Case study

Nutritional, spectral and thermal characteristic of *Lamiaceae* seeds

ABSTRACT

Aims: Species of the family *Lamiaceae* possess a rich tradition of use for flavoring and medicinal purposes. This paper focusses on the nutritional and thermal characteristics of the seeds from eight *Lamiaceae* species: *Gmelina arborea* Roxb., *Hyptis suaveolens* (L.) Poit., *Leonotis nepetifolia* (L.) R.Br., *Ocimum americanum* L., *Ocimum sanctum* L. (Rama Tulsi), *Ocimum tenuiflorum* L. (Krishna Tulsi), *Origanum vulgare* L. and *Tectona grandis* L.f.).

Methodology: The oil, starch, total polyphenol, flavonoid and mineral contents for aforementioned seeds are determined. The FTIR spectroscopy was used to assess the phytoconstituents. The thermogravimetric/derivative thermogravimetric analyses (TG/DTG) and differential scanning calorimetry (DSC) analyses were performed to analyze the decomposition patterns.

Results: The concentrations of oil, starch, total polyphenol, flavonoids and minerals for eight seeds were ranged from 11.8 to 50.4%, 0.22 to 1.84%, 295 to 5842 mg/kg, 1660 to 12680 mg/kg and 11756 to 33927 mg/kg, respectively. Unsaturated oils, polyphenols and lignin were recognized by vibrational spectroscopy. The sequence of thermal effects in the seed pyrolysis process above 100 ^{o}C have been put in relation to seed protein crystallization (endotherm at 200 ^{o}C), oxidation reactions and degradation of hemicellulose and other fiber components (at around 300 ^{o}C), and decomposition of polyunsaturated (at 357 ^{o}C) and mono-unsaturated (at 391 ^{o}C) triglycerides.

Conclusion: *Lamiaceae* seeds are medicinally potential food alternative to the cereals.

Keywords: *Lamiaceae* seed, FTIR, Thermal analysis, Oil, Starch, Polyphenol, Mineral composition.

INTRODUCTION

The *Lamiaceae* or *Labiatae* (Clade: Angiosperms / Eudicots / Asterids. Order: Lamiales) are a family of flowering plants comprising about 200 genera and 3,200 species, commonly with aromatic, herbage, quadrangular stems, and verticillate inflorescences. They are widely cultivated for medicinal, perfumery, culinary and ornamental purposes. [1] Members of this family are a source of essential oils for flavoring and perfumes include the strong aromatic essential oils, tannins, saponins and organic acids. [2, 3] Eight *Lamiaceae* plants, viz. *Gmelina arborea* Roxb., *Tectona grandis* L.f., *Hyptis suaveolens* (L.) Poit, *Leonotis nepetifolia* (L.) R.Br., *Ocimum americium* L., *Ocimum sanctum* L., *Ocimum tenuiflorum* L. and *Origanum vulgare* L., with a widespread distribution in central India are studied herein. *G. arborea* (Malay bush-beech) and *T. grandis* (Bangkok teak) are large deciduous trees harvested for local use as a wood, food and medicine purposes and as a source of oils. [4, 5] *H. suaveolens* (pignut) is a strong-scented herb considered to be stimulant, carminative, endorific and lactagogue[6], which grows as weed over large areas in barrel land in the rainy season. *L. nepetifolia* (Christmas candlestick) is an annual short-lived perennial plant, often found at roadsides, canal and riversides in the rainy season. Other species: *Ocimum americium* L., *Ocimum sanctum* L. (Rama Tulsi, light holy basil), *Ocimum tenuiflorum* L. (Krishna Tulsi, dark holy basil) and *O. vulgare* are perennial and aromatic plants, used in treatments of various diseases. [7] These plants have shown promising properties as functional foods, in pain therapy and as bactericides and fungicides.[8, 9, 10, 11, 12, 13] The chemistry and uses of *G. arborea* and *H. suaveolens* seed oils have been reported [14, 15], but most of the characteristics of *Lamiaceae* seeds from Indian origin remain undescribed. The purpose of this paper is to report the nutritional, mineral and thermal features of the seeds from the eight selected species.

MATERIALS AND METHODS

Sample Collection

Seeds from the eight *Lamiaceae* plants (viz. *G. arborea* (GA), *T. grandis* (TG), *H. suaveolens* (HS), *L. nepetifolia* (LN), *O. americium* (OA), *O. sanctum* (OS), *O. tenuiflorum* (OT) and *O. vulgare* (OV) under study were collected in the Raipur city area, India (21.25°N 81.63°E), and were authenticated by using a standard monograph. [16] The ripening periods of TG, HS and LN; OA, OS, OT and OV; and GA were October-November, December and May, respectively. Their leaves and fruits were collected in the relevant period together with near-surface soil samples in year, 2017.

Sample Preparation

The seeds were separated from their carpels manually. All samples were sundried for one week in a glass room, and further dried in an oven at 50 ^{o}C overnight. Subsequently, they were crushed into fine powder and sieved out particles of mesh size, ≤100 µm. They were stored in the glass bottle and preserved in the refrigerator at -4 ^{o}C.

Analyses

The pH value of the soil was determined by keeping a 5 g sample in a 100-mL conical flask with deionized water (15 mL) overnight. The pH value of the decanted solution was measured with a Hanna Instruments (Woonsocket, RI, USA) pH meter. The moisture content of the seeds was determined by drying the seeds at 105 ^{o}C in an air oven for 6 hr period to the analysis, and mean values were determined. All characterization results are presented on a dry weight (dw) basis.

The oil content in the seeds was determined by extraction from a 5 g powdered sample (kernel of GA and TG, and whole seed of HS, LN, OA, OS, OT or OV) in n-hexane (25 mL as described in literature. [17] The oil content was presented as a percentage on the basis of the dry weight (dw) of the seeds.

AR grade sodium maleate (CAS 371-47-1) buffer, sodium acetate (CAS 127-09-3) buffer, potassium hydroxide (CAS 1310-58-3), amyl glucosidase (CAS 9032-08-0), pancreatic-α-amylase (MDL MFCD00081319), and glucose oxidase–peroxidase was purchased from Megazyme International Ireland Ltd. The starch content of seeds was determined by the enzymatic method. [18]

Analytical grade Folin-Ciocalteu reagent (MDL MFCD00132625), aluminum chloride (CAS 7446-70-0), tannic acid (CAS 1401-55-4), gallic acid (149-91-7) and quercetin (CAS 117-39-5) for the analysis of the phenols were purchased from Sigma–Aldrich. For the analysis of total polyphenol content (TPC), 100 mg of sample (whole seed of GA, TG, HS, LN, OA, OS, OT or OV) in powder form was mixed with 5 mL of an acetone:water mixture (70:30, v/v), and subjected to sonication for 20 minutes at 20 ^{o}C in an ultrasonic bath, according to the procedure described by *Bertaud* et al.[19] The TPC of each extract was determined by use of the Folin-Ciocalteu reagent and expressed as tannic acid equivalents (TAE). [20] The flavonoid content (Fla) was analyzed by the aluminum chloride method and expressed as quercetin equivalents (QE).[21]

A Bruker Tracer 5i portable X-ray fluorescence (pXRF) spectrometer (Serial Number 900F4473), equipped with a 4W rhodium anode and Xflash Silicon Drift Detector (SSD) with a typical resolution of 2028 channels, was employed for the elemental analysis of the seed samples. Four standard reference materials, brown and white cowpea (*Vigna unguiculata* (L.) Walp.) seeds, cowpea and mango leaves with reference values from ICP-OES and MS (As, Mo and Se in mg/kg) after Aqua Regia (HCl: HNO_3, 4:1) digestion were used for validation of the pXRF results. Whereas, standard soil sample (NCS DC 73382 CRM) was used for the soil analysis to generate the precise data base.

The vibrational spectrum in the 400 to 4000 cm^{-1} spectral range was characterized using a Thermo Scientific (Waltham, MA, USA) Nicolet iS50 Fourier-Transform Infrared (FTIR) spectrometer, equipped with an in-built diamond attenuated total reflection (ATR) system, with a 1 cm^{-1} spectral resolution and 64 scans.

Thermogravimetric/derivative thermogravimetric analyses (TG/DTG) and differential scanning calorimetry (DSC) analyses were conducted with a Perkin-Elmer (Waltham, MA, USA) STA6000 simultaneous thermal analyzer by heating the samples in a slow stream of N_2 (20 mL/min) from room temperature up to 800 ^{o}C, at a heating rate of 20 ^{o}C /min. Pyris v.11 software was used for data analysis.

RESULTS AND DISCUSSION

Seeds Physical Characteristics

The seeds of the eight *Lamiaceae* under study (GA, TG, HS, LN, OA, OS, OT and OV) were colored from yellow to black and featured different shapes, viz. circular, elliptic, lanceolate, ovate and sagittate (**Fig. 1** and **Table 1**). Apropos of seed weights, *Ocimum* seeds were the smallest, with weights ranging from 0.3 to 1.0 mg per seed, whereas LN, HS, GA and TG seeds ranged from moderate to (very) big size, featuring weights from 2.6 to 481 mg per seed. The moisture content of the seeds varied from 4.2% to 8.1% and had a fare correlation with seed mass (r = 0.75).

Oil and Starch Concentration

As noted above, the oil from *Lamiaceae* seeds has wide medicinal uses. In the seeds from the eight species discussed herein, oil contents ranged from 11.8% to 50.4% (**Table 1**). Among them, GA and TG seeds were highly oily, with lipid fractions in the 41.2 to 50.4% range. Similar composition of oils in some Ocimum GA and TG seeds were reported. [22, 23]

The concentration of total starch in the eight seeds ranged from 0.22% to 1.84%. Four seeds –GA, LN, OM and TG– showed low starch contents (1.24 to 1.84%), while in other seeds it was contained at trace levels (0.22 to 0.64%). The concentration of resistant starch in the seeds ranged from 0.03% to 1.13%, with a high fraction of insoluble starch in seven of the seeds (except for GA), varying from 17% to 78%.

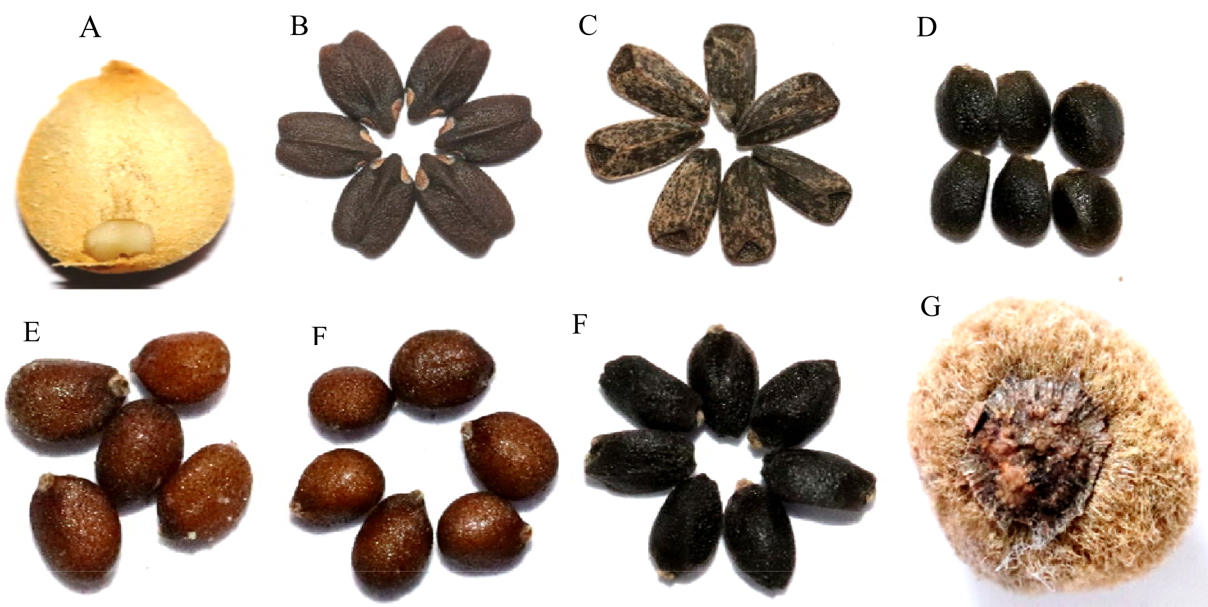


Fig. 1: Seed image: (A) *Gmelina arborea*, (B) *Hyptis suaveolens*, (C) *Leonotis nepetifolia*, (D), *Ocimum americum*, (E) *Ocimum sanctum*, (F) *Ocimum tenuiflorum*, (G) *Origanum vulgare* L., and (H) *Tectona grandis*.

Phenol Concentration

The TPC and Fla contents in the *Lamiaceae* seeds varied from 295 to 5842 mg/kg and from 1660 to 12680 mg/kg (in TAE and QE, respectively). These contents were noticeably lower than the TPC and Fla concentration in their leaves, which varied from 15406 to 29900 mg/kg and from 9804 to 34800 mg/kg, respectively. The basil (*Ocimum*) and *T. grandis* species were the richest in flavonoids.

Mineral Concentration

The sum of the concentrations of the 19 elements under analysis (P, S, Cl, K, Rb, Mg, Ca, Sr, Ba, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Mo and Pb) in the GA, HS, LN, OA, OS, OT, OV and TG seeds was found to be 11756, 22629, 30977, 23586, 27133, 18641, 33927 and 22077 mg/kg, respectively. Their reduced concentration in the GA seeds (whole seed, including the carpel) was noticed.

P, S, K, Rb, Mg, Ca, Sr, Mn, Fe, Cu and Zn were detected in all eight seeds, and were in the 2954 to 6829, 884 to 2543, 3304 to 16284, 4 to 17, 1047 to 2862, 567 to 11368, 6 to 94, 10 to 68, 86 to 1239, 7 to 49 and 11 to 120 mg/kg range, respectively (**Table 1**). Cobalt was identified in all seeds (except GA and LN) at traces level, 1 mg/kg. Barium was detected in HS, OA and OS seeds at low levels (ranging from 13 to 25 mg/kg). Other toxic elements, such as Ti, V, Cr, Mo and Pb, were detected in the OS seeds also at low levels, in the range of 2 - 70 mg/kg. Clusters of mineral elements at high concentrations were identified for the seeds of three species: P-Mg-Ca-Mn, for LN; Rb-Sr-Ti-V-Cr-Fe-Mo-Pb, for OS; and S-Cu, for HS. The maximum K and Zn concentrations were detected in the OV and GA seeds.

For comparative purposes, the concentration of trace elements in the leaves of HS was tested. Their total concentrations were remarkably higher in the leaves, 42241 mg/kg, probably due to coordination with polyphenols. Elements i.e. S, Cl, K, Mg, Ca and Fe were the dominated elements in the leaves. The concentration of elements i.e. P, S, Cl, K, Rb, Mg, Ca, Sr, Ti, Cr, Mn, Fe, Mo and Pb in the dried HS leaves was found to be 820, 1925, 6733, 24376, 6, 1979, 5028, 50, 114, 11, 175, 1020, 4 and 4 mg/kg.

Table 1. Physico-chemical characteristics of Lamiaceae seeds

Parameter	Gmelina Arborea	Hyptis Suaveolens	Leonotis Nepetifolia	Ocimum Americum	Ocimum Sanctum	Ocimum Tenuiflorum L.	Origanum Vulgare L.	Tectona Grandis
Color	LY	DBr	SBl	B	DBr	DBr	B	LBr
Shape	Obovate	Sagitate	Lanceolate	Narrow ovate	Broad ovate	Broad ovate	Elliptic	Circular
Mass, mg	94.7	5.0	2.6	1.1	0.3	0.3	1.0	481
Moisture,%	7.5	6.4	4.2	4.9	5.2	5.5	4.2	8.1
Oil,%	50.4	17.2	30.3	13.4	12.7	11.8	14.8	41.2
Total starch, %	1.42	0.22	1.84	1.82	0.45	0.62	0.64	1.24
Resistant starch, %	0.03	0.08	0.31	1.13	0.31	0.34	0.50	0.41
Percentage of resistant starch, %	2.1	36	17	62	69	55	78	33
Seed (Leaf), TPh, mg/kg	1447 (21476)	4181 (23875)	3538 (16042)	2117 (15406)	295 (28900)	5842 (25898)	750 (29900)	4904 (25580)
Seed (Leaf), Fla, mg/kg	1660 (34800)	2420 (9804)	2260 (16538)	4080 (9966)	12680 (18900)	4280 (24295)	2880 (28900)	5900 (21548)
P, mg/kg	4880	3634 (820)	6829	4631	3983	3630	4738	2954
S, mg/kg	1507	2543(1925)	2235	1940	1678	1537	2096	884
Cl, mg/kg	ND	ND (6733)	ND	ND	ND	ND	183	ND

K, mg/kg	3304	4355 (24376)	7165	7775	6950	5544	16284	11816
Rb, mg/kg	10	6 (6)	11	9.0	17	14	7.0	4.0
Mg, mg/kg	1047	2070 (1979)	2862	1804	2775	1189	2339	1120
Ca, mg/kg	567	9736 (5028)	11368	7201	10186	6363	7917	5060
Sr, mg/kg	6	21(50)	29	59	94	18	29	26
Ba, mg/kg	ND	14	ND	13	25	ND	ND	ND
Ti, mg/kg	ND	ND (114)	ND	ND	70	ND	ND	ND
V, mg/kg	ND	ND	ND	ND	2.0	ND	ND	ND
Cr, mg/kg	ND	ND(11)	ND	ND	5.0	ND	ND	ND
Mn, mg/kg	66	44 (175)	68	10	43	21	25	34
Fe, mg/kg	219	145 (1020)	346	86	1239	255	235	160
Co, mg/kg	ND	1.0	ND	1.0	1/0	ND	1.0	1.0
Cu, mg/kg	30	49	36	12	13	13	30	7.0
Zn, mg/kg	120	11	28	45	48	57	43	11
Mo, mg/kg	ND	ND (4)	ND	ND	2.0	ND	ND	ND
Pb, mg/kg	ND	ND (4)	ND	ND	2.0	ND	ND	ND

LY = Light yellow, DBr = Dark brown, SBl = Salty black, B = Black, DBr = Dark brown, LBr = Light brown

Bioaccumulation

The pH value of soil solutions (n = 8) was ranged from 7.5 to 8.9, with a mean value (p = 0.05) of 8.1 ± 0.4. The concentrations of Cl, P, S, K, Rb, Mg, Ca, Sr, Mn, Fe, Cu and Zn elements were in the following ranges: 109 to 161, 118 to 185, 190 to 280, 1101 to 1170, 3 to 8, 1180 to 1740, 4480 to 7852, 40 to 59, 1000 to 1480, 13400 to 19700, 30 to 58 and 17 to 28 mg/kg, respectively (with mean values of 138 ± 13, 154 ± 16, 243 ± 22, 1504 ± 137, 6 ± 1, 1504

± 137, 6402 ± 800, 51 ± 5, 1278 ± 117, 17055 ± 1549, 48 ± 6 and 24 ± 3 mg/kg, respectively). Among them, K, Mg, Ca, Mn and Fe were the dominated elements in the near-surface soil.

Three nutrients (P, S ad K) were found to be hyperaccumulated in all seeds with respect to their mean soil values, with bioaccumulation factors in the range of 19 to 44, 4 to 10 and 2 to 11, respectively (with mean values of 29, 7 and 6, respectively). On the other hand, in HS leaves, Cl and K were the elements that were strongly hyperaccumulated (bioaccumulation factors of 49 and 17, respectively).

Correlation Coefficients

The taxonomy of eight *Lamiaceae* plants under study are different, and they can be grouped into three classes: (*i*) GA and TG; (*ii*) HS and LN; and (*iii*) OA, OS, OT and OV. The correlation coefficient values for the different parameters under analysis were computed for group (*iii*) and are shown in **Table 2**. A high correlation among oil, S, P, K and Cl nutrients was found. Several elements (Mg, Ca, Sr, Ba, Ti, V, Cr, Mn and Fe) featured high correlations, suggesting their role as cofactor elements in the bioaccumulation of each other. Rb co-factor element showed a good correlation with heavy metals (Ti, V, Cr, Fe, Cu, Zn, Mo and Pb), while Co cofactor element had a high correlation with P, S, Mg, Ca and Sr. Elements i.e. Rb, Mg, Ca, Sr, Ba, V, Cr, Mn, Mo and Pb had an excellent correlation in their accumulation pattern.

Table 2: Correlation coefficient matrix for the Lamiaceae seed elements

	Oil	Sta	TPh	P	S	Cl	K	Rb	Mg	Ca	Sr	Ba	Ti	V	Cr	Mn	Fe	Co	Cu	Zn	Mo	Pb
Oil	1																					
Sta	0.16	1																				
TPh	-0.68	0.03	1																			
P	0.93	0.52	-0.62	1																		
S	0.97	0.38	-0.61	0.98	1																	
Cl	0.86	-0.26	-0.40	0.62	0.75	1																

K	0.94	-0.12	-0.52	0.75	0.85	0.98	1															
Rb	-0.80	-0.50	0.15	-0.85	-0.87	-0.69	-0.75	1														
Mg	0.48	-0.30	-0.95	0.36	0.37	0.30	0.39	0.12	1													
Ca	0.14	-0.40	-0.80	0.03	0.03	0.00	0.07	0.46	0.94	1												
Sr	-0.07	0.04	-0.66	0.02	-0.07	-0.41	-0.29	0.50	0.73	0.85	1											
Ba	-0.20	0.06	-0.56	-0.08	-0.19	-0.53	-0.41	0.58	0.64	0.80	0.99	1										
Ti	-0.25	-0.46	-0.52	-0.33	-0.36	-0.33	-0.30	0.77	0.73	0.92	0.86	0.86	1									
V	-0.25	-0.46	-0.52	-0.33	-0.36	-0.33	-0.30	0.77	0.73	0.92	0.86	0.86	1.00	1								
Cr	-0.25	-0.46	-0.52	-0.33	-0.36	-0.33	-0.30	0.77	0.73	0.92	0.86	0.86	1.00	1.00	1							
Mn	-0.12	-0.80	-0.46	-0.37	-0.31	0.01	-0.02	0.67	0.71	0.86	0.56	0.53	0.89	0.89	0.89	1						
Fe	-0.27	-0.58	-0.47	-0.40	-0.40	-0.28	-0.27	0.79	0.71	0.90	0.78	0.78	0.99	0.99	0.99	0.94	1					
Co	0.72	0.28	-0.95	0.78	0.73	0.33	0.49	-0.33	0.81	0.63	0.63	0.53	0.33	0.33	0.33	0.18	0.25	1				
Cu	0.83	-0.31	-0.39	0.58	0.71	1.00	0.97	-0.65	0.31	0.02	-0.41	-0.53	-0.31	-0.31	-0.31	0.05	-0.24	0.31	1			
Zn	-0.90	-0.34	0.86	-0.93	-0.92	-0.57	-0.71	0.62	-0.66	-0.39	-0.33	-0.22	-0.03	-0.03	-0.03	0.04	0.04	-0.94	-0.53	1		
Mo	-0.25	-0.46	-0.52	-0.33	-0.36	-0.33	-0.30	0.77	0.73	0.92	0.86	0.86	1.00	1.00	1.00	0.89	0.99	0.33	-0.31	-0.03	1	
Pb	-0.25	-0.46	-0.52	-0.33	-0.36	-0.33	-0.30	0.77	0.73	0.92	0.86	0.86	1.00	1.00	1.00	0.89	0.99	0.33	-0.31	-0.03	1.00	1

Vibrational Characterization

The ATR-FTIR spectra of the seeds samples under study are depicted in **Fig. 2**. The main bands and their assignments are summarized in **Table 3**. Peaks at around 3300 (ν O-H) are characteristic absorption bands from cellulose.[25] Other prominent bands attributed to cellulose are those at 1317-1305 cm^{-1} (C-H vibration), 1159-1154 cm^{-1} (*ν* C-O-C in bridge, asymmetric), 1059-1057 cm^{-1} (>CH-O-CH_2), 1035-1027 cm^{-1} (*ν* C-O), 921-896 cm^{-1} (*ν* C-O-C in bridge, symmetric) and 668-665 cm^{-1} (*β*-glycosidic linkage). Peaks indicative of the presence of hemicellulose are those which appear at 1644-1637 cm^{-1} (C=O stretching), 1378-1377 cm^{-1} (-CH_3 symmetric deformation) and 1240 - 1236 cm^{-1} (C-C-O asymmetrical stretching from acetylated glucomannan). Peaks at 2924 - 2922 cm^{-1} (–CH_2 stretching) and 2854 - 2853 cm^{-1} (-CH stretching) indicate the presence of cutine and wax. The peak that appears at 1651 cm^{-1} can be attributed to C=C absorption of cellulose when it is cross-linked and dehydrated, but it also may also appear when the samples are rich in unsaturated oils. This band can be put in relation with the band at 1738 cm^{-1} (C=O stretching), typical of hemicellulose, but which may also be associated with the stretching vibration of the ester carbonyl functional groups of triglycerides. The presence of this band, typical of the vinyl group, could justify the quantitative presence of unsaturated oils in the seeds under study. The sharp, intense C-H wags at 1000 - 997 cm^{-1} are also indicative of vinyl. The bands that appear in *T. grandis* sample at 1606 cm^{-1} (aromatic ring stretching) and at 896 cm^{-1} are typical of lignin. The bands at 1520 - 1505 cm^{-1} (aromatic skeletal vibration) are also typical of lignin. The presence of pectin is indicated by peaks at 1457 - 1455 cm^{-1} (associated with O-CH_3 stretching) for pectic ester and at 1417 - 1411 cm^{-1} (COO^- symmetric stretching vibration) for calcium pectate.[26] Bands near 921 - 916 cm^{-1} probably correspond to α-glycosidic linkage. The bands at 1710 cm^{-1} (conjugated C=O), 1436 cm^{-1} (CH_2 scissoring, known as the marker of crystallinity) and 814 cm^{-1} (aromatic C-H out-of-plane binding or to C-O-C deformation) are not assigned to a particular plant fraction or component. The band at 721 cm^{-1} (due to O-C=O in-plane deformation or a CH_2 rocking deformation) is attributed to phenolic components.

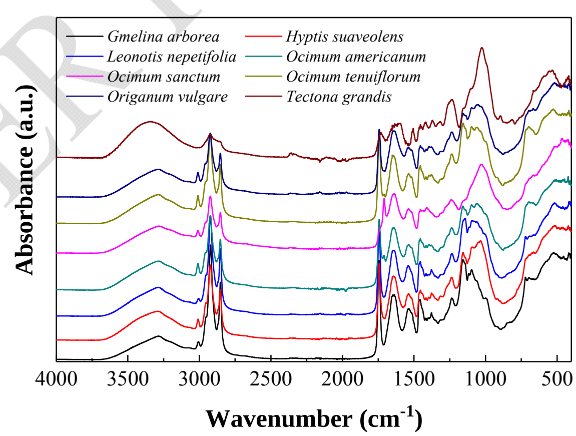


Fig. 2: ATR-FTIR spectra of seed samples from species of the *Lamiaceae* family. Some offset has been added to the *y* axis for clarity purposes.

An interesting feature for the *Lamiaceae* is that they show vibrational spectra similar to those exhibited by other families of the Asterid clade (*Sapotaceae* and *Asteraceae*). Bands at 1651 cm^{-1} and 1644 - 1637 cm^{-1} are in good agreement with those exhibited in *Sapotaceae* for their kernel and coat fractions, respectively. The absence of the bands at 1015 cm^{-1} and ~878 cm^{-1} (apart from that of 795 cm^{-1}) is also a common feature with the *Asteraceae*. The absence of bands at 1574, 1563, 1336, 1138, 1076, 857, 778 and 757 cm^{-1} has been previously observed for *Salvia hispanica* L.[27]

Table 3: Main absorption bands in the ATR-FTIR spectra of seed samples from eight species of the *Lamiaceae* family and their assignments (all wavenumbers are expressed in cm^{-1}).

Gmelina arborea kernel	*Hyptis suaveolens* whole seed	*Leonotis nepetifolia* whole seed	*Ocimum americanum* whole seed	*Ocimum sanctum* whole seed	*Ocimum tenuiflorum* whole seed	*Origanum vulgare* whole seed	*Tectona grandis* whole seed	Assignments
3284	3294	3289	3289	3282	3288	3289	3345	O-H stretching (cellulose)
2922	2924	2922	2924	2924	2924	2924	2923	$–CH_2$ stretching (cutine, wax and pectin)
2853	2954	2853	2854	2853	2853	2853		$–CH_2$ stretching (cutine and wax)
1745	1744	1744	1743		1743	1743	1738	C=O stretch (uronic ester groups in hemicellulose)
		1710	1709	1710				C=O stretching of aldehyde/ketone
	1651				1651		1651	C=C (cellulose) / COO^- symmetric stretching
1637	1644	1640	1644	1639	1645	1640		C=O stretching (hemicellulose)
							1600	C=C-C=C (cellulose) / aromatic ring stretching (lignin)
1535	1538	1540	1537	1539	1538	1539	1538	COO^- symmetric stretching
			1519		1520	1520	1505	aromatic skeletal
1457	1456	1456	1455	1455	1456	1455	1455	$O-CH_3$ stretching
				1436				CH_2 scissoring
								COO^- stretching / typical

	1417	1417	1417	1411	1417	1416	1417	of pyranoside
	1397		1393			1393		CH rocking
1377	1377	1378	1378	1378	1378		1372	$-CH_3$ symmetric deformation (hemicellulose)
								stretching vibration of C-H bending in the CH_2
	1315		1305		1307	1312	1317	C-H (cellulose)
1235	1238	1236	1237	1240	1236	1236	1236	C-C-O asymm stretching, acetylated glucomannan
1158	1158	1143	1159		1158	1156	1154	C-O-C in bridge, asymmetric (cellulose)
1117								C-O (cellulose)
1096	1096	1094	1097		1097	1097	1097	C-O-C stretch in pyranose / fructose and sucrose
			1057		1059	1058		$>CH-O-CH_2$ (cellulose) / -C-O-H (fructose)
	1035			1027			1027	C-O stretching (cellulose) / -C-O-H (glucose)
997					1001			C-H wags, vinyl
	916				921		896 814	C-O-C symmetric / glycosidic linkages (cellulose)
								aromatic C-H out-of-plane binding or C-O-C deformation
721		721						O-C=O in-plane def. or a CH_2 rocking deformation
698		691	695	694	699	695		*cis* C=C
	665	668		665		668	666	*β*-glycosidic linkage (cellulose)
525	510	518	506		525	518		saccharide moieties

Thermal Characterization

Differences in weight loss for the different seeds of the *Laminaceae* family can be observed in the TG curves depicted in **Fig. 3Fig**. Additional DTG peaks and DSC thermal effects are shown in **Fig. 4**. The main endotherm at around 110 ^{o}C can be related both to dehydration and to gelatinization of starch (an order-disorder transition for the starch/moisture system). The small endotherm at around 200 °C indicates seed protein crystallization to β-crystals accompanied by the random-coil → β-form conformational transition. The chain of thermal events above 240 °C began with those related to oxidation reactions, followed by those attributed to the degradation of hemicellulose and other fiber components (at around 300 °C), and by those associated with the decomposition of the polyunsaturated (at 357 °C) and mono-unsaturated (at 391 °C) triglycerides. The very slow weight loss above 450 °C can be attributed to remaining lignin mass loss.

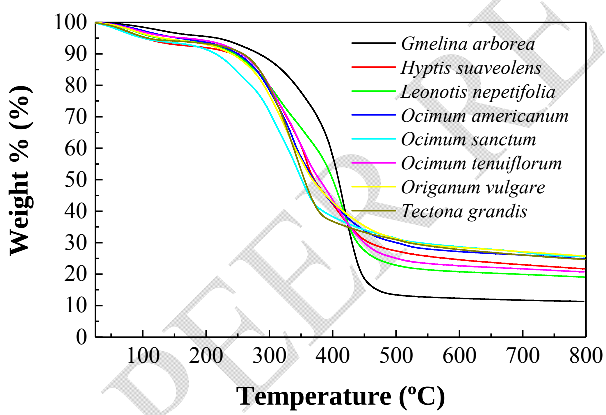


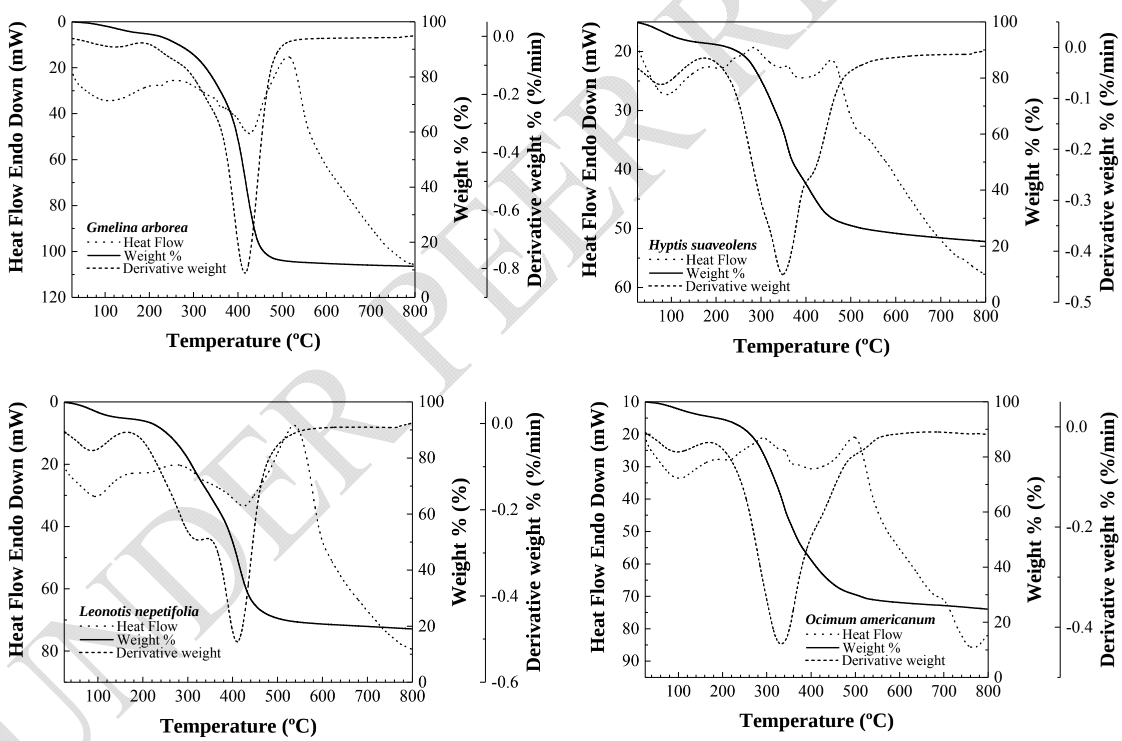
Fig. 3: Comparison of TG curves for seeds from eight species of the *Lamiaceae* family.

CONCLUSIONS

The nutritional potential of the seeds from eight *Lamiaceae* species was assessed by determining proximate and phytochemical composition. Results indicated that the oil contents ranged from 11.8 to 50.4 mg/kg, with the highest levels for *G. arborea* and *T. grandis*. Total polyphenols varied from 295 to 5842 mg/kg (lower than in leaves) and mineral elements from 11756 to 33927 mg/kg (with concentration following the Ca>K>P>S>Mg>Fe>Zn sequence).

Three main nutrients (P, S and K) were found to be hyperaccumulated in all seeds with respect to their mean soil values. Some toxic elements as Ba and Pb were found, albeit at low levels. These results suggest that the seeds of the *Lamiaceae* studied species can be nutritive despite the presence of some toxic components.

The thermal profiles displayed by basil species (*O. americium*, *O. tenuiflorum*, *O. sanctum*) and *O. vulgare* differed from those of *H. suaveolens*, *L. nepetifolia* and *T. grandis*, and all of them were clearly distinguishable from that of *G. arborea*. Differences should be related to lipids (tryglycerides) and lignin contents.



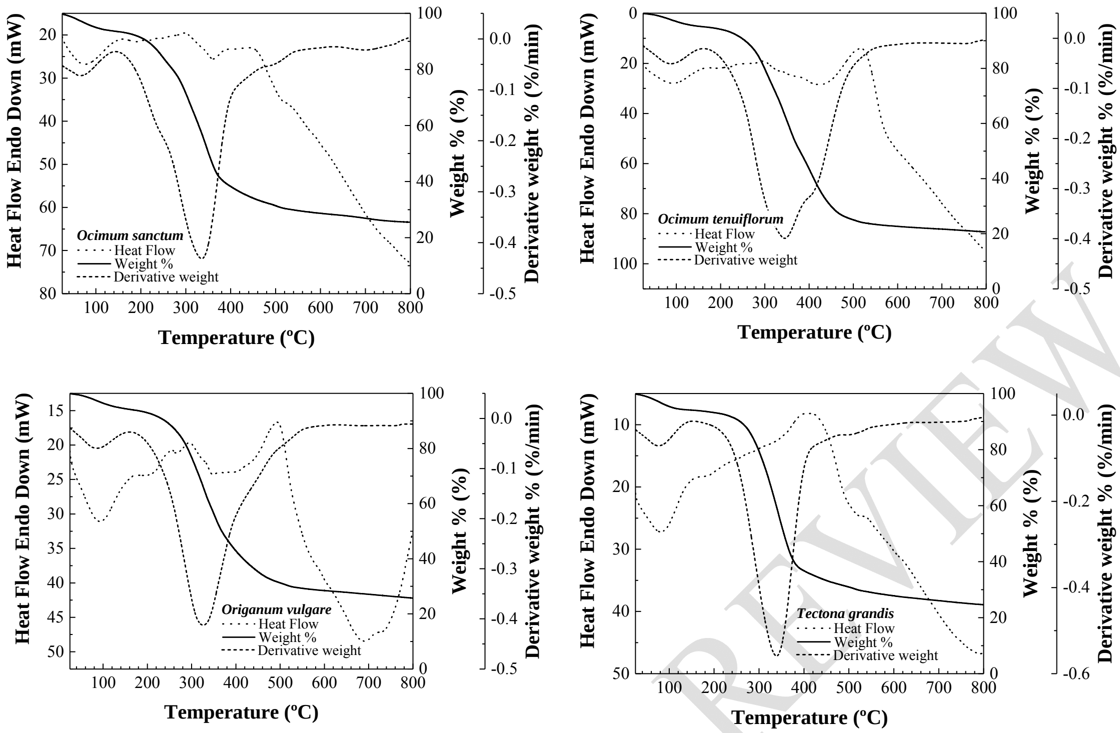


Fig. 4: TG (*solid line*), DTG (*dashed line*) and DSC (*dotted line*) curves for seeds from eight species of the *Lamiaceae* family.

CONSENT

Not applicable.

ETHICS APPROVAL

Not applicable.

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