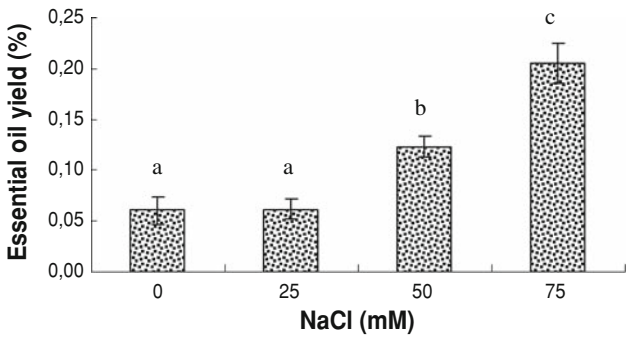

Fig. 1 Salinity impact on essential oil yield (%) of coriander roots after 3 weeks of treatment. Mean of three replicates. (Values with different superscripts (*a–c*) are significantly different at $P < 0.05$)

Analysis of essential oil showed 24 identified compounds which accounted for 95% of the total essential oil constituents (Table 1). (*E*)-2-dodecenal was the major compound (167.57 µg/g DW) followed by decanal (67.28 µg/g DW), (*E*)-2-decenal (46.76 µg/g DW), (*E*)-2-tridecenal (43.46 µg/g DW) and α-thujene (41.55 µg/g DW). Other notable constituents were 2-dodecenol, (*Z*)-myroxide, dodecanal, and tetradecanal which have been also detected by Msaada et al. (2007) with (*E*)-2-dodecenal as the most abundant compound in tunisian coriander different parts.

Changes in essential oil yield and composition have been reported to be influenced by environmental conditions (Gil et al. 2002). However, little is known about the influence of salt stress. As shown in Table 1, (*E*)-2-dodecenal amount increased with raising NaCl concentrations by 27% at 25 mM. Under 50 and 75 mM NaCl, this amount was 3 and 4.8 times higher, respectively in respect to control. Decanal amount increased by 14% with 50 mM and at high salinity, this content was 3.6 times higher. (*E*)-2-decenal amounts increased significantly by about 57 and 97% with 25 and 75 mM, respectively. (*E*)-2-tridecenal amount decreased by 18% with 25 mM. While it increased by 44% at 50 mM and was three times higher under high salinity. These constituents have a floral, pungent, citronellol, fruity and spicy odours, which were detected in leaves (Msaada et al. 2007; Neffati and Marzouk 2008). α-Thujene amounts were significantly reduced at all treatment levels.

The composition of roots essential oil was characterized by the prevalence of aldehydes (Msaada et al. 2007) with a proportion of 70% represented by (*E*)-2-dodecenal (30.8%), followed by the monoterpene alcohols (11.54%) with 2-dodecenol the main component, and the monoterpene hydrocarbons (8.82%). The aldehydes and the monoterpene alcohols amounts were positively correlated with increasing NaCl concentrations. For the major chemical class, this stimulation was about 20% with 25 mM, 2.5 and 4.4 times higher at 50 and 75 mM NaCl, respectively in respect to the control. For the second chemical class, this increase was by 25% at low stress, 3.2

Table 1 Proportions (%) and amounts (μg/g DW) changes of *Coriandrum sativum* roots essential oil under NaCl treatments (mean of three replicates)

RI[a]	RI[b]	Compounds	0 mM		25 mM		50 mM		75 mM	
			%	μg/g DW	%	μg/g DW	%	μg/g DW	%	μg/g DW
929	1,035	α-Thujene	7.31	41.55[a]	0.75	4.65[b]	0.93	15.73[c]	0.49	10.70[d]
939	1,032	α-Pinene	0.81	4.63[a]	0.18	0.98[b]	0.17	2.40[c]	tr	tr
980	1,118	β-Pinene	0.70	3.27[a]	0.19	3.70[a]	1.37	18.34[c]	0.45	9.70[d]
1,005	1,287	Octanal	0.26	0.92[a]	0.29	1.73[a]	1.63	19.95[c]	2.32	50.20[d]
1,105	1,400	Nonanal	0.30	1.04[a]	0.81	4.07[b]	0.59	8.46[c]	1.21	26.10[d]
1,033	1,213	1,8-Cineole	tr	tr	tr	tr	0.75	10.64	tr	tr
1,060	1,186	α-Terpinene	tr	tr	tr	tr	0.27	3.72	0.19	4.20
1,142	1,485	(*Z*)-myroxide	4.50	20.45[a]	1.95	11.08[b]	3.08	26.71[c]	1.02	22.14[a]
1,143	1,532	Camphor	0.24	0.84[a]	0.11	0.63[a]	0.35	3.84[b]	0.29	6.38[c]
1,165	1,702	Borneol	3.85	22.10[a]	3.14	20.96[a]	6.39	74.53[c]	4.41	95.39[d]
1,189	1,693	α-Terpineol	0.42	1.89[a]	tr	0.31[b]	0.24	3.44[c]	0.17	3.58[d]
1,208	1,498	Decanal	11.96	67.28[a]	13.44	69.21[a]	6.63	76.80[b]	11.32	245.05[d]
1,263	1,556	Linalyl acetate	0.14	0.49[a]	tr	0.56[a]	0.18	2.06[b]	0.29	6.18[d]
1,265	1,653	(*E*)-2-decenal	8.74	46.76[a]	14.35	73.30[b]	3.91	50.23[a]	4.27	92.43[d]
1,281	1,792	(*E*)-2-decenol	0.51	2.88[a]	0.57	3.84[b]	0.85	11.64[c]	0.78	16.78[d]
1,287	1,748	Decanol	0.77	3.61[a]	0.94	5.08[b]	0.79	10.50[c]	1.29	27.98[d]
1,310	1,605	Undecanal	1.33	8.68[a]	0.93	4.63[b]	0.36	4.76[b]	1.91	41.30[d]
1,356	2,192	Eugenol	0.17	0.90[a]	0.38	2.10[b]	0.45	5.68[c]	0.26	5.57[c]
1,360	1,752	(*E*)-2-undecenal	1.13	5.77[a]	1.05	5.00[a]	1.18	12.73[b]	3.07	66.56[d]
1,410	1,713	Dodecanal	4.28	23.25[a]	4.83	24.60[a]	1.28	14.62[b]	3.82	82.60[c]
1,480	1,855	(*E*)-2-dodecenal	30.81	167.57[a]	31.77	215.47[b]	38.28	518.54[c]	37.46	811.02[d]
1,581	1,855	(*E*)-2-tridecenal	8.36	43.46[a]	5.55	35.73[b]	4.44	62.59[c]	5.31	114.92[d]
–	2,033	2-dodecenol*	5.98	35.43[a]	7.10	51.78[b]	8.55	106.53[c]	7.16	155.05[d]
1,620	1,919	Tetradecanal	2.85	14.57[a]	3.19	20.99[b]	6.13	83.00[c]	6.78	146.71[d]
Classes										
Monoterpene hydrocarbons			8.82	49.46[a]	1.11	9.32[b]	2.73	40.18[c]	1.14	24.61[d]
Monoterpene alcohols			11.54	65.90[a]	11.81	81.97[b]	16.82	206.64[c]	13.80	298.79[d]
Aldehydes			70.01	379.30[a]	76.20	454.72[b]	64.43	851.68[c]	77.45	1676.89[d]
Others			5.05	22.69[a]	2.54	14.36[b]	4.05	38.29[c]	1.86	40.27[c]

Retention indices relative to *n*-alkanes on (a) apolar column HP-5MS and (b) polar column HP-Innowax

tr: trace (<0.1%)

Values with different superscripts (a–d) are significantly different at $P < 0.05$

* Correct isomer not identified

and 4.5 times higher at moderate and high salinities, respectively in comparison to control. The marked raise of aldehydes amount with an obvious increase of the main components were linked in quantity and quality with increasing NaCl concentrations.

Fatty acid amounts and composition

In Table 2, results on roots fatty acid amounts are reported. Under 25 mM NaCl, total fatty acid amount (TFAA) remains unchanged in respect to the control, while this amount increased significantly by about 51 and 25% at 50 and 75 mM NaCl, respectively. Our results are in agreement with those reported by Flagella et al. (2004), who demonstrated a significant effect of salinity on the oil yield from the seed of sunflower hybrid variety. In addition, Neffati and Marzouk (2008) indicated a significant reduction of total fatty acid amount from the coriander leaves. Royo et al. (2005) reported a minor effect of soil salinity on the oil content of Arbequina olive oil. However, no any change was reported in the oil content of stock (*Matthiola incana*) (Heuer et al. 2005) and *Moringa oleifera* (Farooq et al. 2006) due to effect of salinity.

No earlier studies were reported in the literature regarding the fatty acid profile of coriander roots and the effect of salinity on different fatty acid amounts and on

Table 2 Changes in fatty acid amounts (mg/g DW) from coriander roots under saline conditions

Fatty acid	NaCl (mM)			
	0	25	50	75
C15:0	0.52 ± 0.08[a]	0.22 ± 0.09[b]	1.26 ± 0.10[c]	1.12 ± 0.11[c]
C16:0	4.68 ± 0.11[a]	5.25 ± 0.07[b]	6.41 ± 0.06[c]	4.80 ± 0.08[a]
C16:1n9	0.09 ± 0.02[a]	0.54 ± 0.27[b]	0.37 ± 0.04[c]	0.31 ± 0.04[c]
C18:0	0.47 ± 0.09[a]	1.18 ± 0.05[b]	1.08 ± 0.06[b]	0.80 ± 0.09[c]
C18:1n9	5.61 ± 0.15[a]	3.77 ± 0.19[b]	5.48 ± 0.11[a]	5.21 ± 0.13[c]
C18:2n6	8.91 ± 0.38[a]	9.02 ± 0.17[a]	15.81 ± 0.21[b]	12.64 ± 0.42[c]
C18:3n3	0.66 ± 0.09[a]	0.05 ± 0.02[b]	1.28 ± 0.15[c]	1.44 ± 0.09[c]
C18:4n3	0.11 ± 0.01[a]	0.08 ± 0.01[b]	0.23 ± 0.02[c]	0.10 ± 0.06[a]
TFAC	21.06 ± 1.24[a]	20.12 ± 1.45[a]	31.92 ± 1.73[b]	26.42 ± 1.13[c]

C15:0 (pentadecylic acid); C16:0 (palmitic acid); C16:1n-9 (palmitoleic acid); C18:0 (stearic acid); C18:1n-9 (oleic acid); C18:2n-6 (linoleic acid); C18:3n-3 (α-linolenic acid); C18:4n-3 (stearidonic acid)

Data were mean ± SD of three replicates

TFAA total fatty acid amount

Values with different superscripts (a–c) are significantly different at $P < 0.05$

their proportions. Thus we reported that linoleic (C18:2n-6) was the major fatty acid, followed by oleic (C18:1n-9) and palmitic (C16:0) acids, with proportion of ~43, 26 and 22%, respectively. These three fatty acids represent 90% of coriander roots total fatty acid.

Salinity affects significantly the proportions of major fatty acids. The percentage of linoleic acid (43% in the control) increased significantly only at 50 and 75 mM NaCl by 15 and 11% respectively. Oleic acid percentage (24.5%) decreased significantly with increasing NaCl levels up to 26, 33 and 23% respectively. Palmitic acid proportion (21.6%) increased by 21% under 25 mM, while it decreased by about 7 and 16%, respectively at moderate and high salinities. It was noticed that linoleic and oleic acids were inversely correlated for all treatment levels which indicate a higher activity of Δ12 oleoyl desaturase (Table 3).

Low NaCl concentration (25 mM) did not elicit significant changes in the linoleic acid amount. However, raising NaCl concentration in the medium increased this content by about 77 and 42% under 50 and 75 mM NaCl, respectively. Our data appear apparently in contrast to Smaoui and Cherif (2000) who indicated that linoleic acid amount in cotton seeds was reduced by salt stress. In the presence of 25 mM, the oleic acid amount decreased by about 33%, whereas, weak changes were observed with increasing NaCl levels. However, Parti et al. (2003) reported the

Table 3 Changes in fatty acid composition (%) from coriander roots under saline conditions

Fatty acid	NaCl (mM)			
	0	25	50	75
C15:0	2.74 ± 0.31[a]	1.11 ± 0.09[b]	3.94 ± 0.07[c]	4.26 ± 0.56[c]
C16:0	21.59 ± 0.61[a]	26.11 ± 0.29[b]	20.09 ± 0.53[c]	18.19 ± 0.27[d]
C16:1n-9	0.41 ± 0.08[a]	2.69 ± 0.07[b]	1.15 ± 0.12[c]	1.17 ± 0.16[c]
C18:0	2.30 ± 0.27[a]	5.89 ± 0.35[b]	3.39 ± 0.11[c]	3.01 ± 0.19[c]
C18:1n-9	25.45 ± 0.44[a]	18.72 ± 0.30[b]	17.18 ± 0.26[c]	19.56 ± 0.27[b]
C18:2n-6	43.03 ± 0.84[a]	44.82 ± 0.83[a]	49.53 ± 0.71[b]	47.95 ± 0.12[c]
C18:3n-3	3.33 ± 0.34[a]	0.25 ± 0.05[b]	4.02 ± 0.25[c]	5.49 ± 0.19[c]
C18:4n-3	0.67 ± 0.04[a]	0.42 ± 0.04[b]	0.71 ± 0.04[a]	0.37 ± 0.03[b]
C18:1/C18:2	0.59 ± 0.02[a]	0.42 ± 0.04[b]	0.35 ± 0.04[b]	0.41 ± 0.03[b]
US/S	3.17 ± 0.11[a]	2.13 ± 0.15[b]	3.26 ± 0.09[a]	3.72 ± 0.10[c]

C15:0 (pentadecylic acid); C16:0 (palmitic acid); C16:1n-9 (palmitoleic acid); C18:0 (stearic acid); C18:1n-9 (oleic acid); C18:2n-6 (linoleic acid); C18:3n-3 (α-linolenic acid); C18:4n-3 (stearidonic acid)

Data were mean ± SD of three replicates

Values with different superscripts (a–d) are significantly different at $P < 0.05$

gradual increase in oleic acid with increasing salinity levels. The oleic acid amount of cotton seeds remained unchanged under saline conditions (Smaoui and Cherif 2000). Increasing salinity levels was accompanied by an increase in the palmitic acid amount up to 12 and 37% with 25 and 50 mM, respectively, while high salinity concentration did not affect this amount.

In respect to control, the oleic/linoleic ratio was reduced with raising NaCl concentrations by about 35, 45 and 35% at 25, 50 and 75 mM, respectively. This decrease was accompanied by a higher activity of Δ12 oleate desaturase which is responsible for the desaturation of oleate to linoleate (Garcés and Mancha 1991; Baldini et al. 2002). In contrast to our result, Lagravère et al. (2000) indicated no effect of saline treatment on oleic/linoleic ratio in high oleic sunflower oil (*Helianthus annuus* L.) hybrids. The degree of fatty acid unsaturation is an important factor to maintain the membrane fluidity and to provide the appropriate environment for membrane functions (Xu and Beardall 1997). At 25 mM, the unsaturated to saturated fatty acids ratio (US/S) was reduced by 27% indicating a rigidificate membrane. However, this ratio increased with increasing NaCl concentrations. An increase in the level of unsaturation of root lipids seems to be a common feature of salt-stressed plants. Membranes containing a high proportion of unsaturated fatty acids are more fluid and, therefore, more ion permeable (Table 2) (Mansour et al. 2002).

Conclusions

Essential oil yield of coriander roots was stimulated at moderate and high salinity levels. Essential oil was characterized by the (*E*)-2-dodecenal as the main component about which amount increased significantly with increasing NaCl concentrations. In this case, coriander roots at high salinity may function as a potential essential oil source. The profile of roots fatty acid showed the predominance of linoleic acid with a marked increase of its amounts under 50 and 75 mM NaCl. The oleic/linoleic ratio was reduced with raising NaCl levels which demonstrates a high activity of coriander roots Δ12 oleoyl desaturase indicating the stimulating effect of salt on this enzyme. Raising unsaturated to saturated fatty acid ratio at moderate and high salinity levels increase the plasma membrane permeability to sodium ions.

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