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VOLUME, QUALITATIVE AND VALUE LUMBER YIELD FROM LINDEN LOGS (*TILIA SPP.)*

Josip Ištvanić[1], Alan Antonović[1], Marinko Jaklić[2], Dario Pervan[1*], Karla Vukman[1], Božidar Matin[1], Miljenko Klarić[1]

[1]University of Zagreb, Croatia
Faculty of Forestry and Wood Technology
[2]Joinery and sawmill Pilana Jaklić Ltd.
Email: jistvanic@sumfak.unizg.hr; aantonovic@sumfak.unizg.hr;marinko.jakli97@gmail.com; kkremenj1@sumfak.unizg.hr; bmatin@sumfak.unizg.hr; mklaric@sumfak.unizg.hr;
[*]Corresponding author: dpervan@sumfak.unizg.hr

ABSTRACT

This study compares the volume, qualitative, and value yield of linden logs (*Tilia* spp.) during their processing into sawn boards at the sawmill. A total of 48 logs were selected, divided into four categories: 12 veneer logs for sliced veneer (F class), 12 veneer logs for rotary-cut veneer (L class), 12 sawmill logs of 1st quality class, and 12 sawmill logs of 2nd quality class. The logs were processed using the live sawing method on a log band saw. The resulting sawn boards were categorized by thickness into six groups and assessed for quality across two grades. The highest yield in terms of volume, quality, and value was achieved with veneer logs intended for sliced veneer, while the lowest yield efficiency was recorded for sawmill logs of 2nd quality class.

Keywords: Linden (*Tilia* spp.) veneer logs, sawmilling logs, sawmilling, sawn wood, volume yield, qualitative and value lumber yield.

1. INTRODUCTION

Linden trees (*Tilia cordata* and *Tilia platyphyllos*) are both indigenous to large parts of Europe. The distribution of *T. cordata* primarily spans central and eastern regions, where it is more commonly found. Its range stretches northward to southern areas of Norway and Finland and reaches elevations of up to 1,500 meters in the central Alps. In contrast, *T. platyphyllos* occupies a more limited and fragmented range. Although it extends slightly further south than *T. cordata*, its northern presence only reaches southern Sweden, and it is less frequently encountered in the northern parts of central Europe (Eaton, Caudullo, De Rigo, 2016). Linden trees are typically associated with lowland areas and the lower foothills, rather than mountainous or high-altitude regions. These species have been a consistent part of European woodland ecosystems for over 10,000 years (Lang, 1994). They are commonly found in association with oak and beech forests, and their occurrence is frequently regarded as a sign of ancient woodland areas that have existed continuously since before 1600 CE (Savill, 2013).

In Croatia, the linden tree (*Tilia* spp.) primarily grows in mixed forest stands alongside European beech (*Fagus sylvatica* L.), oak (*Quercus* spp.), and hornbeam (*Carpinus betulus* L.).

Mature specimens typically reach heights of 25–35 m (rarely up to 40 m), with trunk diameters averaging 60–100 cm. It is characterized by a broad, densely branched, elongated-oval crown, with lower branches that usually hang downward. The bole is generally straight and cylindrical, featuring a branch-free section of 10–15 m in length. Linden trees exhibit slow growth rates but are remarkably long-lived, with some individuals surviving up to 1,000 years. The bark undergoes distinct ontogenetic changes: in juvenile trees, it appears greenish-gray, while mature specimens develop darker, deeply

fissured bark. Bark constitutes approximately 14% of the tree's volume, with a density of around 340 kg/m³. In mature trees, the bark of the trunk and main branches can reach a thickness of up to 2 cm. Initially smooth and brown, the bark darkens over time to a blackish-gray hue and develops long, irregular, longitudinal cracks with narrow and short transverse fissures along the edges.

Anatomically (Figure 1), growth rings are distinctly visible, whereas tracheids and wood rays are not discernible to the naked eye. Linden wood is a diffuse-porous species with tracheids of medium diameter (30–90 μm), which are indistinguishable to the naked eye. These vessels are distributed diffusely, either solitarily or in small radial clusters (typically 2–3, rarely 4), with a vessel density of 70–130 per mm². Tile cells are absent. The wood rays are heterocellular (composed of both uniseriate and multiseriate structures), predominantly under 1 mm in height, though some multiseriate rays may reach 1–5 mm. Ray frequency ranges from 5 to 12 rays per millimeter. Axial parenchyma is apotracheal-diffuse, scarcely visible even under magnification. The mechanical tissue consists of libriform fibers and fiber-tracheids as transitional forms. The fibers exhibit a polygonal cross-section with tapered ends and slit-like pits.

Linden wood is lightweight and soft, with a pale coloration ranging from whitish to yellowish, often exhibiting reddish tones and occasionally featuring subtle brownish or greenish streaks or blotches. When straight-grained and free of defects, the wood appears smooth, soft, and possesses a fine, uniform texture. Growth rings are poorly visible, pores are invisible to the naked eye, and wood rays are barely distinguishable without magnification. The wood contains numerous, small tracheae arranged singly, in pairs, in short radial chains, or in groups, often exhibiting spiral thickenings. Linden wood is easy to work with, particularly in cutting and turning operations. It splits easily, nails and screws well, adheres effectively with adhesives, accepts staining and surface treatments successfully, and dries with minimal risk of deformation. However, it has low bending strength and is prone to discoloration and cracking, especially when steamed.

Despite its favorable physico-mechanical properties, linden wood is classified as non-durable under atmospheric exposure and is highly susceptible to attacks by xylophagous fungi and, in particular, insects. Consequently, it is not suitable for outdoor use unless protected from moisture or treated with appropriate preservatives. Fortunately, it responds well to impregnation treatments, rendering it suitable for interior applications but unsuitable for exterior use. It is easily treatable and exhibits excellent flexibility.

Due to its relatively low density, softness, and clean appearance, linden wood was historically used in a wide range of applications. In Europe, linden wood, valued for its light color and softness, is primarily used in sculpture, carving, and turning, as its soft texture allows for clean and smooth cuts in all directions relative to the grain. In contrast, Asian industries prioritize its utilization in plywood and toy manufacturing. Commercially, it is sold as sawn boards and occasionally as peeled veneer, with applications including production of pulp, fiberboard, plywood, sliced veneer, furniture, toys, clogs, molds, pencils, boxes, drawing tools, and musical instruments (Todorović, 2023).

Marenče *et al*. (2020) studied the relationship between standing beech tree quality and the quality of sawmill products. They found that better quality trees produced more high-grade sawlogs and sawn boards, while defects like covered knots and heart defects were key factors lowering quality. Their methods involved full traceability from tree to board using European standards. Although the sample size was small, the study confirmed that early tree assessment can predict final product value. The authors suggest their approach could be applied to other tree species with minor adjustments.

Vilkovský *et al*. (2023) examined the effects of three log-sawing patterns, live sawing, cant, and quarter sawing, on the quantitative and qualitative yield of beech sawn boards. Using six beech logs processed with a horizontal band saw, the study assessed volumetric yield and the proportion of radial lumber, the latter being an indicator of higher quality due to its dimensional stability. Results showed that cant sawing achieved the highest quantitative yield (up to 84%), while quarter sawing provided the highest qualitative yield (up to 62.7% radial wood).

Prka *et al*. (2001) and Ištvanić *et al*. (2011) have studied the volume yield of logs of common walnut (*Juglans regia* L.) at certain stages of sawmill processing. The results have shown that the volume yield of 1st class sawlogs when making sawn boards is around 72%, and for the 2nd class sawlogs, 69%.

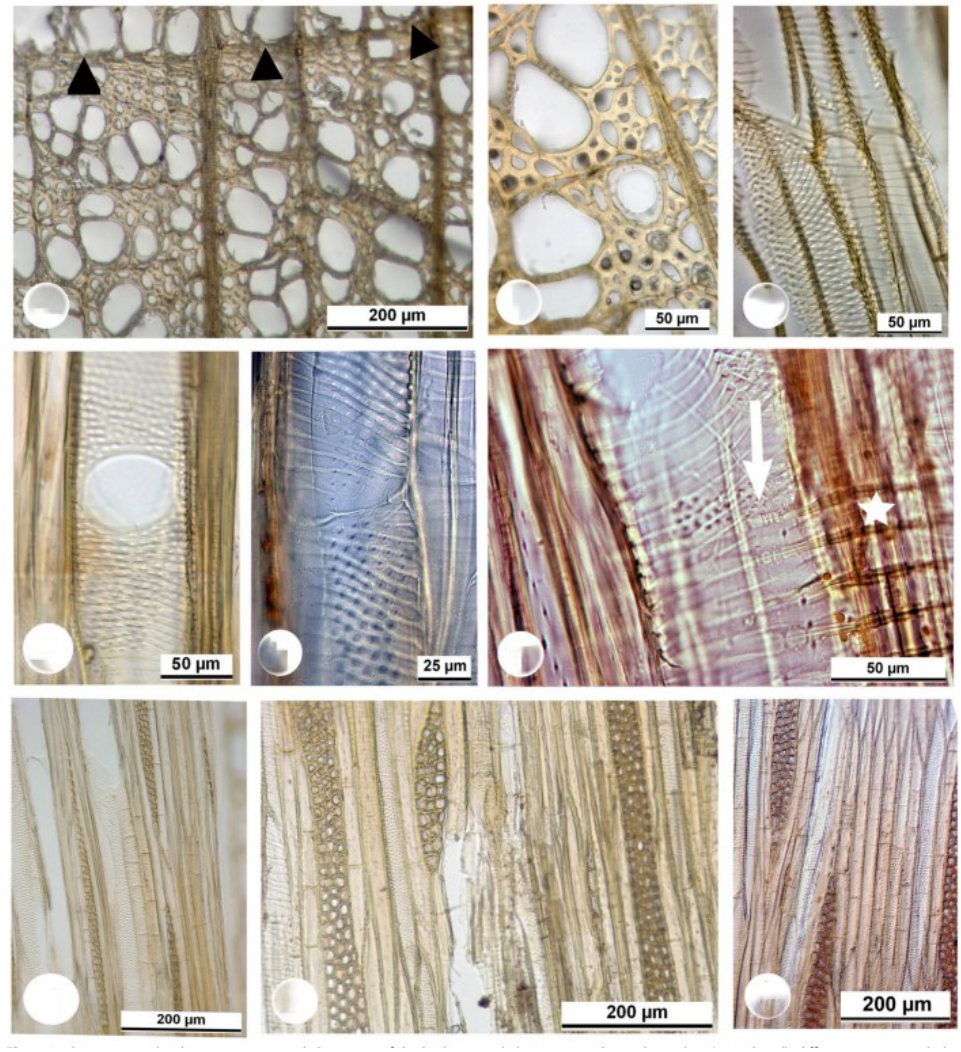


Figure 1. *Anatomical characteristics of linden wood (Gavrilović et al,2024).*

Ištvanić *et al*. (2016) have studied the volume yield of small-sized round wood of common walnut in Croatia. The results have shown that the volume yield of round wood during its processing into sawn boards ranged from 54.34% to 88.83%.

Rabadjiski *et al*. (2015) researched the impact of the quality, diameter, and length of common walnut logs on volume yield in the production of unedged, half-edged, and edged boards. The logs used in the study had diameters ranging from 36 to 55 cm. These results showed the volume yield of round wood was 61.24 to 68.10%.

Smajić *et al*. (2021) had examined the performance indicators of sawmilling Pedunculate oak (*Quercus robur* L.) through both theoretical and experimental approaches. The study focused on logs classified as second and third quality classes according to Croatian standard HRN D.B4.028, with diameters ranging from 30 to 39 cm and a length of 4 m. The logs were sawn into boards of 25 mm and 50 mm nominal thickness using an automated primary sawing line equipped with a vertical log band saw and hydraulic carriage. The study reported a quantity yield of 57.29%, a quality yield of 87.89%, and a value yield of 50.35%, providing a benchmark for the efficiency of sawmill processing in this oak species.

Popadić *et al*. (2014) have explored the impact of different sawing methods on the quantitative and value yields of beech logs containing red heartwood. The study examined 45 logs, evenly divided and processed using round, cant, and live sawing techniques. The findings showed that round and cant sawing produced similar quantitative yields (60.63% and 60.52%, respectively), while live sawing yielded a lower percentage (56.79%). Moreover, live sawing resulted in a reduced proportion of edged

boards and red heartwood timber, as well as fewer small products, ultimately leading to a lower value yield compared to the other two methods.

2. AIM OF RESEARCH

Although linden possesses valuable properties, it remains significantly underutilized in industrial wood processing, especially when compared to more dominant hardwood species such as oak and beech. This underrepresentation is particularly evident in Croatia, where linden is rarely processed on a large scale and is often overlooked in both industry and academic research, especially regarding sawmilling practices.

In light of this context, linden (*Tilia* spp.) represents a promising subject for further scientific investigation. The specific focus of this research is to evaluate the sawing performance of linden veneer logs (intended for sliced and rotary-cut veneer), as well as sawlogs from 1st and 2nd quality classes. The processing will be conducted using the live sawing method on a vertical band sawmill.

The efficiency of the sawing process will be measured using the following key indicators:

- **Volume yield,** expressed as the proportion of log volume converted into sawn boards,
- **Qualitative yield,** assessing the quality of the resulting sawn boards, and
- **Value yield,** which considers the economic efficiency of the process based on the market value of the sawn output.

Linden is typically grouped with other broadleaved trees such as alder, poplar, and birch, which collectively account for only 5.1% of Croatia's total forest area. Nevertheless, rising demand for wood raw material is sparking increased interest in the utilization of lesser-used species. In this context, linden is emerging as a potentially valuable and underexploited resource for the Croatian wood processing industry. The results of this study are expected to support the development of higher value-added wood products from linden, thereby encouraging its broader application within the wood processing industry.

3. OBJECTS AND METHODS OF RESEARCH

3.1. Log selection and measurement

For this research, linden (*Tilia* spp.) veneer and saw logs were used. A total of 48 logs were procured, with 12 logs from each quality class. The minimum log length was 2.4 meters. The minimum mid-diameter of logs was 32 cm. All logs originated from the Forest Administration Slatina, Slatina Forest Office, and were classified according to Croatian standards (HRN EN). Veneer logs for slicing (Class "F") were classified according to HRN EN D.B4.020, requiring a minimum length of 2.0 m and a mid-diameter of at least 35 cm. Logs had to be healthy, straight, with centered pith and uniform grain, and largely free from visual defects. Minor deviations such as small healthy knots and slight internal discoloration were permitted within specified limits. Veneer logs for rotary-cut (Class "L"), classified under HRN EN D.B4.022, required a minimum length of 2.0 m and a mid-diameter of 30 cm. Similar to Class F, they had to be sound and defect-free, with limited tolerance for small healthy knots and internal heart defects not affecting processing.

Saw logs were classified as 1st and 2nd Class according to HRN EN D.B4.028. 1st Class logs had to be straight, healthy, and mostly free of defects, allowing minor imperfections such as small knots, light curvature, and slight end checks. 2nd Class logs permitted a broader range of defects, including medium knots, end cracks, and mechanical damage, within defined limits (Figure 2).

All sample logs were measured without bark for both length and mid-diameter. Descriptive statistical analysis was performed for all examined variables, including mean, standard deviation, minimum, median, and maximum values. Differences in mean values and data groupings for log length and mid-diameter were statistically evaluated to assess significance. These parameters facilitated the analysis of the raw material structure used for experimental sawing. The volume of each individual log was calculated using equation (1). For statistical data analysis on the volume yield, IBM SPSS software was used.

$$V_{log} = \frac{D_{mid}^2 * \pi}{4} * L_{log} \quad [1]$$

Where: V_{log} – log volume $(m)^3$; D_{mid} – mid diameter of the log (m); L_{log} – log length (m).

3.2. Processing logs in the primary sawmill

The primary sawmill, where this study was conducted, was located in Čačinci, Croatia. Mill equipment included a 1600 mm log band saw headrig with an automatic hydraulic-operated carriage, an edger, and a cross-cut circular saw.

All logs were sawn using a band saw according to the specified work order, employing the full log sawing method. Multiple nominal thicknesses were cut from the logs, with the actual thickness of the boards depending on the quality and diameter of each log. Logs of higher quality and greater diameter were used to produce boards of larger thickness, while thinner logs were used for smaller thicknesses. From all logs, unedged sawn boards of nominal thicknesses 29, 33, 55, 66, 110, and 120 mm were produced. Each log was processed individually with the aim of maximizing the yield of the thickest boards, as these have the highest market value. The sawn boards were classified into two quality grades: commercial and sawn boards for further processing according to HRN EN D.C1.031. All boards had to meet minimum dimensions of 14 cm in width and 2 m in length. After sawing, the boards were measured and sorted according to quality class, length, and thickness. The ends of the boards were treated with a protective coating, bark was removed, and the boards were stacked into piles. These piles were then prepared for dispatch to the customer (Figure 1).

All sawn boards produced from the sample logs were measured for thickness, width, and length according to HRN EN 1309-1, and sawn board volume was calculated based on these parameters. The amount of coarse saw residue (slabs, log end off-cuts, edgings, trimmings, etc.) and sawdust was not measured and was not included in the research.

In a primary sawmill, lumber volume yield is defined as the ratio of the sawn board volume and log volume according to equation (2):

$$Y_{vol.y} = \frac{V_{c.board} + V_{f.p.board}}{V_{log}} * 100 \quad [2]$$

Where: $Y_{vol.y.}$ – volume yield (%); V_{log} – log volume (m^3); $V_{c.board}$ – commercial class sawn boards volume (m^3); $V_{f.p.board}$ – sawn boards for further processing (m^3).

The goal of any efficient sawmilling process is not only to maximize the quantitative yield of logs but also to produce boards of the highest possible quality. Efforts should be directed toward obtaining the greatest possible volume of high-value assortments in the best quality grades from each log.

The qualitative yield of logs is expressed through the average quality coefficient of all boards produced from a given log or batch of logs, calculated using the following equation (3):

$$Y_{q.y.} = \frac{V_{c.board} * k_1 + V_{f.p.board} * k_2}{V_{c.board} + V_{f.p.board}} * 100 \quad [3]$$

Where: $Y_{q.y.}$ – qualitative yield; k_1 – quality index of commercial sawn boards; k_2 – quality index of sawn boards for further processing; $V_{c.board}$ – commercial class boards volume (m^3); $V_{f.p.board}$ – sawn boards for further processing volume (m^3).

Commercial-grade boards were assigned a quality index of 1, while sawn boards for further processing were assigned a quality index of 0.5.

Considering only the average quantitative or only the qualitative yield of logs does not always provide a reliable assessment of the efficiency of a specific sawing method from the perspective of sawmill processing. This is due to the inherently antagonistic nature of quantitative and qualitative yield categories.

An indicator that simultaneously accounts for both quantitative and qualitative utilization of logs is the value yield coefficient. It can be calculated as the product of the average quantitative and qualitative yield of a log, as defined by equation (4):

$$Y_{val.y.} = Y_{q.y.} * Y_{vol.y.} \quad [4]$$

Where: $Y_{val.y.}$ *– value yield,* $Y_{q.y.}$ *– qualitative yield;* $Y_{vol.y.}$ *– volume yield*

For the statistical analysis of volume, qualitative and value yield Microsoft Excel and IBM SPSS software were used.



Figure 2. *Linden logs and sawn boards.*

4. RESULTS AND DISCUSSION

The total of 6.405 m^3 of veneer logs for sliced veneer were sawn into 5.115 m^3 sawn boards, 5.286 m^3 of veneer logs for rotary-cut veneer were sawn into 3.946 m^3 sawn boards, 3.875 m^3 of 1st class sawmill logs were sawn into 2.624 m^3 sawn boards, and 5.794 m^3 of 2nd class sawmill logs were sawn into 3.967 m^3 sawn boards.

The distribution of log dimensions by log class is shown in Figure 4 and Figure 5. Descriptive statistical analyses of log dimension data are presented in Table 1, with each log quality group shown separately. A comparison of log diameters and lengths across quality classes is illustrated in Figure 3. and Figure 4.

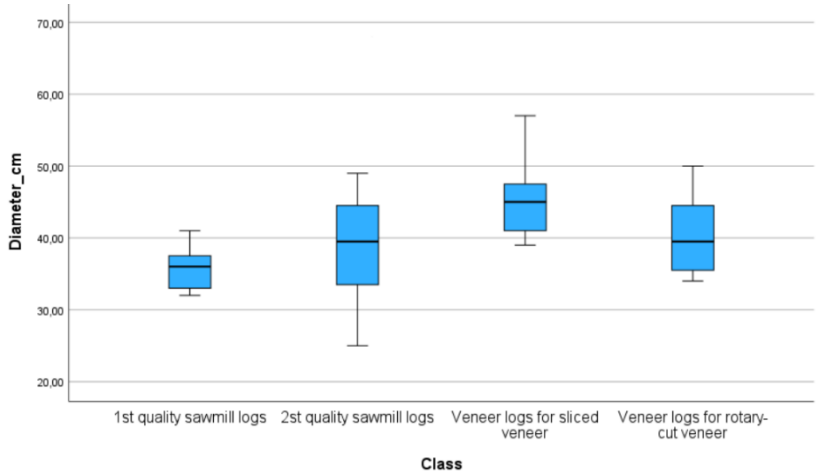


Figure 3. *The distribution of diameters by log class.*

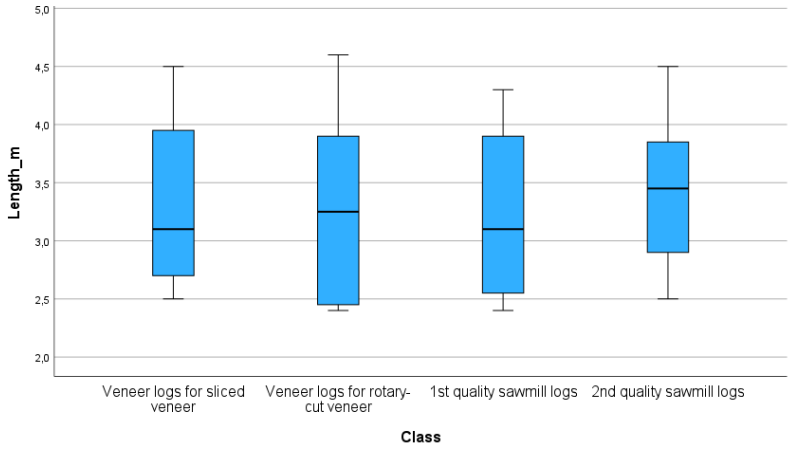


Figure 4. *The distribution of the length of logs by class.*

Table 1. *Descriptive statistics for log diameter and log length by class.*

Class	Variable	N	Minimum	Maximum	Mean	Std. Deviation
Veneer logs for sliced veneer	Diameter (cm)	12	39.00	57.00	45.1667	5.28864
	Length (m)	12	2.5	4.5	3.325	0.7350
Veneer logs for rotary-cut veneer	Diameter (cm)	12	34.00	50.00	40.5000	5.36826
	Length (m)	12	2.4	4.6	3.300	0.7544
1st quality sawmill logs	Diameter (cm)	12	32.00	41.00	35.7500	2.95804
	Length (m)	12	2.4	4.3	3.225	0.6969
2nd quality sawmill logs	Diameter (cm)	12	25.00	66.00	40.2500	10.44575
	Length (m)	12	2.5	4.5	3.442	0.625

The highest average log diameter was recorded in veneer logs intended for sliced veneer, which was expected given that logs designated for this purpose are selected based on the highest quality requirements for the final product. Veneer logs for rotary-cut veneer and 2nd class sawmill logs had similar average diameters. The lowest average diameter was recorded in 1st class sawmill logs. Average log lengths of each class were similar. The distributions of value yield, qualitative yield, and volume yield across different log classes are presented in Figures 5, 6, and 7, respectively. The shares of commercial-grade sawn boards within each log class are illustrated in Figure 8.

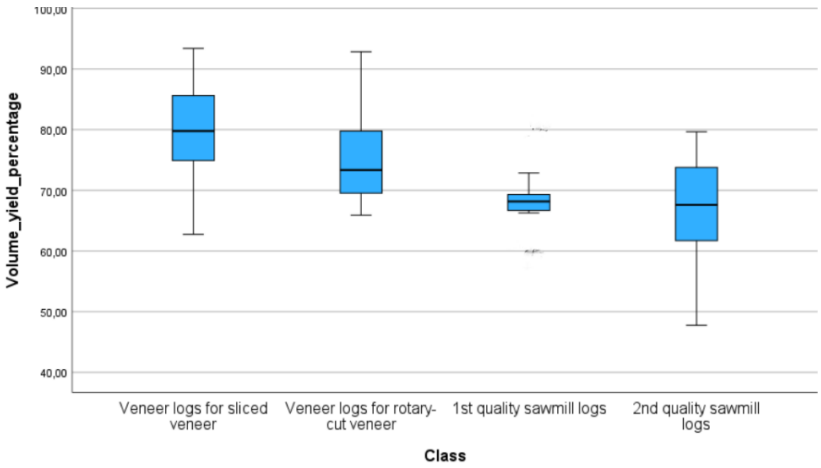


Figure 5. *The distribution of volume yield by log class.*

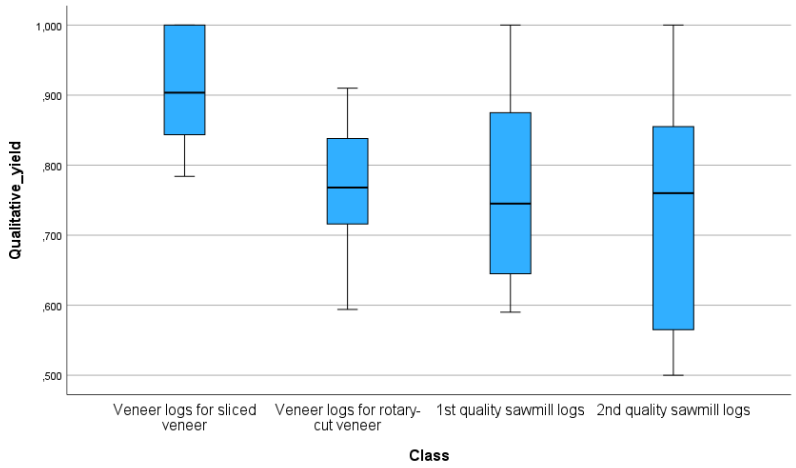


Figure 6. *The distribution of qualitative yield by log class.*

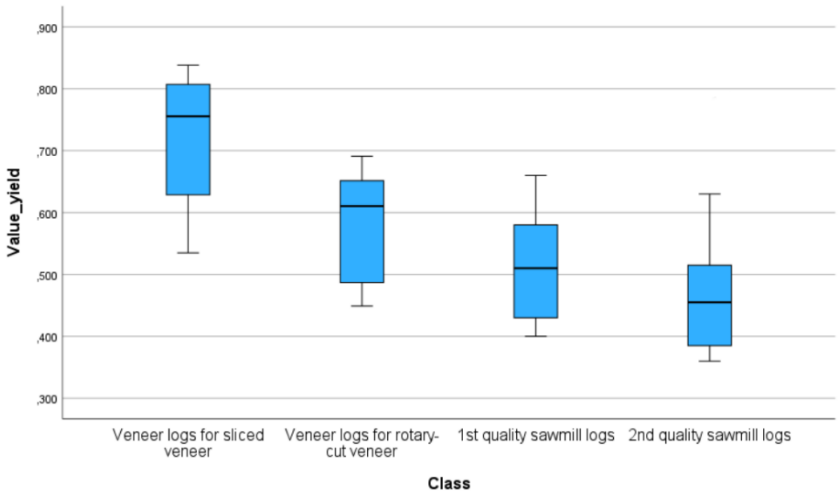


Figure 7. *The distribution of value yield by log class.*

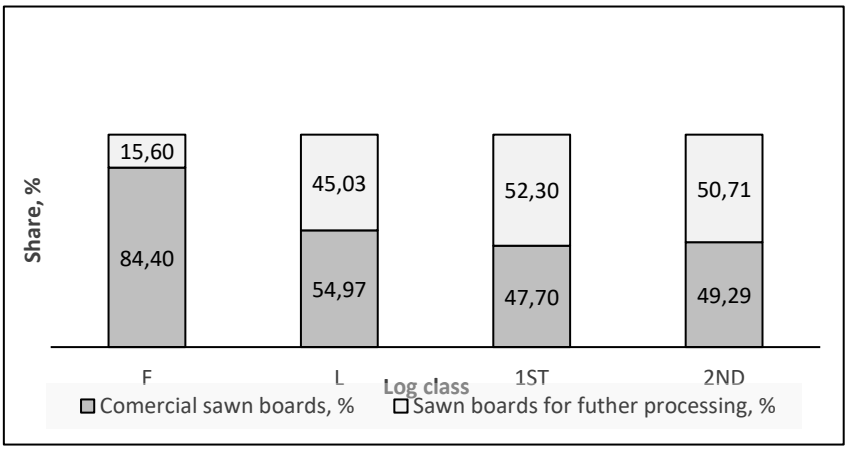


Figure 8. *The distribution of sawn board quality groups by log class.*

In the analysis of lumber volume, qualitative, and value yields, the highest average yields were obtained from veneer logs intended for sliced veneer, followed by veneer logs for rotary-cut veneer, and then by 1st and 2nd class sawmill logs. The qualitative yields of veneer logs for rotary-cut veneer and sawmill logs of the 1st and 2nd classes were comparable. These results appear to be closely associated with the quality and dimensional characteristics of the logs being processed.

The highest share of commercial-grade sawn boards was derived from veneer logs intended for sliced veneer, followed by those for rotary-cut veneer, and lastly by sawmill-grade logs. The shares of commercial boards between 1st and 2nd class sawmill logs were also similar. As indicated in the previous statistical analyses, both classes of veneer logs exhibited slightly greater average diameters and lengths. These dimensional advantages significantly influence volume yield in the production of unedged sawn boards, which was evident in the performance of the veneer logs.

A one-way ANOVA was conducted to assess whether statistically significant differences existed in volume yield, qualitative yield, and value yield among the examined log classes. The results of this analysis are presented in Tables 2, 3, and 4. Subsequently, a Tukey HSD post hoc test was performed to identify between which log classes the observed differences occurred. The results of the post hoc analysis are shown in Tables 5, 6, and 7.

Table 2. *Results of ANOVA for volume yield.*

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1243.136	3	414.379	5.991	0.002
Within Groups	3043.397	44	69.168		
Total	4286.534	47			

Table 3. *Results of ANOVA for qualitative yield.*

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.257	3	0.086	5.399	0.003
Within Groups	0.697	44	0.016		
Total	0.953	47			

Table 4. *Results of ANOVA for value yield.*

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.422	3	0.141	13.370	<0.001
Within Groups	0.463	44	0.011		
Total	0.885	47			

Table 5. *Results of Tukey HSD post hoc test for volume yield.*

Class	Class	Mean Difference	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Veneer logs for sliced veneer	Veneer logs for rotary-cut veneer	3.74412	3.39529	0.690	-5.3213	12.8096
	1st quality sawmill logs	11.13776	3.39529	0.011	2.0723	20.2032
	2nd quality sawmill logs	12.20401	3.39529	0.004	3.1386	21.2695
Veneer logs for rotary-cut veneer	Veneer logs for sliced veneer	-3.74412	3.39529	0.690	-12.8096	5.3213
	1st quality sawmill logs	7.39364	3.39529	0.145	-1.6718	16.4591
	2nd quality sawmill logs	8.45990	3.39529	0.075	-0.6056	17.5253
1st quality sawmill logs	Veneer logs for sliced veneer	-11.13776	3.39529	0.011	-20.2032	-2.0723
	Veneer logs for rotary-cut veneer	-7.39364	3.39529	0.145	-16.4591	1.6718

Class	Class	Mean Difference	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
	2nd quality sawmill logs	1.06625	3.39529	0.989	-7.9992	10.1317
2nd quality sawmill logs	Veneer logs for sliced veneer	-12.20401	3.39529	0.004	-21.2695	-3.1386
	Veneer logs for rotary-cut veneer	-8.45990	3.39529	0.075	-17.5253	0.6056
	1st quality sawmill logs	-1.06625	3.39529	0.989	-10.1317	7.9992

Table 6. *Results of Tukey HSD post hoc test for qualitative yield.*

Class	Class	Mean Difference	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Veneer logs for sliced veneer	Veneer logs for rotary-cut veneer	0.143750	0.051380	0.037	0.00656	0.28094
	1st quality sawmill logs	0.154833	0.051380	0.021	0.01765	0.29202
	2nd quality sawmill logs	0.192333	0.051380	0.003	0.05515	0.32952
Veneer logs for rotary-cut veneer	Veneer logs for sliced veneer	-0.143750	0.051380	0.037	-0.28094	-0.00656
	1st quality sawmill logs	0.011083	0.051380	0.996	-0.12610	0.14827
	2nd quality sawmill logs	0.048583	0.051380	0.781	-0.08860	0.18577
1st quality sawmill logs	Veneer logs for sliced veneer	-0.154833	0.051380	0.021	-0.29202	-0.01765
	Veneer logs for rotary-cut veneer	-0.011083	0.051380	0.996	-0.14827	0.12610
	2nd quality sawmill logs	0.037500	0.051380	0.885	-0.09969	0.17469
2nd quality sawmill logs	Veneer logs for sliced veneer	-0.192333	0.051380	0.003	-0.32952	-0.05515
	Veneer logs for rotary-cut veneer	-0.048583	0.051380	0.781	-0.18577	0.08860
	1st quality sawmill logs	-0.037500	0.051380	0.885	-0.17469	0.09969

Table 7. *Results of Tukey HSD post hoc test for value yield.*

Class	Class	Mean Difference	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Veneer logs for sliced veneer	Veneer logs for rotary-cut veneer	0.141833	0.041888	0.008	0.02999	0.25367
	1st quality sawmill logs	0.207417	0.041888	<0.001	0.09558	0.31926
	2nd quality sawmill logs	0.246583	0.041888	<0.001	0.13474	0.35842

Class	Class	Mean Difference	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Veneer logs for rotary-cut veneer	Veneer logs for sliced veneer	-0.141833	0.041888	0.008	-0.25367	-0.02999
	1st quality sawmill logs	0.065583	0.041888	0.408	-0.04626	0.17742
	2nd quality sawmill logs	0.104750	0.041888	0.074	-0.00709	0.21659
1st quality sawmill logs	Veneer logs for sliced veneer	-0.207417	0.041888	<0.001	-0.31926	-0.09558
	Veneer logs for rotary-cut veneer	-0.065583	0.041888	0.408	-0.17742	0.04626
	2nd quality sawmill logs	0.039167	0.041888	0.786	-0.07267	0.15101
2nd quality sawmill logs	Veneer logs for sliced veneer	-0.246583	0.041888	<0.001	-0.35842	-0.13474
	Veneer logs for rotary-cut veneer	-0.104750	0.041888	0.074	-0.21659	0.00709
	1st quality sawmill logs	-0.039167	0.041888	0.786	-0.15101	0.07267

The ANOVA results for volume yield, qualitative yield, and value yield revealed statistically significant differences among the examined log classes. The post hoc Tukey HSD test indicated that the differences in volume and qualitative yields were statistically significant between veneer logs intended for sliced veneer and second quality sawmill logs. Regarding value yield, the post hoc analysis confirmed statistically significant differences between veneer logs for sliced veneer and both sawmill quality classes, which was expected based on the superior quality and dimensional characteristics of the veneer logs.

Due to the lack of previous studies specifically focused on linden (*Tilia* spp.), direct comparison with existing research was not possible. However, the results obtained in this study are consistent with findings from research on wood species exhibiting similar sawing characteristics, such as beech. For example, the value yield obtained from live sawing of beech logs of comparable quality to the veneer logs for sliced veneer in this study, as reported by Popadić *et al*. (2014), demonstrated similar outcomes. Additionally, as observed by Istvanić (2003), volume yield of beech wood increases with larger log diameters, a trend that aligns with the results of this study. The volume yield values for different diameter classes of beech presented by Istvanić (2003) also closely correspond to those recorded in this research. When compared to the qualitative yield values of pedunculate oak reported by Smajić *et al*. (2023), linden exhibited lower values, which was expected given its anatomical structure and lower wood density. Given the limited representation of linden wood and its sawmill products in current literature, greater attention should be directed toward the economic indicators of efficiency and profitability in the sawmill processing of this species.

CONCLUSIONS

- Linden tree is poorly represented in wood species in Croatia and grows together with beech and oak trees,
- Research on the success of sawmill processing of linden in these areas is very rare,
- Average volume yield of the veneer logs for sliced veneer was 79.76%; the veneer logs for rotary-cut veneer were 75.20%; the 1st class saw logs were 67.81%; and the 2nd class saw logs were 66.74%,
- The veneer logs for sliced veneer proved to produce the best lumber volume yield results. The 2nd class sawmilling logs proved to produce the worst volume yield results,

- The average qualitative yield of the veneer logs for sliced veneer was 0.914, the veneer logs for rotary-cut veneer were 0.770, the 1st class saw logs were 0.759, and the 2nd class saw logs were 0.721,
- The average value yield of the veneer logs for sliced veneer was 0.729, the veneer logs for rotary-cut veneer were 0.580, the 1st class saw logs were 0.514, and the 2nd class saw logs were 0.475,
- Overall, the research results confirm increased volume yield with better log quality and diameter. The results indicate a possibility of rational processing of the researched linden logs in sawmills,
- Statistical analysis showed that there are significant statistical differences between different log classes regarding measured yields,
- Considering the volume yield, there was a significant statistical difference between veneer logs for sliced veneer and 2nd class sawmill logs,
- Considering the qualitative yield, there was a significant statistical difference between veneer logs for sliced veneer and 2nd class sawmill logs,
- Considering the value yield, there was a significant statistical difference between veneer logs for sliced veneer and all the other log classes,
- It would be interesting to conduct further research of linden sawn boards, first in elements, then in glued massive wood panels.

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Author's address

Assistant professor Josip Ištvanić, Ph.D.
Assistant professor Miljenko Klarić, Ph.D.
Associate professor Alan Antonović, Ph.D.
Postgraduate student – project assistant Dario Pervan, mag. ing. techn. lign.
Postgraduate student – assistant Karla Vukman, mag. ing. techn. lign.
Postgraduate student – project assistant Božidar Matin, mag. ing. agr.
Wood Technology Department, Faculty of Forestry, University of Zagreb,
Svetošimunska 23,
10000 Zagreb, Republic of Croatia.

Marinko Jaklić, mag. ing. techn. lign.
Joinery and sawmill Jaklić Ltd.,
Četekovac 77,
33514 Čačinci, Republic of Croatia.