# Oil and fatty acid accumulation during coriander (*Coriandrum sativum* L.) fruit ripening under organic cultivation

*Quang-Hung Nguyen, Thierry Talou, Mureil Cerny, Philippe Evon, Othmane Merah**

*Université Fédérale de Toulouse Midi-Pyrénées, INP-ENSIACET, Laboratoire de Chimie Agro-industrielle, F-31030 Toulouse, France*
*Institut National de Recherche Agronomique, UMR 1010 CAI, F-31030 Toulouse, France*

A B S T R A C T

To evaluate the accumulation of oil and fatty acids in coriander during fruit ripening, a field experiment was conducted under organic cultivation conditions in Auch (near Toulouse, southwestern France) during the 2009 cropping season. The percentage and composition of the fatty acids of coriander were determined by gas chromatography. Our results showed that rapid oil accumulation started in early stages (two days after flowering, DAF). Twelve fatty acids were identified. Saturated and polyunsaturated acids were the dominant fatty acids at earlier stages (2–12 DAF), but decreased after this date. After this stage, petroselinic acid increased to its highest amount at 18 DAF. In contrast, palmitic acid followed the opposite trend. Saturated and polyunsaturated fatty acids decreased markedly and monounsaturated fatty acids increased during fruit maturation. It appears that the fruit of coriander may be harvested before full maturity.

## 1. Introduction

Coriander (*Coriandrum sativum* L.), an annual herb belonging to the Apiaceae family, is a Mediterranean indigenous plant [1]. The species is grown mostly in temperate areas around the Mediterranean basin and in India, China, Thailand, and Eastern Europe [2]. It is used as an herbal condiment in many culinary preparations. The plant is cultivated for its seeds, which are used for many purposes including aromatherapy, food, drugs, cosmetics, and perfumery. The seeds also have medicinal uses in treatment of rheumatism, gastrointestinal complaints, flatulence and gastralgia, worms, insomnia, anxiety, loss of appetite, and glycemia [3,4]. In industry, the main product from coriander is distilled oil and solvent-extracted oleoresin for aroma and flavor production [5]. Coriander oils are familiar not only in the perfumery, food, beverage, and pharmaceutical industries, but also in medicine. They are used as antioxidants, in treatment of nervous disorders, for gut modulation, blood pressure lowering, and diuretic activity, as an anti-diabetic and antimicrobial agent, and in many traditional remedies for various diseases [6–8]. xThe use of coriander seeds as a spice is widespread. Coriander represents 25–40% of curry powder, and is used to flavor liqueurs, being an important flavoring agent in gin production. Coriander seeds are also used in the preparation of baked goods and tobacco products [1].

Interest in coriander seed oil has increased since the European Union authorized the use of coriander oil as a food supplement. The accumulation of oil in coriander seed is thus of great interest for food use. Knowledge of its seed oil accumulation with the aim of maximizing oil production has become important.

* *Corresponding author*. Tel.: +33 534323523; fax: +33 534323597.
E-mail address: othmane.merah@ensiacet.fr (O. Merah).

Petroselinic acid is an unusual fatty acid that occurs primarily in seeds. This fatty acid composes nearly 85% of the total fatty acids of Apiaceae seeds [9]. It can be oxidatively cleaved to produce a mixture of lauric acid, a compound useful in the production of detergents, and adipic acid, a $C_6$ dicarboxylic acid used in the synthesis of nylon polymer [10].

To our knowledge, aside from two reports [10,11], the accumulation of lipids and fatty acids during the seed development of *C. sativum* L. has been little studied. Moreover, both studies were performed under conventional cultivation or in the greenhouse. No study of the accumulation of fatty acids in coriander seeds under organic conditions has been reported. The aim of this study was the evaluation of oil content and fatty acid composition from flowering to maturity of coriander fruits under organic cultivation.

## 2. Material and methods

### 2.1. Location and plant experiment

A field trial was conducted in south-western France at the Regional Centre of Experimentation in Organic Agriculture at Auch (near Toulouse, southwestern France, 43°38′47″ N, 0°35′ 08″ E) during the 2009 cropping season. Sowing was performed on March 23, 2009. Seeds of the French coriander cultivar Dourou (GSN, Riscle, France) were directly sown by hand into the field at a rate of 1.2 g $m^{-2}$ to a depth of 3 cm.

The crops were managed under completely organic and rainfed conditions without chemical addition. Weeds were mechanically removed. The soil was a clay loam (organic matter content: 3.2%; pH 8.1) with a depth of about 1.2 m. Flowering started at the end of May and maturation occurred at the beginning of August.

Table 1 shows temperatures and rainfall during the plant cycle in comparison to weather data for the last 55 years. Indeed, rainfall was at least 50 mm lower than the half-century precipitation observed for the same period in this area. The 2009 growing season was less rainy and hotter than the mean values of 55 years.

**Table 1 – The prevailing weather condition during the 2009 plant cycle.**

| Month | Rainfall | | Temperature | |
|---|---|---|---|---|
| | 2009 | 55 years | 2009 | 55 years |
| January | 95.4 | 65.0 | 4.9 | 5.7 |
| February | 40.4 | 55.9 | 5.8 | 6.9 |
| March | 23.6 | 57.1 | 8.7 | 9.2 |
| April | 105.4 | 66.6 | 11.7 | 11.5 |
| May | 44.4 | 77.2 | 16.8 | 15.3 |
| June | 39.4 | 61.1 | 20.1 | 18.9 |
| July | 41.2 | 47.1 | 21.7 | 21.5 |
| August | 20.0 | 58.3 | 22.7 | 21.3 |
| September | 46.8 | 55.9 | 18.9 | 18.5 |
| October | 35.6 | 56.8 | 15.0 | 14.4 |
| November | 102.2 | 57.2 | 10.9 | 9.0 |
| December | 34.6 | 68.1 | 5.9 | 6.2 |
| Mean: sum over year | 629.0 | 726.3 | | |
| Mean: sum Mar.–Sept. | 320.8 | 423.3 | | |
| Mean: sum May–July | 125.0 | 185.4 | | |

### 2.2. Oil and fatty acid composition measurements

Seed sampling was performed every five (on average) days from flowering to maturity. Harvesting continued from 2 days after flowering (DAF) to 53 DAF. The fruit's color and relative moisture content were adopted as ripening criteria. Seed water content (SWC in % of the seed dry matter) was measured for each sample as an indicator of stage of physiological maturity. Moisture contents were determined by heating in an air oven at 60 °C to constant weight.

Dry coriander seeds were ground in an electric grinder (IKA MF-10-basic Microfine grinder, Sigma Aldich, Frankfurt, Germany). Triplicate samples of 20–30 g were subjected to conventional extraction for 5 h with cyclohexane in the dark. The solvent was removed in a rotary evaporator under low pressure at 35 °C. The vacuum system was used to dry the oil at 35 °C overnight. The oil yield was determined. Oil (20 mg) was extracted in a Soxhlet extractor for 5 h, and then 1 mL *tert*-butyl methyl ether was added. The mixture was filtered through a glass fiber filter (GHP, 0.45 μm, small diameter). At this step 100 μL of filtrate was added to 50 μL of trimethylsulfonium hydroxide 0.5 mol $L^{-1}$ in methanol and stirred gently. Fatty acid analysis was performed by gas chromatography (GC-3900) with a flame ionization detector with a CP-select CB for FAME fused silica WCOT column of length: 50 m, internal diameter: 0.25 mm, and film thickness: 0.25 μm. The carrier gas was helium with a flow rate of 1.2 mL $min^{-1}$ and the split ratio was 1:100. The initial oven temperature was programmed to 185 °C for 40 min, increasing at 15 °C $min^{-1}$ to 250 °C and held for 10.68 min. (analysis time: 55.0 min). The injection and detector temperature were held at 250 °C for 55 min. Analyses were performed in triplicate.

All data were subjected to variance analysis using the GLM procedure of SAS (SAS Institute, Cary, NC, USA). Mean comparisons were performed with a Duncan test at the 0.05 probability level.

## 3. Results and discussion

The changes in oil yield of coriander from flowering period to maturity (53 days) are presented in Table 2. Water content decreased markedly from flowering to maturity (Table 2). Oil yield varied between 4.6% and 25.1% at different stages of fruit ripening (Table 2). Oil content increased gradually from flowering to maturity. Oil content increased threefold from 2 to 12 DAF. At maturity, the oil content reached its highest level (25.1%). The oil yield in the mature stage of ripening was slightly lower than that previously reported for coriander under conventional agriculture [10,12] but higher than the values reported by Angelini et al. [9]. This result was expected, given that organic cultivation is considered a stress condition [13]. Moreover, it is well known that oilseeds produce and accumulate less oil under drought than under favorable conditions [14,15]. This difference may be explained by the genetic origins of the cultivars used in these studies [13]. The oil yield increased rapidly from days 10 to 34 after the flowering sampling period and reached its maximum level at maturity, when the oil yield was maximal and its value was similar to those of other reports describing

**Table 2 – Changes in fatty acid and water content and oil yield during seed maturation in coriander (*Coriandrum sativum* L.) fruit in 2009 from flowering to maturity.**

| Fatty acid (%) | Days after flowering | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 12 | 14 | 18 | 25 | 35 | 53 |
| *Saturated fatty acid (SFA)* | | | | | | | | | |
| C14:0 (myristic acid) | $4.6^{a} \pm 0.9$ | $4.2^{a} \pm 0.7$ | $3.6^{a} \pm 0.4$ | $1.6^{b} \pm 0.3$ | $1.6^{b} \pm 0.4$ | $0.9^{c} \pm 0.2$ | $0.3^{d} \pm 0.1$ | $0.2^{d} \pm 0.0$ | $0.3^{d} \pm 0.1$ |
| C16:0 (palmitic acid) | $20.5^{a} \pm 0.7$ | $21.1^{a} \pm 1.1$ | $20.9^{a} \pm 1.3$ | $10.9^{b} \pm 0.8$ | $7.6^{c} \pm 0.9$ | $4.0^{de} \pm 0.6$ | $3.5^{e} \pm 0.7$ | $3.7^{e} \pm 0.4$ | $5.1^{d} \pm 0.9$ |
| C18:0 (stearic acid) | $5.8^{a} \pm 0.5$ | $5.1^{a} \pm 0.3$ | $6.2^{a} \pm 0.3$ | $1.7^{b} \pm 0.2$ | $1.4^{b} \pm 0.1$ | $0.6^{c} \pm 0.1$ | $0.8^{c} \pm 0.1$ | $0.8^{c} \pm 0.1$ | $1.0^{c} \pm 0.1$ |
| C20:0 (arachidic acid) | $0.1^{c} \pm 0.0$ | $0.2^{b} \pm 0.0$ | $0.3^{a} \pm 0.1$ | $0.3^{a} \pm 0.1$ | $0.3^{a} \pm 0.1$ | $0.2^{b} \pm 0.0$ | $0.1^{c} \pm 0.0$ | $0.2^{a} \pm 0.0$ | $0.1^{c} \pm 0.0$ |
| C22:0 (behenic acid) | $1.6^{b} \pm 0.5$ | $1.5^{b} \pm 0.3$ | $4.0^{a} \pm 0.6$ | $0.0^{c} \pm 0.0$ | $0.0^{c} \pm 0.0$ | $0.0^{c} \pm 0.0$ | $0.0^{c} \pm 0.0$ | $0.0^{c} \pm 0.0$ | $0.0^{c} \pm 0.0$ |
| Total | $32.6^{a} \pm 1.4$ | $32.0^{a} \pm 1.5$ | $34.9^{a} \pm 1.3$ | $14.4^{b} \pm 0.7$ | $10.8^{c} \pm 0.7$ | $5.7^{d} \pm 0.3$ | $4.6^{e} \pm 0.5$ | $4.9^{de} \pm 0.6$ | $6.6^{d} \pm 0.9$ |
| *Monounsaturated fatty acid (MUFA)* | | | | | | | | | |
| C18:1n12 (petroselinic acid) | $2.8^{e} \pm 0.3$ | $3.6^{e} \pm 0.4$ | $7.8^{d} \pm 0.9$ | $48.8^{c} \pm 1.5$ | $59.3^{b} \pm 1.7$ | $74.4^{a} \pm 2.1$ | $76.4^{a} \pm 2.1$ | $74.7^{a} \pm 2.3$ | $71.9^{a} \pm 2.2$ |
| C18:1n9 (oleic acid) | $2.8^{d} \pm 0.2$ | $3.1^{cd} \pm 0.2$ | $3.5^{c} \pm 0.5$ | $6.4^{a} \pm 0.9$ | $6.4^{a} \pm 0.7$ | $4.6^{b} \pm 0.5$ | $4.6^{b} \pm 0.4$ | $4.8^{b} \pm 0.5$ | $6.2^{a} \pm 0.5$ |
| Total | $5.6^{e} \pm 0.6$ | $6.7^{e} \pm 0.6$ | $11.3^{d} \pm 0.8$ | $55.2^{c} \pm 1.2$ | $65.7^{b} \pm 1.9$ | $79.1^{a} \pm 1.8$ | $81.1^{a} \pm 1.9$ | $79.5^{a} \pm 2.3$ | $78.2^{a} \pm 2.8$ |
| *Polyunsaturated fatty acid (PUFA)* | | | | | | | | | |
| C18:2n6 (linoleic acid) | $44.2^{a} \pm 2.1$ | $45.1^{a} \pm 1.9$ | $36.0^{b} \pm 1.8$ | $26.9^{c} \pm 1.5$ | $22.1^{d} \pm 1.6$ | $15.4^{e} \pm 1.0$ | $14.3^{e} \pm 0.9$ | $15.0^{e} \pm 1.3$ | $15.0^{e} \pm 1.2$ |
| C18:3n3 (linolenic acid) | $17.6^{b} \pm 0.9$ | $20.3^{a} \pm 1.1$ | $21.4^{a} \pm 1.6$ | $5.2^{c} \pm 0.5$ | $3.0^{d} \pm 0.1$ | $0.7^{e} \pm 0.0$ | $0.3^{f} \pm 0.0$ | $0.7^{e} \pm 0.0$ | $0.6^{e} \pm 0.1$ |
| Total | $61.8^{a} \pm 2.2$ | $65.4^{a} \pm 2.3$ | $57.4^{b} \pm 1.9$ | $32.0^{c} \pm 1.6$ | $25.1^{d} \pm 1.5$ | $16.1^{e} \pm 2.1$ | $14.6^{e} \pm 2.0$ | $15.7^{e} \pm 1.6$ | $15.6^{e} \pm 2.0$ |
| SFA/PUFA | $0.5^{a} \pm 0.1$ | $0.5^{a} \pm 0.1$ | $0.6^{a} \pm 0.1$ | $0.5^{a} \pm 0.1$ | $0.4^{ab} \pm 0.1$ | $0.4^{ab} \pm 0.0$ | $0.3^{b} \pm 0.0$ | $0.3^{b} \pm 0.0$ | $0.4^{ab} \pm 0.0$ |
| Water content (%) | $95.3^{a} \pm 3.4$ | $90.3^{a} \pm 4.5$ | $80.6^{b} \pm 3.9$ | $74.8^{b} \pm 3.4$ | $74.0^{b} \pm 5.6$ | $63.9^{c} \pm 2.9$ | $55.1^{d} \pm 2.8$ | $30.3^{e} \pm 2.0$ | $10.6^{f} \pm 1.8$ |
| Oil yield (%) | $4.6^{i} \pm 0.2$ | $8.4^{h} \pm 0.2$ | $10.5^{g} \pm 0.3$ | $12.8^{f} \pm 0.2$ | $14.2^{e} \pm 0.3$ | $18.6^{d} \pm 0.5$ | $21.0^{c} \pm 0.4$ | $22.8^{b} \pm 0.5$ | $25.1^{a} \pm 0.4$ |

For each line (each fatty acid) means followed by the same letter are not significantly different based on Duncan's test at the 0.05 probability level.

mature coriander fruit [10,11]. This developmental trend in oil accumulation in coriander fruit was similar to that reported for other species [14,16].

Large accumulations of fatty acids began at 2 DAF. Different trends were observed for the fatty acids. Contents of saturated fatty acids were high from 2 until 10 DAF but declined by half by 12 DAF. This decline continued until full maturity. The representative fatty acid of this category in coriander was palmitic acid, which followed the same trend as the saturated fatty acids. Myristic and stearic acids were also present in higher amounts at 2 DAF and decreased after 10 DAF (Table 2). In contrast, monounsaturated fatty acids, represented mainly by petroselinic acid (50% at 2 DAF and reaching more than 92% at maturity) were present in low amounts at the beginning of seed formation (2 DAF) and rose after 10 DAF. Indeed, the petroselinic acid amount increased tenfold from 2 to 12 DAF and continued this rise, reaching its highest level at 18 DAF (Table 2). The polyunsaturated fatty acid content was highest at 2 DAF and decreased until 18 DAF, remaining stable from this point to maturity (Table 2). Higher levels of polyunsaturated and saturated fatty acids have been reported at earlier stages of fruit ripening [10,11]. The ratio of saturated to polyunsaturated fatty acids decreased markedly during fruit maturation. Similar results have been reported in other oilseed species [14,17]. The level of petroselinic acid was in accord with values previously reported for coriander ranging from 51.6% to 90.7% [5–7]. The highest amount of petroselinic acid was reached between 18 and 35 DAF, in agreement with results of Msaada et al. [10] which emphasized that a period of 32 DAF was sufficient for use of coriander fruits. In our study, opposite developmental trends were observed for palmitic acid (decreasing with fruit ripening) and petroselinic acid (increasing with fruit ripening). This observation could be explained by the role of palmitic acid as a precursor of petroselinic acid [18].

In summary, this study constitutes the first to investigate oil and fatty acid accumulation in coriander during fruit ripening under organic cultivation. Highest oil yield was achieved at full maturity. Fatty acid profiles varied greatly during fruit ripening. At earlier stages, saturated and polyunsaturated fatty acids were higher and decreased with fruit maturation. Petroselinic acid was the major fatty acid after 12 DAF, showing an inverse relationship with palmitic acid that supports a functional correlation between the two fatty acids. This study provided data for use of coriander oil and its composition of fatty acid, in particular petroselinic acid, for industrial applications.

## REFERENCES


[1] J.W. Purseglove, E.G. Brown, C.L. Green, S.R.J. Robbins, Spices, vol. 2, Longman, London & New York, 1981.

[2] J. Pino, P. Borges, E. Roncal, The chemical composition of laurel leaf oil from various origins, Nahrung 37 (1993) 592–595.

[3] M. Emamghoreishi, M. Khasaki, F. Aazam, *Coriandrum sativum*: evaluation of its anxiolytic effect in the elevated plus-maze, J. Ethnopharmacol. 96 (2005) 365–370.

[4] H. Rakhshandeh, H.R. Sadeghnia, A. Ghorbani, Sleep-prolonging effect of *Coriandrum sativum* hydro-alcoholic extract in mice, Nat. Prod. Res. 26 (2012) 2095–2098.

[5] M. Islam, M.M. Hasan, W. Xiong, S. Zhang, C. Lei, Fumigant and repellent activities of essential oil from *Coriandrum sativum* (L.) (Apiaceae) against red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), J. Pest. Sci. 82 (2009) 171–177.

[6] I. Azhar, F. Mazhar, Spices as Medicine, CANIZ Printing Agency, Research Institute of Indusyunic Medicine, Karachi, 2003. 143–144.

[7] Q. Jabeen, S. Bashir, B. Lyoussi, A.H. Gilani, Coriander fruit exhibits gut modulatory, blood pressure lowering and diuretic activities, J. Ethnopharmacol. 122 (2009) 123–130.

[8] M. Isabelle, B.L. Lee, M.T. Lim, W.P. Koh, D. Huang, C.N. Ong, Antioxidant activity and profiles of common vegetables in Singapore, Food Chem. 120 (2010) 993–1003.
[9] L.G. Angelini, E. Moscheni, G. Colonna, P. Belloni, E. Bonari, Variation in agronomic characteristics and seed oil composition of new oilseed crops in central, Italy, Ind. Crop. Prod. 6 (1997) 313–323.
[10] K. Msaada, K. Hosni, M. Ben-Taarit, T. Chahed, M. Hammami, B. Marzouk, Changes in fatty acid composition of coriander (*Coriandrum sativum* L.) fruit during maturation, Ind. Crop. Prod. 29 (2009) 269–274.
[11] G. Lakshminarayana, K.V.S.A. Rao, K.S. Devi, T.N.B. Kaimal, Changes in fatty acids during maturation of *Coriandrum sativum* seeds, J. Am. Oil Chem. Soc. 58 (1981) 838–839.
[12] J. Sriti, W. Aidi-Wannes, T. Talou, B. Mhamdi, G. Hamdaoui, B. Marzouk, Lipid, fatty acid and tocol distribution of coriander fruit's different parts, Ind. Crop. Prod. 31 (2010) 294–300.
[13] M. Alignan, J. Roche, A. Bouniols, M. Cerny, Z. Mouloungui, O. Merah, Effects of genotype and sowing date on phytostanol–phytosterol content and agronomic traits in wheat under organic agriculture, Food Chem. 117 (2009) 219–225.
[14] J. Roche, A. Bouniols, Z. Mouloungui, T. Barranco, M. Cerny, Management of environmental crop conditions to produce useful sunflower oil components, Eur. J. Lipid Sci. Technol. 108 (2006) 287–297.
[15] A. Carrubba, Organic and chemical n fertilization on coriander (*Coriandrum sativum* L.) in a Mediterranean environment, Ind. Crop. Prod. 57 (2014) 174–187.
[16] H. Trémolières, A. Trémolières, P. Mazliak, Effects of light and temperature on fatty acid desaturation during the maturation of rapeseed, Phytochemistry 17 (1978) 685–687.
[17] A.L. Vuorinen, M. Kalpio, K.M. Linderborg, M. Kortesniemi, K. Lehto, J. Niemi, B. Yang, P. Heikki, H.P. Kallio, Coordinate changes in gene expression and triacylglycerol composition in the developing seeds of oilseed rape (*Brassica napus*) and turnip rape (*Brassica rapa*), Food Chem. 145 (2014) 664–673.
[18] E.B. Cahoon, J. Shanklin, J.B. Ohlrogge, Expression of a coriander desaturase results in petroselinic acid production in transgenic tobacco, Proc. Natl. Acad. Sci. U. S. A. 89 (1992) 11184–11188.