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Full Length Research Paper

Pomological traits and proximate chemical composition of Hazelnut (*Corylus avellana* L.) varieties grown in Croatia

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The aim of this research was to determine the pomological traits and proximate chemical composition of economically important Hazelnut (*Corylus avellana* L.) varieties grown in Croatia. Autochthonous variety Istarski duguljasti is the most represented variety in production, followed by introduced varieties Romische Zellernuss and Hallesche Riesen. Research was conducted during four vegetation seasons. Pomological traits (productivity/yield, number of fruits, nut weight, kernel weight, percent kernel) and proximate chemical composition of hazelnuts (fats, carbohydrates, proteins, ash and moisture) were determined. During the period of research, Romische Zellernuss variety had the highest yield; Hallesche Riesen variety had approximately the similar yield, while Istarski duguljasti had the lowest. However, Istarski duguljasti variety demonstrated stability and regular fertility during all years of research. Proximate chemical composition (of fresh material) varied per variety and per year. Fats were predominant compound which content ranged from 61.60 - 67.59 g/100 g, followed by carbohydrates (15.75 - 20.58 g/100 g) and proteins (10.16 - 13.13 g/100 g). Ash content in hazelnut kernel ranged from 2.51 - 2.85 g/100 g, and moisture content from 2.87 - 3.21 g/100 g. Results obtained in research suggest that external and internal parameters of hazelnut quality are influenced by variety, harvest year and their mutual interactions.

Key words: *Corylus avellana* L., hazelnut, kernel weight, kernel percent, chemical composition.

INTRODUCTION

Hazelnut kernels are recommended ingredients of a daily diet due to their nutritional composition and positive effect on human health (Kris-Etherton et al., 1999), and they fit in modern and important functional food concept. In addition, hazelnuts not only provide a refined flavor to food products but also play a major role in human nutrition and health.

Hazelnut production is concentrated in Mediterranean region with Turkey as the largest producer accounting for about 75% of the world crop (Fideghelli et al., 2009; Babadogan, 2008). According to Food and Agriculture Organization data, Croatia ranks 14th in the world with recorded production of 1000 t of shelled hazelnut (FAO, 2007).

Areas under intensive production of hazelnut have been increased significantly in the last couple of years in continental part of Croatia. Istarski duguljasti is the predominant autochthonous variety, followed by introduced varieties Romische Zellernuss and Hallesche Riesen.

Nut and kernel weight, kernel percent, high percentage of fatty acids, protein, carbohydrates and rich mineral composition are main characteristics in evaluating hazelnut kernel quality (Botta et al., 1994; Balta et al., 2006). In recent years, scientific research is directed

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towards investigating chemical composition of hazelnut kernel with the aim to better define its biological value.

Fat is the predominant component (58.2 - 64.10 g/100 g), followed by carbohydrates (15.50 - 21.7 g/100 g), and protein (10.86 - 17.1 g/100 g) (Alasalvar et al., 2003; Amaral et al., 2006; Ruggeri et al.,1998; Xu and Hanna, 2010).

Fat concentration can vary between 50 and 73% depending on a variety. Over 75% of fat present are consisted of unsaturated fatty acids (Koksal et al., 2006).

Research related to nutrition has demonstrated that as little as 30 g of nutrient-dense nuts per day can have a positive effect on health. Moreover, tree nuts are a nutrient –dense, shelf-stable, non perishable, whole food source of valuable micro- and macronutrients, which are considered to be crucial for countries with limited controlled storage or processing facilities (Ternus et al., 2009).

Several authors have identified that inner quality and composition of hazelnut are influenced by cultivar, cultivation area, growing season and agricultural practices. In past research, several authors have identified that genotype, harvest year, progeny, agro-ecological conditions and agricultural practices have major influence on hazelnut composition (Parcerisa et al., 1995; Ackurt et al., 1999; Özdemir et al., 2004; Silva et al., 2005). Therefore, it is important to present results of a research conducted in Orahovica location, where the largest production of hazelnut in Croatia is located.

The objective of this study was to determine the quality traits such as nut and kernel characteristics, of three most represented hazelnut varieties in Croatia.

MATERIALS AND METHODS

The object of the research

The research was carried out on the hazelnut plantation in Orahovica in continental part of Croatia (45°33' 30" N and 17° 52' 30" E). The plantation was planted in typical fruit growing position on 140 - 160 m, and it was at full cropping capacity at the time research was conducted.

Identification of fertility and pomological characteristics as well as proximate chemical composition of hazelnut was carried out during four vegetation seasons. Varieties Istarski duguljasti, Romische Zellernuss and Hallesche Riesen were included in the study. For each variety, 10 trees were selected in complete randomized design. Attention was paid to select plants of similar age, training form and tree habitus, namely to reflect the average condition of given cultivar in the orchard.

Fertility and pomological traits of hazelnut

Yield and number of fruits were determined for each tree separately: total nut weight (by weighing) and total number of fruits (by counting).

In order to determine pomological characteristics of nuts, an average sample of 100 fruits per tree was taken. Pomological measurements of fruit included measurements of total nut weight and kernel weight. Kernel percent was calculated based on shell and kernel weight ratio (nut weight / kernel weight × 100).

Chemical analysis

Determination of moisture, ash, crude protein, fat and carbohydrate contents were carried out in triplicate in five samples for each variety and production year according to AOAC Official Methods (AOAC, 2000). The moisture content was determined by drying at 103±2°C in a oven until constant weight. The ash content was determined by incineration at 525±10°C. Crude protein was estimated by multiplying the Kjeldahl nitrogen content by a factor 6.25. Total fat contents were determined by extracting with petroleum ether using Soxhlet apparatus. Carbohydrates were determined as reducing sugars before and after inversion.

Statistical analysis

Obtained results were statistically analyzed on the basis of the variance analysis (ANOVA) and tested by multiple comparisons of several means simultaneously (Bonferroni test). Basic statistical model includes influences of varieties, years and their interactions, and for characteristics for which data were collected separately for each individual tree, as well as variability of repetitions within the varieties.

RESULTS AND DISCUSSION

Analysis of variance was performed and statistically significant differences were determined per year and per cultivar based on level of significance at $p = 0.01$ and $p = 0.05$ for all studied characteristics. Significant interaction varieties × year was determined for all studied characteristics except for kernel percent.

Yield and number of fruits

From the economic point of view yield is the most important characteristic, and is the end result of a variety, agricultural practices and agro-ecological conditions. Research has shown that yield mostly depends on interaction between variety and vegetation year. During the period of the research Romische Zellernuss had the highest yield, Hallesche Riesen approximately similar, while Istarski duguljasti had the lowest (Figure 1). Our results are similar to results of other authors (Krpina et al., 1994; Čmelik and Mališević, 1996).

Hallesche Riesen variety showed instability for total number of fruits and nut weight characteristics which values varied according to vegetation years. Varieties Istarski duguljasti and Romische Zellernuss were stable for each year of observation with no detected significant variations (Tables 1 and 2). Influence of vegetation year was visible in all varieties; however it had the strongest effect on Hallesche Riesen.

Pomological traits of fruits

Pomological studies involve the following characteristics:

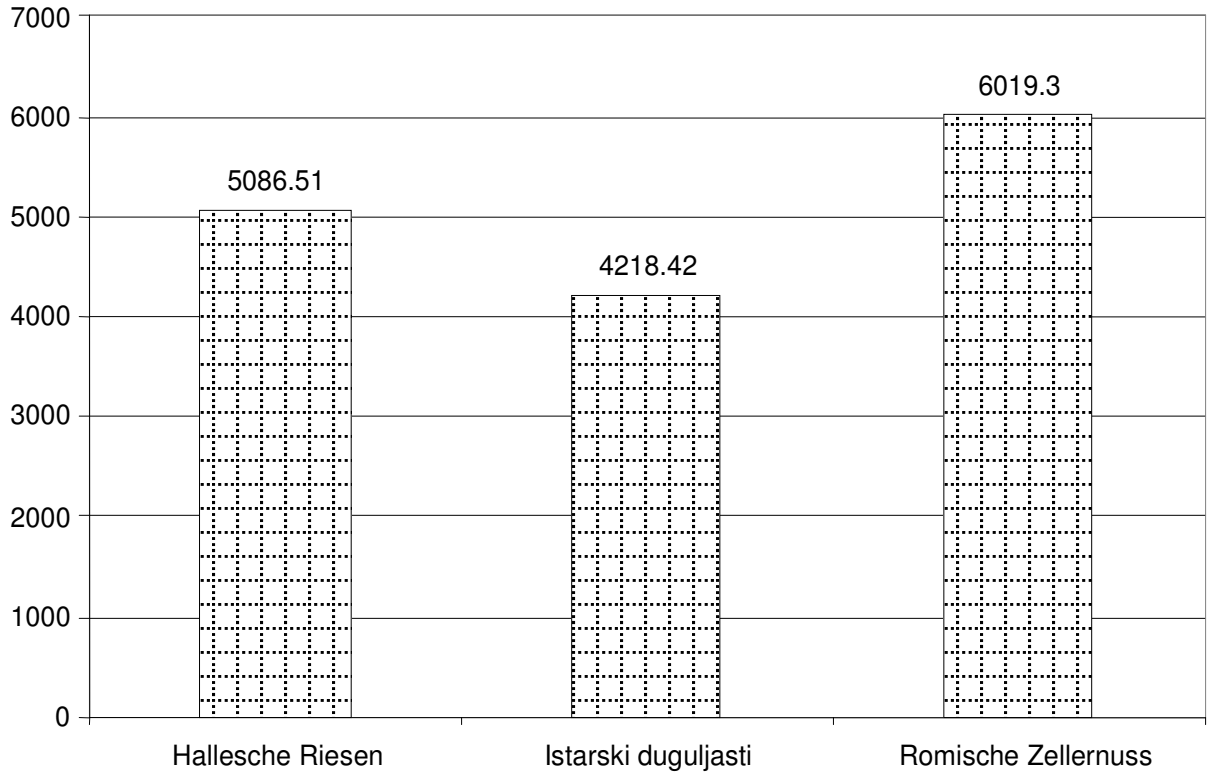

Figure 1. Productivity (yield) per plant (g). 4-years mean for varieties.

Table 1. Production (yield) per plant (g). Means for varieties per year.

Cultivar	2004	2005	2006	2007
Hallesche Riesen	5687,40 abc	6577,90 a	2910,16 e	5170,58 abcd
Istarski duguljasti	4344,60 bcde	4081,80 de	4182,70 cde	4264,59 cde
Romische Zellernuss	5849,00 ab	6114,90 a	6041,40 a	6071,89 a

Means followed by the same letters are not statistically different at $p < 0.05$.

Table 2. Total number of fruits per tree. Means for varieties per year.

Cultivar	2004	2005	2006	2007
Hallesche Riesen	2153.60 ab	2545.70 a	993.48 f	1873.30 bcd
Istarski duguljasti	1600.10 cde	1378.20 def	1230.50 ef	1512.20 def
Romische Zellernuss	2117.00 abc	2201.90 ab	1876.20 bcd	2168.40 ab

Means followed by the same letters are not statistically different at $p<0.05$.

nut weight and kernel weight (Tables 3 and 4). Based on obtained data percent kernel was calculated (Figure 2).

For nut weight characteristic, significant variations between cultivation years were determined. For variety Hallesche Riesen this could be partially connected to the yield, because its fruits were smaller in years with highest yield. For other two varieties similar correlation was not detected. Overall, in our research nut weight ranged between 2.65 - 3.74 g, which is consistent with reports of other authors (Miljković and Prgomet, 1994; Santos et al., 2005; Cristofori et al., 2009). Kernel weight of hazelnut varieties in research ranged from 1.18 - 1.60 g, with

Table 3. Nut weight (g). Means for varieties per year.

Cultivar	2004	2005	2006	2007
Hallesche Riesen	2.80 b	2.65 c	3.17 b	3.04 b
Istarski duguljasti	2.92 bc	3.05 b	3.74 a	3.66 a
Romische Zellernuss	2.90 bc	3.03 b	3.61 a	3.15 b

Means followed by the same letters are not statistically different at $p < 0.05$.

Table 4. Kernel weight (g). Means for varieties per year.

Cultivar	2004	2005	2006	2007
Hallesche Riesen	1.20 cd	1.18 d	1.35 bc	1.31 cd
Istarski duguljasti	1.27 cd	1.33 cd	1.60 a	1.60 a
Romische Zellernuss	1.23 cd	1.28 cd	1.50 ab	1.36 bc

Means followed by the same letters are not statistically different at $p < 0.05$.

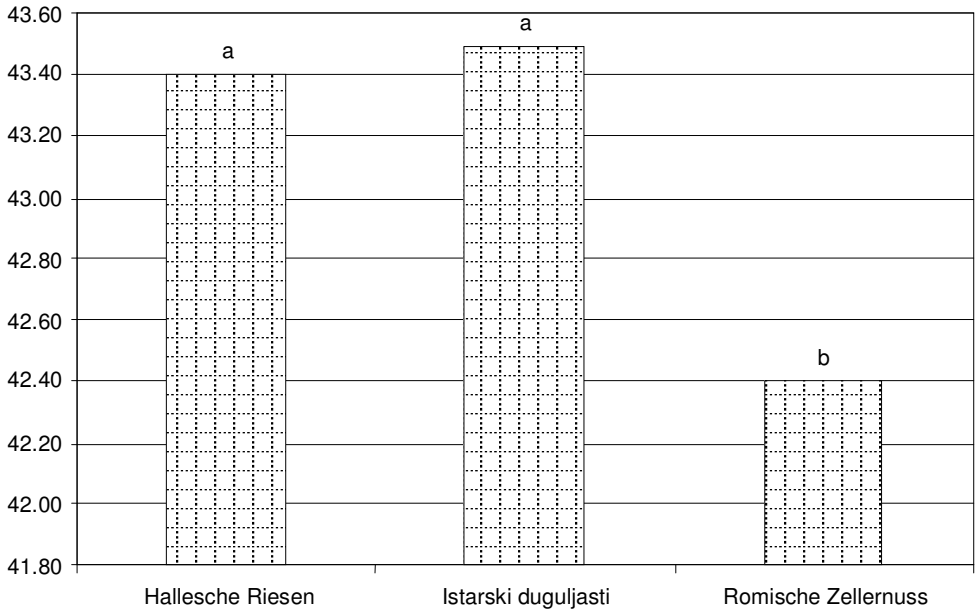

Figure 2. Percent kernel (%). Means followed by the same letters are not statistically different at $p < 0.05$.

significant variations between years of research. Average percent kernel was uniform per year and per variety, and amounted to 43.50% for Istarski duguljasti, 42.40% for Romische Zellernuss and 43.40% for Hallesche Riesen, which is in consistency with previous research done in Istria area (Miljković and Prgomet, 1994).

Absence of larger variations in percent kernel between years of research confirms known fact that percent kernel is a varietal characteristic.

Significant interactions between variety and year were determined in other research as well, due to which differences in pomological traits between studied varieties occurred (Bostan and Günay, 2009; Salvador et al., 2009). This was confirmed by Silva et al. (2005) who stated that climate conditions have strong influence on physical parameters of fruit.

Proximate chemical composition

Results of chemical composition of the three studied cultivars in 4 consecutive-year are shown in Table 5. Fat

Table 5. Chemical composition (g/100 g fresh weight) of 3 hazelnut cultivars grown in Croatia (Mean±SD) harvested in 4 consecutive-years.

Year	Cultivar	Moisture (% fresh weight)	Ash (% fresh weight)	Crude protein (% fresh weight)	Fat (% fresh weight)	Carbohydrates (% fresh weight)
2004	Romische Zellernuss	3.04±0.16	2.85±0.11	11.93±0.27	61.60±2.70	20.58±1.74
	Istarski duguljasti	3.11±0.09	2.51±0.04	13.13±1.24	63.30±2.29	17.96±1.08
	Hallesche Riesen	2.91±0.08	2.65±0.08	11.96±1.22	66.23±1.09	16.24±1.20
2005	Romische Zellernuss	2.96±0.15	2.66±0.16	10.69±0.98	63.64±1.72	20.05±2.23
	Istarski duguljasti	3.12±0.08	2.56±0.05	11.91±0.93	64.54±1.51	17.87±2.56
	Hallesche Riesen	2.87±0.04	2.71±0.09	11.22±0.38	64.87±1.05	18.33±2.11
2006	Romische Zellernuss	3.14±0.07	2.65±0.16	11.26±0.68	62.51±2.02	20.44±1.15
	Istarski duguljasti	3.11±0.08	2.53±0.22	10.16±1.60	64.42±2.57	19.78±1.11
	Hallesche Riesen	2.88±0.06	2.58±0.06	10.68±1.73	65.23±1.16	18.63±0.90
2007	Romische Zellernuss	2.95±0.07	2.68±0.18	10.97±0.78	63.29±2.24	20.11±1.30
	Istarski duguljasti	3.21±0.12	2.59±0.09	10.87±1.39	64.38±0.40	18.96±0.97
	Hallesche Riesen	2.89±0.05	2.61±0.08	11.16±0.11	67.59±1.24	15.75±2.45

was the major compound ranging from 61.60 in Romische Zellernuss to 67.59 g/100 g fresh weight in Hallesche Riesen, followed by carbohydrates and proteins. Ash content in hazelnut kernel ranged from 2.51 - 2.85 g/100 g, and moisture between 2.87 - 3.21 g/100 g.

Results of our research are approximate to results of studies from other countries. According to research of Alasalvar et al. (2003) average fat content in Turkish hazelnut amounts to 61.21 g/100 g. Fat content in hazelnuts grown in Portugal ranges from 59.2 - 69.0 g/100 g (Amaral et al., 2006), and average fat content in some Italian varieties amounts to 64.10 g/100 g (Ruggeri et al., 1998).

Content of carbohydrates in our samples ranged from 15.75 - 20.58 g/100 g which is in line with the research of other authors that state results in range from 15.50 - 21.07 g/100 g (Alasalvar et al., 2003; Amaral et al., 2006; Ruggeri et al., 1998; Xu and Hanna, 2010).

They are followed by proteins which content ranged from (10.16 - 13.13 g/100 g). Results of our research are the closest to the results published by Amaral et al. (2006) for Portuguese hazelnut (9.3 - 12.7 g/100 g), while somewhat higher values were reported by Savage et al. (1997) for hazelnut grown in New Zealand (14.3 - 18.2 g/100 g).

By comparing our research with the studies from other growing areas, it is visible that other factors besides variety had influence on variations of proximate chemical composition.

By applying the analysis of variance (ANOVA) and the test of multiple comparisons (Bonferroni test) with significance level at $p = 0.05$ it was determined that harvest year, variety and their interaction (Figures 3 and 4) had significant influence on proximate chemical composition, which was confirmed by other authors. Erdogan and Aygun (2005) report that fat content in hazelnut kernel varies depending on variety, year and growing location. Özdemir et al. (2001) based on obtained correlations confirms that variety, soil composition and technological measures, especially irrigation and fertilization condition differences in composition of hazelnut kernel.

Similar results, reports Silva et al. (2005) who confirms in his paper that interaction of a variety and a year has influence on chemical composition and pomological traits of hazelnut. Čmelik and Mališević (1996) report that nut chemical composition is under higher influence of insufficient rainfall then to soil conditions. Significant increase of carbohydrates and ash content and decrease of fat content was determined in a drought year.

Influence of a variety and variety × year interaction has significant influence on content of carbohydrates. During all years of research the highest carbohydrates content was determined in variety Romische Zellernuss (20.58 g/100 g fresh weight). The highest fat content had variety Hallesche Riesen. Fat content is influenced by variety and vegetation year. Influence of a year on protein content was equal for all three varieties; however the highest protein content was determined for variety Istarski duguljasti (13.13 g/100 g).

Conclusion

Research has shown significant variability of yield, pomological and chemical characteristics of three most represented hazelnut varieties grown in Croatia. Variety Romische Zellernuss had the highest mean yield; variety

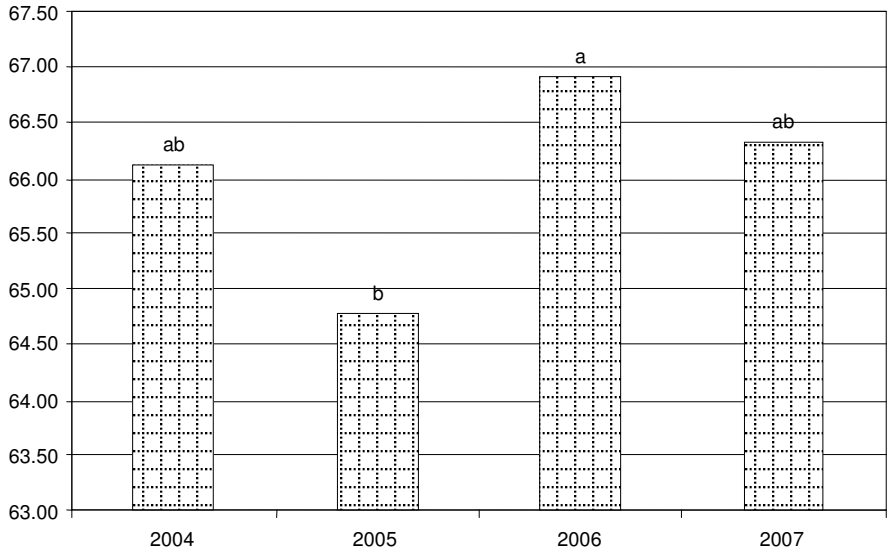

Figure 3. Fat content per year. Means followed by the same letters are not statistically different at $p < 0.05$.

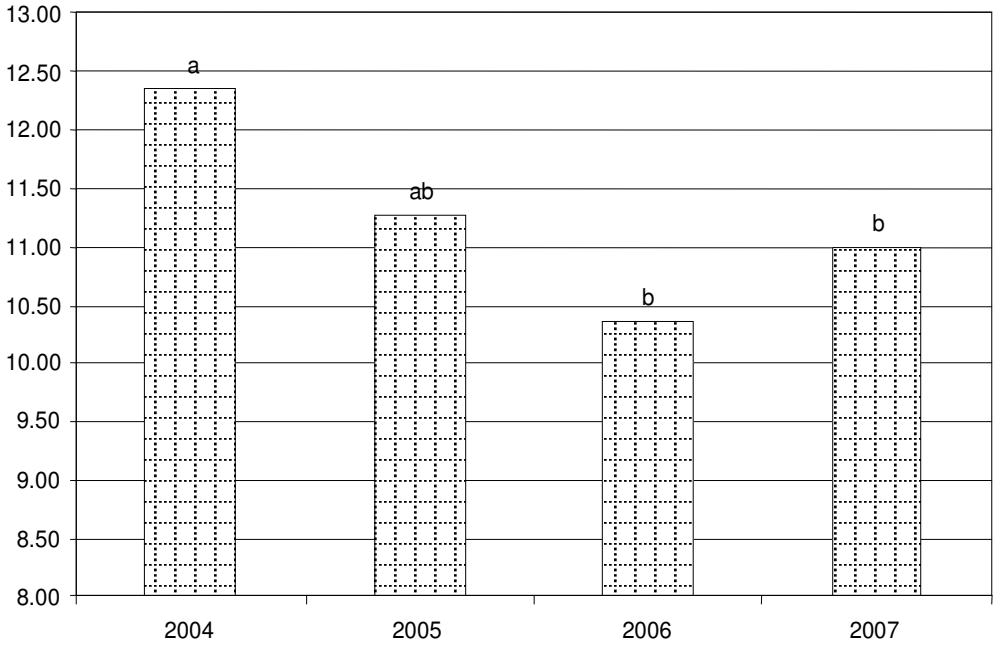

Figure 4. Protein content per year. Means followed by the same letters are not statistically different at $p < 0.05$.

Istarski duguljasti had the lowest, while the yield of Hallesche Riesen was subjected to highest variations between certain cultivation years.

Chemical composition varied between researched years as well; although it was mostly dependable on a variety. Fat dominated in nut composition of all varieties. Fat content was the highest in variety Hallesche Riesen (67.50 g/100 g), followed by Romische Zellernuss (65.83 g/100 g) and Istarski duguljasti (64.79 g/100 g), respectively. On average, proteins accounted for 11.32 g/100 g with no significant differences within varieties. All varieties are distinctive for rich content of carbohydrates

(18.72 g/100 g in average); however Romische Zellernuss can be singled out as the variety with the highest content of carbohydrates in all four years of research.

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