Inferential Statistics of *Quercus* Species in Veneer Cutting

Adela-Eliza Dumitrascu,[a] Emilia-Adela Salca,[b,]* Laurentiu Aurel Mihail,[a]
Valentina Doina Ciobanu,[c] and Elena-Camelia Musat [c]

Quercus species represent 18% of the total forest area in Romania, of which 2% refers to common oak and 10.5% refers to sessile oak. These species are of special importance for Romanian silviculture due to their value in multiple industrial uses. The finest and most efficient use of valuable timber is wood veneer. This paper presents a comparative analysis of the efficiency in veneer cutting for two *Quercus* species, common oak and sessile oak, originating from the Snagov area in Romania. The statistical parameters of veneer efficiency were estimated with high accuracy by using the least squares method with a 95% normal confidence interval based on the Anderson-Darling test and the correlation coefficient. The analysis of inferential statistics used the estimation of the 87th percentile, determining the cumulative density functions for the species under study. More defects were found in common oak logs than in sessile oak logs, which produced more veneer sheets. The veneer efficiency for sessile oak logs was superior to that of common oak logs. These findings might have practical applications in industrial conditions when screening for the best log species with high efficiency in veneer cutting.

Keywords: Common oak; Log defects; Sessile oak; Veneer efficiency

Contact information: a: Department of Manufacturing Engineering, Transilvania University of Brasov, Mihai Viteazul 5, 500174, Brasov, Romania; b: Faculty of Wood Engineering, Transilvania University of Brasov, Universitatii 1, 500068, Brasov; c: Department of Silviculture and Forest Engineering, Transilvania University of Brasov, Sirul Beethoven 1, 500123, Brasov, Romania;
** Corresponding author: emilia.salca@unitbv.ro*

INTRODUCTION

The *Quercus* genus belongs to the Fagaceae family, and it comprises of about 350 to 500 species with great technical, economical, and ecologic potential (Kubitzki 1993; Viscosi *et al.* 2009). *Quercus* species are spread throughout the northern hemisphere down to the equator (Axelrod 1983). They are found in Asia, North America, Europe, and Africa. Approximately 20 oak species grow in the Mediterranean area. In Europe 27 native species of *Quercus* genus are found, of which the common oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* (Mattuschka) Liebl.) are the two most common and valuable species (Mabberley 1990; Petritan *et al.* 2012).

These species adapt to extremely variable habitats, from sea level to 4000 m in the Himalayas, and from swamps to deserts. Oaks are considered post-pioneer and light demanding species (Timbal and Aussenac 1996). In terms of site requirements, common oak and sessile oak may grow together on a wide range of soils. The former grows in wet areas, while the latter is quite tolerant to drought and poor soil (Popa *et al.* 2013).

Thomas *et al.* (2002) reported that various abiotic and biotic factors have been related to oak decline in Europe, and several studies in last decade show the role of oaks in their natural range (Friedrichs *et al.* 2009; Mérian *et al.* 2011). Sessile oak copes better with expected climate change in pure and mixed stands (Bergès *et al.* 2005).

Romania is located in the continental temperate region and therefore presents optimal conditions to grow *Quercus* species (FAO 1995). Romanian forests consist of 69.3% hardwood species and 30.7% softwoods. The main species are 32% beech, 19% spruce, 18% oak, 17% diverse hard hardwoods, 7% diverse soft hardwoods, 5% fir, and 2% other softwoods. *Quercus* species comprise 2% common oak and 10.5% sessile oak (Ministry of Water and Forests 2016). Sessile oak covers 500,000 ha in Romania, and it is the most widespread indigenous *Quercus* species (Nicolescu 2010). Pure common oak and mixed *Quercus* stands are located in Romania in low hilly and subcolinary meadows under a fragmented repartition, but they are well-represented at altitudes from 140 m to 350 m. The species grow on luvo-soils under a relatively wet and cold climate with annual average temperatures of about 6 °C to 9 °C and precipitations of about 600 mm to 900 mm. These valuable species present special importance for the Romanian economy (Şofletea and Curtu 2007; Budeanu *et al.* 2016).

Various publications have approached the two species under scientific screening related to wood quality (Zhang *et al.* 1994; Feuillat and Keller 1997; Doussot *et al.* 2002; Attocchi 2015), defects (Kruch and Nicolescu 2010; Kruch 2011; Dumitrascu *et al.* 2013), genetic variations and control of specific features (Savill *et al.* 1993; Mosedale *et al.* 1996; Kremer and Zanetto 1997), and regeneration patterns in relation with the environment (Indreica and Kelemen 2011; Annighofer *et al.* 2015).

Quercus species timber has been the most demanded and highly valued timber in the European market (Bary-Lenger and Nebout 1993). Its position dominates the flooring and joinery industry (UNECE/FAO 2012). Common oak and sessile oak present a considerable economic value in the wood processing industry especially; they are used in construction, furniture manufacturing and veneer production, barrels, and fencing (Kruch and Nicolescu 2010; Nicolescu 2010; Todaro *et al.* 2012; Annighofer *et al.* 2015).

In Romania several home-grown wood species are used for decorative veneer production, such as larch, oak, maple, walnut, cherry, ash. Two of the *Quercus* species, namely the common oak and sessile oak are granted with a special attention in the art furniture industry. There is no mass veneer production for these species.

The most efficient use of any valuable species is through its veneer by using modern veneer production technology (Ozarska 2013). The value of a veneer tree is determined by the interaction of several factors, such as the timber stand, site, and soil type (Feuillat and Keller 1997). Only high-quality, defect-free logs are used to produce veneers, and each wood species is individually processed based on the cutting scheme set by the company (Musat *et al.* 2016, 2017). The quality of logs in the production line gives the yield in veneer cutting at the end (Lutz 1977; Wiedenbeck *et al.* 2003; Dobner *et al.* 2013; McGavin *et al.* 2014).

The classification of quality defects of wood species is specified in the European standard SR EN 1316-1 (2013) with respect to common oak and sessile oak, which also includes the quantified sapwood width for logs quality classification. Also, the standard classifies the *Quercus* logs for veneer into three grades according to their diameter, length, and non-acceptable defects.

The major difficulty hindering the high-efficiency marketing of such wood species is the fact that most of the features and defects newly introduced into SR EN 1316-1 are not reflected in the Romanian standards, such as the frequency of spreading, size, and log distribution (Dumitrascu *et al.* 2013).

This paper presents a comparative analysis of the efficiency in veneer cutting for two *Quercus* species, common oak and sessile oak, originating from the Snagov area in Romania by using inferential statistics. The statistical parameters of veneer efficiency were estimated with high accuracy by using the least squares method with a 95% normal confidence interval based on the Anderson-Darling test and the correlation coefficient. The analysis of inferential statistics used the estimation of the 87th percentile, determining the cumulative density functions for the species under study. The study aims to identify and evaluate the possible differences that may appear in regard to the efficiency in veneer cutting when considering the quality defects and number of veneer sheets. Findings of this study might have brief practical applications under industrial conditions when screening for the best species with high efficiency in veneer cutting.

EXPERIMENTAL

Materials

Logs of two species, common oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* (Mattuschka), were purchased from Snagov Forest Direction in Romania. The Snagov Direction, subordinated to the National Forest Direction, administrates the state public forests from the northern part of Ilfov County and provides silvicultural services to the private forests in the area. The forests of Snagov Direction are distributed in the flat plains area surrounding Bucharest and are part of the famous Vlasia Forests. The Snagov Direction has a total surface of 9495 ha with the following composition: 53% *Quercus* species, of which 35% is pedunculated oak; 23% hard hardwoods, 20% soft hardwoods, and 4% other species.

Method

A total of 215 logs were selected according to the SR EN 1316-1 (2013) standard from the same location of Snagov region; 165 common oak logs and 50 sessile oak logs have been analyzed with the consideration that the samples size was representative. In accordance with the specified standard the selection criteria are both quantitative and qualitative. The main statistical parameters of common oak and sessile oak raw material are detailed in Table 1.

Table 1. Descriptive Statistic of Raw Material for the Analyzed Species

Characteristics	Common oak				
	Minimum	Median	Maximum	Mean	Standard Deviation
Diameter (cm)	44	64	94	64.638	11.196
Length (m)	2.2	2.9	3.9	3.0281	0.3949
Volume (m^3)	0.3950	0.9620	2.4980	1.0334	0.4047
Sessile oak					
Diameter (cm)	62	75	94	76.72	10.45
Length (m)	2.7	2.9	3.6	2.9759	0.3008
Volume (m^3)	0.8690	1.4790	2.4980	1.4154	0.4657

The efficiency in veneer cutting was determined based on total losses in veneer production (Musat *et al.* 2016), while the efficiency in special veneer cutting was expressed as the number of finished products resulting from 1 m^3 wood and ranked in the first quality class (Dumitrascu *et al.* 2013). The same veneer cutting technology was applied for common oak and sessile oak logs (Musat *et al.* 2017). The logs were cut into splitwoods and heat-treated, and sliced veneer sheets of 0.55 mm thickness were obtained from each log. The veneer sheets were subjected to drying, conditioning, and sizing at the end of the processing line.

To compare the two wood species, a statistical analysis was gradually applied to the efficiency in veneer and special veneer cutting, the number of veneer sheets, and the distribution of log defects.

No more than two acceptable defects were allowed to occur on the same log, such as the following: curvature and buds, wood studs and buds, insect holes and buds, conicity and buds, curvature and wood studs, and buttress roots and buds. The results indicated an acceptable level of defects for the logs under study.

The experimental data analysis was performed by using Minitab. In order to estimate the statistical parameters of efficiency in veneers and special veneers cutting, the statistical analysis consists of identifying the statistical distribution using the Anderson-Darling goodness-of-fit test (NIST 2013). The statistical model was validated considering 95% confidence interval and the estimated correlation coefficient. When using the Minitab program, the parameters can be estimated by two estimation methods: maximum likelihood and least squares. In this regard, the statistical parameters of veneer efficiency and special veneer efficiency were estimated with high accuracy by using the least squares method with a 95% normal confidence interval.

To make a comparative analysis between the veneer and special veneer efficiency for the two species, the cumulative density functions were used. The method allowed the estimation of 87th percentile specific to each species.

RESULTS AND DISCUSSION

The parameters estimation of veneer efficiency for common oak and sessile oak is presented in Tables 2 and 3, and the distribution analysis of veneer efficiency for the two species is shown in Figs. 1 and 2.

The probability plot was used to evaluate whether or not a data set followed a given distribution and to compare different sample distributions. The visual inspection on the probability plots revealed that the analyzed samples were homogeneous. The estimated values of the Anderson-Darling test and the correlation coefficient indicated that the analyzed data followed the normal distribution with a confidence interval of 95% and a value of parameter $p \geq 5\%$, as displayed in Figs. 1 and 2.

The comparative analysis of the efficiency in veneers and special veneers cutting used the estimation of the 87^{th} percentile by determining the cumulative density functions for the species under study (Figs. 3 and 4).

The statistical significance of the differences between species regarding the veneer and special veneer efficiency showed that the sessile oak logs presented a better cutting efficiency than the common oak logs. This conclusion was also supported by the number of veneer sheets obtained from the sessile oak logs (Fig. 5).

Table 2. Parameters Estimation of Veneer Efficiency for Common Oak

Parameter	Standard Error	95% Normal CI		Goodness of Fit	
		Lower	Upper	Anderson-Darling (AD) adjusted	Correlation coefficient
Mean	20.2267	743.554	822.841	0.563	0.994
Standard deviation	14.4502	248.200	304.944		

Table 3. Parameters Estimation of Veneer Efficiency for Sessile Oak

Parameter	Standard Error	95% Normal CI		Goodness of Fit	
		Lower	Upper	Anderson-Darling (AD) adjusted	Correlation coefficient
Mean	36.4260	927.868	1070.66	0.752	0.984
Standard deviation	27.5179	149.005	258.238		

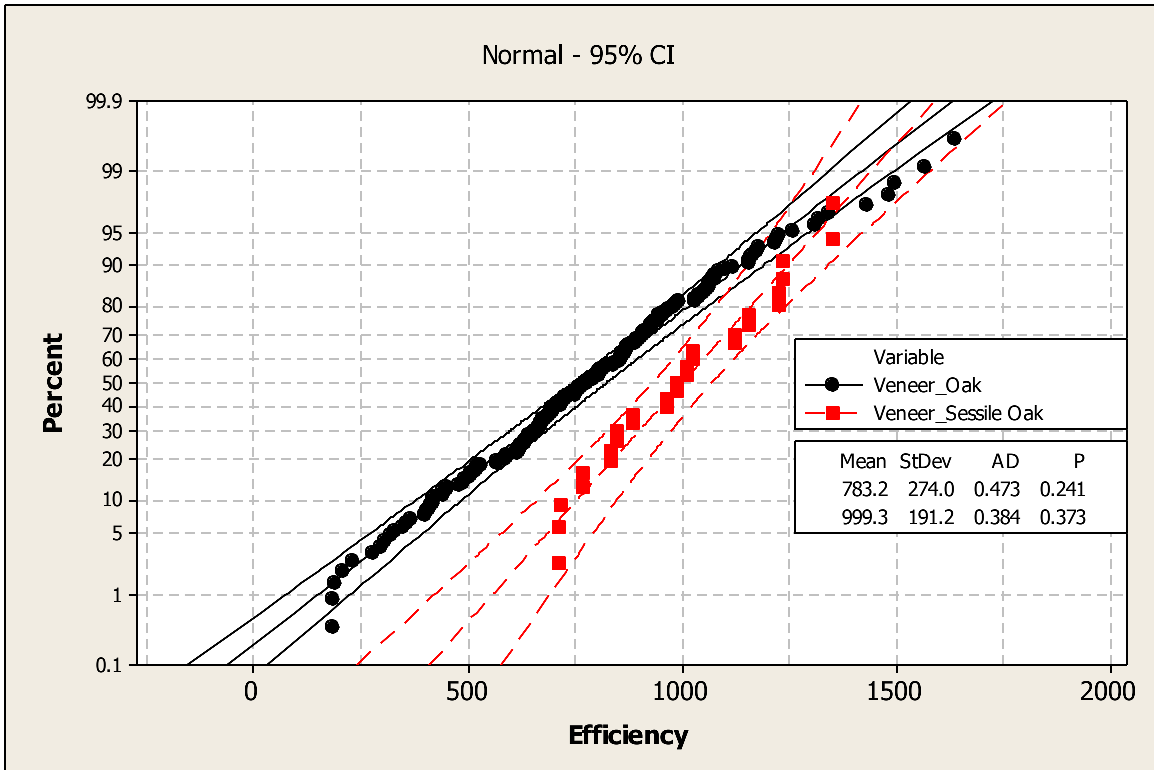

Fig. 1. Distribution analysis of veneer efficiency for common oak and sessile oak logs

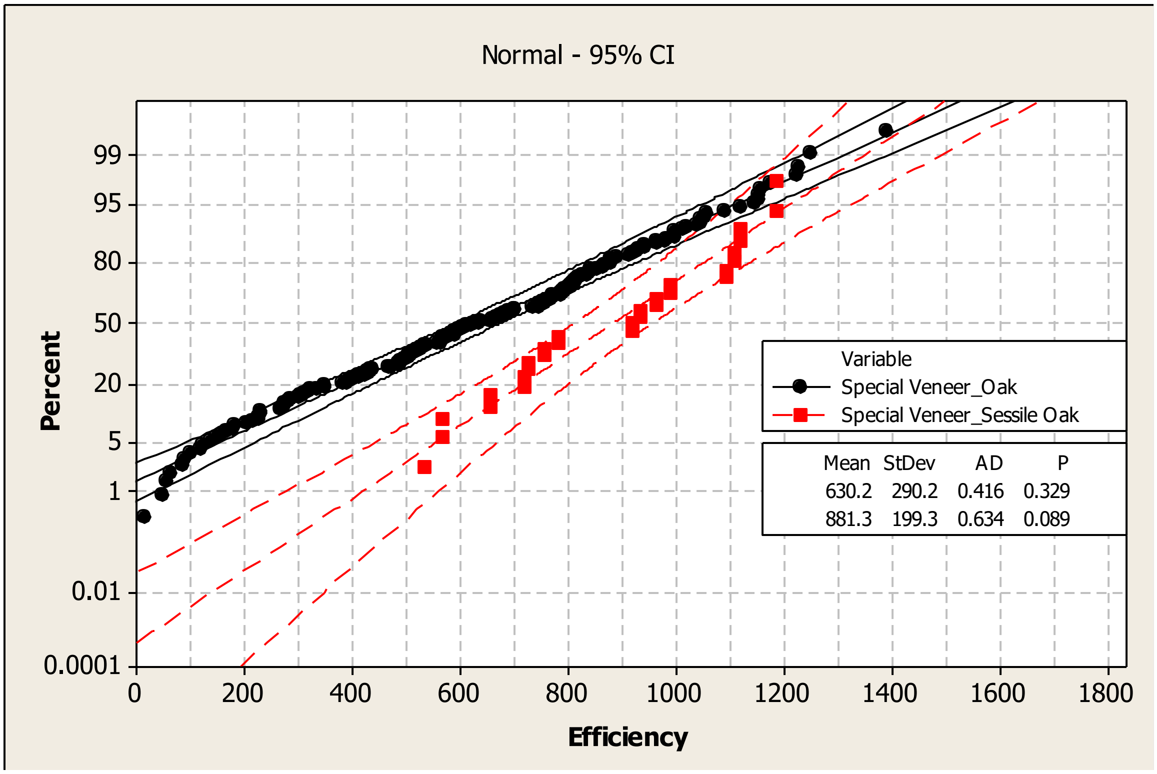

Fig. 2. Distribution analysis of special veneer efficiency for common oak and sessile oak logs

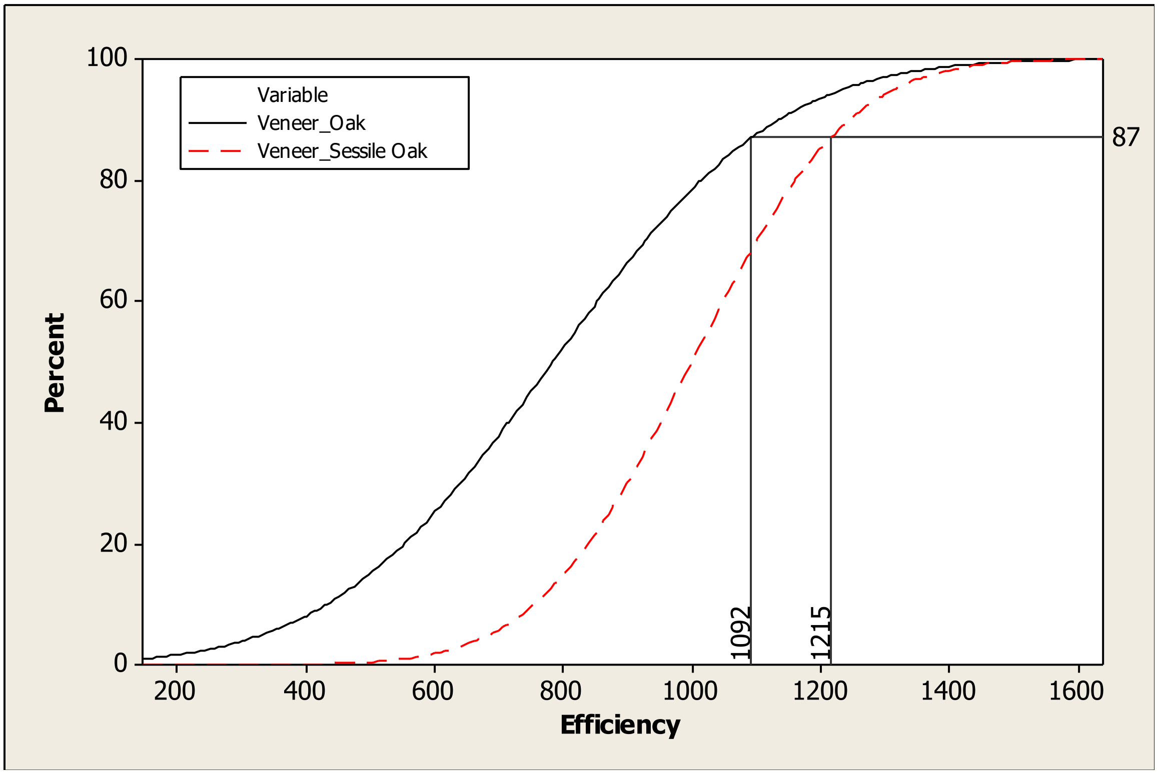

Fig. 3. Cumulative density function of veneer efficiency for common oak and sessile oak logs

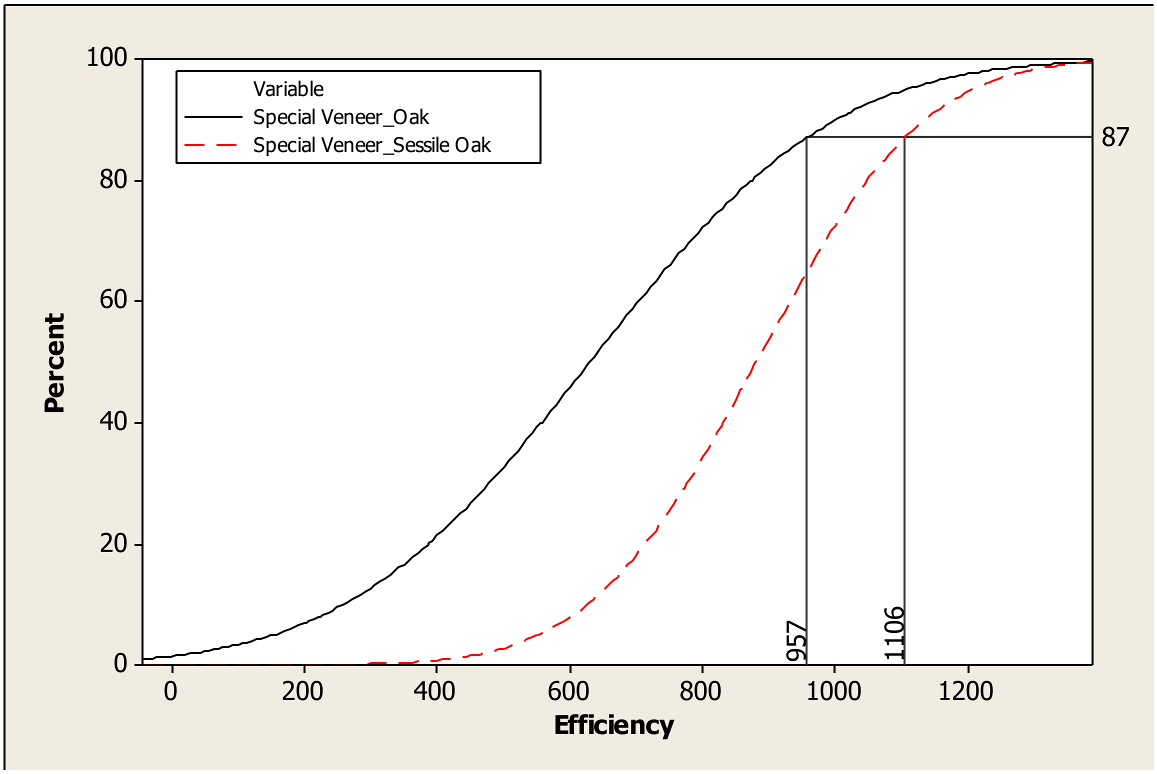

Fig. 4. Cumulative density function of special veneer efficiency for common oak and sessile oak logs

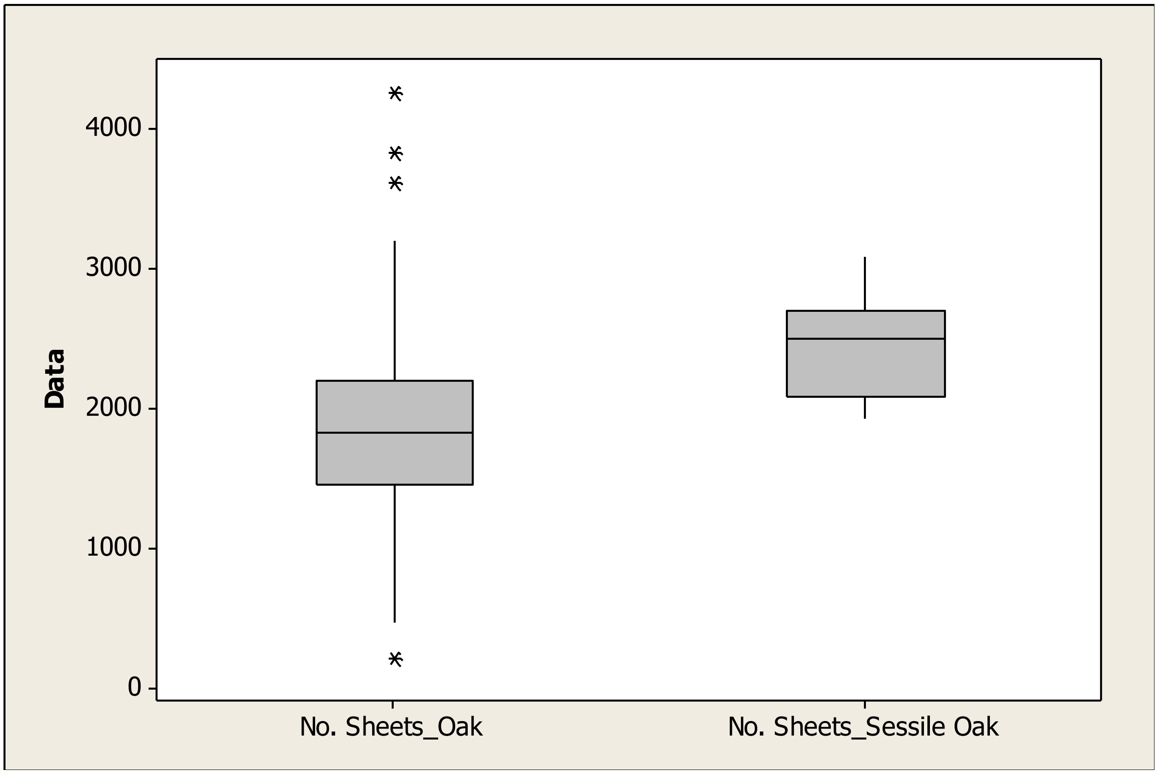

Fig. 5. Comparative analysis of number of veneer sheets from common oak and sessile oak logs

The boxplot diagram indicated that the sessile oak presented a higher median value when compared to common oak, even when three values of the common oak exceeded the maximum estimated limit. It was also observed that the data dispersions were comparable.

Table 4. Comparative Analysis of the Veneer Efficiency

Species	87th Percentile		No. of sheets		
	Veneer efficiency	Special veneer efficiency	Median	Minimum	Maximum
Common oak	1092	957	1830	217	4260
Sessile Oak	1215	1106	2500	1930	3090

The differences displayed in Table 4 were also influenced by the quality acceptable defects of the raw material in accordance with SR EN 1316-1 (2013). The veneer efficiency in the case of sessile oak logs was superior to common oak logs, and it was confirmed by the low rate of defects within the log samples under study growing under the same location conditions.

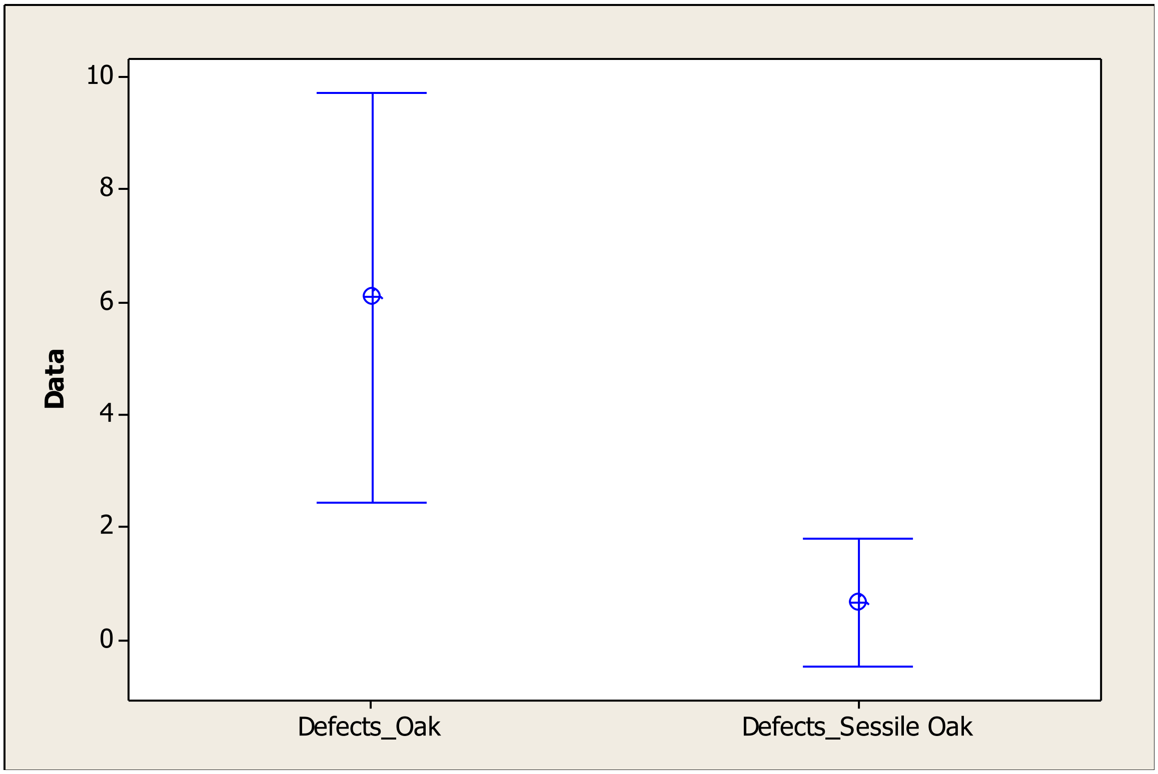

Fig. 6. Interval plot of defects for common oak and sessile oak logs

The statistical significance of the differences between the two species in regard to their defects approached the comparison of mean values with the 95% confidence interval (Fig. 6). The conicity, curvature, insect holes, buds, wood studs, and buttress roots were the defects identified and accepted on sessile oak and common oak logs.

CONCLUSIONS

1. The cumulative density functions specific to each of the two species allowed for inter-comparison of the veneer and special veneer efficiency when considering the 87th percentile estimation with a confidence interval of 95%.
2. The log quality defects were found for both species in accordance with the specific standard, and they influenced the veneer efficiency in both cases.
3. The log quality influenced the veneer efficiency. It was found that common oak logs presented more defects than sessile oak logs, which produced more veneer sheets. Moreover the veneer efficiency for sessile oak logs was found to be superior to that of common oak logs.
4. The findings of this study might have brief practical applications under industrial conditions when screening for the best species with high efficiency in veneer cutting.

ACKNOWLEDGMENTS

The authors are grateful to Transilvania University of Brasov for the support to perform this study.

REFERENCES CITED

Annighöfer, P., Beckschäfer, P., Vor, T., and Ammer, C. (2015). "Regeneration patterns of European oak species (*Quercus petraea* (Matt.) Liebl., *Quercus robur* L.) in dependence of environment and neighborhood," *PLoS ONE* 10(8), e0134935. DOI: 10.1371/journal.pone.0134935

Attocchi, G. (2015). *Silviculture of Oak for High-Quality Wood Production*, Ph.D. Dissertation, Swedish University of Agricultural Sciences, Alnarp, Sweden.

Axelrod, D. I. (1983). "Biogeography of oaks in the Arcto-Tertiary province," *Ann. Mo. Bot. Gard.* 70(4), 629-657. DOI: 10.2307/2398982

Bary-Lenger, A., and Nebout, J.-P. (1993). *Le chêne* [*The Oak*], Perron, Alleur, Belgium.

Bergès, L., Chevalier, R., Dumas, Y., Franc, A., and Gilbert, J.-M. (2005). "Sessile oak (*Quercus petraea* Liebl.) site index variations in relation to climate, topography and soil in even-aged high-forest stands in northern France," *Ann. For. Sci.* 62(5), 391-402. DOI: 10.1051/forest:2005035

Budeanu, M., Stuparu, E., and Tanasie, S. (2016). "Identificarea de noi resurse genetice forestiere de cvercinee cu adaptabilitate ridicata," [Identification of new forest genetic resources of *Quercus* with high adaptability], *Genetica forestiera. Anul XXI* [*Forest Genetics. Year XXI*] 21(38), 21-26.

Dobner Jr., M., Nutto, L., and Higa, A. R. (2013). "Recovery rate and quality of rotary peeled veneer from 30-year-old *Pinus taeda* L. logs," *Ann. For. Sci.* 70(4), 429-437. DOI: 10.1007/s13595-013-0274-z

Doussot, F., De Jéso, B., Quideau, S., and Pardon, P. (2002). “Extractives content in cooperage oak wood during natural seasoning and toasting. Influence of tree species, geographic location and single-tree effects,” *J. Agric. Food Chem.* 50(21), 5955-5961. DOI: 10.1021/jf020494e

Dumitrașcu, A.-E., Ciobanu, V. D., and Lepădătescu, B. (2013). “Valorization of wood resources for the cutting of decorative veneer in the context of sustainable development of Romanian forests,” *BioResource*s 8(3), 4298-4311. DOI: 10.15376/biores.8.3.4298-4311

FAO. (1995). “Forestry in Romania,” (http://www.fao.org/docrep/w3722E/w3722e23.htm), Accessed 11 May 2018.

Feuillat, F., and Keller, R. (1997). “Variability of oak wood (*Quercus robur* L., *Quercus petraea* Liebl.) anatomy relating to cask properties,” *Am. J. Enol. Viticult.* 48(4), 502-508.

Friedrichs, D. A., Trouet, V., Büntgen, U., Frank, D. C., Esper, J., Neuwirth, B., and Löffler, J. (2009). “Species-specific climate sensitivity of tree growth in Central-West Germany,” *Trees* 23, 729-739. DOI: 10.1007/s00468-009-0315-2

Indreica, A., and Kelemen, M. (2011). “Phytosociological studies of the forests with sessile oak and Norway spruce from south-eastern Transylvania,” *Ann. For. Res.* 54(1), 73-88.

Kremer, A., and Zanetto, A. (1997). “Geographical structure of gene diversity in *Quercus petraea* (Matt.) Liebl. II. Multilocus patterns of variation,” *Heredity* 78(5), 476-489. DOI: 10.1038/hdy.1997.76

Kruch, J., and Nicolescu, V. N. (2010). “The particularity of sapwood in industrial sorting of sessile oak (*Quercus petraea* Liebl.) and oak (*Quercus robur* L.) logs [*Particularitatea alburnului in sortarea industrial a bustenilor de gorun*],” *Revista Padurilor* [*The Journal of Forests*] 1, 3-9.

Kruch, J. (2011). “The double alburnum, the most severe defect for oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* (Matt.) Liebl.) logs in industrial sorting [*Lunura, cel mai sever defect pentru bustenii de stejar si gorun in sortarea industriala*],” *Revista Padurilor* [*The Journal of Forests*] 126(5), 37-45.

Kubitzki, K. (1993). “Fagaceae,” in: *The Families and Genera of Vascular Plants*, K. Kubitzki, J. G. Rohwer, and V. Bittrich (eds.), Springer, Berlin, Germany, pp. 301-309. DOI: 10.1007/978-3-662-02899-5_33

Lutz, J. F. (1977). *Wood Veneer: Log Selection, Cutting and Drying* (Technical Bulletin No. 1577), U.S. Department of Agriculture Forest Products Laboratory, Madison, WI.

Mabberley, D. J. (1990). *The Plant Book*, Cambridge University Press, Cambridge, United Kingdom.

Mérian, P., Bontemps, J.-D., Bergès, L., and Lebourgeois, F. (2011). “Spatial variation and temporal instability in climate-growth relationships of sessile oak (*Quercus petraea* [Matt.] Liebl.) under temperate conditions,” *Plant Ecol.* 212, 1855-1871. DOI: 10.1007/s11258-011-9959-2

Ministry of Water and Forests. (2016). “Raport privind starea padurilor Romaniei 2016 [Forestry report on Romanian forests 2016],” (http://apepaduri.gov.ro/wp-content/uploads/2014/07/Raport-starea-pa%CC%86durilor-2016.pdf), Accessed 11 May 2018.

Mosedale, J. R., Charrier, B., and Janin, G. (1996). "Genetic control of wood colour, density and heartwood ellagitannin concentration in European oak (*Quercus petraea* and *Quercus robur*)," *Forestry* 69(2), 111-124. DOI: 10.1093/forestry/69.2.111

Musat, E.-C., Salca, E.-A., Dinulica, F., Ciobanu, V. D., and Dumitrascu, A.-E. (2016). "Evaluation of color variability of oak veneers for sorting," *BioResources* 11(1), 573-584. DOI: 10.15376/biores.11.1.573-584

Musat, E.-C., Salca, E.-A., Ciobanu, V. D., and Dumitrascu, A.-E. (2017). "The influence of log defects on the cutting yield of oak veneer," *BioResources* 12(4), 7917-7930. DOI: 10.15376/biores.12.4.7917-7930

McGavin, R. L., Bailleres, H., Lane, F., Blackburn, D., Vega, M., and Ozarska, B. (2014). "Veneer recovery analysis of plantation eucalypt species using spindleless lathe technology," *BioResources* 9(1), 613-627. DOI: 10.15376/biores.9.1.613-627

Nicolescu, V.-N. (2010). "Ecology and silviculture of sessile oak (*Quercus petraea* (Matt.) Liebl.) in Romania," *Spanish Journal of Rural Development* 1(2), 35-50. DOI: 10.5261/2010.GEN2.03

NIST (2013). "Anderson-Darling Test Engineering Statistics Handbook," available at: www.itl.nist.gov/div898/handbook/eda/section3/eda35e.htm

Ozarska, B. (2013). *A Manual for Decorative Wood Veneering Technology*, Project No: PRA295-1213, Department of Agriculture, Fisheries and Forestry (DAFF), Forest & Wood Products Australia.

Petritan, A. M., Biris, I. A., Merce, O., Turcu, D. O., and Petritan, I. C. (2012). "Structure and diversity of a natural temperate sessile oak (*Quercus petraea* L.) – European beech (*Fagus sylvatica* L.) forest," *Forest Ecol. Manag.* 280, 140-149. DOI: 10.1016/j.foreco.2012.06.007

Popa, I., Leca, S., Craciunescu, A., Sidor, C., and Badea, O. (2013). "Dendroclimatic response variability of *Quercus* species in the Romanian intensive forest monitoring network," *Not. Bot. Horti Agrobo.* 41(1), 326-332. DOI: 10.15835/nbha4119015

Savill, P. S., Kanowski, P. J., Gourlay, I. D., and Jarvis, A. R. (1993). "Genetic and intratree variation in the number of sapwood rings in *Quercus robur* and *Quercus petraea*," *Silvae Genet.* 42(6), 371-375.

SR EN 1316-1. (2013). "Hardwood round timber—Qualitative classification. Part 1: Oak and beech [Lemn rotund de foioase. Clasificare calitativă. Partea 1: Stejar şi fag]," Romanian Society for Standardization, Bucharest, Romania.

Şofletea, N., and Curtu, L. (2007). *Dendrologie [Dendrology]*, Editura Universităţii Transilvania [Transilvania University Publishing House in Brasov], Brasov, Romania.

Thomas, F. M., Blank, R., and Hartmann, G. (2002). "Abiotic and biotic factors and their interactions as causes of oak decline in Central Europe," *Forest Pathol.* 32(4-5), 277-307. DOI: 10.1046/j.1439-0329.2002.00291.x

Timbal, J. and Aussenac, G. (1996). "An overview of ecology and silviculture of indigenous oaks in France," *Ann. For. Sci.* 53(2-3), 649-661. DOI: 10.1051/forest:19960243

Todaro, L., Zanuttini, R., Scopa, A., and Moretti, N. (2012). "Influence of combined hydro-thermal treatments on selected properties of Turkey oak (*Quercus cerris* L.) wood," *Wood Sci. Technol.* 46(1-3), 563-578. DOI: 10.1007/s00226-011-0430-2

UNECE/FAO (2012). "Forest Products Annual Market Review 2011-2012," *Geneva Timber and Forest Study Paper* 30, 1-161.

Viscosi, V., Fortini, P., Slice, D. E., Loy, A., and Blasi, C. (2009). "Geometric morphometric analyses of leaf variation in four oak species of the subgenus *Quercus* (Fagaceae)," *Plant Biosyst.* 143(3), 575-587. DOI: 10.1080/11263500902775277

Wiedenbeck, J., Wiemann, M., Alderman, D., Baumgras, J., and Luppold, W. (2003). *Defining Hardwood Veneer Log Quality Attributes* (General Technical Report NE-313), Northern Research Station, USDA Forest Service, Newtown Square, PA.

Zhang, S. Y., Nepveu, G., and Eyono Owoundi, R. (1994). "Intratree and intertree variation in selected wood quality characteristics of European oak (*Quercus petraea* and *Quercus robur*)," *Can. J. Forest Res.* 24(9), 1818-1823. DOI: 10.1139/x94-235

Article submitted: May 15, 2018; Peer review completed: June 28, 2018; Revised version received: July 14, 2018; Accepted: July 19, 2018; Published: July 20, 2018.
DOI: 10.15376/biores.13.3.6766-6777