Peumo (Cryptocarya alba), a Native Fruit of Chile

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The peumo (*Cryptocarya alba*) is a native fruit from central Chile that belongs to the Lauraceae family. To characterize the development and the potential health benefits of this edible fruit, quality and physiological parameters, along with antioxidant capacity, were evaluated during three clearly defined developmental stages of the fruit in two seasons.

functional food antioxidants peumo

1. Background

The peumo [*Cryptocarya alba* (Molina) Looser] is a Chilean Lauraceae tree with an endemic spread from Maule to the Araucania Regions. It is considered a threatened species in some areas of Chile, mainly due to overexploitation and habitat destruction [1]. Concerning its ecological importance, peumo is one of the representative species of the sclerophyllous forest of the central zone of Chile, including boldo (*Peumus boldus*), quillay (*Quillaja saponaria*), and hawthorn (*Acacia caven*) [2]. All sclerophyllous species are frequently used in low water consumption gardens. Likewise, quillay and boldo are species with interesting pharmacological and industrial applications of their compounds, being an important source of saponins [3] and boldine [4], respectively.

Despite no agro-industrial use, peumo leaves have been used in traditional medicine like infusion or ointment [2][5]. On the other hand, this tree has beautiful and pink-colored berries (**Figure 1**), called peumos, collected and consumed by the Mapuche Amerindians, principally as a cold infusion, since pre-Colombian times. This fruit is composed of edible and pink skin, with intense flavor and aroma at maturity, and a large seed like a nut; these characteristics have allowed its gastronomic use in recent years [2].

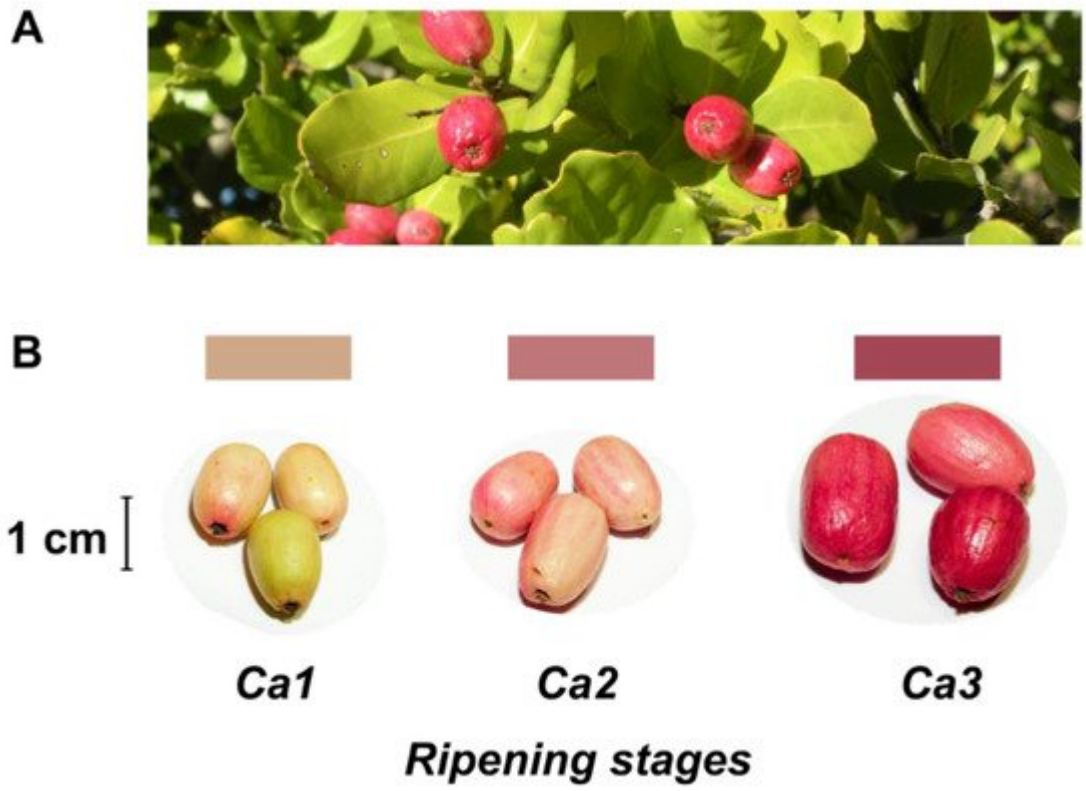

Figure 1. Leaves and fruits of peumo tree. (**A**) Leaves and fruits of peumo [*Cryptocarya alba* (Molina) Looser]; (**B**) Three different development stages of peumo fruit. Photography credit: Lida Fuentes.

The essential oil of this species was reported to be composed mainly of 1-terpinen-4-ol and p-cimol [6], while the cryptofolione derivative has been the only compound isolated from the edible fruits [7]. Domínguez and Martínez (2002) [8] reported that the peumo fruit skin has many polyphenols, but it is unclear if this potential is linked to a particular genotype. Simirgiotis (2013) [9] reported a high antioxidant capacity (9.12 ± 0.01 mg·mL^{-1}), determined by DPPH assay in ripe fruit and flavonoid glycosides, phenolic acids, anthocyanins, and flavonoid aglycons as the major phenolic compounds in fruit and aerial parts of peumo extracts.

The antioxidant capacity of native Chilean fruits like murtilla (*Ugni molinae* Turcz.) (10,770 ± 453), maqui (*Aristotelia chilensis* (Molina) Stuntz) (19,850 ± 966), and calafate (*Berberis* sp.) (25,662 ± 3322), determined by oxygen radical absorbance capacity (ORAC: µmol TE/100 g fresh weight), has been described as higher than commercial berries such as raspberries (6903 ± 1019), blueberries (8869 ± 334), and blackberries (9043 ± 1253) [10]. Furthermore, this antioxidant capacity has been associated with a high functional potential [10][11][12]. Likewise, water-soluble extracts of maqui berry have been reported to prevent the oxidation of copper-induced low-density lipoprotein (LDL), adipogenesis, and inflammatory actions, and to protect human endothelial cell cultures [12][13][14][15][16].

The quality, physiological parameters, and potential health benefits of many attractive native fruits could be affected by inadequate handling postharvest. Therefore, knowledge about the fruit's physiological and physicochemical parameters before studying the healthy potential of native fruit is relevant.

2. Characterization of Quality and Physiological Parameters during Fruit Development of the Peumo Fruit

The present study classified three developmental stages of peumo (*C. alba*) fruits (**Figure 1**). A constant boost in fruit fresh and dry weights was registered according to ripening during the first harvest season, and non-significant differences between Ca2 and Ca3 stages were observed during the second season (**Table 1**). The water activity displays non-significant differences during ripening, with a similar decrease throughout both seasons. The fruit length increased during both seasons, while the diameter only increased for the 2017 season; despite the above, the fruits have a thin shape in all analyzed stages and both seasons (**Figure 1**, **Table 1**). The fruit firmness displays a constant reduction during ripening in both seasons, with firmness in ripe fruit near 5 N (**Table 1**).

Table 1. Changes in physicochemical and physiological parameters during fruit development of peumo fruit for the 2017 and 2018 harvest seasons.

Parameter	Developmental Stages					
	Harvest Season 2017			Harvest Season 2018		
	Ca1	Ca2	Ca3	Ca1	Ca2	Ca3
Ethylene production	nd*	nd*	nd*	nd*	nd*	nd*
Oxygen consumption (mg Kg^{-1} h^{-1})	6.73 ± 0.00 a	5.85 ± 0.04 b	1.88 ± 0.04 c	6.98 ± 0.01 a	5.99 ± 0.02 b	2,07 ± 0.02 c
CO_2 production (mg Kg^{-1} h^{-1})	8.53 ± 0.00 a	7.49 ± 0.04 b	3.29 ± 0.04 c	6.86 ± 0.04 a	6.43 ± 0.02 b	5.30 ± 0.51 c
Firmness (N)	7.54 ± 0.20 a	5.99 ± 0.23 b	4.97 ± 0.15 c	7.93 ± 0.76 a	6.04 ± 1.14 b	5.03 ± 0.65 c
pH	5.66 ± 0.00 c	5.75 ± 0.00 b	5.90 ± 0.01 a	6.12 ± 0.05 a	6.26 ± 0.02 a	6.26 ± 0.03 a
TA (%)	nd*	nd*	nd*	nd*	nd*	nd*
SSC (°Brix)	24.72 ± 2.18 b	32.50 ± 1.78 a	38.06 ± 4.16 a	30.00 ± 2.50 a	25.83 ± 1.44 a	29.17 ± 1.44 a
Length (cm)	1.25 ± 0,02 b	1.34 ± 0.02 b	1.59 ± 0.05 a	1.76 ± 0.10 b	2.08 ± 0.04 a	2.10 ± 0.04 a
Diameter (cm)	0.91 ± 0.02 c	0.97 ± 0.01 b	1.08 ± 0.02 a	1.21 ± 0.04 a	1.25 ± 0.02 a	1.22 ± 0.01 a
L/D	1.38 ± 0.02 b	1.38 ± 0.02 b	1.47 ± 0.03 a	1.45 ± 0.05 b	1.66 ± 0.02 a	1.73 ± 0.05 a
FW (g)	0.58 ± 0.03 c	0.79 ± 0.02 b	1.19 ± 0.05 a	1.75 ± 0.17 a	2.08 ± 0.08 a	1.99 ± 0.05 a

Parameter		Developmental Stages					
		Harvest Season 2017			Harvest Season 2018		
		Ca1	Ca2	Ca3	Ca1	Ca2	Ca3
DW (g)		0.32 ± 0.02 c	0.46 ± 0.01 b	0.69 ± 0.03 a	1.07 ± 0.11 a	1.26 ± 0.06 a	1.13 ± 0.03 a
$Humidity_{wet\ basis}$		43.10 ± 0.43 a	41.77 ± 0.54 b	40.34 ± 0.47 b	42.29 ± 0.46 a	41.35 ± 1.20 a	40.70 ± 0.63 b
$Humidity_{dry\ basis}$		75.76 ± 0.29 a	71.74 ± 0.05 b	67.61 ± 0.07 b	73.27 ± 0.16 a	70.49 ± 0.55 a	66.86 ± 0.12 b
Water activity		0.81 ± 0.01 a	0.78 ± 0.02 a	0.77 ± 0.04 a	0.78 ± 0.02 a	0.76 ± 0.02 a	0.78 ± 0.05 a
Color (CIElab*)	L*	69.67 ± 0.88 a	67.13 ± 1.08 a	68.21 ± 1.20 a	71.83 ± 0.82 a	58.17 ± 1.03 b	43.14 ± 1.10 c
	a*	10.66 ±1.28 b	14.19 ± 1.81 a	13.43 ± 1.89 a	10.64 ± 0.78 c	29.44 ± 1.04 b	41.14 ± 0.76 a
	b*	19.36 ± 0.63 a	20.05 ± 1.38 a	17.80 ± 1.31 b	18.57 ± 0.48 a	11.70 ± 0.59 b	11.10 ± 0.28 b
	C	22.10 ± 1.43 a	24.56 ± 2.28 a	22.31 ± 2.30 a	21.07 ± 2.47 c	31.87 ± 0.98 b	42.61 ± 0.77 a
	h°	61.16 ± 0.56 a	54.71 ± 1.03 b	52.97 ± 1.17 b	60.27 ± 2.30 a	21.92 ± 1.49 b	15.12 ± 0.33 c

Data correspond to the mean ± SE. Different letters point to significant differences between developmental stages in each harvest season ($p \leq 0.05$). SSC, soluble solids content; TA, titratable acidity; FW, fresh weight; L/D, length and diameter ratio; DW, dry weight. Statistical analysis: One-Way ANOVA. Tukey ($p < 0.05$). nd*, not detected.

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Concerning color changes during fruit development of the peumo (**Table 1**), the hue angle (h°) displayed a significant decrease during ripening in both seasons. In contrast, the L* and b* decreased significantly only in the second season. A higher increase of a* in the ripe stage was observed in the 2018 season. Nevertheless, the instrumental color obtained suggests the increase in red color during peumo ripening; the obtained data were not precise according to the visual color (**Figure 1**).

In the present study, the CO_2 production of fruits decreases continually until the end of ripening during both seasons (**Table 1**). Indeed, ethylene production was not detected at any stage of peumo fruits (**Table 1**) in both seasons, suggesting a fruit's non-climacteric behavior.

3. Antioxidant Capacity, Total Polyphenol, and Flavonoid Content during Fruit Development of the Peumo Fruit

Determinations of total antioxidant capacity by four different methods (FRAP, TEAC, DPPH, and ORAC assays) indicated that the increase in antioxidant capacity, according to the ripening progress, displayed significant differences between the Ca1 and Ca3 stages. This trend was similar to those observed for total polyphenols content (TPC) and total flavonoids content (TFC) (**Table 2**). However, no differences were observed in the ORAC

method for the second season. The TPC in ripe peumo was near 17 mg GA/g FW, and TFC was near 9 mg QE/g FW in both seasons; these values were higher than those determined for ripe blueberries in the 2018 season (TPC:2.75 mg GA/g FW and TFC: 2.12 mg QE/g FW).

Table 2. Total polyphenol content (TPC), total flavonoid content (TFC), antioxidant capacity by FRAP, TEAC, DPPH, and ORAC methods, during the development of peumo fruits for the 2017 and 2018 harvest seasons. GAE, gallic acid equivalent; QE, quercetin equivalent; TE, trolox equivalent.

Development Stage	TPC [mgGAE/gFW]		TFC [mgQE/gFW]		FRAP [µmol $FeSO_4$/gFW]		TEAC [mmol TE/gFW]		DPPH [IC_{50} µg/mL]		ORAC [mmol TE/gFW]	
Season 2017												
Ca1	11.19 ± 0.7.4	b	7.34 ± 0.27	c	28.62 ± 0.95	b	4.34 ± 0.34	c	6.84 ± 0.17	b	n.a.	
Ca2	13.70 ± 1.03	b	8.52 ± 0.33	b	35.96 ± 0.36	a	7.23 ± 0.32	b	6.89 ± 0.54	b	n.a.	
Ca3	17.87 ± 1.57	a	9.21 ± 0.28	a	38.34 ± 0.33	a	8.09 ± 0.22	a	8.72 ± 0.14	a	n.a.	
Season 2018												
Ca1	12.85 ± 1.16	c	6.98 ± 0.21	c	29.49 ± 2.36	b	5.02 ± 0.39	b	7.69 ± 0.90	b	0.208 ± 0.010	a
Ca2	15.15 ± 0.71	a	8.46 ± 0.39	b	35.94 ± 1.23	a	7.12 ± 0.18	a	7.09 ± 0.19	a	0.199 ± 0.002	a
Ca3	17.61 ± 0.60	a	9.44 ± 0.18	a	37.08 ± 0.75	a	7.91 ± 0.30	a	8.35 ± 0.53	a	0.188 ± 0.002	a
Blueberry	2.75 ± 0.2		2.12 ± 0.44		4.95 ± 0.28		1.25 ± 0.30		11.36 ± 0.96		0.032 ± 0.000	

Data correspond to the means ±SE of four replicates of fruit mix for each stage and season. Different letters point to significant differences between developmental stages in each parameter ($p \leq 0.05$). n.a., not analyzed.

The principal component analysis (PCA) of antioxidant capacity for the 2017 (**Figure A1**A) and 2018 (**Figure A1**B) harvest seasons describes a similar behavior for FRAP, TFC, and TEAC analysis. However, DPPH and TPC have different behavior for each season, with a high correlation with the other antioxidant variables in the 2017 season and a mainly orthogonal location (not correlated) for 2018 season. The correlation between antioxidant analysis for the 2017 (**Table A1**) harvest season describes a significant correlation, where FRAP, TEAC, and TFC are the most correlated. Nevertheless, we have a different correlation for the 2018 (**Table A2**) season, where TPC and DPPH describe not correlated behavior. However, FRAP, TEAC, and TFC still present a positive correlation between them in the season.

4. Composition of Peumo Fruit Extract

The chemical composition of peumo fruit extract was determined by non-target analysis using U-HPLC/MS LTQ in both positive and negative modes (**Figure 2**). Identified compounds (**Table 3**) included many flavonoids, alkaloids, and lignins. The main part of flavonoids was represented by quercetin and its derivatives and metabolites, followed by proanthocyanidins (namely procyanidins), phenols (catechin and epicatechin) and polyphenols (chlorogenic acid and its analogue, 4-caffeoylquinic acid), flavones (luteolin 7-O-glucuronide, sexangularetin), and other flavonoids. Lignans were represented by 4-O-methylcedrusin and (+)-lariciresinol. Alkaloids were represented by cryprochine and its stereoisomer. The high content of flavonoids could be responsible for the antioxidant and anti-inflammatory activity of peumo extract. Also, the ORAC value of peumo extract (500 mg/mL) was 0.637 ± 0.061 mmol/g DW (**Table 3**).

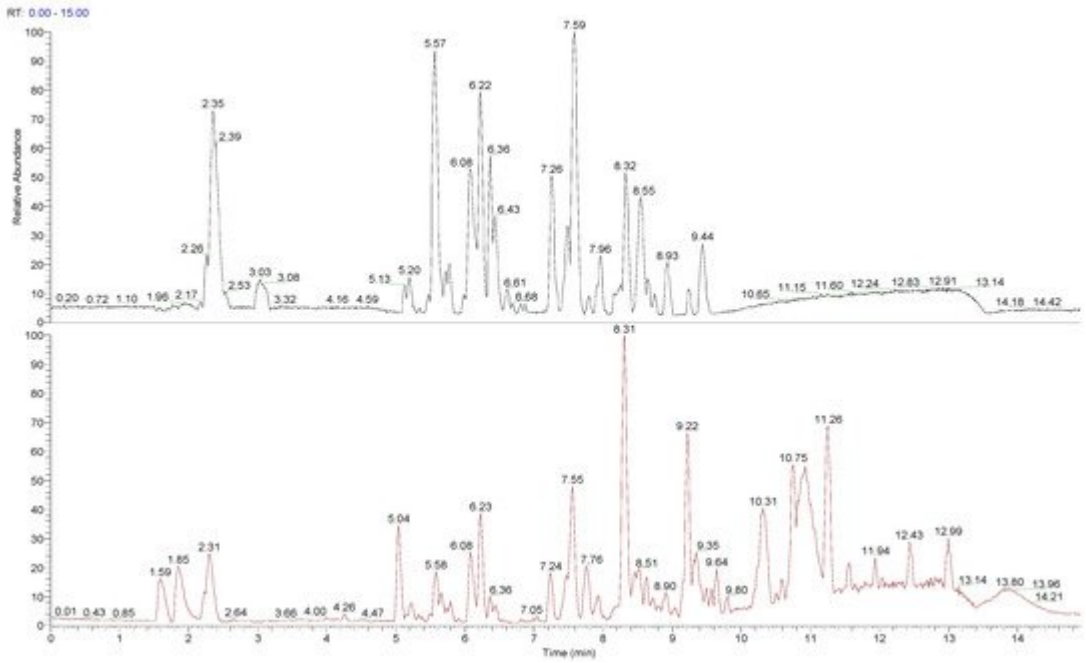

Figure 2. Total ion chromatogram (TIC) for peumo, presented in negative and positive modes.

Table 3. Identification of compounds and antioxidant capacity from the methanol extract of peumo fruits, by LC-MS and MS/MS data. The principal peaks were individually analyzed, and the potential molecules were identified. Also, total polyphenol content (TPC), total flavonoid content (TFC), and antioxidant capacity by ORAC methods were determined. GAE, gallic acid equivalent; QE, quercetin equivalent; TE, trolox equivalent.

RT (min)	$[M + X]^+$ (m/z)	$[M - X]^-$ (m/z)	[M] (m/z)	Fragments	MF	Tentative Compound
2.35	343.1236 $[M + H]^+$	341.1112 $[M - H]^-$ 683.2303 $[2M - H]^-$	342	−89.0227, 101.0226, 119.0330, 143.0329, 161.0433, 179.0537	$C_{12}H_{22}O_{11}$	Sucrose

RT (min)	$[M + X]^+$ (m/z)	$[M - X]^-$ (m/z)	[M] (m/z)	Fragments	MF	Tentative Compound
5.04	316.2121 $[M + H]^+$		315	102.0916, 123.1169, 184.1695, 255.1590	$C_{19}H_{25}NO_3$	Cryprochine Isocryprochine
5.13	867.2132 $[M + H]^+$	865.2036 $[M - H]^-$	866	−287.0587 −407.0808 −451.1076 −577.1406 −695.1471 713.1580 −739.1739 −847.0959	$C_{45}H_{38}O_{18}$	Procyanidin C_1
5.20	579.1500 $[M + H]^+$ 1155.2760 $[2M + H]^+$	577.1387 $[M - H]^-$ 1153.2665 [2M − H]−	578	−289.0744 −407.0809 −425.0918 −451.1076	$C_{30}H_{26}O_{12}$	Procyanidin B_1 Procyanidin B_2
5.57	355.1025 $[M + H]^+$ 377.0845 $[M + Na]^+$	353.0900 $[M - H]^-$ 707.1879 $[2M - H]^-$	354	135.0458 179.0362	$C_{16}H_{18}O_9$	4-Caffeoylquinic acid
	579.1500 $[M + H]^+$	577.1386 $[M - H]^-$	578		$C_{30}H_{26}O_{12}$	Procyanidin B_1 Procyanidin B_2
	867.2131 $[M + H]^+$	865.2020 $[M - H]^-$	866		$C_{45}H_{38}O_{18}$	Procyanidin C1
6.08	355.1027 $[M + H]^+$ 377.0846 $[M + Na]^+$ 731.1894 $[2M + Na]^+$	353.0903 $[M - H]^-$ 707.1885 $[2M - H]^-$	354	191.0575	$C_{16}H_{18}O_9$	Chlorogenic acid
6.22	291.0863 $[M + H]^+$ 313.0680 $[M + Na]^+$	289.0737 $[M - H]^-$ 353.0900 579.1549 $[2M - H]^-$	290	−179.0357, 205.0516 245.0811	$C_{15}H_{14}O_6$	Catechin, Epicatechin
6.35	470.1659 $[M + H]^+$ 492.1486 $[M + Na]^+$	468.1540 $[M - H]^-$ 937.3156 $[2M - H]^-$	469	292.1217, 424.1651		Unidentified

RT (min)	$[M + X]^+$ (m/z)	$[M - X]^-$ (m/z)	[M] (m/z)	Fragments	MF	Tentative Compound
6.43	355.1024 $[M + H]^+$ 731.1821 $[2M + Na]^+$	353.0901 $[M - H]^-$ 707.1879 $[2M - H]^-$	354	−191.0568	$C_{16}H_{18}O_9$	Analogue of chlorogenic acid 4-Caffeoylquinic acid
7.26	465.1031 $[M + H]^+$ 487.0849 $[M + Na]^+$	463.0912 $[M - H]^-$	464	301.0380 178.9999 151.0046	$C_{21}H_{20}O_{11}$	Isoquercitirin Hyperoside
	435.0926 $[M + H]^+$ 457.0743 $[M + Na]^+$	433.0801 $[M - H]^-$	434	−301.0381	$C_{20}H_{18}O_{11}$	Reynoutrin Quercetin 3-O-α-D-arabinopyranoside Quercetin 3-O-xyloside
7.48	551.1037 $[M + H]^+$ 573.0854 $[M + Na]^+$	549.0919	550			(−)-Rubrichalcolactone
		505.1018 $[M - H]^-$	504			(6-(5,7-dihydroxy-2-(4-hydroxy-3-methoxyphenyl)-4-oxo-4H-chromen-8-yl)-3,4,5-trihydroxytetrahydro-2H-pyran-2-yl)methyl acetate
7.59	449.1081 $[M + H]^+$	447.0963 $[M - H]^-$	448	−301.0378	$C_{21}H_{20}O_{11}$	Quercetin 3-O-α-D-rhamnopyranoside
7.76	353.1361 $[M + H]^+$ 376.2120 $[M + Na]^+$	351.1412 $[M - H]^-$ 375.1473 $[M + Na-H]^-$	352	335.1254	$C_{22}H_{40}O_3$	cryptorigidifoliol A
7.96	463.1238 $[M + H]^+$	461.1119 $[M - H]^-$	462		$C_{22}H_{22}O_{11}$	Isorhamnetin-3-O-rhamnoside Luteolin 7-O-glucuronide
8.30	360.2155 $[M + H]^+$	359.1525	358	313.1465, 327.1466, 341.1624	$C_{20}H_{24}O_6$	(+)-Lariciresinol 4-O-Methylcedrusin
8.93	263.1641 $[M + H]^+$ 285.1458 $[M + Na]^+$		262	165.0546	$C_{16}H_{22}O_3$	1′R*,3′S*,4′R*,5′S*,6S-6-[(4′-ethyl-9′-oxabicycle[3.3.1]non-6′-en-3′-yl)methyl]- 5,6-dihydro-2H-pyran-2-one
9.21	376.2599 $[M + H]^+$	374.2470 $[M - H]^-$	375	209.1284 275.1754		Unidentified

RT (min)	$[M + X]^+$ (m/z)	$[M - X]^-$ (m/z)	[M] (m/z)	Fragments	MF	Tentative Compound
	398.2415 $[M + Na]^+$			293.1861 302.1864		
9.44		315.1620		−118.0428 −163.0409 −271.1726	$C_{16}H_{12}O_7$	Sexangularetin
10.31	305.1747 $[M + H]^+$ 327.1568 $[M + Na]^+$		304			Unidentified
10.75	247.1694 $[M + H]^+$ 269.1513 $[M + Na]^+$		246	173.1328 229.1592	$C_{15}H_{18}O_3$	Ethyl 5-hydroxy-7-phenyl-2,6-heptadienoate
11.26	249.1850 $[M + H]^+$ 271.1668 $[M + Na]^+$		248	133.1016 231.1750	$C_{16}H_{24}O_2$	(4R,6S)-10-Phenyl-1-decene-4,6-diol

Antioxidant capacity of peumo extract	
ORAC (mmol/g DW	0.637 ± 0.061
TPC (mgGAE/gDW)	23.81 ± 3.06
TFC (mgQE/gDW)	18.84 ± 3.33

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