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Usporedba morfoloških i fizikalnih svojstava plodova triju sorata lijeske *(Corylus avellana L.)*

A comparison of morphological and physical characteristics of three different haselnut varieties (*Corylus avellana* L.)

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SAŽETAK

U pokusu usporedbe morfoloških i fizikalnih svojstava ploda lijeske (*Corylus avellana* L.) uključene su sorte: 'Istrska dolgoplodna leska', 'Tonda gentile delle langhe' i 'Fertile de coutard'. Pomoću izmjerenih morfoloških osobina: veličina ploda po promjeru i visini te masa ploda; i fizikalnih količina: sila, deformacija ploda i potrebna energija za lom ljuske ploda analizirana je mogućnost strojnog lomljenja ljuske. Maksimalna sila (367,04 N) za lomljenje lješnjaka po promjeru izmjerena je kod sorte 'Istrska dolgoplodna leska', a za lomljenje po visini kod sorte 'Fertile de coutard' (526,15 N). Najveća deformacija kod lomljenja lješnjaka izmjerena je po visini (1,00 mm) i promjeru (1,11 mm) kod sorte 'Istrska dolgoplodna leska'. Najveći utrošak energije za lomljenje lješnjaka po visini potreban je kod sorte 'Fertile de coutard' (0,24 J), a za lomljenje ljuske po promjeru lješnjaka kod sorte 'Istrska dolgoplodna leska' (0,22 J). Na temelju morfoloških i fizikalnih svojstava za strojno lomljenje najpovoljnija je sorta 'Istrska dolgoplodna leska'.

Ključne riječi: lješnjak, morfološke osobine, fizikalna svojstva, diskriminantna analiza

ABSTRACT

Morphological and physical characteristics of three hazelnut (*Corylus avellana* L.) varieties (‘Istrska dolgoplodna leska’, ‘Tonda gentile delle langhe’ and ‘Fertile de coutard’) were examined in the trial to determine the parameters of the machine for mechanical crushing of hazelnuts. Three morphological characteristics (height, diameter and mass) and three physical characteristics (force, shell deformation and energy impact for shell crushing) were measured on the laboratory device. The maximum force (367.04 N) for crushing hazelnut shells by the diameter was measured with ‘Istrska dolgoplodna leska’, while for crushing by the height the maximum force was determined with the ‘Fertile de coutard’ variety (526.15 N). The biggest shell deformation in crushing by the height (1.00 mm) as well as by the diameter (1.11 mm) was measured with ‘Istrska dolgoplodna leska’. The most energy for crushing the shell

by the nut height was required by 'Fertile de coutard' (0.24 J), while for crushing the shell by the diameter 0.22 J the most energy was spent by 'Istrska dolgoplodna leska'. According to the morphological and mechanical characteristics of the shell, the 'Istrska dolgoplodna leska' variety was suggested to be the most suitable for mechanical crushing.

Key words: hazelnut, morphological characteristics, linear discriminant analysis

INTRODUCTION

After a machine for mechanical crushing of hazelnuts has been devised, technical characteristics of hazelnuts affecting its operation must be determined. The operating principles of a hazelnut crushing machine originate from the renowned stone grinding units and other solid substances modified in order to crush nuts. In Slovenia, a nut crusher had been patented (Bernik, 2002). Its concept was used in a research analyzing construction solutions and the applicability of nut crushers (Gombač, 2005). Crushers exist in many construction varieties, which are divided into two groups according to direction of the crushing force. The first group includes machines which enable a two-sided application of force onto a hazelnut. The rigid crushing surfaces in the crusher have a constant tapered cylinder interspace, allowing a constant shift of plates in translatory motion, with an opening at the bottom, through which hazelnuts which have been crushed. That is why, when hazelnuts are not of the same thickness or height, kernels can be severely damaged. This nut crushing method requires a preliminary sorting of hazelnuts according to their thickness. In the light of machine's technical requirement, it is essential to be acquainted with morphological characteristics of hazelnuts in order to assure efficient high quality hazelnut crushing.

The second group of hazelnut crushing machines operates by the impact principle with the force being applied to a hazelnut only from the upper or from the lateral side. The deformation of a hazelnut shell occurs in the form of shell destruction or shell damage (i.e. a crack in the shell) caused by an internal tension in the shell. The construction of such a device must take into account the size of the relevant shell deformations for each hazelnut variety. This method requires hazelnuts being sorted according to the kernel mass, as the latter affects the relevant impulse causing shell destruction.

The relevant technical characteristics of the input material include the basic morphological and physical characteristics of hazelnuts (Özdemir, 1997; Güner et al. 2003; Bernik, 2004). The aim of our research conducted on a random

sample of three hazelnut varieties, i.e. 'Istrska dolgoplodna leska', 'Tonda gentile delle langhe' and 'Fertile de coutard', was to measure the height and the diameter of hazelnuts as well as to determine their mass, followed by a compression test involving measurement of shell firmness and deformations occurring due to the friction.

The article presents a detailed description of the force and energy needed for the crushing of the three hazelnut varieties when crushed by the height or by the width.

MATERIALS AND METHODS

The trial included 68 hazelnuts of the 'Istrska dolgoplodna leska' variety, 70 hazelnuts of the 'Tonda gentile delle langhe' variety and 67 hazelnuts of the 'Fertile de coutard' variety. All hazelnuts were collected in the 2006 growing season in a trial field located in the vicinity of Maribor.

Firstly, the height and the diameter of each hazelnut were measured with a sliding calliper. Then, each hazelnut was weighed on an analytical balance to within ± 0.01 g.

Furthermore, a pressure test determining shell firmness was conducted, for which a special pressure press was used. In each measurement, a hazelnut was clamped between the vice jaws ensuring a firm grip of the sample during the procedure. Then, data were registered in a computer, with the latter being an integral part of the pressure test device.

Force required for the shell destruction was monitored and measured. Immediately before the shell crushing, work (J) required for the shell crushing was also measured on the basis of the deformation size (mm) and the force used (N).

We assumed that physical conditions for hazelnut crushing depended on the crusher force direction, which might be connected with the morphological characteristics of hazelnuts.

In order to be able to present results of the multiple range statistical analysis of the measurements and the comparison of the morphological characteristics of the three hazelnut varieties, data were analyzed and graphical representation was made using the Statgraphics software.

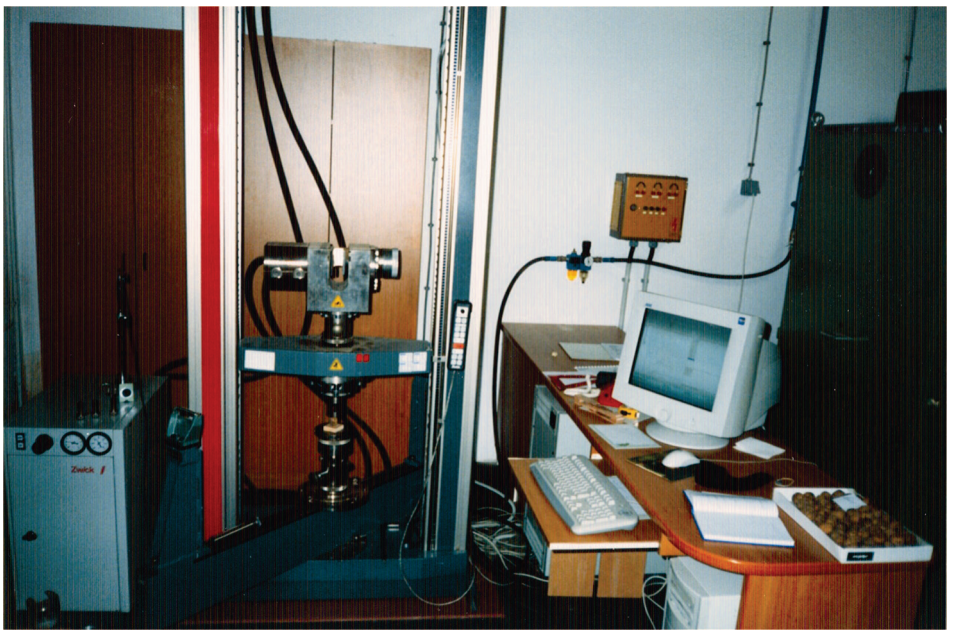

Figure 1: Experimental pressure press

RESULTS

Morphological characteristics of hazelnuts

With regard to hazelnut mass, the Shapiro-Wilk test (Shapiro and Wilk, 1965) showed a statistically significant difference of the empirical distribution in comparison with the normal distribution in the 'Fertile de coutard' variety. This was due to the presence of five solitary trees and a slight data skew. We shall, nevertheless, assume that the above-mentioned data skew concerning the empirical distribution was caused by a bad choice of the hazelnut sample, which is why further statistical analysis shall be performed on the assumption that the mass of all three hazelnut varieties has been distributed normally. With regard to the other two variables (diameter and nut height), the Shapiro-Wilk test proved that the distribution was normal in all three varieties.

Basic descriptive statistics for all three varieties is presented in Table 1, while the univariate analysis of variance is shown in Table 2. Furthermore, Table 1 also includes the 95 % confidence intervals for the average. Coefficients of variation in this trial amounted to 13.6 % for the nut mass, 4.5 % for the nut height and 4.9 % for the nut diameter.

Table 1: Median, average, standard error and confidence intervals for the nut mass, height and diameter

Dependent variable	Variety	n	Median	Average	Standard error	The 95 % confidence interval	
						Lower limit	Upper limit
Mass (g)	'Fertile de coutard'	67	2.55	2.62 (c)	0.32	2.00	3.24
	'Istrska dolgoplodna leska'	68	2.45	2.43 (a)	0.32	1.81	3.86
	'Tonda gentile delle langhe'	70	2.00	1.94 (b)	0.32	1.32	2.56
Height (mm)	'Fertile de coutard'	67	20.50	20.67 (b)	0.91	18.89	22.45
	'Istrska dolgoplodna leska'	68	23.20	23.12 (c)	0.91	21.34	24.89
	'Tonda gentile delle langhe'	70	16.90	16.74 (a)	0.91	14.96	18.51
Diameter (mm)	'Fertile de coutard'	67	20.30	20.26 (c)	0.89	18.48	22.04
	'Istrska dolgoplodna leska'	68	17.80	17.71 (b)	0.89	15.93	19.49
	'Tonda gentile delle langhe'	70	16.80	16.76 (a)	0.89	14.98	18.53

(a), (b), (c) in the 'Average' column represent statistically significant differences according to Duncan's Multiple Range Test, where (a) is the lowest average and (c) is the highest average.

The results of ANOVA (Table 2) proved the existence of statistically significant differences in the average values of all three variables among the three varieties ($p < 0.0000$). According to Duncan's Multiple Range Test ($\alpha = 0.05$), varieties differ pairwise in all three morphological characteristics. The 'Fertile de coutard' variety grows averagely the heaviest hazelnuts (2.62 g), followed by the 'Istrska dolgoplodna leska' variety (2.43 g) and the 'Tonda gentile delle langhe' variety (1.94 g). Averagely, the 'Istrska dolgoplodna leska' variety grows hazelnuts of the largest height (23.11 mm), followed by the 'Fertile de coutard' variety (20.67 mm) and the 'Tonda gentile delle langhe' variety (16.74 mm). Averagely, the 'Fertile de coutard' variety grows hazelnuts of the widest parameter (20.26 mm), followed by the 'Istrska dolgoplodna leska' variety (17.71 mm) and the 'Tonda gentile delle langhe' variety (16.76 mm).

Physical characteristics of hazelnuts

Basic descriptive statistics for the measurement of the maximum force applied by the nut height and by the nut diameter for all three varieties is shown in Table 3.

Table 3: Descriptive statistics for the maximum force applied by the nut height and by the nut diameter for all three hazelnut varieties

Hazelnut variety	Force (N) measured by the height	Force (N) measured by the diameter
'Istrska dolgoplodna leska' Average	(b) 411.36	(b) 367.04
Std. error	17.38	20.19
Median	392.67	349.47
Minimum	225.22	190.38
Maximum	551.05	540.21
'Tonda gentile delle langhe' Average	(b) 365.36	(a) 227.47
Std. error	21.95	14.69
Median	378.27	226.82
Minimum	40.35	105.77
Maximum	491.85	359.25
'Fertile de coutard' Average	(c) 526.15	(b) 352.04
Std. error	25.77	16.45
Median	508.76	364.59
Minimum	303.61	189.32
Maximum	745.18	498.09

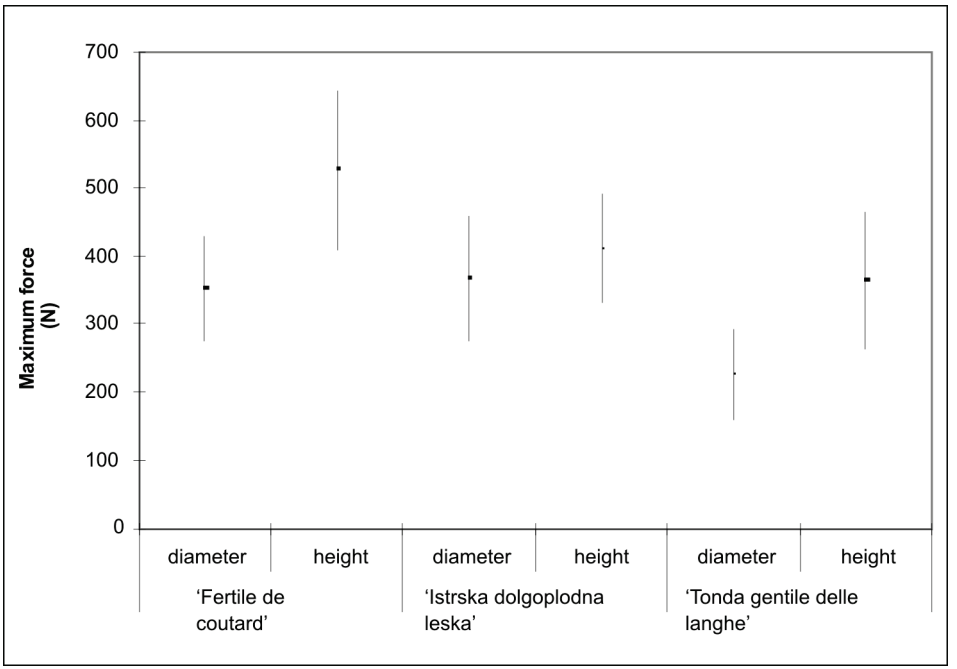

Figure 2: The average maximum force (N) in each treatment

Figure 2 shows that, in comparison with the method of crushing by the diameter, an averagely bigger force is needed in the method of crushing by the height (the 'Istrska dolgoplodna leska' variety, on the other hand, proved no statistically significant differences between the diameter and height). When hazelnuts were crushed by the height, the 'Fertile de coutard' variety stood out, requiring an averagely bigger maximum crushing force (526.2 N), while no statistically significant differences occurred with the other two varieties.

Where force was applied by the diameter, the 'Tonda gentile delle langhe' variety stood out, requiring an averagely smaller crushing force (227.5 N), while no statistically significant differences occurred with the other two varieties.

Table 4: Descriptive statistics for the shift caused by force application by the nut height and by the nut diameter for all three hazelnut varieties

Hazelnut variety	Shift (mm) measured by the height	Shift (mm) measured by the diameter
'Istrska dolgoplodna leska' Average	(a, b) 1.00	(a) 1.11
Std. error	0.04	0.05
Median	1.02	1.16
Minimum	0.70	0.46
Maximum	1.31	1.40
'Tonda gentile delle langhe' Average	(b, c) 0.83	(c) 0.72
Std. error	0.05	0.07
Median	0.86	0.62
Minimum	0.29	0.31
Maximum	1.12	1.52
'Fertile de coutard' Average	(a, b) 0.98	(b, c) 0.85
Std. error	0.07	0.05
Median	0.89	0.79
Minimum	0.59	0.41
Maximum	1.79	1.24

(a), (b), (c) represent statistically significant differences according to Duncan's Multiple Range Test

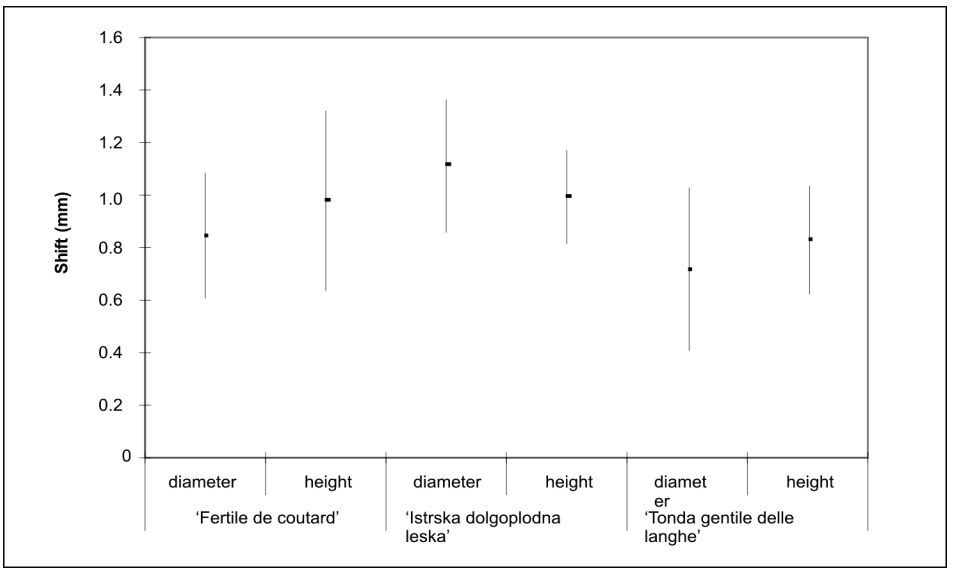

Figure 3: The average shift (mm) in each treatment

When the force was applied by the height, there were no statistically significant differences, whereas when the force was applied by the diameter, statistically significant differences occurred between the 'Istrska dolgoplodna leska' and the 'Fertile de coutard' varieties, as well as the 'Istrska dolgoplodna leska' and the 'Tonda gentile delle langhe' varieties. Between the 'Tonda gentile delle langhe' and the 'Fertile de coutard' varieties, there were no statistically significant differences either.

Table 4 shows the basic descriptive statistics of the measurements of shift with the application of force by the nut height and by the nut diameter for all three varieties. The largest shift in the hazelnut crushing by the height occurred with the 'Istrska dolgoplodna leska' variety (1.00 mm), followed by the 'Fertile de coutard' variety (0.98 mm) and the 'Tonda gentile delle langhe' variety (0.83 mm).

Furthermore, the same variety proved to have the largest shift in the hazelnut crushing by the diameter (1.11 mm), followed by the 'Fertile de coutard' variety (0.85 mm) and the 'Tonda gentile delle langhe' variety (0.72 mm).

Table 5: Descriptive statistics for the work caused by force application by the nut height and by the nut diameter for all three hazelnut varieties

Hazelnut variety	Work [J] measured by the height	Work [J] measured by the diameter
'Istrska dolgoplodna leska'		
Average	(a) 0.22	(a, b) 0.22
Std. error	0.02	0.02
Median	0.21	0.22
Minimum	0.08	0.05
Maximum	0.38	0.37
'Tonda gentile delle langhe'		
Average	(c) 0.14	(c) 0.09
Std. error	0.01	0.01
Median	0.15	0.09
Minimum	0.01	0.02
Maximum	0.21	0.17
'Fertile de coutard'		
Average	(a) 0.24	(b, c) 0.16
Std. error	0.02	0.02
Median	0.21	0.14
Minimum	0.09	0.04
Maximum	0.48	0.33

(a), (b), (c) represent statistically significant differences according to Duncan's Multiple Range Test

Table 5 shows the basic descriptive statistics of the measurement of work with the application of force by the nut height and by the nut diameter for all three varieties. With both the 'Tonda gentile delle langhe' (0.14 J) and the 'Fertile de coutard' (0.24 J) varieties, the method of hazelnut crushing by the height required averagely more energy than the method of crushing by the diameter, with the exception of 'Istrska dolgoplodna leska' (0.22 J) requiring the same average energy in both crushing methods.

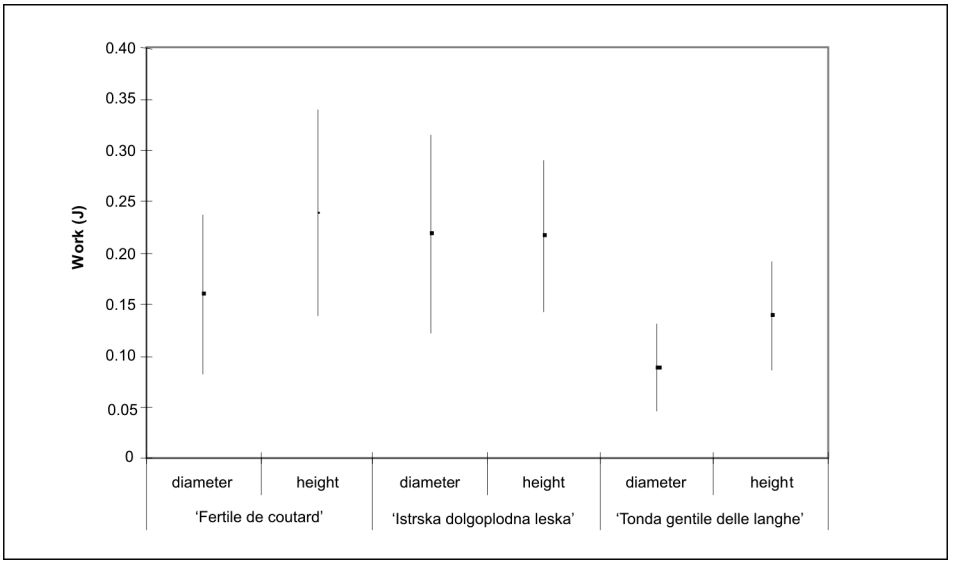

Figure 4: The average work (J) in each treatment

When comparing the average energy required according to the force application, there were no statistically significant differences between the 'Istrska dolgoplodna leska' variety (0.22 J) and the 'Fertile de coutard' variety (0.16 J) in the application of force by the diameter. 'Tonda gentile delle langhe' (0.09 J), on the other hand, required significantly less average energy in order to crush hazelnuts.

When force was applied by the height, the 'Tonda gentile delle langhe' variety (0.14 J) stood out in comparison with the average work required. This variety required the least energy in hazelnut crushing, while there were no statistically significant differences between the 'Istrska dolgoplodna leska' and the 'Fertile de coutard' varieties.

CONCLUSION

Measurement results regarding the three morphological characteristics of hazelnuts (mass, height and diameter) showed the occurrence of statistically significant differences in all three characteristics among the chosen varieties ('Istrska dolgoplodna leska', 'Tonda gentile delle langhe' and 'Fertile de

coutard'). On the basis of the measurement results regarding the physical characteristics of hazelnuts it was determined that:

- maximum force in hazelnut crushing by the diameter was required by the 'Istrska dolgoplodna leska' variety (367.04 N),
- the largest shift in hazelnut crushing by the height and by the diameter occurred in the 'Istrska dolgoplodna leska' variety (1.00 mm or 1.11 mm),
- the largest amount of energy in hazelnut crushing by the height was required by the 'Fertile de coutard' variety (0.24 J), while the largest amount of energy in hazelnut crushing by the diameter was required by the 'Istrska dolgoplodna leska' variety (0.22 J).

The measured crushing force values showed statistically significant differences in the mechanical characteristics of the three varieties. These differences are essential for the planning of the basic hazelnut crusher parameters, a machine otherwise hard to be constructed in an efficient manner. Crushing force setting is thus one of the basic parameters needed in the hazelnut crusher.

On the basis of the results it is assumed that 'Istrska dolgoplodna leska' is the most suitable variety for the mechanical crushing of hazelnuts. In this variety, an equal force applied by the height and by the diameter is particularly important, even if it requires a somewhat higher maximum crushing force in comparison with the other two varieties studied.

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