

## Fatty Acid Methyl Ester Composition of Some Turkish Apiaceae Seed Oils: New Sources for Petroselinic Acid

Nurgün Küçükboyacı<sup>a,\*</sup>, Fatma Ayaz<sup>a</sup>, Nezaket Adıgüzel<sup>b</sup>, Barış Bani<sup>c</sup> and Ahmet Ceyhan Gören<sup>d</sup>

<sup>a</sup>Department of Pharmacognosy, Faculty of Pharmacy, Gazi University, 06330, Ankara, Turkey

<sup>b</sup>Department of Biology, Faculty of Science, Gazi University, 06500, Ankara, Turkey

<sup>c</sup>Department of Biology, Faculty of Arts and Science, Kastamonu University, 37200, Kastamonu, Turkey

<sup>d</sup>TUBITAK UME, Group of Chemistry, 41470, Kocaeli, Turkey

nurgunkucukboyaci@gmail.com

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Dedicated to Prof. Dr. Wilhelm Fleischhacker on account of his 85th Birthday.

The seed oils of twenty-six species of Apiaceae belonging to the genera *Bunium*, *Cnidium*, *Ferula*, *Ferulago*, *Heracleum*, *Hippomarathrum*, *Malabaila*, *Myrrhoides*, *Olymposciadium*, *Pimpinella*, *Prangos*, *Szovitsia*, *Trigonasciadium*, *Trinia* and *Zosima*, collected in Turkey, were investigated for their oil content, and amount of petroselinic acid (PA), as well as for the composition of their fatty acid methyl esters (FAMES) by GC-MS. Seed oil content ranged from 7.1% in *Szovitsia callicarpa* to 29.3% in *Ferula haussknechtii*. The results showed that the seed oils of the studied species contained high amounts of PA (1.2-72.2%), followed by significant amounts of linoleic (LA, 13.8-50.8%) and oleic (OA, 4.2-61.6%) acids. PA was found in all the analyzed species, except for *Olymposciadium caespitosum*, which belongs to a monotypic endemic genus of the family. According to data from our study, PA was found to be predominantly in the seed oils of *Hippomarathrum cristatum* (72.2%), *Trinia glauca* (64.9%) and *Bunium microcarpum* (59.7%) and, therefore these species might be considered as new sources of PA, and represent a potential oleochemical raw material. This is the first extensive study of the composition of Turkish Apiaceae species. The high amounts of PA may also have chemotaxonomic significance.

**Keywords:** Apiaceae, Seed oil, Petroselinic acid, FAMES, GC-MS.

Petroselinic acid (PA, 18:1Δ6) is an important compound the double bond of which can be oxidatively split to form lauric (12:0) and adipic (6:0) acids, which are used in the manufacture of surfactants, soap, detergents and plastics. Therefore, it is a valuable oleochemical raw material and also provides an opportunity for production of industrially useful materials such as lauric and adipic acids, as shown in Figure 1 [1a-1c]. PA is one of the most common fatty acids in Apiaceae Lindl. (Umbelliferae) seed oils. The genera of Apiaceae have been reported as useful sources of PA [1a,1c-f]. In the oleochemical industry, new plant sources are needed to obtain PA in the highest yield for its economic production.

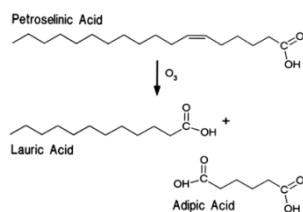


Figure 1: Petroselinic acid and its industrial products.

The Apiaceae family comprises ca 275 genera and 2850 species. In Turkey, it is represented by nearly 100 genera including native, hybrid and cultivated taxa [2a-2d]. In a few studies, PA, an unusual fatty acid, was determined as the predominant constituent of the seed oils of Apiaceae taxa [3a-3d]. It has also been reported that the high amounts of PA were of chemotaxonomic significance for the family [3a,3b]. It is obvious that the number of Apiaceae species that have been analyzed for their fatty acid profiles is still limited and further research to find potential PA sources from this family are needed.

In this study, the amount of PA as well as the FAMES composition of the seed oils of 26 taxa of Apiaceae grown in Turkey was analyzed by GC-MS. Among them, *Ferulago blancheana*, *Heracleum platytaenium*, *Malabaila lasiocarpa*, *Prangos meliocarpoides* var. *meliocarpoides*, *P. platychnaena* and *P. uechtritzii* are endemic species. Also, *Olymposciadium caespitosum*, belonging to a monotypic endemic genus, was analyzed [2a,2b]. The location of these taxa is summarized in Table 1.

The percent oil and FAMES distribution are given in Table 2. Seed oil content ranged from 7.1% in *Szovitsia callicarpa* to 29.3% in *Ferula haussknechtii* (1.2-72.2%). PA was determined as the main fatty acid in the seed oils of many of the studied taxa, as seen in Table 2. High amounts of unsaturated fatty acid methyl esters (UFAMES) were also found as follows linoleic (LA, 18:2Δ9,12) (13.8-50.8%) and oleic acids (OA,18:1Δ9) (4.2-61.6%) in all the investigated species. According to the results of our GC-MS analysis, high amounts of PA were found in the seed oils from *Hippomarathrum cristatum*, *Trinia glauca* and *Bunium microcarpum* with 72.2, 64.9 and 59.7%, respectively. The lowest amount of PA (1.2%) was detected in the oil of *Myrrhoides nodosa*.

LA was the predominant component of the seed oil of *M. nodosa* and *Hippomarathrum microcarpum* (50.8 and 36.9%, respectively). The highest amount of OA was determined in the seed oil of *O. caespitosum* with 61.6%, and the lowest in the seed oil of *H. cristatum* (4.2%). The seed oil of *O. caespitosum* interestingly had no PA but the highest amount of OA, while the seed oil of *H. cristatum* contained the highest amount of PA, but the lowest of OA (Table 2).

**Table 1:** Species location of 26 taxa of Apiaceae from Turkey.

Species	Locality	Voucher number
<i>Bunium microcarpum</i> Freyn & Bormm. ex Freyn	B10 Iğdır: Tuzluca-Kağızman, 19 km from Tuzluca, <i>Artemisia</i> steppe, 1000 m, 02.07.2004	NA 5339
<i>Cnidium silaifolium</i> (Jacq.) Simonkai subsp. <i>orientale</i> Boiss.	B6 Adana: Tufanbeyli, Kirazlıyurt village, Haldede hill, on rock, 1500-1700 m, 28.07.2005	BB 3298
<i>Ferula haussknechtii</i> H.Wolff ex Rech.f.	B9 Van: Ereğ mountain, above Susaniş village, alpine steppe, 2100 m, 05.07.2001	NA 3935
<i>Ferula hermonis</i> Boiss.	B6 Adana: Saimbeyli, above Naltaş village, Bozoğlan hill, <i>Cedrus libani</i> forest, 1600-1700 m, 25.07.2006	BB 4582
<i>Ferulago asparagifolia</i> Boiss.	B6 Adana: Tufanbeyli, Ayvat-Tozlu villages, Kürebeli district, open oak forest, 1600 m, 27.08.2006	BB 4719
<i>Ferulago blancheana</i> Post ex Boiss.	B6 Adana: Tufanbeyli, above Akdere village, Karakaya hill, stony slope, 2100-2200 m, 13.09.2007	BB 5769
<i>Ferulago platycarpa</i> Boiss. & Balansa	B6 Adana: Tufanbeyli, Çiftlik-Naltaş villages, Burunluk hill, <i>Pinus nigra</i> forest, 1500-1600 m, 24.07.2006	BB 4542
<i>Heracleum pastinacifolium</i> K. Koch	B6 Kayseri: Tomarza, Beydağı, Kırkpınar upland, steppe, 2600-2700 m, 24.08.2006	BB 4691
<i>Heracleum platytaenium</i> Boiss.	A4 Ankara: Kızılcahamam, Soğuksu National Park, 1500 m, open forest, 22.09.1992	NA 1153
<i>Hippomarathrum cristatum</i> Boiss.	C1 Aydın: Didim, seaside, sandy places, 28.08.2006	NK 2601
<i>Hippomarathrum microcarpum</i> (M.Bieb.) B. Fedtsch.	A9 Kars : Esenkent-Başgedikler, 1650 m, meadow, 01.08.2004	NA 6155
<i>Malabaila lasiocarpa</i> Boiss.	C9 Van: Çatak, Dalbastı village, surroundings of Narlı bridge, stony slope, 1400-1600 m, 08.06.2003	BB 1808
<i>Malabaila secacul</i> Boiss.	B6 Adana: Tufanbeyli, Çiftlik-Naltaş villages, Burunluk hill, <i>Pinus nigra</i> forest, 1700 m, 07.06.2006	BB 3957
<i>Myrrhoides nodosa</i> (L.) Cannon	C9 Van: Çatak, Büyükağaç-Belenoluk villages, rocky place, 1300-1450 m, 19.03.2003	BB 1577
<i>Olymposciadium caespitosum</i> H. Wolff	A4 Karabük: Keltepe, above Sorgun upland, Büyükdüz district, alpine steppe, 2000 m, 19.09.1996	NA 3052
<i>Pimpinella affinis</i> Ledeb.	C9 Van: Çatak, surroundings of Şeytanderesi, 1350-1500 m, 12.07.2005	BB 2194
<i>Pimpinella aromatica</i> M. Bieb.	C9 Van: Çatak, Dalbastı village-Belbuka upland, open oak forest, 1350-1600 m, 20.07.2002	BB 1276
<i>Prangos meliocarpoides</i> Boiss. var. <i>meliolepis</i>	B6 Adana: Tufanbeyli, Ayvat-Tozlu villages, open oak forest, 1600-1800 m, 06.06.2006	BB 3912
<i>Prangos pabularia</i> Lindl.	B9 Van: Ereğ mountain, above Susaniş village, steppe, 2100 m, 05.07.2001	NA 3934
<i>Prangos platychlaena</i> Boiss.	B9 Van: Gevaş, Altıncağ-Göründü, near lake, 1710 m, 02.06.2001	NA 3714
<i>Prangos uechtritzi</i> Boiss. & Hausskn.	A9 Kars: Sarıkamış, 1-2 km to Çamyazı village, <i>Astragalus steppe</i> , 2300m, 27.07.2004	NA 5908
<i>Prangos uloptera</i> DC.	B9 Van: Ereğ mountain, Susaniş village, alpine steppe, 2400 m, 05.07.2001	NA 3937
<i>Szovitsia callicarpa</i> Fisch. & C.A. Mey.	A9 Kars: Kağızman-Tuzluca, 1200 m, salty places, 24.06.2001	NA 3866
<i>Trigonascidium viscidulum</i> Boiss. & Hausskn. ex Boiss.	C9 Van: Çatak, Şeytanderesi-Yeniköy, open oak forest, 1400-1600 m, 03.06.2003	BB 1729
<i>Trinia glauca</i> (L.) Dum.	A4 Karabük: Keltepe, Gölyazı-Zirve, steppe, 1900m, 19.09.1996	NA 3058
<i>Zosima absinthifolia</i> Link	B6 Adana: Saimbeyli, Naltaş-Gökmenler villages, Menteşesirtı hill, <i>Pinus nigra</i> forest, 1500 m, 09.06.2006	BB 4162

**Table 2:** Oil yields (% w/w) and FAME composition of 26 taxa of Apiaceae from Turkey\*.

Species	Oil yield (w/w %)	14:0	16:0	16:1 Δ9	17:0	18:0	18:1 Δ6	18:1 Δ9	18:1 Δ1	18:2 Δ9, 12	18:3 Δ9,12, 15	20:0	20:1 Δ11	22:0	22:1 Δ9	24:0	SFA MEs	UFA MEs
<i>Bunium microcarpum</i>	15.4	0.1	3.5	0.2	0.1	0.5	59.7	18.7	1.5	14.3	0.2	0.1	0.2	0.1	-	0.1	4.5	94.8
<i>Cnidium silaifolium</i> subsp. <i>orientale</i>	15.5	0.2	15.0	0.7	-	2.1	37.3	14.2	1.2	22.5	5.4	-	0.4	0.2	-	0.1	17.6	81.7
<i>Ferula haussknechtii</i>	29.3	0.2	10.4	0.2	0.8	3.1	35.5	18.4	0.9	24.9	3.5	-	0.9	0.4	-	0.2	15.0	84.3
<i>F. hermonis</i>	14.5	0.2	4.9	-	0.9	1.9	46.5	12.2	0.7	27.1	3.8	-	0.4	0.5	-	0.3	8.5	90.9
<i>Ferulago asparagifolia</i>	20.0	-	5.6	0.2	-	1.5	42.7	20.3	1.4	26.3	0.9	-	0.2	0.4	-	-	7.4	92.1
<i>F. blancheana</i>	12.5	0.1	5.6	0.2	-	0.9	54.6	11.9	1.1	24.9	0.6	-	0.2	0.5	-	0.2	7.3	92.5
<i>F. platycarpa</i>	15.8	0.2	4.8	-	-	1.3	52.2	17.3	0.8	22.3	0.3	-	0.2	0.2	-	-	6.4	93.2
<i>Heracleum pastinacifolium</i>	21.3	0.1	7.3	0.4	0.1	1.4	36.4	16.6	1.2	34.5	0.8	-	0.5	-	0.1	0.3	9.2	90.5
<i>H. platytaenium</i>	15.8	0.1	6.8	0.1	0.2	1.6	47.8	12.5	1.2	27.1	0.5	0.2	0.3	0.4	0.1	0.1	9.3	89.7
<i>Hippomarathrum cristatum</i>	15.8	0.1	5.2	0.3	-	1.2	72.2	4.2	1.2	13.8	0.3	-	0.1	0.6	-	0.2	7.3	92.1
<i>H. microcarpum</i>	9.0	0.2	13.5	0.1	-	6.4	7.5	26.5	1.2	36.9	6.7	-	0.4	0.2	-	-	20.2	79.3
<i>Malabaila lasiocarpa</i>	9.4	0.4	5.8	0.2	0.1	3.2	50.4	16.6	0.8	18.3	2.5	-	0.6	0.4	-	0.3	10.2	89.4
<i>M. secacul</i>	26.2	-	7.1	-	-	2.5	46.7	15.1	0.9	26.7	0.3	-	0.2	0.1	-	-	9.6	90.0
<i>Myrrhoides nodosa</i>	26.8	-	18.3	-	-	3.6	1.2	24.6	-	50.8	0.8	-	-	0.3	-	-	22.1	77.5
<i>Olymposciadium caespitosum</i>	26.7	-	4.5	0.1	-	1.0	-	61.6	1.0	29.4	0.6	-	0.4	0.2	-	0.1	5.7	93.2
<i>Pimpinella affinis</i>	26.9	0.2	18.6	0.2	0.2	4.3	28.7	16.6	1.5	25.6	2.1	-	0.9	-	0.2	0.2	23.5	75.8
<i>P. aromatica</i>	11.1	0.1	11.7	0.3	0.2	3.0	32.2	15.6	1.6	29.4	3.5	-	0.8	0.4	0.2	0.2	15.6	83.6
<i>Prangos meliocarpoides</i> var. <i>meliolepis</i>	19.1	-	7.0	0.3	-	1.2	48.1	9.5	1.5	29.7	1.7	0.1	0.2	0.1	-	-	8.2	91.2
<i>P. pabularia</i>	25.8	0.1	5.5	0.3	-	1.0	51.6	14.0	1.3	24.8	0.6	0.1	0.2	0.1	-	-	6.8	92.8
<i>P. platychlaena</i>	18.3	-	6.2	-	0.1	1.2	52.3	10.7	1.1	26.6	0.8	0.2	0.2	0.1	-	-	7.7	91.8
<i>P. uechtritzi</i>	20.8	-	5.4	-	-	1.5	47.1	14.0	1.0	30.0	0.3	0.1	0.1	0.1	-	-	7.0	92.6
<i>P. uloptera</i>	25.4	-	4.8	0.3	0.1	1.0	56.9	13.0	1.2	21.8	0.3	-	0.2	-	-	-	5.9	93.7
<i>Szovitsia callicarpa</i>	7.1	0.5	4.8	-	-	2.4	52.6	20.9	1.4	14.7	0.8	0.1	0.6	0.4	-	0.2	8.4	91.0
<i>Trigonascidium viscidulum</i>	7.3	0.2	9.2	0.2	0.2	2.8	45.6	17.0	1.1	20.5	1.6	0.3	0.2	0.3	0.1	0.2	13.2	86.3
<i>Trinia glauca</i>	9.1	-	3.8	0.2	-	0.9	64.9	7.1	1.4	19.2	0.7	-	0.3	0.2	-	0.4	5.2	93.9
<i>Zosima absinthifolia</i>	14.5	0.1	7.6	0.1	0.1	4.0	43.7	16.3	1.3	24.5	1.2	-	0.2	0.3	-	0.1	12.1	87.4

\* GC/MS analyses were replicated three times (Mean RSD value is 0.1%), **SFAMEs**: saturated fatty acid methyl esters, **UFAMEs**: unsaturated fatty acid methyl esters.

The amount of UFAMEs in these seed oils was found to be highest in *B. microcarpum* (94.8%), as shown in Table 2. The highest amount of saturated fatty acid methyl esters (SFAMEs) was in *Pimpinella affinis* seed oil (23.5%). Kleiman & Spencer [3a]

reported that almost all species of Apiaceae, Araliaceae and Garryaceae contained PA in the seed oils and the distribution of PA from Apiaceae was on the average 57%. In this study, the amounts ranged from 1.2 to 72.2% in the oils, with an average of 36.7%,

**Table 3:** Literature review of fatty acid content of studied Apiaceae taxa.

Species	Collected cites	Parts	Oil yield (wt %)	16:0	18:0	18:1A6	18:1A9	18:2 A9, 12	18:3 A9,12,15	Ref
<i>Bunium paucifolium</i> DC.	Turkey	S+P	22.2	3.8	0.3	73.2	5.8	15.1	0.5	[3a]
<i>B. persicum</i> (Boiss.) B. Fedtsch.	Pakistan	S+P	13.6	6.0	0.1	56.0	13.9	23.0	0.4	[3a]
<i>Cnidium monnieri</i> (L.) Cusson	Korea	S+P	39.2	2.1	0.8	58.2	4.5	32.6	0.5	[3a]
<i>Ferula assa-foetida</i> (L.)	Turkey	S+P	10.4	3.8	1.0	76.5	5.3	12.8	0.1	[3a]
<i>F. communis</i> L.	Israel	S+P	9.2	4.3	1.1	78.1	4.4	10.5	0.9	[3a]
<i>F. communis</i> L. subsp. <i>glanca</i> Rouy & Camus	Yugoslavia	S+P	13.7	7.7	0.9	70.8	8.8	11.8	0.2	[3a]
<i>F. galbaniflua</i> Boiss. & Buhse	Yugoslavia	S+P	46.9	7.7	0.3	52.4	14.3	25.1	0.1	[3a]
<i>F. oopoda</i> (Boiss. & Buhse) Boiss.	Pakistan	S+P	19.1	5.2	0.6	52.4	13.3	27.8	0.1	[3a]
<i>F. ovina</i> (Boiss.) Boiss.	Pakistan	S+P	36.3	6.1	1.0	50.1	18.8	23.9	-	[3a]
<i>Ferulago longistylis</i> Boiss.	Turkey	S	22.0	6.0	1.2	52.5	16.1	24.1	0.1	[3a]
<i>F. pauciradiata</i> Boiss. & Heldr.	Turkey	S	19.7	7.1	1.3	44.0	9.1	26.1	4.5	[3b]
<i>F. trachycarpa</i> Boiss.	Turkey	S	7.3	tr	tr	-	68.1	23.0	0.3	[3c]
<i>F. trachycarpa</i>	Turkey	S	9.1	tr	tr	-	73.6	18.0	0.3	[3c]
<i>Myrrhoides nodosa</i> (L.) Cannon	Yugoslavia	S+P	8.3	12.1	1.4	1.0	26.0	59.3	-	[3a]
<i>Heracleum lanatum</i> Michx.	USA	S	21.0	4.2	1.4	34.9	19.5	38.3	0.4	[3a]
<i>H. pinnatum</i> C.B. Clarke	Pakistan	S+P	21.7	3.7	0.8	57.6	16.6	20.1	0.1	[3a]
<i>H. platyaenium</i> Boiss.	Turkey	S+P	19.0	5.3	1.1	52.3	14.7	25.6	0.1	[3a]
<i>H. sphondylium</i> L.	Turkey	S+P	23.9	5.0	0.6	56.3	12.2	24.9	0.4	[3a]
<i>H. sphondylium</i> L. subsp. <i>montanum</i> (Schleicher ex Gaud.) Briq.	Yugoslavia	S+P	21.2	5.2	1.1	47.4	14.4	31.7	-	[3a]
<i>H. sphondylium</i> L. subsp. <i>orsinii</i> (Guss.) H. Neumayer	Yugoslavia	S+P	15.9	4.4	0.5	55.6	14.2	24.6	0.1	[3a]
<i>H. sphondylium</i> L. subsp. <i>sibiricum</i> (L.) Simonakai	Yugoslavia	S+P	19.8	4.6	1.1	51.6	13.0	29.1	-	[3a]
<i>H. platyaenium</i> Boiss.	Turkey	S	11.2	4.6	1.2	64.2	3.9	20.6	0.3	[3b]
<i>H. trachyloma</i> Fisch. & C. A. Mey.	Turkey	S	11.8	4.4	1.3	52.0	7.0	27.7	0.3	[3b]
<i>H. crenatifolium</i> Boiss.	Turkey	S	7.6	4.8	1.2	52.3	9.9	26.2	0.4	[3b]
<i>H. sphondylium</i> subsp. <i>artinense</i>	Turkey	S	17.2	5.1	1.5	39.4	11.6	36.4	0.4	[3b]
<i>Hippomarathrum bossieri</i> Reut. & Hausskn.	Pakistan	S+P	20.2	2.7	2.2	49.0	25.2	20.4	-	[3a]
<i>H. cristatum</i> (DC.) Boiss.	Yugoslavia	S+P	8.6	7.1	1.3	54.4	16.9	19.8	0.3	[3a]
<i>H. microcarpum</i> (Bieb.) Fedtsch.	Turkey	S+P	14.1	15.0	5.3	6.5	20.5	37.8	6.5	[3a]
<i>H. pauciradiatum</i> (Heldr. & Halacsy) Heldr. & Halacsy	Turkey	S	31.3	4.5	0.4	66.0	13.8	14.7	0.2	[3a]
<i>Malabaila involucrate</i> Boiss.	Yugoslavia	S+P	8.0	4.9	2.0	62.2	13.3	16.5	0.2	[3a]
<i>M. lasiocarpa</i> Boiss.	Turkey	S+P	12.0	7.3	0.8	53.0	20.3	17.3	-	[3a]
<i>M. secacul</i> (Mill.) Boiss.	Turkey	S+P	16.0	3.9	1.5	47.0	13.4	32.6	0.4	[3a]
<i>M. pastinacifolia</i> Boiss. & Balansa	Turkey	S	22.3	4.5	0.9	57.7	9.3	22.9	0.5	[3b]
<i>Pimpinella anisum</i> L.	South Africa	S+P	23.9	4.7	1.1	48.9	21.7	21.2	0.5	[3a]
<i>P. diversifolia</i> DC.	Pakistan	S+P	29.4	4.4	0.1	75.4	6.0	13.5	-	[3a]
<i>P. kotschyana</i> Boiss.	Turkey	S+P	18.4	10.8	1.0	37.5	20.8	28.6	1.0	[3a]
<i>P. peregrina</i> L.	Israel	S+P	19.8	5.7	1.2	70.2	6.6	15.6	0.6	[3a]
<i>P. saxifrage</i> L.	Yugoslavia	S+P	29.0	4.5	0.5	46.6	16.6	31.4	0.1	[3a]
<i>P. stewartii</i> (Dunnn) E. Nasir	Pakistan	S+P	25.2	9.2	1.1	54.5	9.6	24.8	0.2	[3a]
<i>P. thellungiana</i> H. Woff var. <i>gustavobegiana</i> (Koidz.) Kitam.	Korea	S+P	24.2	4.3	0.9	42.2	14.1	37.8	0.4	[3a]
<i>P. tragium</i> Vill.	Yugoslavia	S+P	27.0	4.2	0.5	58.2	14.0	27.8	0.3	[3a]
<i>Prangos acaulis</i> (DC.) Bormm.	Turkey	S	25.3	9.3	0.4	52.7	20.3	16.2	-	[3a]
<i>Prangos asperula</i> Boiss.	Turkey	S	26.0	5.6	0.7	53.6	17.4	22.0	-	[3a]
<i>Prangos ferulacea</i> (L.) Lindl.	Turkey	S	31.8	5.3	0.3	59.2	14.7	19.6	-	[3a]
<i>Prangos ferulacea</i> (L.) Lindl.	Turkey	S+P	28.5	6.1	0.8	50.8	20.5	20.1	0.1	[3a]
<i>P. pabularia</i> Lindl.	Pakistan	S+P	27.0	6.2	0.8	52.0	15.1	25.2	-	[3a]
<i>P. pabularia</i> Lindl.	Turkey	S	28.7	8.4	0.8	51.8	9.0	28.9	-	[3a]
<i>P. uloptera</i> DC.	Turkey	S	33.6	4.9	0.8	61.6	8.5	21.9	1.7	[3a]
<i>P. platychlaena</i> Boiss.	Turkey	S	18.7	5.4	1.3	50.4	11.3	25.5	0.5	[3b]
<i>P. uechtritzi</i> Boiss. & Hausskn.	Turkey	S	22.8	5.4	1.0	47.8	9.8	30.4	0.4	[3b]
<i>Zosima absinthiifolia</i> (Vent.) Link	Pakistan	S+P	18.9	5.9	0.6	45.5	21.7	25.2	0.3	[3a]

S: seed; S+P: seed+pericarp; tr: trace; -: not detected.

which is somewhat lower than the value found by Kleiman & Spencer. They found the highest amount of PA in the seed oil of *Apium leptophyllum* (Pers.) F. Muell. (86.5%) [3a].

Hondelmann [3b] determined the amount of PA to be 30.3-81.6% in the seed oils of 26 species of Apiaceae. In a related study with nine species of the family gathered from Turkey the PA content of the seed oils ranged from 39.4-64.2%, yielding an average PA content of 51.8 %. PA was also found in the seed oil of *H. platyaenium* (64.2%) at a high level [3c]. Moreover, in a recent study by Ngo-Duy *et al.* [3d], the seed oils of four species of Apiaceae were analyzed with respect to their fatty acid composition, and PA was identified in the seed oils of *Carum carvi* L. (40.6%), *Daucus carota* L. (68.1%), *Apium graveolens* L. (64.3%) and *Petroselinum crispum* (Mill.) A. W. Hill (75.1%). Interestingly, in a study conducted by Erdemoglu *et al.* [3e], it was noted that the samples of *Ferulago trachycarpa* Boiss. contained no PA, but prominently OA.

The literature results are summarized in Table 3 comparing the major fatty acid contents of all studied taxa from Apiaceae growing in different countries. In comparison with the published data, the fatty acid compositions of the species in our study were found to yield similar oil contents and FAME distribution with respect to the PA, LA and OA contents. PA was determined to be 54.4% in the seed oil of *Hippomarathrum cristatum* from Yugoslavia [3a]. This result is lower than in our study (72.2%). PA was also detected in the seed oil of *Heracleum platyaenium* from Van, Turkey (64.2%) [3c], whereas a 47.8% level was recorded for the seed oil from the Ankara region.

In summary, our study provides additional data on the fatty acid profiles of Apiaceae seed oils from Turkey. Also, this is the first time that the FAMEs composition of the seed oils of *B. microcarpum*, *Cnidium silajifolium* subsp. *orientale*, *F. haussknechtii*, *Ferula hermonis*, *Ferulago asparagifolia*, *F.*

*blancheana*, *Ferulago platycarpa*, *Heracleum pastinacifolium*, *O. caespitosum*, *P. affinis*, *Pimpinella aromatica*, *P. meliocarpoides* var. *meliocarpoides*, *S. callicarpa*, *Trigonosciadium viscidulum* and *T. glauca* have been reported. A number of Apiaceae species are already cultivated as natural resources of medicinal, aromatic and food plants and other members of the family may have potential as industrial crops [1c,1f,3a,4a,4b]. In particular, Apiaceae plants have been known as potential sources of PA, an oleochemical raw material which is used in the oleochemical and pharmaceutical industries [1a,1c,1f]. According to our findings, most taxa had PA at high levels. Among them, *H. cristatum* (72.2%), *T. glauca* (64.9%) and *B. microcarpum* (59.7%) may be considered as important sources of PA and be cultivated for industrial use.

## Experimental

**Plant materials:** Mature seeds were collected from their natural habitats in Turkey (see Table 1). They were dried and identified by Prof. Nezaket Adıgüzel (Gazi University) and Asst. Prof. Barış Bani (Kastamonu University). Voucher specimens were retained in the Herbarium of GAZI.

**Oil extraction and transesterification:** The collected seeds were separated from plant materials and dried in the shade. They were kept in the dark at 20–24°C, with a relative humidity ratio between 50–70%. The weighed seeds were ground with anhydrous sodium sulfate to absorb moisture and then extracted with light petroleum (Merck Co., USA) for 4 h in a Soxhlet apparatus. The solvents were evaporated to dryness under vacuum at 40°C and the residues were stored at 4°C. In order to analyze the fatty acid composition of the seed oils, total fatty acids were converted to FAMES using borontrifluoride methanol mixture (Merck Co., USA) according to

Morrison and Smith's method (1 mL reagent per 4–16 mg of seed oil) [5]. The FAMES were dissolved in 1 mL of CH<sub>2</sub>Cl<sub>2</sub> prior to each analysis and injected into a GC-MS apparatus. Three samples of each species were used to determine the average FAME compositions.

**GC-MS:** The FAMES were analyzed using a Trace 2000 GC series gas chromatograph (Thermo Fischer Scientific, Inc., ON, CA) and a Thermo mass spectrometer. The separation was carried out in a SGE BPx70 column (Fischer Scientific, Inc., 60m x 0.25 mm i.d., 0.25 µm film thickness). Helium was used as the carrier gas at a flow rate of 1 mL/min. The oven temperature was kept at 100°C for 5 min, programmed to 240°C at a rate of 4°C/min and kept constant at 240°C for 5 min. The injection and source temperatures were 250°C and 220°C, respectively. The MS interface temperature was 240°C. The injection volume was 0.5 µL with a split ratio of 1:30. Injections of samples were made in triplicate. EI/MS were recorded at 70 eV ionization energy. The mass range used was from *m/z* 50 to 650 amu. The scan time was 0.5 sec. with 0.1 interscan delay. The library search was carried out using NIST, Wiley GC-MS and TUBITAK-UME libraries. A Supelco™ 37 component FAME mixture (Catalog no:47885-U) was used for the comparison of qualitative and quantitative identification of the FAME components in the GC chromatograms. The relative percentage of each FAME was calculated from the total ion chromatogram by a computerized integrator.

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