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IMPACT OF LENGTH AND DIAMETER VARIATIONS IN BEECH (*Fagus sylvatica* L.) SAWLOGS ON THE YIELD AND WASTE

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ABSTRACT

This study evaluates the yield and waste distribution in beech (*Fagus sylvatica* L.) sawlogs, focusing on the influence of log length and diameter. Two log lengths, 4.0 m and 5.0 m, were analysed across various diameter classes. The research examines the relationship between log geometry and the quantitative utilisation of raw materials, emphasising the impact on sawn timber yield, coarse waste, fine waste, and shrinking allowance.

Experimental sawings were conducted on a vertical bandsaw in a saw mill optimised for moderate-capacity production. Statistical analysis of the data reveals significant differences in yield efficiency between the two log lengths. Logs with shorter lengths (4.0 m) demonstrated lower quantitative yield compared to longer logs (5.0 m) due to reduced taper effects and enhanced sawmill processing efficiency. Similarly, larger diameters were correlated with increased sawn timber yield, whereas smaller diameters resulted in higher proportions of waste. The waste distribution analysis highlighted that coarse waste formed the largest component, followed by fine waste, both influenced by log dimensions and quality. Precision in sawmill operations was demonstrated by the diminishing allowance, which provided a small but constant proportion to all logs. The findings underscore the importance of optimising log selection and processing parameters to maximise resource efficiency and minimise waste.

This study provides insights into sustainable practices in beech sawlog processing, supporting the development of optimised sawing techniques for improved material utilisation. The results contribute to a better understanding of how log characteristics impact industrial processing outcomes, informing decision-making for sawmill operations and forest management strategies.

Keywords: beech, coarse waste, fine waste, quantitative yield, sawlogs, shrinking allowance

1. INTRODUCTION

In sawmilling, the utilisation of raw materials is defined either as the yield of sawn timber or as the comprehensive use of raw materials—sawlogs. During the sawing process, in addition to sawn lumber, other products such as parquet blanks, wooden elements, laths, and similar items are also obtained. The efficiency of a sawmill is influenced by several factors, including the wood species being processed, yield, the quality of the raw material, workforce skill level, production costs, energy consumption, and overall productivity.

In the Republic of North Macedonia, sawmills vary significantly in capacity, processing logs ranging from 1,500 to over 20,000 m³ annually. This variability creates a challenge in accurately assessing the industry, leading to the conclusion that generalised analyses and results may not fully reflect the actual situation.

To ensure the findings of this research are relevant, an average-capacity sawmill representative of Macedonian processing conditions was selected as the object of research. The chosen sawmill processes between 2,500 and 3,000 m³ of sawlogs annually. The subject of this study is the company “Markisto”, located in the village Leskoec, Ohrid. The sawmill facility spans 3,000 m², including 1,000 m² of covered space and 2,000 m² of open area. It features log storage, a sawmill hall, and storage for sawn lumber. The surface designated for log storage, the sawmill, covered areas, roads, and ancillary structures are either concreted or covered with crushed stone. The storage of logs is well-organised, based on the available space. The sawmill hall houses primary processing equipment—a bandsaw—as well as secondary processing machines for crosscutting and ripping assortments. A separate building accommodates equipment for tool preparation and maintenance, including an electromechanical workshop for sawmill upkeep. The raw materials processed include both hardwood and softwood species, classifying the sawmill as a "mixed" facility. This versatility is advantageous economically, particularly for smaller-capacity sawmills.

Sawing was conducted using a "purpose-driven" method to produce specific assortments, wooden elements, and similar products with precise dimensions. The assortments undergo natural air-drying followed by convective drying in kilns.

With advancements in equipment and the integration of modern processing technologies, efforts are directed toward maximising quantitative yield while producing high-quality sawn assortments. Simultaneously, there is a focus on the rational use of wood resources. This approach underscores the necessity of understanding the impact of certain technological factors on maximum quantitative yield, including:

- Diameter, length, and curvature of the log;
- Thickness of the saw blade and kerf width;
- Sawing plan (method of sawing);
- Allowances for wood shrinkage;
- Degree of processing for sawn lumber;
- Utilisation of coarse waste;
- Wood moisture content;
- Sawmill technology configuration (single-phase or two-phase processing).

This research primarily focused on studying these technological factors, which directly influence the maximum quantitative yield. Quantitative yield is defined as the amount of sawn assortments obtained from the processing of one or more sawlogs. To achieve the research objectives, a series of experimental sawings were conducted using beech (*Fagus sylvatica* L.) sawlogs of first, second, and third-class quality. The sawing was performed on primary processing machines–bandsaws, employing various sawing plans, and the assortments were dimensioned in terms of length and width on secondary processing machines–circular saws.

Beech was chosen as the wood species of interest because of the dominant usage in the woodworking industry. It is the most widely used hardwood species because the forests in the country are dominated by this species. The assortments obtained as the result of processing the beech sawlogs are used mainly in the furniture industry, for chairs and tables, and a certain amount is used for veneer production. According to Rabadziski (2019), for the manufacturing conditions, the yield for the beech sawlogs is in the range from 48.00 to 52.00%. The yield for first-class quality beech sawlogs ranges from 47.00 to 52.00%, and for second-class quality from 49.00 to 54.00% (Šoškič, Popovič 2004). Among other factors, the type of machine used to carry out the primary sawing significantly influences the quantitative yield. When processing beech sawlogs of first- and second-class quality, 4.0 m in length and diameter from 26.0 to 55.0 cm on a bandsaw, the yield ranges from 48.00 to 58.00%. When processing the logs with the same parameters on a rip saw, the yield is in the range from 46.00 to 57.00% (Rabadziski 1991). According to Brežnjak (2000), the classic processing technology of beech sawlogs, using a bandsaw, gives an overall yield from 50.00 to 52.00%. The percentage of fine and coarse waste differs according to the technology used and the anatomical properties of the sawlogs, as well as the utilisation of the coarse waste. The coarse waste can be further utilised to maximise efficiency with the production of parquet blanks and small elements. This is a sustainable and mindful way to navigate the utilisation of the sawlogs and is friendly for the environment.

2. MATERIAL AND METHODS

The focus of this research is on sawlogs of European beech (*Fagus sylvatica* L.) of first, second and third-class quality. The raw materials were processed by the company "MARKISTO". The sawlogs were sourced from the public enterprise "Makedonski Šumi." These sawlogs (Figure 1) were processed using a bandsaw, with the processing method tailored to the specific wood species and their characteristics. Following processing, sawlogs were converted into sawn assortments of specified dimensions.

Figure 1. *Beech sawlogs (Fagus sylvatica* L.*)*

Beech, being the dominant deciduous wood species in primary processing in the Republic of North Macedonia, was selected as the focal point of the analysis. This species is abundantly available across the country, and the industry primarily uses what is most accessible. Beech lumber is extensively used in the furniture industry for crafting tables and chairs. The choice of wood species was based on the availability within the sawmill's operational capacity at the time of data collection.

The analysis included sawlogs with lengths of 4.0 m and 5.0 m. The quality class of the logs was not considered during grouping. Instead, logs were grouped based on their lengths and mean diameters. The processing yielded boards, planks, and wood elements. Lower-quality zones and coarse waste of the logs were used to produce parquet blanks. The sawing was conducted according to the sawing plan shown in Figure 2.

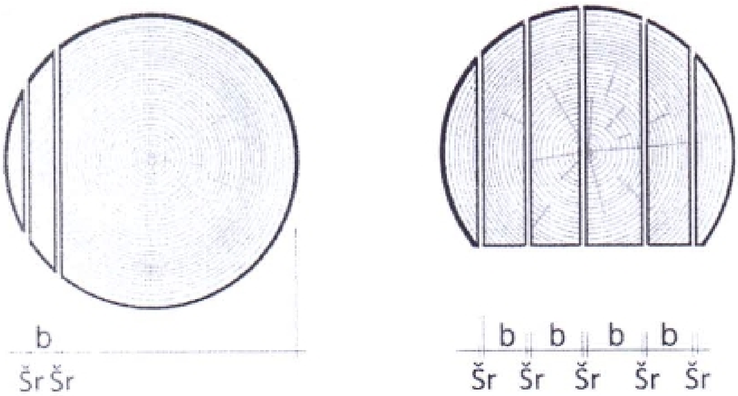

Figure 2. *Sawing plan,*
b – assortment thickness, $š_r$ – kerf width

The logs were grouped into 6 groups, according to the mean diameter, as follows: 30.0–34.0 cm; 35.0–39.0 cm; 40.0–44.0; 45.0–49.0; 50.0–54.0; 55.0–59.0.

A total of 40 beech logs with a combined volume of 25.929 m³ were analyzed. The logs were divided into six diameter classes, each with a range of 5 cm. The analysed logs belonged to first, second, and third-class quality. The small-end diameter ranged from 31.0 to 56.0 cm, the large-end diameter from 33.0 to 60.0 cm, and the mean diameter from 52.0 to 58.0 cm. Diameter taper, a key indicator of maximum quantitative yield, ranged from 0.25 to 2.75 cm/m.

The analysis included 40 logs of 5.0 m length with a total volume of 32.169 m³, also divided into six groups based on mean diameters with a 5 cm interval. The small-end diameter ranged from 28.0 to 56.0 cm, the large-end diameter from 31.0 to 56.0 cm, and the mean diameter from 30.0 to 59.0 cm. Diameter taper ranged from 0.40 to 2.20 cm/m.

The study was carried out under real-time production and operating conditions, with no intervention in the working environment or processing method. Observations were made on the conditions and outcomes. Measurements of log lengths, small-end diameters, and large-end diameters were recorded. Logs were classified according to Macedonian standards MKC EN D.B4.028/1:1990, MKC EN D.C1.022, and MKC EN 1316-1:2013.

The following calculations were carried out after the measurements:

a) Mean diameter
b) Log volume
c) Diameter taper
d) Maximum quantitative yield

Measurements were conducted in the log yard using a wooden calliper and a steel tape. The wooden calliper, graduated in centimetres, was used to measure log diameters. The steel tape, 10 meters long and divided into meters, centimetres, decimetres, and millimetres (for the first meter), was used for length measurements. All measured parameters were documented in pre-prepared tables.

According to the MKC EN 1313-2:2010 standard for sawn timber, lumber must have a moisture content below 22%, ideally between 12% and 18% for the local climate. For this research, volumetric shrinkage was calculated, with beech showing a volumetric shrinkage of 17.5%, according to Kolin, 2000.

Mathematical calculations provided absolute values, while descriptive statistics and regression analysis were employed for statistical processing. Data analysis was conducted in relative values, expressed as percentages.

3. RESULTS AND DISCUSSION

In the sawmill technology of wood processing, the utilisation of logs is defined either as yield in the form of sawn timber or as the comprehensive use of raw material. The efficiency of sawmill operations is determined by several factors, including the wood species being processed, the quality of the sawlogs, the skill level of the workforce, energy consumption, production costs, productivity, and more.

Our research focused on beech sawlogs with a moisture content ranging from 45.0% to 50.0%, from which assortments with approximately the same moisture levels were produced. The raw material processing technology in the analysed sawmill facility employs a two-phase process. The two-phase technology means that the obtained lumber is thermally treated for the purpose of drying, so the first phase will be the sawing of the sawlogs, and the second phase will be the drying of the assortments. The lumber undergoes appropriate hydrothermal treatment to ensure high-quality sawmill products.

The analysis of maximum quantitative yield for beech sawlogs was conducted separately for logs with lengths of 4.0 and 5.0 m. Based on the results obtained for both lengths, a comparative analysis of yield rates was performed. Alongside the percentage of maximum quantitative yield, we also examined the percentage of volume shrinkage and diameter taper. Diameter taper was analysed as a significant factor influencing yield rates. Although the analysed sawmill capacity is equipped with more than one primary sawing machine, the primary sawing was conducted on a vertical bandsaw type PRIMULTINI 1200. The kerf width was 3.0 mm. For the purpose of dimensioning the lumber, transversal and longitudinal circular saws were used with a kerf width of 4.0 mm.

The overall balance of sawing beech logs with a length of 4.0 meters is presented in Table 1.

Based on the data in Table 1, it can be concluded that the quantitative yield rate for 4.0 m long beech logs is 48.50%, while total waste accounts for 51.50%. These logs belonged to first, second, and third-class quality. Of the total waste, coarse waste constitutes the largest proportion (28.52%), which includes trimmings, offcuts, and slabs. Fine waste consists of sawdust, a by-product of primary and secondary sawing processes. In this study, wood dust was not quantified. The volume shrinkage for beech amounts to 17.5% for each individual sawmill product or 8.49% of the total log volume. The total log volume was 25.929 m³, while the volume of produced sawmill products (planks, boards, and wooden elements) was 12.58 m³.

The overall balance for sawing 5.0 m long beech logs is presented in Table 2.

From the data in Table 2, it can be concluded that the quantitative yield rate for 5.0 m long beech logs, from first, second, and third-class quality, is 54.75%. Total waste constitutes 45.25%, with coarse waste having the largest share (21.87%). Volume shrinkage accounts for 9.58% of the total log volume. The total volume of 5.0-meter-long beech logs was 32.169 m³, while the total volume of processed sawmill elements resulting from sawing was 17.61 m³.

Table 1. *Beech (Fagus sylvatica L.) yield for the 4.0 m long sawlogs*

Overall balance	[m^3]	[%]
1.Sawn lumber	12.58	**48.50**
2.Coarse waste	7.39	28.52
3.Fine waste	3.76	14.49
4.Shrinking allowance	2.20	8.49
Total (2+3+4)	13.35	**51.50**
Total (1,2,3,4)	25.93	100.00

Table 2. *Beech (Fagus sylvatica L.) yield for the 5.0 m long sawlogs*

Overall balance	[m^3]	[%]
1.Sawn lumber	17.61	**54.75**
2.Coarse waste	7.03	21.87
3.Fine waste	4.44	13.80
4.Shrinking allowance	3.08	9.58
Total (2+3+4)	14.55	**45.25**
Total (1,2,3,4)	32.17	100.00

To compare the yield of beech logs and examine parameters affecting the yield, an analysis was conducted based on the length and diameter class of the logs. The analysis aimed to investigate the impact of log length and diameter class on the percentage of maximum quantitative yield. Descriptive statistics and regression analysis were employed. The study examined utilisation, coarse and fine waste, volume shrinkage, and diameter taper, with results presented in accompanying tables and figures.

From Table 3, it can be concluded that the highest yield occurs in the sixth diameter class for both lengths. The first diameter class exhibits similar yield rates across all classes except the second, where the difference is approximately 10.00%. The lowest yield rate is observed in the second diameter class (35.91%) for 4.0 m logs, while the highest is in the sixth diameter class (54.88%) for 5.0 m logs. This indicates that as log diameter and length increase, the percentage of quantitative yield also rises. Data suggest that with a 1.0 m increase in log length, at the same average diameter, yield can increase by up to 10.00%. However, factors such as anatomical defects, diameter taper, log curvature, and quality class must also be considered when assessing higher utilisation percentages.

Maximum quantitative yield is a complex concept, especially for beech, due to its specific anatomical structure, including the presence of false heartwood, which can significantly reduce utilisation. Sawing plans aim to incorporate the heartwood into as few assortments as possible. Assortments from the central zone, particularly those containing false heartwood, pose challenges during artificial drying. To enhance beech utilisation, parquet blanks are produced from coarse waste and lower-quality log zones.

Table 3. *Descriptive statistics for beech (Fagus sylvatica* L.*) sawlogs yield*

Diameter group	Length	Mean	Standard deviation	Standard error	95% confidence interval		Minimum	Maximum
					Lower bound	Upper bound		
[cm]	[m]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
1	2	3	4	5	6	7	8	9
1. 30.0 - 34.0	4.0	46.62	2.85	1.16	43.63	49.61	43.79	51.67
	5.0	46.10	1.96	0.80	44.04	48.16	43.28	48.47
2. 35.0 - 39.0	4.0	41.16	5.04	1.90	36.50	45.82	35.91	48.39
	5.0	51.24	5.56	2.10	46.10	56.38	44.21	59.54
3. 40.0 - 44.0	4.0	46.09	3.91	1.48	42.48	49.70	40.29	51.52
	5.0	52.84	2.35	0.89	50.66	55.02	50.22	56.39
4. 45.0 - 49.0	4.0	49.08	2.95	1.50	45.99	52.17	45.54	53.08
	5.0	53.60	2.66	1.08	50.81	56.39	50.73	57.93
5. 50.0 - 54.0	4.0	49.57	4.23	1.60	45.66	53.48	43.37	56.41
	5.0	56.48	2.78	1.05	53.91	59.05	53.28	60.08
6. 55.0 - 59.0	4.0	52.07	4.01	1.51	48.36	55.78	45.38	56.29
	5.0	59.52	3.24	1.22	56.52	62.52	54.88	64.69

A graphical representation of the relationship between diameter class and utilisation percentage for both lengths is shown in Figure 3. The correlation coefficient (R^2) suggests that for 4.0 m long beech logs, yield increases with an increase in mean diameter. However, for 5.0 m long logs, the correlation is weaker, suggesting that other factors influence utilisation. Length is significant, but diameter taper has a more substantial impact and will be further examined.

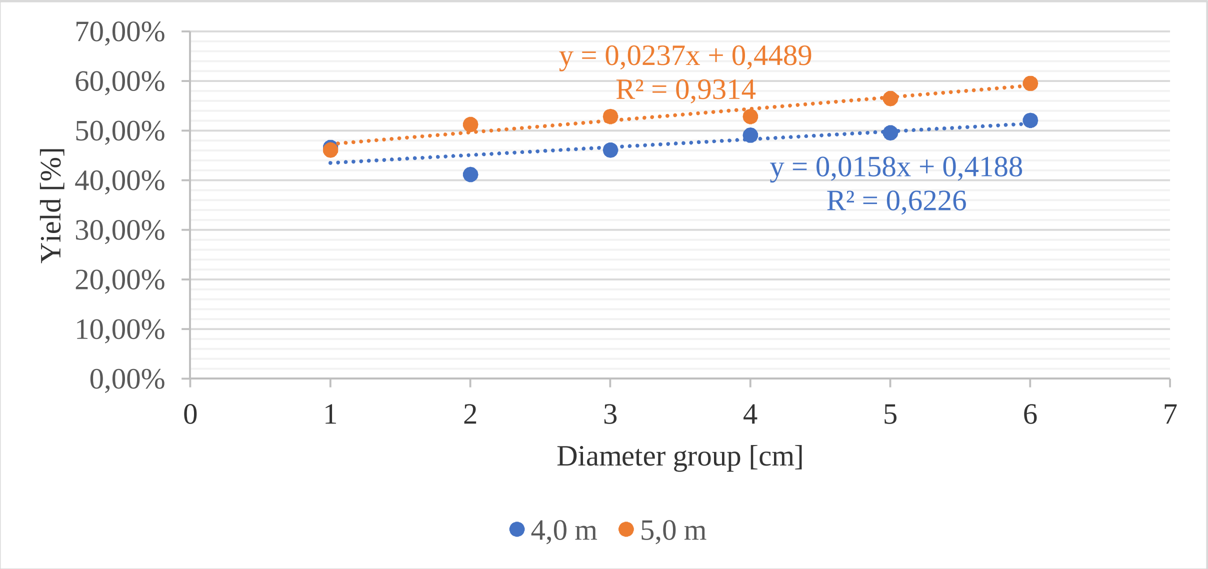

Figure 3. *Relationship between the yield and mean diameter in beech (Fagus sylvatica* L.*) sawlogs*

Tables 4 and 5 present statistical values for diameter taper and volume shrinkage, respectively. Graphs illustrating these relationships are provided in Figures 4 and 5. These analyses confirm the importance of geometric factors and their influence on utilisation rates, waste proportions, and overall efficiency.

Table 4. *Descriptive statistics beech (Fagus sylvatica* L.*) sawlogs diameter taper*

Diameter group [cm]	Length [m]	Mean [cm/m]	Standard deviation [cm/m]	Standard error [cm/m]	95% confidence level Lower bound [cm/m]	95% confidence level Upper bound [cm/m]	Minimum [cm/m]	Maximum [cm/m]
1	2	3	4	5	6	7	8	9
1. 30.0 - 34.0	4.0	0.92	0.38	0.15	0.53	1.31	0.25	1.25
	5.0	0.83	0.54	0.22	0.26	1.40	0.40	1.60
2. 35.0 - 39.0	4.0	1.79	0.37	0.14	1.45	2.13	1.25	2.00
	5.0	1.00	0.63	0.24	0.42	1.58	0.40	2.00
3. 40.0 - 44.0	4.0	1.86	0.63	0.24	1.28	2.44	1.50	3.00
	5.0	1.29	0.45	0.17	0.88	1.70	0.80	1.80
4. 45.0 - 49.0	4.0	1.00	0.59	0.24	0.38	1.62	0.25	1.50
	5.0	0.97	0.37	0.15	0.58	1.36	0.40	1.20
5. 50.0 - 54.0	4.0	1.43	0.91	0.34	0.59	2.27	0.25	2.75
	5.0	1.20	0.48	0.18	0.76	1.64	0.80	2.20
6. 55.0 - 59.0	4.0	1.39	0.40	0.15	1.02	1.76	1.00	2.00
	5.0	1.00	0.60	0.23	0.45	1.55	0.20	2.00

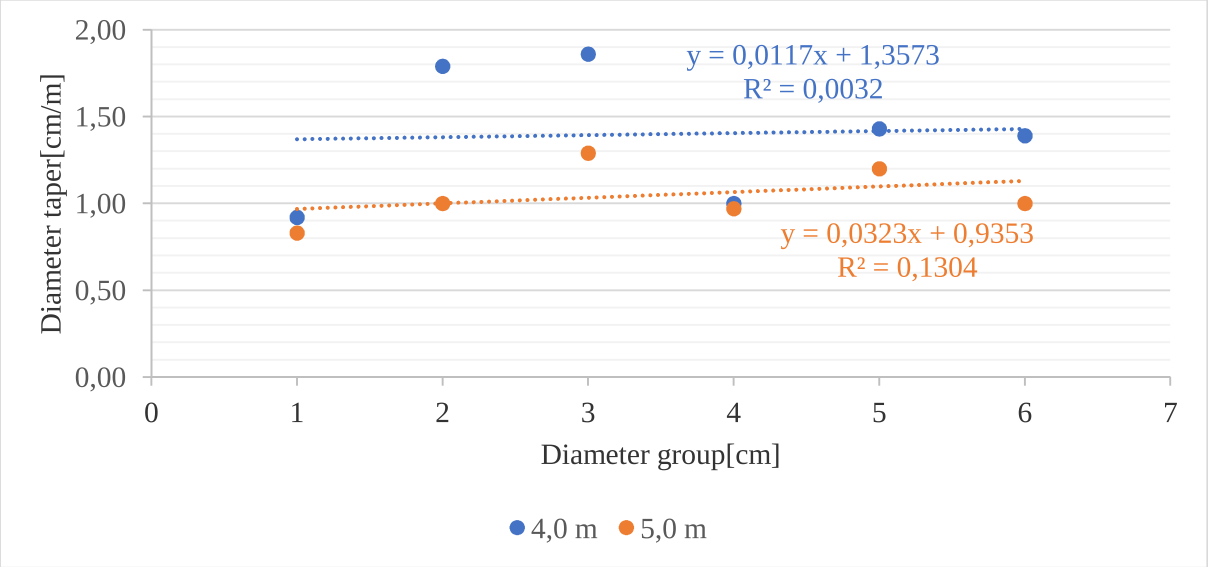

Figure 4. *Relationship between the diameter taper and mean diameter in beech (Fagus sylvatica* L.*) sawlogs*

According to the data presented in Table 4, it can be concluded that the diameter taper in beech sawlogs with a length of 4.0 m ranges from 0.25 to 3.00 cm/m, while the diameter taper in logs with a length of 5.0 m ranges from 0.40 to 2.20 cm/m. The diameter taper is greater in sawlogs with a length of 4.0 m, which means that the yield is also lower in these logs. According to the values, a small number of logs are classified as logs with a full mass (Mihajlov 1968), i.e., the largest number of processed logs belongs to the third-class quality, and only a small number to the first-class quality. With an increase in the length of the log, with large values of the diameter taper, the quantitative yield decreases. For maximum quantitative yield, at high values of diameter taper, the process of primary sawing is carried out along the axis of the log, i.e., parallel to the growth axis of the trunk, since in this way the greatest yield of the additional zone of the log is achieved.

From Figure 4, it can be noted that there is no clear relationship between the diameter group and the diameter taper for both lengths. The values are quite diverse for each diameter group and length individually, so it can be concluded that the diameter decline reduces yield with increasing length of the sawlogs, since it is more pronounced for longer sawlogs. The diameter taper is predetermined by the geometry of the tree, and the quantitative yield is influenced by the diameter taper, so it can be concluded that the percentage of the maximum quantitative yield is also predetermined by the geometry of the raw material (cylindricality, curvature, etc.).

Table 5. *Descriptive statistics beech (Fagus sylvatica* L.*) sawlogs shrinking allowance*

Diameter group	Length	Mean	Standard deviation	Standard error	95% confidence interval		Minimum	Maximum
					Lower bound	Upper bound		
[cm]	[m]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
1	2	3	4	5	6	7	8	9
1. 30.0 - 34.0	4.0	8.16	0.50	0.20	7.64	8.68	7.66	9.04
	5.0	8.07	0.34	0.14	7.71	8.43	7.57	8.48
2. 35.0 - 39.0	4.0	7.20	0.88	0.33	6.38	8.02	6.28	8.47
	5.0	8.97	0.97	0.37	8.07	9.87	7.74	10.40
3. 40.0 - 44.0	4.0	8.07	0.68	0.26	7.44	8.70	7.05	9.02
	5.0	9.25	0.41	0.16	8.87	9.63	8.79	9.87
4. 45.0 - 49.0	4.0	8.59	0.52	0.21	8.05	9.13	7.97	9.29
	5.0	9.38	0.46	0.19	8.89	9.87	8.88	10.14
5. 50.0 - 54.0	4.0	8.67	0.74	0.28	7.99	9.35	7.61	9.87
	5.0	9.88	0.49	0.18	9.43	10.33	9.32	10.51
6. 55.0 - 59.0	4.0	9.11	0.70	0.26	8.46	9.76	7.94	9.85
	5.0	10.42	0.57	0.21	9.90	10.94	9.60	11.32

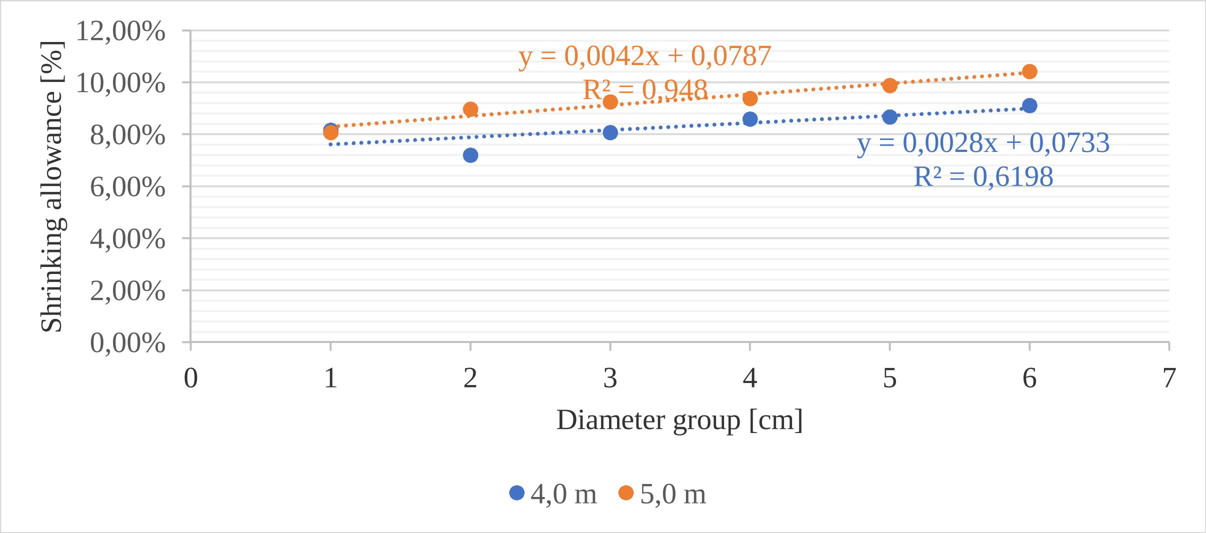

Figure 5. *Relationship between the shrinking allowance and mean diameter in beech (Fagus sylvatica* L.*) sawlogs*

According to the data in Table 5 and Figure 5, it can be concluded that for beech logs with a length of 4.0 m, the shrinking allowance increases with an increase in the average diameter, while for logs with a length of 5.0 m, no strong relationship was observed between the shrinking allowance and the diameter group. With an increase in the quantitative yield, the share of the shrinking allowance also increases. The volumetric allowance for beech is 17.5% for each sawmill product individually, so it can be concluded that the larger the volume of the resulting sawmill products, the greater is the share of the allowance in the total percentage of waste.

The comparison between the yield of beech sawlogs with a length of 4.0 m and 5.0 m is shown in Table 6 and Figure 6.

Table 6. *Comparison between the yield of 4.0 and 5.0 m long beech (Fagus sylvatica* L.*) sawlogs*

Overall balance	4.0 m [%]	5.0 m [%]
1.Sawn lumber	48.50%	54.75%
2.Coarse waste	28.52%	21.87%
3.Fine waste	14.49%	13.80%
4.Shrinking allowance	8.49%	9.58%

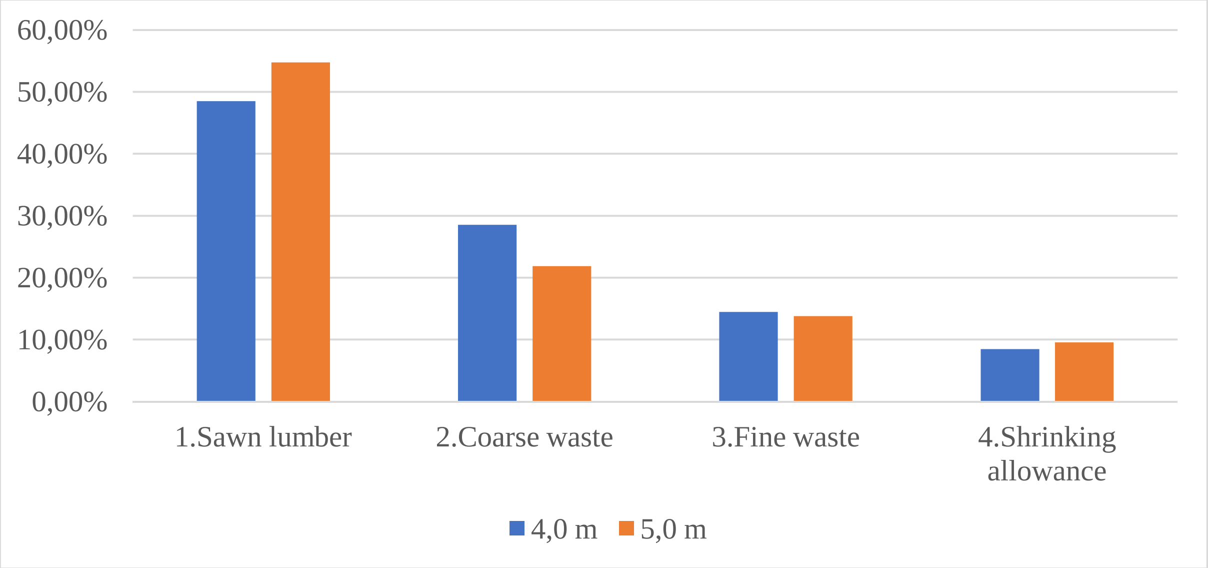

Figure 6. *Comparison between the yield of 4.0 and 5.0 m long beech (Fagus sylvatica* L.*) sawlogs*

Based on Table 6 and Figure 6, it can be concluded that the percentage of quantitative yield is higher for sawlogs with a length of 5.0 m. Logs longer than 5.0 metres include a higher amount of coarse waste. Fine waste is nearly comparable throughout both lengths. The share of oversize is higher for logs with a valley of 5.0 m, which is a consequence of the higher percentage of quantitative utilisation.

Based on the above, it can be concluded that the quantitative utilisation of beech sawmill logs increases with increasing mean diameter and length of the logs. Coarse and fine wastes are related to the quality class and type of sawmill products obtained as a result of whipping. The share of shrinking allowance in total waste is related to the volume of sawmill products, so the larger the volume, the greater the share of the shrinking allowance. The percentage of quantitative yield of beech sawlogs ranges within the limits available from the literature, according to Rabadziski (2019) (48.00–53.00%). Beech as a wood species is particularly interesting for analysis because it is a valued wood species with a wide range of usage, and on the other hand, it provides relatively small percentages of quantitative yield. Generally, only half of the volume of logs is utilised in sawmill products. This is due to the presence of anatomical errors in this wood species.

4. CONSLUSIONS

This study provides a comprehensive assessment of how variations in length and diameter influence the yield and waste distribution in beech (*Fagus sylvatica* L.) sawlogs. By focusing on sawlogs with lengths of 4.0 m and 5.0 m across various diameter classes, we identified significant trends and interdependencies between log geometry and processing outcomes. These findings are instrumental in optimising sawmill operations and promoting sustainable resource utilisation. The results underscore the critical role of log dimensions in determining quantitative yield. Longer logs (5.0 m) exhibited higher yield percentages compared to shorter logs (4.0 m), with differences reaching up to 10.00%. This discrepancy can be attributed to reduced taper effects and improved processing efficiencies associated with longer logs. Similarly, logs with larger diameters consistently achieved higher yields, highlighting the importance of diameter class in maximising resource efficiency. The sixth diameter class recorded the highest yield for both lengths, reaffirming the advantage of processing larger logs.

While log geometry emerged as a dominant factor, the study also highlighted the influence of quality class and inherent anatomical characteristics, such as false heartwood. Beech, as a hardwood species, presents unique challenges due to its structural attributes, which often necessitate specialised sawing patterns to minimise wastage. False heartwood, in particular, poses significant constraints, as it reduces the usability of central zones and complicates drying processes. Strategies such as converting coarse waste into parquet blanks or other secondary products prove effective in mitigating these challenges, offering avenues for value addition and waste reduction.

The analysis of waste components provided further insights into the efficiency of sawmilling processes. Coarse waste accounted for the largest share of total waste, followed by fine waste and shrinking allowance. These proportions varied with log dimensions, emphasising the need for tailored processing approaches. Coarse waste, comprising trimmings, slabs, and offcuts, was significantly influenced by diameter taper, which emerged as a key determinant of yield efficiency. Logs with pronounced taper exhibited lower utilisation rates due to increased waste generation during sawing. The study reaffirms the importance of precise log grading and preprocessing to mitigate the impact of taper on yield. The volumetric shrinking allowance was found to be consistent across all logs, reflecting the precision of sawing processes. However, the share of shrinking allowance increased with quantitative yield, suggesting a proportional relationship between the volume of sawn products and the allowance. This parameter, though minor in overall contribution, remains integral to accurate yield calculations and efficient material planning.

The findings have practical implications for the woodworking and sawmilling industries. By prioritising the processing of larger and longer logs, sawmills can enhance their yield efficiency while minimising waste. Moreover, integrating advanced techniques for the utilisation of coarse and fine waste can significantly improve sustainability metrics. The production of value-added products from waste components aligns with global trends toward circular economy practices, contributing to resource conservation and environmental stewardship. In conclusion, the study provides valuable insights into the interplay between log characteristics and sawmill efficiency, emphasising the importance of optimising processing parameters for sustainable outcomes. By leveraging the findings, industry stakeholders can make informed decisions to enhance productivity, reduce waste, and promote the responsible use of natural resources. Beech, as a highly valued species, holds significant potential for efficient utilisation, provided that the inherent challenges associated with its anatomical properties are adequately addressed. This research contributes to a deeper understanding of sawmilling dynamics and supports the ongoing evolution of sustainable practices in the wood processing industry.

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