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THE INFLUENCE OF THE QUALITY OF POPLAR LOGS ON THE YIELD IN THE PRODUCTION OF VENEER PACKAGING

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ABSTRACT

Poplar logs of F, L, I, and II quality classes were used in the research. The logs are first cut to the appropriate size and then rotary peeled into standard elements for veneer packaging. According to the results of the research, a significantly higher quantitative utilisation (71.93% and 75.55%) was obtained with F and L class logs compared to quality class I and II logs (58.83% and 53.69%, respectively). However, according to the corrected coefficients of economic profitability of processing, it was the least profitable to process logs of F class, followed by class I, and finally class II, while logs of class L were the most profitable for processing.

Keywords: poplar, wooden crates for packaging, quantitative utilisation and financial effect

1. INTRODUCTION

All types of product packaging are called by one name—packaging. The packaging protects the product from various mechanical, physical, chemical, microbiological, climatic, and other influences. The current primacy on the market is held by wooden crates—as an ecological product that gives the best price-quality ratio compared to plastic and cardboard ones (Van Acker 2016). During their production, the percentage of waste is very small, and almost 100% of the raw material is utilized. Pellets can be produced from the waste (Pradhan et al. 2018), which are further used to obtain thermal energy to heat the production plant or dryer within the company. The waste also is often sold, which allows companies to make additional profit and consequently have a higher degree of self-sustainability. As wooden crates are organic pigs, they do not pollute nature when they get into it. Given that the world is increasingly turning to products that do not pollute the natural environment and tends to reduce the use of plastic, it is clear that wooden crates represent a solution that is optimal in the given circumstances.

In the Republic of Serbia, wooden crates are most often made from poplar wood, which has the appropriate mechanical, physical, and chemical properties (Klašnja et al. 2007). The poplar wood has the appropriate toughness to withstand the load it carries for the transport of fruits and vegetables, and on the other hand, it is "soft" enough for quick and easy processing (Shu et al. 2017). The poplar wood also provides satisfactory aesthetic characteristics (Lovrić et al. 2014) and, most importantly, does not retain odours that could affect the final quality of the product.

1.1 The aim of the research

The goal of this research was to determine the degree of utilisation of different types of poplar logs in the production of elements for crates. Due to the disproportionate difference in the price of logs among classes, the question arose: Which class is optimal for processing in terms of utilisation and profitability? The assumption is that F or L class logs have a higher utilisation than other classes, but this difference does not necessarily mean a better economic balance at the end.

The attention must be paid to this issue over a longer period of time, where the market situation in terms of prices and availability of raw materials should be analysed and monitored and compared with the price of the finished product. The current timber market is very volatile, and the situation changes from month to month, if not in shorter periods of time. This issue becomes more and more important. Producers generally rely on bottom-line profits while ignoring current market shifts, and they are often late to adapt to new conditions.

2. MATHERIALS AND METHODS

For the research, poplar logs of F, L, I, and II class poplar were sorted according to the SRPS D.B4.028 standard. Logs were brought from forest farms in Vojvodina and stored at the log storage facility of Banija-Pal DOO, Serbia. The reason for this type of control is to avoid potential errors during data collection in further research. The moisture content of the logs, as well as their mechanical properties, was not taken into account because they did not significantly affect the final results. Since the goal of the research is to investigate the utilisation of raw materials, the measurements were related to the dimensions of the log (diameter, length, bark thickness). One specimen was selected from each log class (Figure 1), and the volume of each of them was measured before and after debarking. After measuring the volume, further logs processing and the produced assortments were monitored. The assortments were counted, and their total volume was calculated, which was later compared to the initial volume of the log.

Figure 1: *Poplar logs*

3. LOGS VOLUME MEASURING

After logs were selected, the length, mean diameter, and bark thickness of each log were measured before being sent to the debarker. The length was measured twice because the bases are not clearly formed, so the length varied depending on the place of measurement. The length was measured using a regular tape measure. A large wooden calliper was used to measure the middle diameter, and the measurement was made in the middle and at the ends, at each point of measurement, by cross-positioning the calliper. Bark thickness was measured at three positions from the base of the log to its end. For each dimension that was measured (length, diameter, and bark thickness), the mean value of multiple measurements was taken at each point to obtain more accurate results.

After all necessary measurements were made, the logs were transported for debarking. Transport was carried out using a forklift. After removing the bark, on each log the places where the cutting should be done are marked with a marker. The length of the logs depended on the production needs. Logs marked in this way were transported by chain conveyor to the cutter. The volume of full-length logs and cut logs was calculated according to Rieke's (Newton's) formula:

$$V = \frac{(g0 + 4gs + gn)}{6} * L \quad (1)$$

g_0 – the base surface area at the thinner end of the log in m^2
g_s – the base surface area at the middle of the log in m^2
g_n – the base surface area at the thicker end of the log in m^2
L – log length in m.

The logs were further transported to the peeler, where the elements for the crates were made. After rejecting the scrap, the elements that satisfied in quality were stacked on the cart (picture 2) until the complete log had been processed and the final number of elements was obtained. The elements were then manually counted. After they were counted, the elements were transferred to the line to form the bottom of the crates. The line consists of a series of moulds and automatic guns for joining elements. The elements were placed on the line manually. The formed crate bottoms were then stacked and transported to the crate forming line. The elements that will make up the sides of the crates, as well as the elements that represent vertical reinforcements at the joints of the sides, are brought to the line. The entire methodology was aimed at monitoring the acquisition of elements and counting them in order to obtain their quantity and their volume.

Figure2: *Elements after peeling of poplar logs*

4. RESULTS AND ANALYSIS

4.1 Logs and residue proportion

The lengths of the logs are determined by the needs of production, as well as by the maximum utilisation of raw materials. In relation to production needs, i.e., in relation to the production program of the company itself, the lengths of the logs vary. In the analysed production period, lengths of 63 cm, 53 cm, 43 cm, 47 cm, and 33 cm were represented. It is important to note that the class of raw material has no influence here and that it does not affect the determination of the dimensions for obtaining the elements, but they are determined by the needs of production.

Table 1: *Utilisation of logs by classes*

Class	Log volume without bark (m^3)	Number of cut logs (pcs)	Volume of cut logs (m^3)	Utilisation (%)
F	0.846	5	0.820	96.95
L	0.515	8	0.502	97.47
I	0.157	4	0.152	97.10
II	0.656	9	0.567	86.34

According to the results (Table 1), it can be seen that cut logs have a much higher percentage of participation in the volume of logs in the F, L, and I classes than in the II class. The reason for this is the length of the logs of F, L, and I class, which corresponded more to the length of the modules than was the case in the II class log. Another reason was the presence of cracks in Class II logs, so the log had to be shortened additionally. As a third reason that affected the result, the curvature of the Class II log prevented the entry of the log into the debarker, so it was necessary to cut off certain parts of the log in order to obtain the appropriate shape.

4.2 Assortments and their share

After logs peeling, the main assortments for making elements for crates were obtained (Tables 2 and 3), as well as secondary assortments for forms and cubes for pallets. (Table 4). The term assortments refer to elements that meet the quality and dimensions criteria required for the production of crates. Usable scrap refers to elements that could not be used in full, but their dimensions allowed us to shorten them to obtain an element for the shorter side of the crate. The shapes (rest rolls) represent the rest of the logs that could not be processed due to the technical characteristics of the machine. They are later processed into cubes that were used as pallet feet. After data collection and processing, the following results were obtained:

Table 2: *Share of assortments (elements) for crates obtained from cut logs*

Class of log	Dimensions of elements			Volume of elements (m^3)	Number of elements	Total volume of elements (m^3)	Elements share (%)
	Length (m)	Width (m)	Thickness (m)				
F	0.291	0.056	0.0013	0.000021	27852	0.590	71.93%
L	0.494	0.053	0.004	0.000104	3620	0.379	75.55%
I	0.593	0.054	0.004	0.000128	700	0.090	58.83%
II	0.437	0.084	0.0016	0.0000587	5179	0.304	53.69%

Table 3: *Share of usable scrap for the production of crate elements*

Class of log	Dimensions of elements			Volume of elements (m^3)	Number of elements	Total volume of elements (m^3)	Scarp share (%)
	Length (m)	Width (m)	Thickness (m)				
F	0.291	0.056	0.0013	0.000021	5362	0.045	5.54%
L	0.494	0.053	0.004	0.000104	477	0.020	3.98%
I	0.593	0.054	0.004	0.000128	177	0.009	5.95%
II	0.437	0.084	0.0016	0.0000587	956	0.022	3.96%

Table 4: *Share of shapes and cubes for pallets*

Class of log	Volume of shapes (m^3)	Shapes share (%)	Volume of cubes (m^3)	Cubes share (%)
F	0.036	4.39	0.031	3.81
L	0.045	8.96	0.039	7.68%
I	0.028	18.42	0.025	16.39
II	0.052	9.17	0.041	7.17%

According to the above table, it is obvious that the obtained elements participate in a much higher percentage in F and L class logs (71.93% and 75.55%) than in I and II class logs (58.83% and 53.69%). A number of factors contributed to obtaining such results:

1) The first and most essential factor is the diameter of the log being processed. By increasing the diameter of the log, there is a reduction in the proportion of shapes, which results in obtaining more elements for the production of crates. This effect is especially pronounced in the Class I log, which had the smallest diameter of all the tested logs;

2) The second factor is the log class, because F and L class logs have fewer errors in the structure of the log and have a more regular shape, which enables processing without the appearance of large gaps between the elements. In the II class log, cracks appeared on the log itself, and for this reason the log could not be processed to an optimal extent. There were also errors in the structure of the wood, so the percentage of total scrap was high (21.91%);

3) The third factor refers to the elements' stated size since the likelihood of employing useable scrap that emerges during peeling increases with the parts' lower dimensions.

4.3 Justification of using F and L logs in the production of crates

Logs buyers are conditioned by JP VOJVODINAŠUME in the sense that when purchasing I and II class logs, they must also buy a certain part of F and L class logs; the question arises whether it is economically profitable to use F and L class logs in the production of crates. As Euro-American poplar is mostly used in production, for that reason their prices were also analysed. According to the official price list of JP VOJVODINAŠUME (year 2022), the price of F class per cubic meter is 80.16 EUR per m^3, L class 62.79 EUR per m^3, I class 48.97 EUR per m^3, and II 38.49 EUR per m^3.

According to this price list, the prices of the examined logs are as follows:

1. F class log – EUR 69.50
2. L class log – EUR 31.96
3. First class log – EUR 9.31
4. Second class log – EUR 25.25

The elements obtained from L and I class logs are the elements that are most often used in the production of crates, so the profitability coefficient was calculated in relation to them. For this reason, a correction was made to the amount of elements obtained from F and II class logs, which are smaller in volume and are used exclusively for making paths or strengthening crates. The volume of elements obtained from L and I class logs is five times higher than the volume of elements from F class and twice that of the volume of elements obtained from II class. If we take into account that an average of 20 elements is necessary for one three-row crate, the number of crates obtained from each class of examined logs is as follows:

1. From the F class log, 27852/20 ≈ 1393 pieces were obtained;

The elements obtained from F logs are 5 times smaller in volume than the elements obtained from L and I class logs and they were used only in the production of floors, so the amount obtained is divided by 5. Therefore, the amount of crates from F class logs is: 1393/5 ≈ 278 pieces.

2. From L class logs, 3620/20 ≈ 181 pieces were obtained;
3. From class I logs, 700/20 ≈ 35 pieces were obtained;
4. From class II logs, 5179/20 ≈ 259 pieces were obtained;

The volume of elements obtained from Class II logs is about 2 times smaller than the volume of L and Class I, so the amount obtained is divided by 2. The amount of crates obtained from Class II logs is 259/2 ≈ 130 pieces.

The average price of a three-row crate on the market for smaller quantities (smaller quantities refer to quantities less than 1500 pieces.) is ≈ 1 EUR or 117.5 RSD. Taking this into consideration, the values in euros of the obtained products from each class are as follows:

1. F class log – 278 EUR
2. L class log – 181 EUR

3. Class I log – 35 EUR
4. Class II log - 130 EUR

In order to determine whether some class is more or less profitable, we need to compare the market price of the log with the market price of the cost of the obtained products. This ratio shows us how many times money was earned on each log.

The F class log cost EUR 69.50, and the value of the obtained products is EUR 278. When we divide these two values, we get the following result: 278/69.5 = 4.01. This shows us that the income was 4 times more money than the cost price of the log. For L class, the result is the following: 181/31.96 = 5.68. In class I it is 35/9.31 = 3.76, and in class II it is 130/25.25 = 5.16.

Table 5: *Profitability coefficients*

F class	4,01
L class	5,68
I class	3,76
II class	5,16

The results show that the highest profitability is in the processing of class L logs and the lowest in class I logs. The characteristics of the logs should certainly be taken into account, primarily the diameter of the log. In the case of Class I log, the diameter of the log was significantly smaller, and thus the fewest elements were obtained. If we equalise the volumes of I and II class logs and assume that the utilisation of class I logs is the same, we would get the following result:

The volume of a Class II log is 0.656 m^3, and 130 crates were obtained from it. The volume of a Class I log is 0.157 m^3, and 35 crates were obtained from it.

If we assume that the utilisation of class I logs remained the same, then the obtained elements participate in the same percentage (58.83%), which means approximately 0.383 m^3 of elements from a class I log that has a volume of 0.656 m^3. One element has a volume of 0.000128 m3 so we would get approximately 2992 elements from a Class I log. If we know that one crate is made of 20 elements, it can be concluded that from 2992 elements, 2992/20 ≈ 150 crates can be made.

The value of the crates obtained from such class I log would be EUR 150. A class I poplar log, according to the official price list of JP VOJVODINAŠUME, costs 48.97 EUR/m^3, so a log with a volume of 0.656 m^3 would cost 48.97*0.656= 32.12 EUR. When we compare the market price of the log and the selling price of the product, we get 150/32.12 = 4.67.

Table 6: *Corrected profitability coefficients*

F class	4,01
L class	5,68
I class	4,67
II class	5,16

5. CONCLUSIONS

From all this, it can be concluded that the least profitable log is the F class. The results show that the L class is the most lucrative, followed by the II class, although accounting for the highest percentage of total scraps (22.12%), because the price is lower than in other classes while still producing a sufficient amount of product to justify its use. These results were obtained on the basis of a smaller sample that was examined, and a long-term and thorough examination of which class of logs is the most profitable in this type of production should certainly be undertaken.

The production of veneer crates as an activity that deals with the production of an ecological product, with the maximum utilisation of raw materials, perfectly fits into world trends. The trends are such that there is an aspiration towards as little pollution of nature as possible, and crates, compared to other types of product packaging, have the possibility of recycling in a large percentage. And in the production process itself, all by-products that are obtained are used to the greatest extent possible, enabling a lower need for energy sources while not polluting nature.

The justification for using F and L class logs in the production of veneer crates, from an economic point of view, most likely exists. However, the question arises: Are veneer crates a product that should be made from F and L logs economically? Although the L class showed the highest profitability coefficient, it was not significantly higher than that of I and II class logs, while it was even the smallest in the case of F class logs. Other types of poplar-based products should be considered from F and L grade logs that would be more cost-effective than crates like plywood or similar.

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