Comparison of Fatty Acid and Triacylglycerol Compositions of Different Hazelnut Varieties (*Corylus avellana* L.) Cultivated in Catalonia (Spain)

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The fat content and fatty acids and triacylglycerol contents determined by GC and HPLC, respectively, of different native hazelnut varieties and some other varieties introduced from Italy are shown. Samples were cultivated in two areas (Reus and Falset), the principal hazelnut producers of the province of Tarragona (Catalonia, Spain). Our experimental results show that oleic acid and linoleic acid are the most important fatty acids and that the main triacylglycerols are triolein, linoleyldiolein, and palmityldiolein. Statistical data processing (ANOVA) of experimental results show that the native varieties Negret and Castanyera have significantly higher values than the other varieties tested in this study for linoleic acid and the triacylglycerols dilinoleylpalmitin and trilinolein; in contrast, the Italian variety Tonda Gentille shows significantly lower values for the same compounds than the other varieties.

Keywords: *Hazelnut varieties; fat content; fatty acid and triacylglycerol composition; Catalonia (Spain)*

INTRODUCTION

Spain is the third most important producer of hazelnuts in the world (behind Turkey and Italy), contributing about 4% to the total hazelnut world production (FAO, 1992). In 1990 Spain produced about 316 000 metric tons of hazelnuts (Ministerio de Agricultura Pesca y Alimentación, 1990). The main region of hazelnut production in Spain is the province of Tarragona, which represents about 85% of total production. In Tarragona 80% of this production is made up of the native variety cv. Negret. Other varieties are also cultivated but in smaller quantities, i.e., Castanyera, Culplá, Gironell, and Pauetet, as well as some Italian varieties, Sant Giovanni, Tonda Italiana, Tonda Romana, Tonda Gentille delle Langue, Tonda di Giffoni, etc., which were introduced as a consequence of their higher commercial value.

In previous works we reported the influence of geographical origin and environmental conditions on the fatty acid (Parcerisa et al., 1993) and triacylglycerol compositions (Parcerisa et al., 1994) of some hazelnut varieties cultivated in Spain. In the present work the results of fat, fatty acid, and triacylglycerol compositions of the main varieties cultivated today in this region are shown. The purpose of this study is to determine whether there are significant differences between varieties in relation to fatty acid and triacylglycerol compositions among three consecutive harvesting years. Similar studies have been performed on the same components in relation to hazelnut samples (Bazan, 1975; Bhati et al., 1986; Contini et al., 1991a,b; Dijk Van, 1975; Fincke, 1980; Geeraert and Sandra, 1987; Geeraert and Slopper, 1983; Hadorn et al., 1977; Hadorn and Zurcher, 1967; Neubeller, 1990; Shewry et al., 1972; Zurcher and Hadorn, 1975).

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METHODS

Samples. Sixty hazelnut samples corresponding to 10 varieties were analyzed: Pauetet ($n = 7$), Culplà ($n = 7$) Negret ($n = 14$), Castanyera ($n = 3$), Gironell ($n = 6$), Tonda Italiana ($n = 5$), Tonda Gentille ($n = 3$), Sant Giovanni ($n = 4$), Tonda Romana ($n = 6$), and Tonda di Giffoni ($n = 5$). All samples were collected from the same cultivars during the second half of September for the three harvests between 1990 and 1992 by trained workers of the Institut de Recerca i Tecnologia Agroalimentaries (Generalitat of Catalonia). Collection was made at two locations of hazelnut production in Reus, near the sea, and in Falset, in the mountains; both are situated in the province of Tarragona (Catalonia, Spain). Unshelled samples were stored at 0 °C until analyzed.

Fat Content. The total fat content was determined in accordance with the AOAC Method 27006 (AOAC, 1984).

Fatty Acid Composition. Hazelnut oils were obtained by pressure extraction (300 kg cm^{-2}) of shelled and crushed hazelnuts.

Fatty acids were determined by GLC based on the method proposed by Slover and Lanza (1979). Fatty acid methyl esters were prepared with boron trifluoride (20% of BF_3 in methanol, Merck) and extracted with *n*-hexane.

Gas chromatography conditions were as follows: oven temperature, 210 °C (20 min); injector temperature, 270 °C; detector temperature, 300 °C. The stationary phase was a 50 m × 0.25 mm capillary column coated with 100% cyanopropylpolysiloxane (CPSil-88, Chrompack). The chromatograph was a Perkin-Elmer Sigma Model 2000 coupled to a Nelson Perkin-Elmer integrator.

FAME identification was based on retention times compared to pure standard FAME purchased from Sigma Chemical Co. Quantification was made by internal normalization as a semiquantitative response of data.

0021-8561/95/1443-0013$09.00/0

Table 1. Mean ($\bar{x}$) and Standard Deviation (SD) Results for Fat and Fatty Acid Contents of Hazelnut Samples: C16:0 (Palmitic Acid), C16:1 (Palmitoleic Acid), C18:0 (Stearic Acid), C18:1 (Oleic Acid), C18:2 (Linoleic Acid), C18:3 (Linolenic Acid), and C20:1 (Eicosenoic Acid)

		fat		C16:0		C16:1		C18:0		C18:1		C18:2		C18:3		C20:1	
variety	N	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Castanyera	3	59.5	6.87	5.89	0.33	0.25	0.02	1.69	0.22	77.05	4.53	14.86	4.88	0.11	0.04	0.14	0.06
Culpla	7	59.53	2.84	5.92	0.55	0.27	0.05	2.28	0.34	81.57	1.4	9.31	1.25	0.16	0.06	0.19	0.08
Gironell	6	57.22	9.93	5.5	0.39	0.25	0.05	1.88	0.39	77.16	5.41	14.91	5.86	0.11	0.05	0.18	0.04
Negret	14	61.42	6.61	5.57	0.39	0.26	0.05	1.78	0.33	77.08	3.9	14.99	4.18	0.12	0.05	0.22	0.14
Pauetet	7	60.3	4.58	6.05	0.14	0.28	0.04	1.85	0.24	78.17	4.46	13.37	4.61	0.11	0.04	0.17	0.03
Sant Giovanni	4	61.13	4.27	5.86	0.53	0.28	0.05	1.64	0.3	80.67	2.78	11.3	3.56	0.15	0.03	0.15	0.09
Tonda Gentille	3	64.1	8.64	6.48	0.59	0.31	0.05	2.3	0.16	84.05	0.76	6.62	0.22	0.12	0.02	0.15	0.04
Tonda Giffoni	5	59.26	5.18	5.4	0.46	0.22	0.05	2.05	0.16	78.67	3.33	13.38	3.7	0.12	0.04	0.2	0.02
Tonda Italiana	5	58.96	7.39	5.44	0.42	0.25	0.04	2.04	0.15	80.42	2.52	11.53	2.58	0.14	0.05	0.18	0.01
Tonda Romana	6	60.9	8.85	6.33	0.6	0.4	0.3	1.97	0.23	80.68	4.39	10.41	5.15	0.11	0.03	0.14	0.05
total	60	60.23	6.37	5.79	0.52	0.28	0.11	1.97	0.38	79.1	4.03	12.58	4.5	0.12	0.05	0.18	0.08

Table 2. Mean ($\bar{x}$) and Standard Deviation (SD) Results for Triacylglycerol Contents of Hazelnut Samples: LLL (Trilinolein), LLO (Dilinoleylolein), LLP (Dilinoleylpalmitin), LOO (Linoleyldiolein), PLO (Palmityllinoleylolein), PLP (Palmityllinoleylpalmitin), OOO (Triolein), POO (Palmityldiolein), POP (Palmityloleylpalmitin), PPP (Tripalmitin), SOO (Stearyldiolein), and SOP (Stearyloleylpalmitin)

		LLL		LLO		LLP		LOO		PLO		PLP		OOO		POO		POP		PPP		SOO		SOP	
variety	N	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Castanyera	3	1.99	0.34	6.38	2.74	1.22	0.41	20.38	4.36	4.91	1.07	0.45	0.21	45.72	6.34	13.27	1.82	1.01	0.31	0.19	0.17	3.74	0.4	0.51	0.18
Culpla	7	0.88	0.12	3.47	0.56	0.83	0.38	15.39	1.34	3.57	0.31	0.38	0.22	51.92	2.45	14.11	1.02	1.09	0.39	0.75	0.87	6.17	0.75	1.36	0.74
Gironell	6	1.84	1.06	6.16	3.36	1.22	0.59	18.99	5.14	4.45	1.26	0.59	0.24	46.37	7.93	12.8	2.16	1.33	0.39	0.45	0.14	4.47	0.96	0.88	0.35
Negret	14	1.67	0.58	6.49	2.39	1.21	0.41	20.86	3.99	4.93	0.92	0.45	0.16	46.0	5.41	12.42	2.35	1.03	0.39	0.46	0.32	3.89	1.07	0.68	0.42
Pauetet	7	1.41	0.62	5.68	2.36	1.15	0.33	18.95	4.47	4.86	1.09	0.32	0.11	46.31	6.28	13.9	1.82	1.31	0.57	0.43	0.27	4.43	1.24	1.03	0.56
Sant Giovanni	4	0.99	0.38	4.51	1.92	0.56	0.3	17.19	4.41	4.22	0.73	0.54	0.27	49.83	3.13	15.47	3.75	0.72	0.18	0.71	0.7	4.4	0.92	0.73	0.54
Tonda Gentille	3	0.63	0.24	2.15	0.3	0.52	0.16	11.93	1.26	2.98	0.14	0.56	0.39	55.02	2.66	16.84	1.5	1.64	1.05	0.46	0.59	5.84	0.61	1.31	0.6
Tonda Giffoni	5	1.62	0.32	6.04	1.99	1.04	0.15	19.56	3.79	4.19	0.81	0.46	0.12	48.45	5.25	12.38	1.71	0.87	0.17	0.36	0.29	4.41	0.5	0.56	0.2
Tonda Italiana	5	1.26	0.38	4.25	1.4	0.7	0.24	16.53	2.41	3.68	0.44	0.42	0.23	49.48	4.9	14.08	1.67	1.39	0.85	0.87	0.97	5.78	1.5	1.46	1.03
Tonda Romana	6	1.08	0.72	4.15	2.71	0.93	0.42	15.59	5.45	4.02	1.13	0.46	0.21	49.66	6.51	15.46	2.57	1.68	0.58	0.89	0.94	4.82	1.52	1.27	0.37
total	60	1.39	0.67	5.2	2.44	1.0	0.43	18.10	4.43	4.31	1.01	0.45	0.2	48.32	5.69	13.73	2.37	1.2	0.54	0.56	0.57	4.69	1.27	0.96	0.71

Triacylglycerol Contents. A 0.2 g sample of oil was weighed in a curled test tube, and the sample was dissolved with 2 mL of acetone (HPLC grade, Merck). The solution was filtered through a 13 mm × 0.45 μm nylon filter (Lida Manufacturing Corp.).

Triacylglycerols were determined by HPLC using a Perkin-Elmer (Series 10) chromatograph coupled to a Rheodyne loop (150 μL) injector and a Perkin-Elmer LC-25 refraction index detector. Chromatograms were plotted on a Hewlett-Packard 3390A integrator. The rate of flow was 1 mL/min at 25 °C. The amount of sample injected was 10 μL.

The stationary phase was a 25 cm × 4 mm Spherisorb ODS-2 (5 μm) column (Tracer Analytica). The mobile phase was a mixture of acetone–acetonitrile (HPLC grade, 64/36 v/v) with an isocratic program.

Taking into account the selectivities (α, relative retention times to the triolein), peaks were identified according to the logarithms of α in relation to homogeneous triglycerides (Sigma) and to reference standard oils (Goiffon et al., 1981; Hernández et al., 1991; Parreño et al., 1993). Quantification of the peaks was made by internal normalization as a semiquantitative response of data.

Statistical Calculations. Statistical data processing was carried out on the STATGRAPHICS v 5.0 statistical software using an IBM PS/1 computer Model 174.

RESULTS

The mean and standard deviation (SD) for fat and fatty acid results are shown in Table 1; the corresponding results for triacylglycerol proportions are given in Table 2.

The average total fat content for all shelled nut varieties shows a value of 60.23% (SD = 6.37). Seven fatty acids were identified and quantified (Figure 1): oleic acid ($\bar{x}$ = 79.10%, SD = 4.03), linoleic acid ($\bar{x}$ = 12.58%, SD = 4.5), palmitic acid ($\bar{x}$ = 5.79%, SD = 0.52), stearic acid ($\bar{x}$ = 1.97%, SD = 0.38), eicosenoic acid ($\bar{x}$ = 0.18%, SD = 0.08), linolenic acid ($\bar{x}$ = 0.12%, SD = 0.05), and palmitoleic acid ($\bar{x}$ = 0.28%, SD = 0.11). These values are expressed as internal normalizations.

In relation to triacylglycerol composition 12 main triacylglycerols were detected and quantified (Figure 2): triolein (OOO) ($\bar{x}$ = 48.32%, SD = 5.69), linoleyldiolein (LOO) ($\bar{x}$ = 18.10%, SD = 4.43), palmityldiolein (POO) ($\bar{x}$ = 13.73%, SD = 2.37), dilinoleylolein (LLO) ($\bar{x}$ = 5.20%, SD = 2.44), stearyldiolein ($\bar{x}$ = 4.69%, SD = 1.27), palmityllinoleylpalmitin (PLO) ($\bar{x}$ = 4.31%, SD = 1.01), trilinolein (LLL) ($\bar{x}$ = 1.39%, SD = 0.67), palmityloleylpalmitin ($\bar{x}$ = 1.20%, SD = 0.54), dilinoleylpalmitin (LLP) ($\bar{x}$ = 1.00%, SD = 0.43), stearyloleylpalmitin (SOP) ($\bar{x}$ = 0.96%, SD = 0.71), tripalmitin (PPP) ($\bar{x}$ = 0.56%, SD = 0.57), and palmityllinoleylpalmitin (PLP) ($\bar{x}$ = 0.45%, SD = 0.2). These values are expressed as internal normalization.

DISCUSSION

The variety Tonda Gentille has the maximum fat content value (64.10%), whereas the variety Tonda Italiana shows the minimum (58.96%). Nevertheless, the analysis does not reveal any statistical differences between varieties.

If we consider the main fatty acids (oleic and linoleic acids), the variety Tonda Gentille has by far the highest value for oleic acid (84.05%) while also showing the lowest value for linoleic acid (6.62%). The varieties

Table 3. Significant Differences Recorded among All Varieties

	Culplà	Gironell	Negret	Pauetet	Sant Giovanni	Tonda Gentille	Tonda Giffoni	Tonda Italiana	Tonda Romana
Castanyera	SOO, PLO, LLL	NS[a]	LLP	NS	LLP, LLL	SOO, LOO, PLO, LLP, LLL, C18:2, C18:0	POO	SOO	LLL
Culplà		SOO, LLL, C18:2, C18:0	SOO, LOO, PLO, LLP, LLL, C18:2, C18:0	SOO, PLO, C18:0	SOO, C18:0	NS	SOO, LLL, C18:0	C18:0	SOO, C18:0
Gironell			NS	C16:0	LLP, LLL	LOO, LLP, LLL, C16:0, C18:0, C18:2	POO	SOO, LLP	POO, LLL, C16:0
Negret				C16:0	POO, LLP	SOO, LOO, POO, PLO, LLP, LLL, C16:0, C18:2, C18:0	NS	SOO, LOO, PLO	LOO, POO, PLO, LLL, C16:0, C18:2
Pauetet					LLP	LOO, PLO, LLP, C18:0, C18:2	C16:0	SOO, PLO, C16:0	NS
Sant Giovanni						NS	POO	C18:0	SOO
Tonda Gentille							LOO, POO, LLL, C16:0, C18:2	C16:0	NS
Tonda Giffoni								SOO	POO, C16:0
Tonda Italiana									C16:0

[a] NS, not significant.

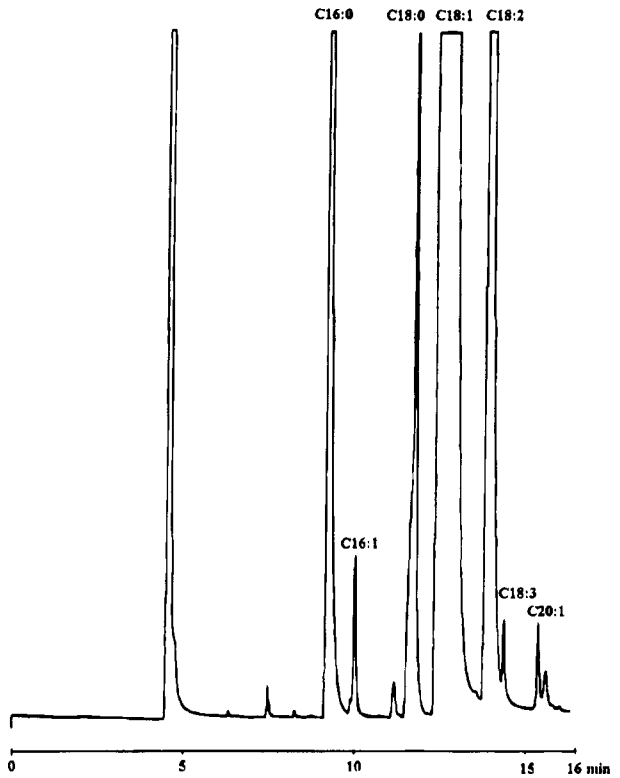

Figure 1. Typical chromatogram showing the different FAME peaks by gas chromatography (sample, Castanyera, 1990).

Castanyera, Gironell, and Negret show the lowest values for oleic acid (77.05%, 77.16%, and 77.08%, respectively); in addition, the same varieties show the highest values for linoleic acid (14.86%, 14.91%, and 14.99%, respectively). The one-way analysis of variance (ANOVA) reveals statistically significant differences ($\alpha = 0.05$) between some varieties for the following fatty

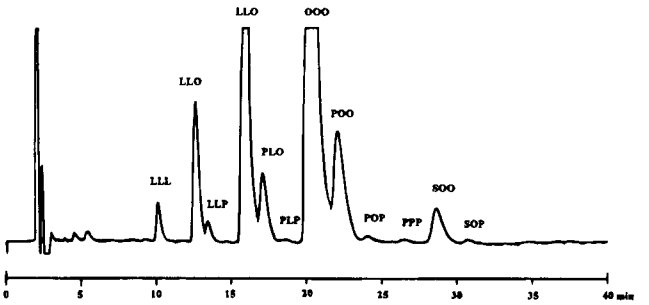

Figure 2. Typical chromatogram showing the different triacylglycerol peaks by HPLC (sample, Negret, 1990).

acids: palmitic acid ($p = 0.0002$), stearic acid ($p < 0.0001$), and linoleic acid ($p = 0.0351$).

Results for the most important triacylglycerols, OOO, LOO, and POO (Table 2), reveal the highest values for OOO (55.02%) and POO (16.84%) in the variety Tonda Gentille; however, this variety has the lowest proportion for LOO (11.93%). The varieties Castanyera and Negret show the lowest values for OOO (45.72% and 46.00%, respectively); in contrast, these varieties show the highest values for LOO (20.38% and 20.86%, respectively), while the varieties Tonda di Giffoni, Gironell, and Negret show the lowest values for POO (12.38%, 12.80%, and 12.42%, respectively). Triacylglycerol contents of LLO, LLP, and LLL are not great, but as they are the most unsaturated triacylglycerols, they influence the stability of oils. The variety Tonda Gentille has the lowest values for LLO (2.15%), LLP (0.52%), and LLL (0.63%). In contrast, the varieties Castanyera, Gironell, and Negret show the highest values for LLO (6.38%, 6.16%, and 6.64%, respectively), LLP (1.22%, 1.22%, and 1.21%, respectively), and LLL (1.99%, 1.84%, and 1.67%, respectively). The one-way analysis of variance (ANOVA) has revealed statistically significant differences ($\alpha = 0.05$) between some varieties for the following triacylglycerols: SOO ($p = 0.0025$), LOO ($p = 0.0328$),

POO ($p = 0.025$), PLO ($p = 0.015$), LLP ($p = 0.021$), and LLL ($p = 0.015$).

Table 3 shows the parameters that are significantly different following the comparison of all varieties with the rest [95% least significant difference (lsd) multiple range test]. From these results it can be concluded that the Italian variety Tonda Gentille is clearly distinct from the Spanish varieties: Castanyera, Gironell, Negret, and Pauetet. Also, we observed significant differences between the varieties Negret and Culplà.

ACKNOWLEDGMENT

We give special thanks to M. Egea and M. Miralles for the preparation of hazelnut samples. This research work has received the financial support of Instituto Nacional de Investigaciones Agrarias (INIA 9082, 1990) (Spanish Council).

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Received for review May 11, 1994. Accepted September 28, 1994.[⊗]

[⊗] Abstract published in *Advance ACS Abstracts,* November 1, 1994.