Lipid Class and Fatty Acid Compositions of Edible Tissues of *Peucedanum graveolens*, *Mentha arvensis*, and *Colocasia esculenta* Plants[1]

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Lipids were isolated from the young edible tissues of three plants, namely leaves and stems of *Peucedanum graveolens* syn. *Anethum graveolens* syn. *Anethum sowa* (dill) and *Mentha arvensis* (field mint, corn mint, labiata) and leaves and leaf stalks of *Colocasia esculenta* syn. *Colocasia antiquorum* (taro, elephant ears, dasheen, eddo, cocoyam). The lipid contents on dry-weight basis were 7.1 and 2.4% in the leaves and stems of *P. graveolens*, 6.2 and 2.0% in the leaves and stems of *M. arvensis*, and 9.7 and 3.5% in the leaves and leaf stalks of *C. esculenta*, respectively. Lipid classes were separated by silicic acid column chromatography and thin-layer chromatography and estimated. Among the nonpolar lipids, pigments were the major components. Monogalactosyl diglycerides and digalactosyl diglycerides were the chief constituents of glycolipids. Phosphatidylcholine was the predominant phospholipid in all except for phosphatidylglycerol in the *P. graveolens* leaves. Among the constituent fatty acids, determined by gas–liquid chromatography, the major ones were linolenic (18:3) and palmitic (16:0) in the leaves and linoleic (18:2) and palmitic in the other tissues.

Peucedanum graveolens Linn. syn. *Anethum graveolens* Linn. syn. *Anethum sowa* Kurz (dill) of Umbelliferae, *Mentha arvensis* Linn. (field mint, corn mint, labiata) of Labiatae, and *Colocasia esculenta* Schott syn. *Colocasia antiquorum* Schott (elephant ears, taro, dasheen, eddo, cocoyam) of Araceae are widely cultivated plants for medicinal and food uses. The leaves, stems, and leaf stalks of these plants are used in culinary preparations of India. There is no informaiton on the lipids of these tissues, and this paper reports the nature and contents of the lipid classes and their constituent fatty acids.

MATERIALS AND METHODS

Materials. The plants of *P. graveolens*, *M. arvensis*, and *C. esculenta* were approximately 40, 25, and 65 days old, after sowing. Typical young fresh plants normally used in culinary preparations were purchased in a local vegetable market. All the leaves and stems of *P. graveolens* and *M. arvensis* and leaves and leaf stalks of *C. esculenta* were separated, pooled to form composite samples, and processed immediately.

Methods. The experimental procedures for extraction of total lipids with chloroform–methanol and their purification, separation into nonpolar lipids, glycolipids (GL), and phosopholipids (PL) and their sub-classes by silicic acid column chromatography and thin-layer chromatography (TLC), respectively, identification with specific spray reagents, and determination of fatty acid composition by gas–liquid chromatography (GLC) were described in detail (Lakshminarayana et al., 1984). The nonpolar lipid classes were estimated by gravimetry. The contents of GL and PL classes were determined by GLC of methyl esters of the constituent fatty acids using methyl heptadecanoate as internal standard. This ester and other lipid standards for reference were obtained from Applied Science Laboratories, University Park, PA, Prof. K. Subba Rao, University of Hyderabad, Dr. N. Patnaik, Centre for Cellular and Molecular Biology, Hyderabad, and colleagues.

RESULTS AND DISCUSSION

Leaves. The lipid contents in the leaves *P. graveolens*, *M. arvensis*, and *C. esculenta* were 7.1, 6.2, and 9.7% on a dry-weight basis, respectively. The lipids were quantitatively fractionated into nonpolar lipids, GL and PL by column chromatography and their subclasses by TLC. The lipid class composisitions are shown in Table I. The leaves contained significant quantities of nonpolar lipids as do the leaves of spinach, barley (Zill and Harmon, 1962), and red clover (Weenink, 1962). Among the nonpolar lipids, pigments constituted a major class. The contents of mono-, di-, and triacylglycerols (MAG, DAG, TAG) were not as high as observed in other leaf lipids (Weenink, 1961). Monogalactosyl diglycerides (MGDG) were predominant in GL, except in *P. graveolens* where they equalled digalactosyl diglycerides (DGDG). With the exception of lucerne (alfalfa), other leaves studied contained more MGDG than DGDG (O'Brien and Benson, 1964; Hawke,

Table I. Lipid Class Compositions (Weight Percent) of *P. graveolens*, *M. arvensis*, and *C. esculenta* Plant Tissues[a,b]

	P. graveolens		*M. arvensis*		*C. esculenta*	
lipid class	leaves	stems	leaves	stems	leaves	stems
nonpolar lipids	32.2	34.9	37.3	40.9	39.6	38.8
pigments	5.9	5.4	7.5	9.2	9.9	8.1
hydrocarbons	4.6	4.4	4.9	6.0	5.0	4.7
sterol esters	4.0	3.6	2.2	3.3	3.8	4.1
ester waxes	0.0	0.0	0.0	0.0	2.3	0.0
TAG	2.3	2.4	4.9	6.0	3.3	5.8
fatty acids	4.2	5.0	1.3	0.7	2.9	3.2
alcohols	0.0	0.0	2.0	0.0	0.0	0.0
sterols	4.4	5.2	3.9	5.8	2.2	4.8
DAG	3.7	4.6	4.1	5.1	3.0	2.6
MAG	0.0	0.0	4.0	0.0	2.9	0.0
unidentified	3.1	4.3	2.5	4.8	4.3	5.5
glycolipids	44.7	42.1	37.1	27.7	33.2	29.6
ESG	0.0	4.3	0.0	0.4	1.8	1.7
MGDG	21.9	24.3	16.9	21.6	16.5	15.1
cerebrosides	0.0	0.0	0.5	0.0	2.0	0.0
DGDG	22.5	13.5	12.1	5.2	7.5	8.5
SQDG	0.3	0.0	7.6	0.5	5.4	4.3
phospholipids	23.1	22.8	25.6	31.4	27.1	31.6
cardiolipin	0.7	0.4	0.0	0.9	1.8	1.6
PG	12.8	5.8	4.1	8.2	5.4	7.8
PE	0.3	0.8	1.8	0.7	2.9	5.8
PI	0.2	0.0	3.9	0.0	4.4	4.3
PC	9.1	15.8	15.8	21.6	12.7	12.1

[a] Tetradecane, myristyl palmitate, methyl stearate, sesame oil, commercial monoglycerides, oleic acid, and stigmasterol were used for identification of nonpolar lipids. Authentic glycolipid and phospholipid classes, including sulfolipids, were used as reference. [b] Overall recovery of total lipids after column chromatography followed by TLC was 93.0–97.1%.

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Table II. Fatty Acid Composition of Lipid Classes of *P. graveolens* Leaves

lipid class	fatty acid,[a] wt %											
	12:0	14:0	14:1	16:0	16:1	18:0	18:1	18:2	18:3	20:0	22:0	others
nonpolar lipids												
sterol esters	5.3	9.0	0.6	23.5	0.7	6.0	18.8	14.8	20.6	0.5	0.2	nd
TAG	1.0	3.2	0.6	17.8	tr	9.5	15.1	36.6	20.2	nd	1.0	nd
fatty acids	nd	nd	nd	4.1	nd	14.9	14.8	21.6	44.5	nd	nd	nd
DAG	3.8	9.5	1.1	27.7	tr	9.5	17.2	11.9	5.3	8.7	6.2	nd
glycolipids												
MGDG	0.1	0.1	nd	1.1	tr	0.1	46.5	1.4	49.9	0.2	nd	0.5
DGDG	nd	0.1	nd	0.5	tr	0.1	47.6	0.9	50.1	0.1	nd	0.5
phospholipids												
cardiolipin	5.3	4.7	0.9	27.5	2.9	7.1	13.9	9.0	28.3	0.2	nd	nd
PG	0.3	0.5	0.1	22.3	5.4[b]	1.6	5.2	13.6	50.4	0.2	nd	0.2
PE	1.6	0.9	nd	27.7	3.8	4.4	6.1	12.0	43.4	nd	nd	nd
PI	7.0	4.2	0.8	42.8	nd	17.6	14.9	6.3	5.9	0.5	nd	nd
PC	0.1	0.2	nd	23.0	5.4	1.0	4.0	19.3	46.5	0.2	0.2	nd

[a] Duplicate values for methyl esters in standard mixtures by GLC analysis varied within 10% for minor components (<5%) and within 3% for others. [b] *trans*-3-Hexadecenoic acid. Key: nd = not detected; tr = trace (<0.1%).

Table III. Fatty Acid Composition of Lipid Classes of *M. arvensis* Leaves

lipid class	fatty acid,[a] wt %										
	12:0	14:0	14:1	16:0	16:1	18:0	18:1	18:2	18:3	20:0	others
nonpolar lipids											
sterol esters	6.5	9.5	2.9	20.5	1.4	4.7	7.1	4.9	40.4	1.2	0.9
TAG	2.2	2.9	0.3	16.4	0.6	3.5	9.9	13.8	48.0	1.5	0.9
fatty acids	8.3	6.8	0.8	26.8	1.3	12.8	11.8	3.8	14.8	12.0	0.8
DAG	2.0	5.2	0.6	15.9	2.1	5.7	4.4	6.2	56.8	0.5	0.6
MAG	2.6	6.7	0.2	13.9	2.8	1.7	2.9	5.5	63.3	0.3	0.1
glycolipids											
MGDG	0.3	0.5	nd	4.6	nd	0.7	1.4	3.0	88.8	0.6	0.1
DGDG	0.1	0.2	nd	3.9	nd	0.8	1.0	2.4	91.0	0.6	nd
SQDG	nd	nd	nd	4.3	nd	0.8	0.9	2.4	91.1	0.5	nd
phospholipids											
PG	3.2	5.8	2.2	15.2	1.7[b]	6.4	7.8	5.8	52.0	nd	nd
PE	3.3	6.6	3.7	17.4	1.2	4.7	9.3	5.2	47.9	0.2	nd
PI	5.0	9.0	2.0	17.8	1.6	4.6	4.6	7.7	47.4	0.3	nd
PC	1.9	4.1	0.1	11.8	1.4	2.6	2.7	3.7	70.8	0.3	nd

[a,b] See Table II.

Table IV. Fatty Acid Composition of Lipid Classes of *C. esculenta* Leaves

lipid class	fatty acid,[a] wt %									
	12:0	14:0	14:1	16:0	16:1	18:0	18:1	18:2	18:3	20:0
nonpolar lipids										
sterol esters	2.5	2.1	tr	12.8	0.4	18.0	16.5	19.6	25.8	2.3
ester waxes	4.3	1.8	0.2	22.3	0.7	13.6	21.2	20.9	10.2	4.8
TAG	0.4	1.4	tr	23.8	tr	10.6	15.8	16.1	31.3	0.6
fatty acids	1.1	1.4	0.1	26.4	tr	11.8	12.6	21.4	24.8	0.4
DAG	3.4	3.4	nd	23.2	nd	8.5	9.4	22.1	24.5	3.5
MAG	3.6	3.3	0.4	22.0	tr	5.8	17.6	19.1	28.2	nd
glycolipids										
ESG	9.4	4.6	0.3	28.1	0.3	9.9	13.7	16.8	16.9	nd
MGDG	nd	0.2	nd	4.0	nd	5.6	5.7	6.1	78.4	nd
cerebrosides	6.0	4.1	nd	18.6	nd	11.1	12.8	9.8	33.3	4.3
DGDG	0.6	1.1	nd	6.8	nd	8.9	9.4	10.6	62.6	nd
SQDG	2.2	1.3	nd	14.8	nd	10.3	14.6	20.9	35.9	1.1
phospholipids										
cardiolipin	3.3	4.6	tr	20.1	0.6	6.8	11.8	19.1	33.4	0.3
PG	1.3	0.9	nd	21.9	6.2[b]	5.1	8.6	11.8	44.2	0.1
PE	2.0	1.1	nd	25.8	0.6	7.8	14.9	20.5	27.3	nd
PI	0.8	0.3	nd	33.6	0.5	10.1	17.8	21.1	15.6	0.2
PC	0.7	0.4	tr	28.2	1.0	6.8	9.8	17.6	35.1	0.4

[a,b] See Table II.

1973). A significant quantity of sulfoquinovosyl diglycerides (SQDG) was also found. This lipid class has been established as an important component of chloroplast lipids (Wintermans, 1960) and appears to have some function in photosynthesis (Klopfenstein and Shigley, 1967). Among the PL, phosphatidylcholine (PC) was the major component, except for phosphatidylglycerol (PG) in *P. graveolens*. PC and PG are also the main phospholipids in other plant leaves (Kates and Marshall, 1975; Kates, 1960), PG is important for photosynthetic apparatus (Wintermans, 1960).

The leaf lipids were characterized by their high degree of unsaturation due to the presence of large amounts of 18:3, which is reported to be generally concentrated in the chloroplasts. The major fatty acids of leaves in general are linolenic (18:3), palmitic (16:0), and linoleic (18:2) (Hitchcock and Nichols, 1971; Kaimal and Lakshminarayana, 1970; Gopalakrishnan et al., 1982a,b) and were found

Table V. Fatty Acid Composition of Lipid Classes of *P. graveolens* Stems

lipid class	fatty acid,[a] wt %											
	12:0	14:0	14:1	16:0	16:1	18:0	18:1	18:2	18:3	20:0	22:0	others
nonpolar lipids												
sterol esters	6.8	nd	nd	29.8	tr	6.0	15.0	36.5	5.9	nd	nd	nd
TAG	1.0	2.1	0.3	10.7	tr	4.6	7.6	23.0	33.1	5.6	0.9	nd
fatty acids	7.1	6.0	0.6	36.9	nd	20.0	16.6	2.7	10.1	nd	nd	nd
DAG	4.7	6.7	1.0	37.5	2.9	11.7	16.5	4.8	4.1	0.7	nd	9.3
glycolipids												
ESG	6.8	nd	nd	29.8	tr	6.0	15.0	36.5	5.9	nd	nd	nd
MGDG	2.7	2.5	0.3	21.5	0.8	4.3	8.7	49.2	9.4	nd	0.1	0.3
DGDG	0.4	0.3	nd	4.2	tr	0.7	30.6	6.6	55.6	0.1	nd	1.4
phospholipids												
cardiolipin	4.9	3.5	0.8	39.2	nd	12.8	16.0	15.1	7.1	nd	nd	0.5
PG	0.7	0.8	0.3	27.2	2.6	2.2	4.4	30.8	30.8	0.1	nd	nd
PE	1.5	nd	nd	40.8	nd	6.9	7.4	35.7	7.7	nd	nd	nd
PC	1.2	1.4	0.4	25.1	3.5	3.0	5.7	24.0	34.9	0.1	nd	nd

[a,b] See Table II.

Table VI. Fatty Acid Composition of Lipid Classes of *M. arvensis* Stems

lipid class	fatty acid,[a] wt %											
	12:0	14:0	14:1	16:0	16:1	18:0	18:1	18:2	18:3	20:0	22:0	others
nonpolar lipids												
sterol esters	5.3	10.9	tr	26.0	1.2	15.9	13.3	12.5	10.3	1.0	1.8	1.8
TAG	3.6	3.3	0.4	22.0	tr	5.8	17.6	19.1	28.2	nd	nd	nd
fatty acids	12.9	10.0	2.1	34.7	nd	21.4	9.6	2.2	1.7	4.1	1.3	nd
DAG	nd	10.9	0.7	36.0	tr	14.8	19.2	9.8	5.1	3.1	nd	0.4
glycolipids												
ESG	8.9	12.2	nd	28.6	nd	11.7	12.7	13.8	11.6	0.5	nd	nd
MGDG	nd	6.6	1.6	27.7	1.5	10.0	11.6	12.5	25.5	3.0	nd	nd
DGDG	8.0	6.7	0.6	27.8	nd	10.1	9.9	16.7	17.4	2.8	nd	nd
SQDG	3.4	3.4	0.0	23.2	nd	8.5	9.4	22.1	24.5	3.5	2.0	nd
phospholipids												
cardiolipin	10.0	8.5	1.9	28.2	nd	14.6	28.0	3.4	1.7	3.8	nd	nd
PG	1.4	1.4	0.4	17.6	1.3	4.6	6.1	15.4	50.6	0.9	nd	nd
PE	11.5	10.5	1.3	24.2	nd	12.3	12.3	10.5	14.3	1.5	1.6	nd
PC	9.5	9.2	tr	32.6	tr	15.0	17.0	7.1	5.1	2.5	nd	1.0

[a,b] See Table II.

Table VII. Fatty Acid Composition of Lipid Classes of *C. esculenta* Leaf Stalks

lipid class	fatty acid,[a] wt %									
	12:0	14:0	14:1	16:0	16:1	18:0	18:1	18:2	18:3	20:0
nonpolar lipids										
sterol esters	4.0	1.8	tr	18.9	1.1	9.9	13.8	25.9	19.8	4.8
TAG	3.3	0.8	0.1	21.3	tr	6.8	13.1	37.5	15.8	1.3
fatty acids	0.9	0.3	nd	28.6	nd	7.1	9.6	39.4	13.3	0.8
DAG	2.2	1.2	0.1	26.1	0.2	10.3	14.9	24.7	20.0	0.3
glycolipids										
ESG	6.6	2.3	0.3	23.4	nd	13.8	16.1	23.3	11.9	2.3
MGDG	1.1	0.3	nd	10.2	nd	6.6	8.2	12.5	61.0	0.1
DGDG	1.8	0.6	nd	9.9	nd	5.9	9.8	14.9	57.1	nd
SQDG	2.0	2.3	nd	20.1	nd	8.9	14.5	32.0	19.8	0.4
phospholipids										
cardiolipin	1.9	1.1	nd	25.1	0.3	10.0	11.8	28.6	21.1	0.1
PG	0.8	0.5	0.1	21.8	0.5	6.9	8.8	33.6	26.6	0.4
PE	3.2	1.1	0.2	26.4	0.1	5.6	11.1	33.4	18.8	0.1
PI	4.1	3.2	0.1	28.5	0.2	6.1	9.3	31.0	17.3	0.2
PC	0.6	1.3	tr	24.6	0.1	8.4	10.6	38.4	15.7	0.3

[a,b] See Table II.

to be present in varying proportions among different lipid classes of leaves of the three plants (Tables II–IV). PG contained in appreciable concentration *trans*-3-hexadecenoic acid, which is frequently reported in PG fraction of photosynthetic tissues (Hitchcock and Nichols, 1971).

Stems. The stems of *P. graveolens* and *M. arvensis* contained respectively 2.4 and 2.0% of lipids on a dry-weight basis. The lipid class compositions are shown in Table I. Information on individual lipid class and fatty acid compositions of stem lipids is scanty. The pigments constituted a major portion of nonpolar lipids. The GL consisted of MGDG, which predominated over esterified steryl glycosides (ESG), DGDG, and SQDG. Among the PL, PC was the major component followed by PG. The major fatty acids, namely 16:0, 18:2, and 18:3, were present in varying proportions among different lipid classes (Tables V and VI). The stems of *Sterculia foetida* (Kaimal and Lakshminarayana, 1970), *Althaea rosea* (Gopalakrishnan et al., 1982b), and *Hibiscus esculentus* (Gopalakrishnan et al., 1982a) also contained these fatty acids in similar proportions.

Leaf Stalks. The lipid content of *C. esculenta* leaf stalks amounted to 3.5% on a dry-weight basis. About one-third of the quantity of total lipids was accounted for

by nonpolar lipids while the remainder comprised GL and PL in approximately equal concentrations. The chief constituents of the nonpolar lipids GL and PL were pigments, MGDG and PC, respectively (Table I). The major fatty acids were 18:2 and 16:0 except for 18:3 in the MGDG and DGDG (Table VII).

ABBREVIATIONS USED

GLC, gas–liquid chromatography; TLC, thin-layer chromatography; GL, glycolipids; PL, phospholipids; MGDG, monogalactosyl diglycerides; DGDG, digalactosyl diglycerides; SQDG, sulfiquinovosyl diglycerides; PC, phosphatidylcholine; PE, phosphatidylethanolamine; PI, phosphatidylinositol; PG, phosphatidylglycerol; TAG, triacylglycerols; DAG, diacylglycerols; MAG, monoacylglycerols; ESG, esterified steryl glycosides. Fatty acids are denoted by the number of carbon atoms followed after colon by number of double bonds.

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cis-Canthaxanthin and Other Carotenoid-like Compounds in Canthaxanthin Preparations

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Canthaxanthin is a nonprovitamin A carotenoid used as a food coloring agent, oral skin-coloring agent, and research tool in the investigation of biological effects of carotenoids. Reversed-phase HPLC analyses of extracts of canthaxanthin beadlets, capsules, and tablets showed the presence of four closely eluting compounds with absorption maxima ranging from 450 to 474 nm. One peak cochromatographed with and had an absorption spectrum identical with that of *all-trans*-canthaxanthin, and another had an absorption spectrum identical with that of *cis*-canthaxanthin. The ratio of *all-trans*- to *cis*-canthaxanthin in these preparations was approximately 3:1. *cis*- and *all-trans*-canthaxanthin and the two unknown carotenoid-like compounds were absorbed by chicks when fed in beadlet form, as evidenced by the presence of all four compounds in extracts of chick liver and hepatic membranes. The four compounds had different photosensitivities and may have different biological effects; therefore, determination of isomeric composition may be of importance in the interpretation of studies involving canthaxanthin.

Canthaxanthin (4,4′-diketo-β-carotene) is a naturally occurring carotenoid pigment found in several marine species, birds, edible mushrooms, and algae (Klaui and Bauernfeind, 1981). Canthaxanthin is also used in synthetic form as a color additive in human foodstuffs, as an over-the-counter oral skin-coloring (tanning) agent for human use, as a poultry feed additive to obtain a desired color in body fat and egg yolks, and for a number of research purposes. Canthaxanthin is very similar in structure to the well-known provitamin A carotenoid β-carotene but has no vitamin A activity as both β-ionone rings are substituted with oxygen (Figure 1). Since canthaxanthin cannot be metabolized to retinol, it is a potentially valuable research tool for differentiating carotenoid effects from effects associated with vitamin A.

Canthaxanthin, like most carotenoids, is lipid-soluble and susceptible to oxidative degradation. However, a stabilized beadlet form has been developed that is dispersible in aqueous solutions. These beadlets contain

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