The Influence of Log Defects on the Cutting Yield of Oak Veneer

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The quality of logs entering the production line is important because it controls the quality and yield of veneer. In Romania, *Quercus* species represent 18% of the total forests, and of which 2% is exclusively the pedunculate oak. The wood of pedunculate oak is hard and elastic, and it has a good natural durability. Due to such features it also has multiple uses in the furniture industry, construction, joinery, and cooperage works. The present work highlights the influence of some characteristics of the raw material on the cutting yield of veneer in the case of pedunculate oak logs purchased from different regions. Defects in the raw material had a certain negative influence on the veneer quality. The defects were identified and prioritized using the Pareto diagram.

Keywords: Oak; Log defects; Veneer; Yield; Pareto diagram

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INTRODUCTION

There is a large range of covering materials in the furniture market (Jimenez *et al.* 2016). However, veneer is still considered an important design element in the production of furniture, doors, flooring, ceiling, car manufacturing, and paneling for walls, boats, and aircraft interiors (Ozarska 1999; Tenorio *et al*. 2011). Just as no two trees are alike, each sheet of veneer is unique (Musat *et al*. 2016). It has its own individual character acting either as a visible surface of the finished product or contributing less to the appearance when used as an inner surface. High quality sliced or peeled veneers are used as face veneers (Hapla *et al*. 2002; Cassens 2003).

Despite modern production technology, veneer production requires experience and craft skills (Melo *et al*. 2014). To produce veneer, the logs are segregated into quality grades and each wood species is individually processed (Kral and Hrazsky 2003; Dumitrascu *et al*. 2013).

While large diameter logs that are clear of defects can be used for veneer production, other logs may still be suited and valuable for veneer. Sweep, log end splits, knots, and many other characteristics are evaluated when grading a log (Afrifah and Frimpong-Mensah 2014). These raw material characteristics affect the production of high-quality veneers (Mercker and Hopper 2004; Huang *et al*. 2012). Factors of interest include the overall conditions of the timber stand, site, and soil type influence the wood properties, tree geometry and form, and growth rate. Further on, the resulting log is subjected to processing to obtain the veneer product, and all these combined factors influence the product quality (Feuillat and Keller 1997; Doussot *et al*. 2002; Hamilton *et al*. 2015; Gilbert *et al.* 2017). The quality of logs entering the production line is important because it controls the quality and yield of veneer that can be obtained (Wiedenbeck *et al.* 2003).

The yield of veneer varies with log diameter, log quality (including straightness of the blocks), diameter to which the log is peeled, and the efficiency with which the veneer is cut and utilized (Huang *et al.* 2012; Olufemi 2012). Studies performed on veneer yield in various wood species have shown how veneer recovery can be estimated from log grades (Lutz 1977; Dobner *et al*. 2013; McGavin *et al*. 2014; Denes *et al*. 2017).

Among the valuable wood species used for veneers, *Quercus* species generate special interest from furniture manufacturers (Todaro *et al.* 2012). The common or pedunculate oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* Matt.) represent important hardwood species spread along the European continent. In Romania, *Quercus* species represent 18% of the total forests, of which 2% are exclusively pedunculate oak. In 2015, a total of 1456,000 m^3 of *Quercus* species round wood was harvested in Romania (INSSE 2016).

Oak is an important wood species due to its special qualities and aesthetic value. The pedunculate oak is adaptable to various climatic conditions, but it is a relatively demanding species in regard to soil features (Şofletea and Curtu 2007; Martinik *et al*. 2014). The wood of pedunculate oak is hard and elastic, and it has a good natural durability. It has multiple uses in furniture, construction, joinery, and cooperage works (Şofletea and Curtu 2007).

Defects are present in all wood species. They are measured and then assessed against predetermined grading rules to assign a quality grade. The European standard SR EN 1316-1 (2001), which used four grading classes exclusively, has been replaced with the new standard SR EN 1316-1 (2013), which classifies *Quercus* logs for veneer into three grades according to their diameter, length, and non-acceptable defects.

Veneer companies are selective in which logs they use and are interested in the most profitable solution with regard to the log price for a given quality, processing costs, *etc*. The log grader estimates the quantity and quality of veneers to be produced from the wood, without actually seeing it (Dumitrascu *et al*. 2017).

The purpose of the present work is to highlight the influence of some characteristics of the raw material upon the cutting yield of veneer in the case of pedunculate oak logs. To emphasize the importance of the oak log quality, the studies were performed based on the analysis of oak log defects achieved in three Romanian regions, namely Dâmbovita, Giurgiu, and Olt counties, as well as a region in Croatia.

EXPERIMENTAL

Materials

The pedunculate oak logs (*Quercus robur* L.) used for this study were purchased from three locations in Romania, namely: Târgovişte in Damboviţa County, Bolintin in Giurgiu County, and Reşca in Olt County, as shown in Fig. 1, and another location in Croatia. The location in Croatia was considered to evaluate the possible differences that may appear in regard to the cutting yield of veneer or special veneer when compared with the oak logs native in Romania. The three selected sites in Romania are all located in the

Southern part of the country; however they present different and particular climatic conditions (www.aboutromania.com).

Targoviste region, at the contact area between the Getic Subcarpathians and the Romanian plain, benefits from a favorable position, near the parallel of 45°. The continental climate of an annual average temperature of 9.9 °C and thermal amplitude of 22 °C, and an average annual amount of 627 mm precipitations show that there are favorable conditions for the development of plants in the area, including oak forests and mixed forests of oak and lime trees.

Bolintin area is situated in the centre of the Romanian Plain in the holm between the rivers Arges (west) and Sabar (east). The area is one of very hot summers (average temperature in June 30 °C), average yearly rainfalls (545 mm), and relatively cold winters with strong blizzards at irregular intervals and periods of warming. The climate correlated to the hydrological complex in the territory determines the existence of the Quercus forests, in combination with other wood species such as lime, ash, maple, poplars.

Olt county belongs to the two great geography types: the Getic Plateau and Wallachian Plain; it has a temperate-continental climate, a little wetter in the north and drier in the south. The soil quality considerably varies between the plain and the forests. The cultivated land represents 80.5% of the county's area, while forests and other vegetation lands represent 10.6% only, with mixed forests of oaks, poplars, and willows, specific to the Reşca area, in the central part of the county.

Fig. 1. Locations in Romania where the oak logs were purchased

A total of 58 oak logs were selected from each location according to SR EN 1316-1 (2013). The volume of each log was calculated based on diameter and length before starting the veneer production process.

Table 1. Distribution of Oak Logs Based on Diameter Category

Diameter Category		Number of Pieces per Location			
Class No.	Diameter (cm)	Târgovişte	Reşca	Bolintin	Croatia
I	40 to 55	13	1	2	-
II	56 to 70	26	23	37	36
III	71 to 85	18	21	18	22
IV	>85	1	13	1	-

Method

The veneer cutting technology was described previously in a study on oak logs (Musat *et al*. 2016). Two to four splitwoods were cut from each log. Prior to veneer cutting a hydrothermally treatment in hot water at 80 °C to 90 °C for 20 h was applied, and then veneer sheets of about 0.55 mm thickness were sliced. These sheets were dried in three temperature steps, such as 100, 120, and 132 °C up to a final moisture content of about 12.6%, conditioned, and sized at the end of the process technological line.

For data analysis, descriptive statistics were used to establish and confirm the normal distribution of the values. For each of the 58 trees taken from each location the minimum, maximum, average, and median values, standard error, and standard deviations values were calculated. The diameter, length, volume, area, cutting yield of veneer and special veneer, and number of veneer sheets were also obtained from the technological process. The cutting yield of special veneer was expressed as the amount of finished products resulting from 1 m^3 wood and ranked in the first quality class as has been already presented (Dumitrascu *et al*. 2013), the conditions of admissibility on quality classes being in accordance with STAS 1122 (2008).

The study also refers to the estimation of the cumulative relative frequency of the defects present in oak logs, such as buds, insect holes, wood studs, curvature, buttress roots, and conicity. The specific location of these defects was analyzed using the Pareto diagram, and a comparative analysis was performed using a box plot diagram.

The Pareto diagram analysis applied to the oak raw material focused on the identification and prioritization of the main categories of defects, which influence the quality of special veneers. A Pareto chart is a basic quality control tools used to highlight the most frequently occurring defects, most common causes of defects, or most frequent causes of customer complaints (Dumitrascu *et al*. 2013).

A cumulative percentage line helps to judge the added contribution of each category. Pareto charts can help to focus improvement efforts on areas where the largest gains can be made. In addition, by using a graphical approach, such as MiniTab (Frost 2013) the extent to which the volume of the logs entering into the technological flow influenced the cutting yield of veneer and special veneer, was verified.

RESULTS AND DISCUSSION

The descriptive statistics applied to oak logs and veneer by source location are presented in Table 2.

Table 2. Descriptive Statistics Applied to Oak Logs and Veneer by Source Location

Characteristics	Statistical Parameter					
	Minimum	Maximum	Mean	Median	Standard error	Standard deviation
Târgovişte						
Diameter (cm)	46	87	66	67	1.40	10.63
Length (m)	2.5	3.5	3.1	2.9	0.05	0.36
Volume (m^3)	0.550	2.562	1.114	1.057	0.05	0.38
Cutting yield of veneer (m^2/m^3)	236.96	1710.85	788.94	808.72	35.91	273.46
Cutting yield of special veneer (m^2/m^3)	18.30	1518.10	589.87	551.21	41.47	315.84
Surface (m^2)	228.43	2684.33	893.78	805.61	61.37	467.38
Number of sheets	1040	4480	1974	1940	74.86	570.14
Reşca						
Diameter (cm)	52	98	75	75	1.49	11.37
Length (m)	2.5	3.9	3.2	2.9	0.06	0.43
Volume (m^3)	0.615	2.823	1.435	1.328	0.06	0.48
Cutting yield of veneer (m^2/m^3)	161.60	1504.35	735.50	725.31	36.00	274.13
Cutting yield of special veneer (m^2/m^3)	73.33	1397.59	637.19	639.02	36.48	277.81
Surface (m^2)	143.86	2273.80	936.18	925.82	68.75	523.58
Number of sheets	200	3052	2012	2107	87.53	666.62
Bolintin						
Diameter (cm)	52	90	67	67	1.11	8.43
Length (m)	2.3	3.9	3.2	3.1	0.06	0.48
Volume (m^3)	0.689	2.227	1.166	1.247	0.05	0.35
Cutting yield of veneer (m^2/m^3)	107.90	1187.72	793.56	799.23	21.52	163.87
Cutting yield of special veneer (m^2/m^3)	104.85	1164.50	725.94	738.24	22.09	168.23
Surface (m^2)	140.39	1946.96	864.26	808.61	48.08	366.15
Number of sheets	712	2755	1815	1781	58.89	418.03
Croatia						
Diameter (cm)	57	84	69	69	0.92	6.99
Length (m)	2.2	3.7	3.1	3.1	0.06	0.47
Volume (m^3)	0.622	1.814	1.152	1.126	0.04	0.29
Cutting yield of veneer (m^2/m^3)	62.93	1200.26	785.00	814.34	25.07	190.96
Cutting yield of special veneer (m^2/m^3)	0	1116.80	694.86	753.81	29.23	222.62
Surface (m^2)	53.24	1688.28	908.01	869.14	41.87	318.90
Number of sheets	1350	2800	2006	1989	46.44	353.67

The average values were very close to the median values, indicating that the values of each parameter were normally distributed. Hapla *et al*. (2002) reported an average yield of sliced beech veneers of about 841 m^2/m^3 with a veneer thickness of 0.55 mm. Kral and Hrazsky (2003) also evaluated the qualitative yield of oak veneer ranging from 58.4 to 60.3%, while in beech veneer of 0.6 mm thickness the yield ranged between 46.8 and 51.6%. In a previous study, Dumitrascu *et al.* (2017) obtained similar values for sessile oak logs native to the Târgovişte region such as mean log diameter of 66 cm and yield values of veneer and special veneer at about 865m^2/m^3 and 735m^2/m^3, respectively.

Defects of Oak Log from Various Locations

It was noticed that in several cases an oak log presented a single defect, two defects, or even three defects. The distribution of defects that appeared on the oak logs purchased from the four regions is highlighted in Fig. 2.

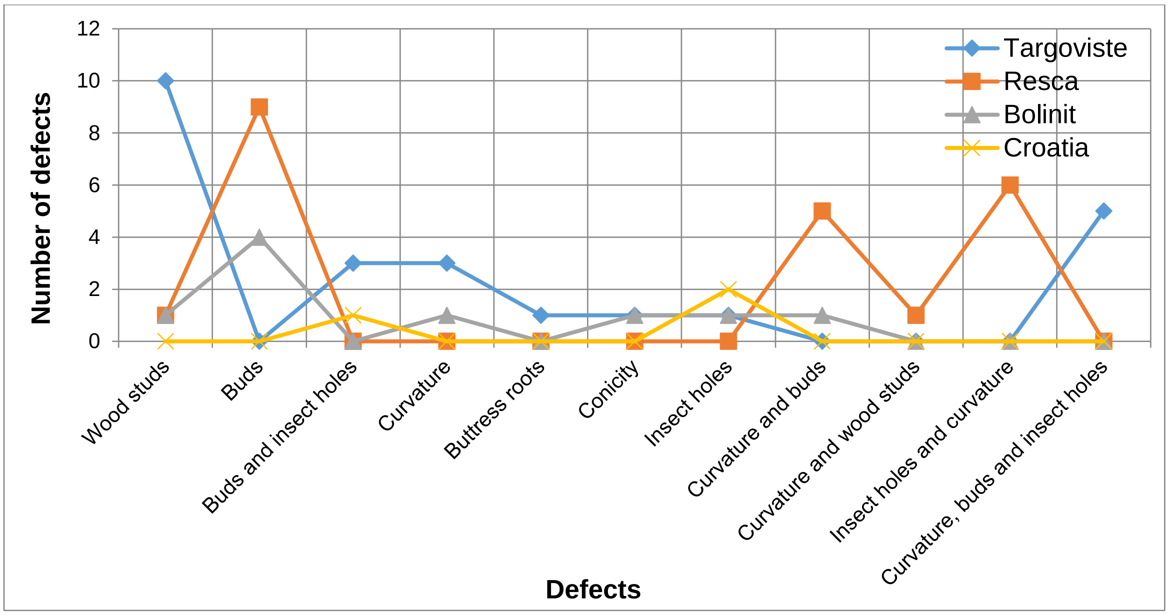

Fig. 2. Distribution of defects in oak logs collected

To obtain the expected cutting yield of veneer, it is essential to understand the defects category from the analyzed area. The influence of the raw material on the yield of veneer and special veneer was highlighted through the comparative analysis of defects using Pareto diagrams, as shown in Figs. 3 through 6. The Pareto analysis technique was applied to identify, analyze, and prioritize the main category of defects specific to round oak wood. Negative influences on the quality of decorative veneers were based on the estimation of the cumulative relative frequency.

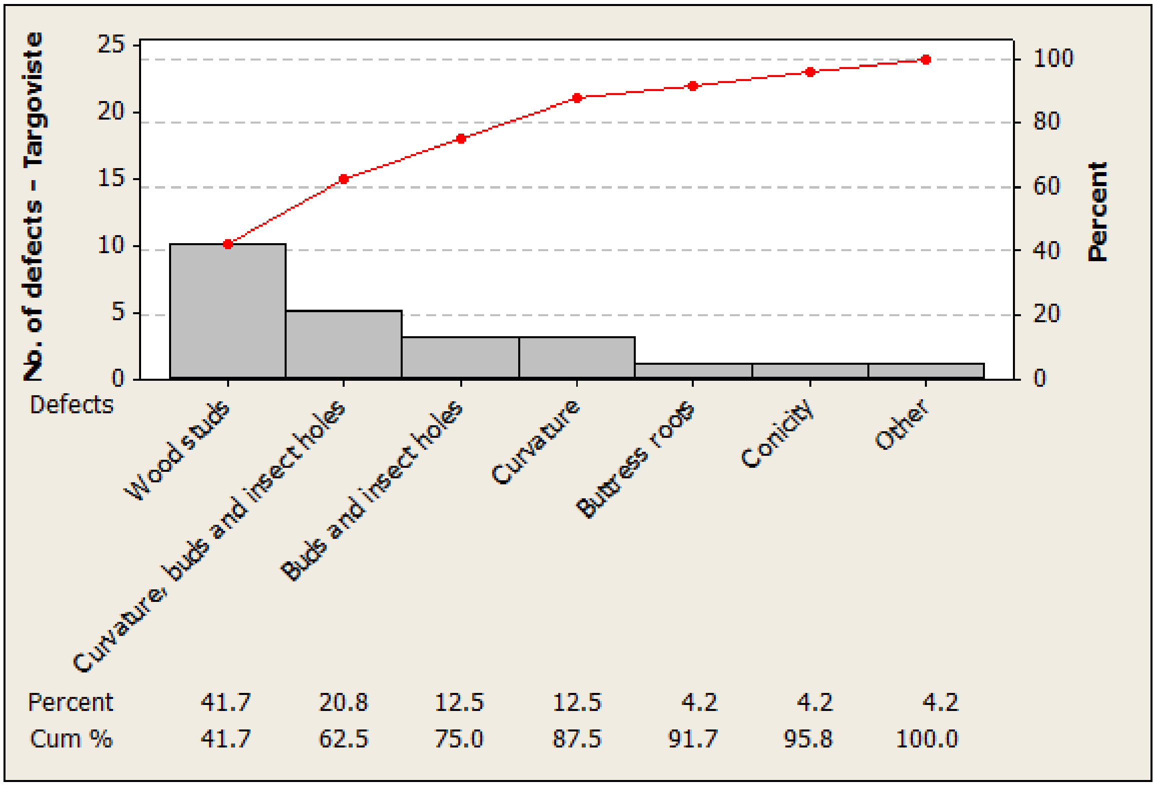

Fig. 3. Pareto diagram for specific quality defects in oak from the Târgovişte region

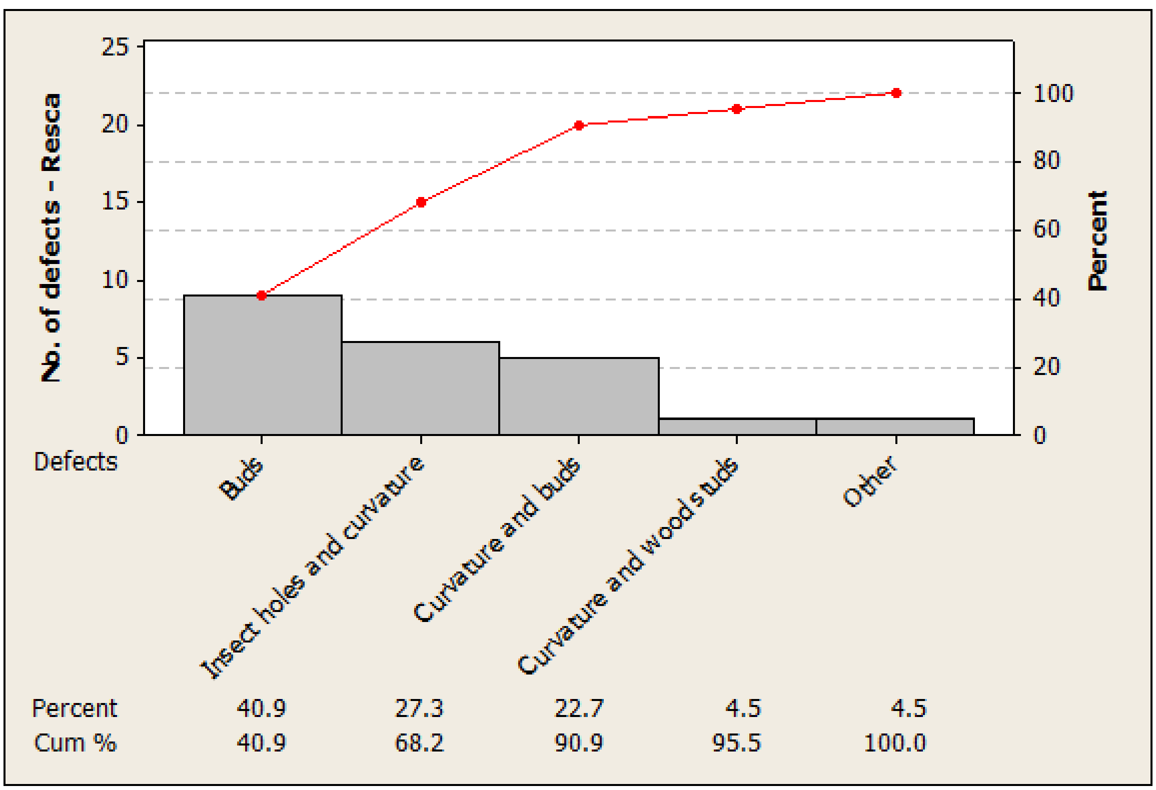

Fig. 4. Pareto diagram for specific quality defects in oak from the Resca region

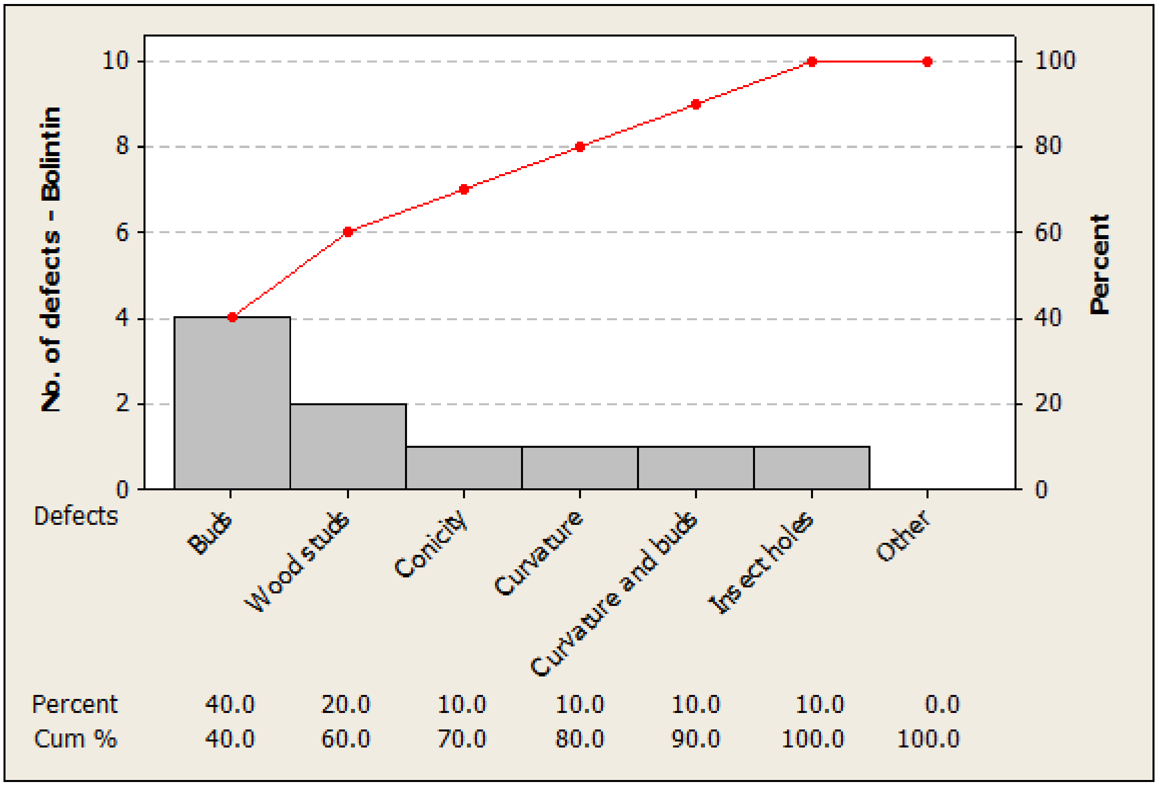

Fig. 5. Pareto diagram for specific quality defects in oak from the Bolintin region

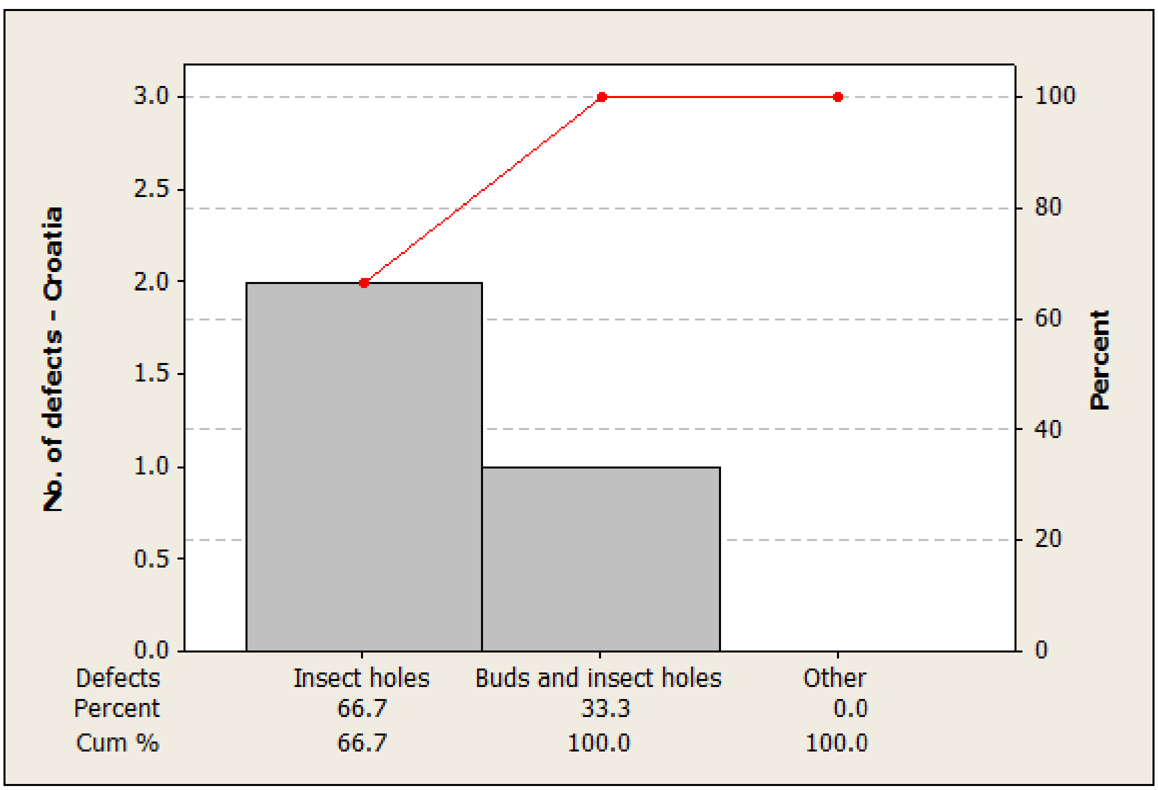

Fig. 6. Pareto diagram for specific quality defects in oak from Croatia

Based on the Pareto analysis, the main quality defects of oak logs from the different regions are listed in order of importance, as follows:

- Târgovişte region: 62.5% were caused by the first two categories of defects – wood studs and curvature, and buds and insect holes (Fig. 3);
- Reşca region: 68.2% were caused by the first two categories of defects – buds and insect holes and curvature (Fig. 4);
- Bolintin region: 60% were caused by the first two categories of defects – buds and wood studs (Fig. 5);
- Croatia region: 66.7% were caused by only one category of defects – insect holes (Fig. 6).

Influence of the Wood Log Volume upon the Cutting Yield of Veneer and Special Veneer

The presence of acceptable defects on the wood material influenced the cutting yield obtained during the veneer production. As expected, a high volume did not always result in a high cutting yield, but this aspect was instead isolated and influenced by the types of defects (Fig. 7 and Fig. 8).

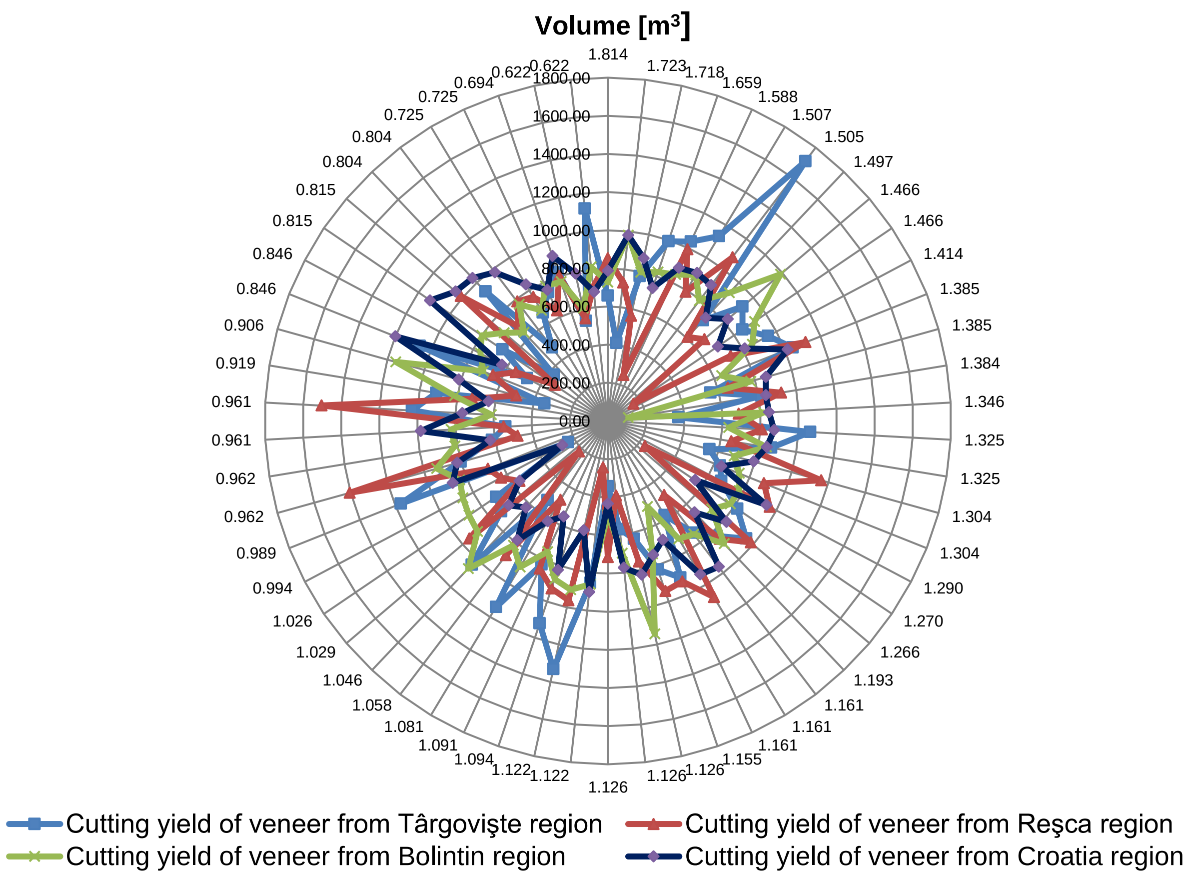

Fig. 7. Influence of the wood volume upon the cutting yield of veneer from the analyzed region

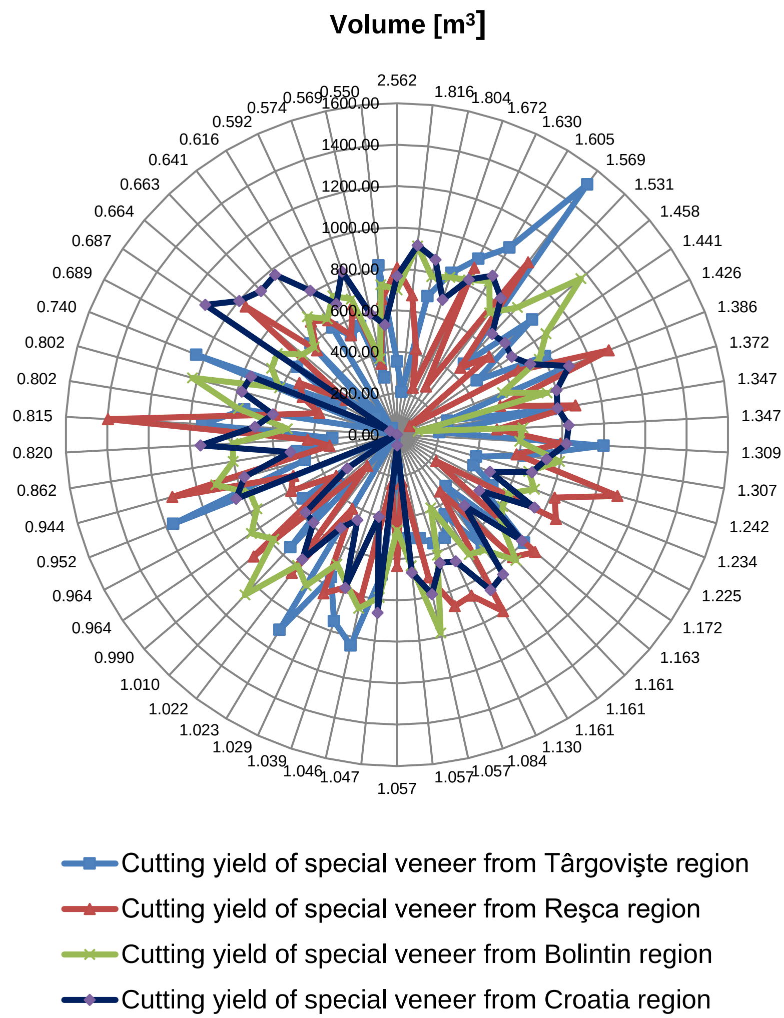

Fig. 8. Influence of the wood volume upon the cutting yield of special veneer from the analyzed region

Table 3 presents the highest values obtained for the cutting yield of veneer and special veneer in relation to the volume of the oak logs.

Table 3. Representative Values of the Cutting Yield of Veneers in Relation to the Wood Log Volume

Location	Veneer		Special Veneer	
	Cutting Yield (m^2/m^3)	Volume (m^3)	Cutting Yield (m^2/m^3)	Volume (m^3)
Târgovişte	1710	1.569	1518	1.569
Reşca	1500	1.022	1397	1.022
Bolintin	1187	1.502	1164	1.502
Croatia	1200	0.846	1116	0.815

Analysis of the Cutting Yield of Veneer Obtained for the Four Regions

The wood material purchased from the Bolintin region recorded the best cutting yield of veneer. For wood purchased from Croatia, a similar median value was obtained. Moreover, for two other regions in Romania, Târgovişte and Reşca, the obtained data were comparable (Figs. 9 and 10).

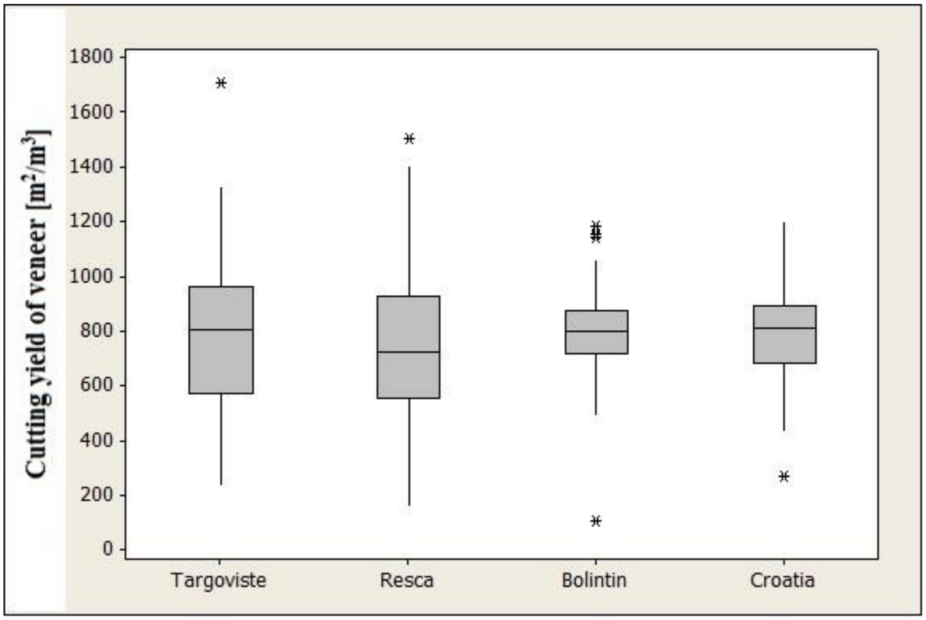

Fig. 9. Comparative analysis on the cutting yield of veneer for the analyzed regions

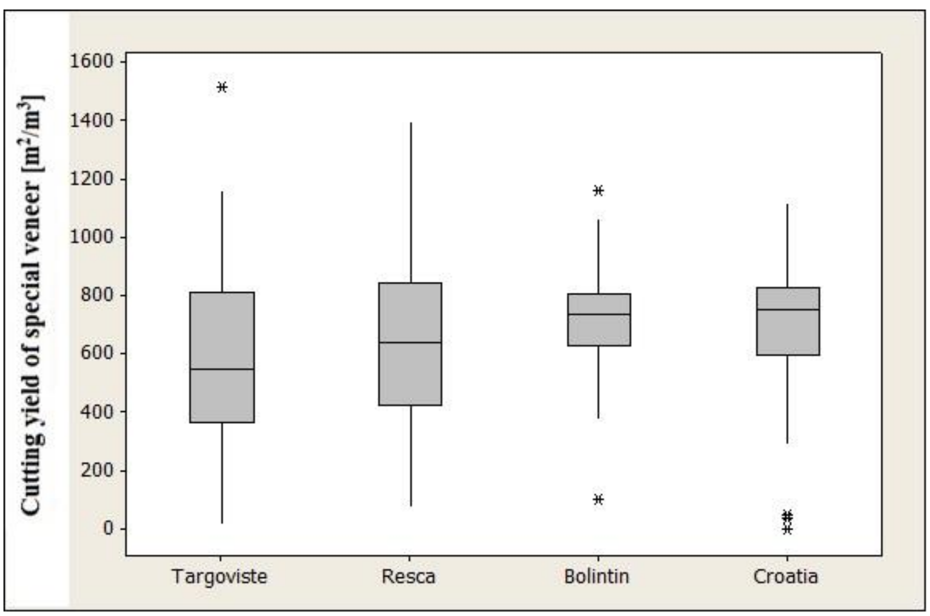

Fig. 10. Comparative analysis on the cutting yield of special veneer for the analyzed regions

Based on the cutting yield of special veneer, the following hierarchy of locations for the oak logs was established: Bolintin, Croatia, Reşca, and Târgovişte. The observed median value for the oak logs in Croatia was higher than in the Bolintin region, but the dispersion of data indicated that the oak logs from Bolintin region presented a superior cutting yield. Furthermore, for the acquisition of wood mass, the geographic region was an influencing factor on veneer quality, as given by the indicator of a special veneer cutting yield.

CONCLUSIONS

1. Regarding the cutting yield of veneer, the geographic origin of logs influenced their quality given by the indicator of special veneer yield, which varied among locations based on the climatic and soil condition.
2. The most important defects in the oak logs from all four regions in Romania were buds, wood studs, curvature, and insect holes, while for the oak logs in Croatia, defects such as buds and insect holes were the most common.
3. The implementation of Pareto diagram made it possible to identify and to prioritize the admissible defects of row material specified in standard. Therefore, decisions can be made with regard to their acceptance or removal. This approach offers benefits for production by reducing the acquisition cost of logs and by improving the use of limited resources.

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