SHORT COMMUNICATION

Fatty acid content profile and main constituents of Corylus avellana kernel in wild type and cultivars growing in Italy

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ABSTRACT
The kernel composition (moisture, ash, protein, carbohydrate, calories, fat, monounsaturated and polyunsaturated fatty acids) of two hazelnut (Corylus avellana L.) cultivars (‘Tonda Gentile Trilobata’ and ‘Tonda Gentile Romana’) and of two wild types growing in different climatic conditions (north-west and central Italy) was evaluated. The main kernel component was fatty acid (65.9 ± 1.8%, mean value), and the most abundant fatty acid in hazelnut was oleic acid (C\textsubscript{18:1}) (83.5 ± 1.0%, mean value). The saturated fatty acids are the minor compounds in kernel hazelnut, resulting in a unsaturated fatty acid to saturated (U/S) fatty acid ratio of 9.0 ± 1.6. Compared to other tree nuts and vegetable oils, hazelnut oil is among the ones with the highest contents of monounsaturated and the lowest content of saturated fatty acid. Thus, hazelnut may be beneficial for the human diet preventing cholesterol-based atherosclerosis and ischemic cardiovascular diseases.

1. Introduction
Corylus avellana L. (hazelnut) is one of the most popular tree nuts worldwide and ranks second in tree nut production after almond (Shahidi et al. 2007). This species is selected for...
the high quality kernel having a major role in human nutrition and health (Cristofori et al. 2008). Due to their organoleptic characteristics, *C. avellana* kernels are consumed all over the world, not only as a fruit but also in a diversity of manufactured food products (Sciubba et al. 2014). In fact, it has a special composition of fats, protein, carbohydrate, dietary fibre, vitamins (vitamin E), minerals, phytosterols (mainly β-sitosterol), antioxidant phenolics, polyphenols and squalene (Sciubba et al. 2014). In particular, fatty acid (about 60% of the kernel) of *C. avellana* kernel has a profile very similar to that of olive oil, with oleic (C\(_{18:1}\))-acid and linoleic (C\(_{18:2}\))-acid being the main fatty acids in both the oils (Cristofori et al. 2008). The benefits of *C. avellana* kernel inclusion in the human diet are mainly related to the high presence of monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) (Cristofori et al. 2008) having an important role in decreasing blood pressure and total blood cholesterol level in human (Torabian et al. 2009). However, nutritional and chemical composition (i.e. fatty acid profile, protein and carbohydrate) of *C. avellana* is in relationship with variety, geographical origin, climate, ecology of the species as well as cultural applications (Köksal 2002). For instance, it is well known that different pedologic situations can produce significant modifications in the molecular pattern of a natural organism (Venditti et al. 2012). Thus, in our study, we analysed kernel composition (i.e. ash, moisture, protein, fat and carbohydrate) with a special focus on the fatty acid profile in *C. avellana* wild plants and orchards from different geographical areas (north-west and central Italy). In particular, the fatty acids composition was determined as methyl esters by gas chromatography coupled to a mass spectrophotometer.

2. Result and discussion

Kernel composition, including percentage of moisture, ash, fat, protein, carbohydrate and calories of the six investigated kernel samples are shown in Table 1. In particular, kernel moisture is 89% higher (mean value of N\(_{1}\)–N\(_{3}\)) in the three kernel samples from the north-west of Italy compared to the samples from the central Italy. This result can be justified by different climate conditions, mainly related to the rainfall distribution through the year particularly in the period between July and August (50% higher rainfall in north-west) which is crucial for kernel composition since physiological processes is in close relationship with soil water availability (Cristofori 2005). The protein content also shows significantly variations, with the highest values in C\(_{1}\) and C\(_{2}\) (18.7 ± 0.854%, mean value) compared to N\(_{1}\)–N\(_{3}\) and C\(_{3}\). This result can be related to the irrigation treatment having a positive effect on seed nitrogen content and overall in the biochemistry of protein biosynthesis (Cristofori 2005). Moreover, based on the results reported by Sciubba et al. (2014) for three Italian hazelnut cultivars, glutamate and alanine are the most abundant amino acids in kernel. Net photosynthesis rates are influenced by environmental factors (i.e. light, temperature, CO\(_{2}\) concentration, water availability and soil nutrients) as well as plant-related factors (plant structure, leaf morphology and age). Moreover, the photosynthates demand by sink organs (i.e. seed, fruit) can determine photosynthetic supply (Gifford & Evans 1981). The result of the regression analysis shows a strong positive correlation (Table 2) between the percentage of kernel carbohydrate and the net photosynthetic rates with the highest \(P_{N}\) rates associated with higher carbohydrate percentage. Thus, the lowest carbohydrate content (9.9 ± 0.7%, mean value) and the lowest \(P_{N}\) rates (9.0 ± 0.4 μmol CO\(_{2}\) m\(^{-2}\) s\(^{-1}\), mean value) in N\(_{3}\) and C\(_{3}\) can be justified by the absence of any horticultural practices mainly fertilising and pruning in the
two wild populations. Otherwise, the common pruning practices in *C. avellana* orchards result in a 17% $P_N$ increase (mean value of $N_1$, $N_2$, $C_1$ and $C_2$). Considering the *C. avellana* capacity to perform well in full sunlight conditions by several adaptations at leaves level (Catoni et al. 2015), the canopy opening through pruning practices improves light penetration favouring net carbon fixation by taking advantage of a greater portion of light exposed leaves. Moreover, the fatty acid amount depends on the *in situ* carbohydrate production and availability (Cristofori 2005). As a consequence of their insolubility in water and consequently, in the difficulty in phloem/xylem transport, lipids in seeds and fruits are mainly synthesised directly in the reserve sites, using sucrose (SUCR) or other sugars as substrate (Bignami et al. 2002). In this respect, Sciubba et al. (2014) highlight, among the carbohydrates, the highest concentration for sucrose in *C. avellana* kernel. Thus, the fatty acid content in kernel is significantly correlated with the carbohydrate content (Table 2). The heart-healthy fatty acids (i.e. MUFAs and PUFAs) account for 90% of the total fatty acids (Figure 1). In particular, among MUFAs, which is the main group of fatty acid in hazelnut oil, oleic acid (C18:1) ranges from 81% in $N_3$ to 84% in $N_2$. PUFAs accounts for 6% of the total fatty acid, with linoleic acid (C18:2) ranging from 4.8% in $N_2$ to 10.9% in $N_3$ while the saturated fatty acids are the minor compounds. In fact, the average ratio of unsaturated fatty acid to saturated fatty acid (U/S) is 9.0 ± 1.6, according to the results of Cristofori et al. (2008). In particular, the linoleic acid (C18:2) content is related to the environmental growing conditions of the populations, mainly related to the soil composition, cultural practices such as uses of fertilizer and irrigation (Parcerisa et al. 1995). Moreover, the higher C18:2 Percentage observed in the wild populations suggests a lower storage capability due to its less stability (Serra Bonvehí & Ventura Coll 1997). In fact, during storage, the lipid fraction can be subjected to hydrolysis and oxidation, resulting in undesirable odours and flavours, reduction of the nutritional value of the kernels (Ghirardello et al. 2013) and thus affecting the economic value. The linoleic acid content varied inversely with the oleic acid content (Table 2) according to Cristofori et al. (2008), and

### Table 1. Kernel composition of the six *Corylus avellana* kernel samples ($C_1$–$C_3$ from central Italy; $N_1$–$N_3$ from north-west Italy). Mean ± standard deviation ($n = 30$). Means within a column followed by the same letter are not significantly different (ANOVA, $p \leq 0.05$). Coefficient of variation from central (CV$_{C}$) and north-west Italy (CV$_{N}$) samples are shown.

|       | Moisture (%) | Ash (%) | Fat (%) | Protein (%) | Carbohydrate (%) | Energy (kcal) |
|-------|--------------|---------|---------|-------------|------------------|---------------|
| $C_1$ | 2.94 ± 0.76ab| 2.45 ± 0.31a| 63.7 ± 0.5a| 19.3 ± 0.44a| 11.6 ± 1.4ab| 697 ± 4abd    |
| $C_2$ | 2.92 ± 0.75ab| 2.08 ± 0.24bc| 64.9 ± 1.5ac| 18.1 ± 0.45b| 12.1 ± 1.8b| 704 ± 8bd    |
| $C_3$ | 2.22 ± 0.16b| 2.27 ± 0.21ab| 68.6 ± 0.4b| 16.4 ± 0.4c| 10.5 ± 0.5ab| 725 ± 2c    |
| CV$_C$| 0.26         | 0.13     | 0.03     | 0.07        | 0.13             | 0.02         |
| $N_1$ | 4.91 ± 0.48 cd| 2.31 ± 0.20ab| 66.5 ± 1.8cb| 13.8 ± 0.3d| 12.4 ± 1.7b| 704 ± 10d    |
| $N_2$ | 4.11 ± 1.08ac| 2.23 ± 0.24abc| 66.9 ± 2.4b| 15.0 ± 0.26e| 11.7 ± 2.2ab| 709 ± 15bd   |
| $N_3$ | 6.33 ± 3.39d| 1.96 ± 0.26c| 64.8 ± 0.8ac| 17.4 ± 0.40f| 9.4 ± 2.9a| 691 ± 16a    |
| CV$_N$| 0.43         | 0.12     | 0.03     | 0.10        | 0.23             | 0.02         |

### Table 2. Regression equations and correlation coefficients ($R$) are shown.

| Regression equation | $R$ |
|---------------------|-----|
| Net photosynthesis vs. carbohydrate | y = 0.6485x + 2.6762 | 0.8804 |
| Fatty acid vs. carbohydrate | y = −0.3718x + 70.108 | −0.3626 |
| Linoleic acid vs. oleic acid | y = −0.4634 + 44.032 | −0.4995 |

* $p \leq 0.05$.
** $p \leq 0.001$. 

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C_{18:2} results in less than 9% of total fatty acids, except in N_3, that is considered a critical threshold value by the food industry (Arcoleo 1991). The above considerations are confirmed by the principal component analysis (PCA) which extracted two components accounting for 93% of the total variance and of which 73.8% is due to the component 1 and 19.2% to component 2 (Figure 2). Along the first component, the PCA completely separates C_3 and N_3 from the others samples by their higher percentage of linoleic acid (C_{18:2}), while along the second component C_1 and N_2 result separately by each other in the second quadrant by their higher percentage of oleic acid (C_{18:1}).

Figure 1. Percentage of oleic (C_{18:1}) linoleic (C_{18:2}) palmitic (C_{16:0}) and stearic (C_{18:0}) acid in the considered kernel samples (C_1–C_3 from central Italy; N_1–N_3 from north-west Italy) (n = 12).

Figure 2. PCA carried out using the analysed fatty acid (oleic acid, linoleic acid, palmitic acid and stearic acid). Component 1 accounted for 73.8% of the total variance, and component 2 for 19.23%.
3. Conclusion

On the whole, our results show a kernel composition in terms of moisture and ash very similar to that of Turkish hazelnut as reported by Alasalvar et al. (2003), while show a 35% lower percentage of carbohydrate but a higher presence of protein and fat (by 11 and 7%, respectively) resulting in a higher energy value. Moreover, when comparing the fatty acid profile of Italian hazelnut with Turkish hazelnut (Köksal et al. 2006) we found a higher presence of C\textsubscript{16:0}, C\textsubscript{18:0} and C\textsubscript{18:1} (by 41, 45 and 8%, respectively) and a 13% lower presence of C\textsubscript{18:2}. With regard to the Spanish hazelnut analysed by Parcerisa et al. (1995), we found a 10% higher fat content and a 24% lower moisture, while regarding the fatty acid profile the Italian hazelnut has a 9 and 28% higher presence of C\textsubscript{18:1} and C\textsubscript{16:0} respectively, and a 53 and 27% lower C\textsubscript{18:2} and C\textsubscript{18:0} respectively. Moreover, comparing our results with that reported by Hosseinpour et al. (2013) for hazelnut cultivars growing in Iran, we found a 37, 33, 13 and 18% lower percentage of moisture, ash, protein and carbohydrate, respectively, but a 14% higher fat content. In particular, the so higher moisture percentage can be justified by the significantly higher average annual precipitation found in Iran compared to Italy. Thus, the Italian hazelnut analysed in this study show a higher percentage of fat and a higher presence of oleic acid in the kernel compared to the Turkish, Spanish and Iranian hazelnuts. Moreover, based on our results the greater differences between the cultivar and the wild type can be observed in the linoleic acid (C\textsubscript{18:2}) percentage, which is higher in the wild type, resulting in a lower storage capability. As stated above, this feature affecting the storage capability can have implications in terms of the economic value highlighting that the kernel quality is better in the two analysed cultivars with respect to the wild hazelnut. In conclusion, as an excellent source of MUFA, hazelnuts may be beneficial because it prevents cholesterol-based atherosclerosis and ischemic cardiovascular diseases.

Disclosure statement

No potential conflict of interest was reported by the authors.

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