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The influence of selected factors on the share of by-products in sawmill processing

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Abstract: *The influence of selected factors on the share of by-products in sawmill processing.* The work presents the results of character research and the share of by-products generated at the stage of processing the raw material timber in sawmill plants. For identification purposes individual forms of by-products and their participation in sawmill processes is important to separate the basic ones technological features that shape them. Type and quantity of by-products are primarily dependent on the type being processed raw material and production volume determining the technologies used processing. The research was carried out by means of a diagnostic survey, in selected ones wood industry plants processing round hart wood and softwood. Medium and small wood plants were included the most numerous group of sawmill enterprises. An analysis was made indicative and comparative. Depending on the species layout, it was established share of piece products degree of disintegration (chips, sawdust, wood dust, etc.). Factors that influence the quantity have been determined generated by-products for use own and for sale to wood biomass customers.

Keywords: sawmill, round timber, by-products, efficiency

INTRODUCTION

Wood by-products are some of the most important components of solid biofuels, which are a renewable energy sources (RES) [Frühwald 2003; Ratajczak et al., 2012, Vis et al. 2016]. Solid biofuels include organic biological substances such as firewood (slivers, round timber, woodchips), briquettes, pellets, forestry waste (branches, poles, cross-cuts, shrubs, brushwood and root wood), waste from the wood industry (shavings, sawdust) and from the paper industry. Plantation fuels providing energy and organic residues of annual plants from farms and gardens are a separate group [Energy from renewable sources, 2017; O'Brien andBringezu2018].

According to Directive 2009/28/EC [Directive 2009], the EU member-states need to ensure that in 2020 energy from renewable sources will have a specific share in the gross final energy consumption. Poland needs to achieve the target of 15%.

According to the data published by EUROSTAT [Eurostat 2018], in 2016 11 out of the 28 EU member-states met the national targets assumed for 2020. It is noteworthy that there was a high share of the post-communist countries in this group, but without Poland.

It is a matter of concern that the share of renewable energy sources in the final energy consumption decreased in Poland. Between 2013 and 2016) this share fluctuated around 11% [Eurostat 2018]. In view of this situation, meeting the target of 15% in 2020 is at high risk.

Regulations supporting the development of green, renewable energy [Hruzik 2006; Chudobiecki et al., 2009; Verkerk 2011; Jonsson 2012] should be based on research on the technological, economic and ecological aspects related with the formation and use of wood by-products.

In view of this economic perspective, it seems justified to develop research so as to optimize the use of wood by-products as wood biomass (Renewable Energy Sources Act, Article 2, Point 3 [Ustawa.. 2015].

Sawmill waste (waste pieces, sawdust and shavings) plays a key role in the process of using wood by-products. Timber production generates about 37.5% of by-products from the in put material. As far as multi-stage processing is concerned (the production of floorboards, panelling, blockboards, etc.), the total amount of wood by-products may range from 43% to 58% [Mikołajczak 2011; Wieruszewski&Mikołajczak 2017].

The sawmill industry is particularly important in the wood sector due to the quantity of raw material processed and the considerable use of wood by-products. About 40% of the annual supply of wood in Poland is processed by the sawmill industry (Table 1).As can be seen in the list, the supply of wood in Poland mostly corresponds to the structure of the forest cover. Coniferous tree species are the most common (68.7%), and pine-trees are predominant (58.1% of the forest area).Oak, beech, birch and aspen-trees are predominant deciduous species. Spruce-trees or spruce and beech-trees predominate in the mountains. The share of other species, chiefly deciduous ones, is increasing as they occupy more than 31.3% of the forest areas. Species monocultures are being abandoned.

Table 1. The wood assortment structure in Poland in 2016 (thousand m^3)

Specification	Removals by assortments in those. m^3					
	Total	General purpose wood (sawn wood, construction timber)	Long wood	Special wood (veneer, face veneer)	Industrial uses (fibrous masses, particle board)	Fuel
Coniferous wood (timber)	30 078	13 502	269	87	14 553	1 666
Non-coniferous (timber)	9 052	2 512	-	206	4 468	1 866
Slash (coniferous and non-coniferous wood)	1 771	-	-	-	382	1 389
Total	40 901	16 014	269	293	19 403	4 921

Source: the authors 'compilation based on [GUS, Leśnictwo 2017]

In Poland medium enterprises are the most important entities generating by-products as a result of primary wood processing. They process 20,000-50,000 m^3 of wood raw material per annum. These enterprises are characterized by high technical and technological level. They are equipped with modern band saws and circular saws, which guarantee individual processing of valuable hardwood and process-oriented company management. Modern technology and agile management methodologies lead to high quality of production and minimization of the amount of wood by-products [Mikołajczak & Wieruszewski 2017].

MATERIAL AND METHODS

The aim of the study was to determine the share of wood by-products in sawmill processing in Poland. The study attempted to determine the form and amount of wood by-products which could be used to supply energy. The range of the research was also defined.
The research was based on the assumption that the type and structure of wood by-products made in wood-processing enterprises were mostly influenced by technological and species factors related with the production process.

The research was conducted in selected enterprises which processed up to 50,000 m3of wood raw material per annum. These are medium enterprises, which are the largest group of wood-processing enterprises. The research was based on the assumption that the enterprises had similar technological equipment. Each of them had de barkers and wood chippers, which enabled cutting pieces of wood (wings, slaps and edgings). Edgings were usually processed by means of wood chippers.

Diversified species of softwood (pinewood, spruce-wood) and hardwood (oak-wood, beech-wood, maple-wood, alder-wood and hornbeam-wood) were analyzed in order to find the model of the structure of wood by-products generated as a result of processing. Figure 1 shows the species structure of wood processed in the enterprises under study.

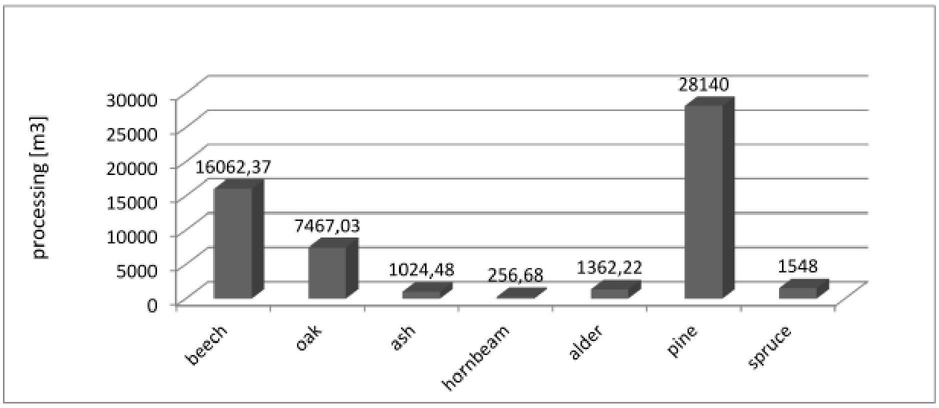

Figure 1. Species structure of hardwood processing in analysed enterprises of the wood industry (sawmills)
Source: own elaboration

The following major groups of wood by-products were identified:

1) sawdust
2) wings, slaps and edgings
3) woodchips
4) bark.

The research was conducted in a selected region of Poland (Greater Poland, West Pomeranian, Lower Silesian Voivodeships), which was characterized by relatively high concentration of medium wood-processing enterprises between 2013 and 2017. Five enterprises processing hard wood and/or softwood (subject range) were selected for the research. The study was based both on existing data and data acquired specially for the research. Secondary data were acquired from sources of public statistics, including the 'Forestry' database of the Central Statistical Office in Warsaw. Primary data were acquired directly in the enterprises under study.

The direct survey method was used in the study. The production processes in the enterprises were analyzed in detail. The collected data were aggregated using basic measures describing the volume of production and sales. In consequence, the results were summarized using the methods of comparative and descriptive analysis.

RESULTS AND DISCUSSION

Sawdust

The amount of sawdust produced as a result of processing ranged from 4% to 14% of the volume of round wood processed. The share depended on such factors as the type of tools used for round woodcutting, the diameter of round wood processed and the type of the final sawn product, i.e. the size of the cross-section of sawn timber.

As results from the analysis of data obtained in the wood-processing enterprises, the smallest amounts of sawdust waste were generated when band saws working at a kerf width of 2.2-2.8 mm were used for the production of timber. When circular saws were used, the share of sawdust waste amounted to 12-16%.Much larger amounts of sawdust were generated during wood processing on multi-blade circular saws, where the kerf width exceeded 4.8 mm.

The amount of sawdust is determined by saw couplings (dependent on final products) and the availability of optimal wood assortments. The production of sawdust waste increases along with higher fragmentation of wood assortments and smaller diameters of raw material to be sawn. These factors reduce timber production efficiency.

Table 2 shows the amount of sawdust generated during the sawing of hardwood and softwood. We assumed a standardized system of the processing of basic hardwood species, where large-size raw material predominated, and the processing of softwood in the same dimensional group. For comparative analysis the measurement data concerning the sawdust volume were standardized and expressed as steres (st) or cubic meters (m^3), using the conversion factor applied in the sawmills under study, i.e. 1 st = 0.33 m^3.

Table 2. The amount of sawdust generated by the wood-processing enterprises between 2013 and 2017 (1 st = 0.33 m^3)

Specyfication	Type of wood	Measurement unit	Year				
			2013	2014	2015	2016	2017
Average volume processed per annum	hardwood	m^3	24362	23131	22156	26340	25482
The volume of sawdust		m^3	1876	1712	1507	2239	1809
		st	5684	5187	4565	6785	5482
Share of sawdust		%	7,7	7,4	6,8	8,5	7,1
Average volume processed per annum	softwood	m^3	31283	30223	27950	30719	29781
The volume of sawdust		m^3	3676	3146	3248	3825	3574
		st	11139	9534	9842	11590	10829
Share of sawdust		%	11,8	10,4	11,6	12,5	12,0

Source: the authors 'compilation

The research showed that the sawmills generated 6-8% of hardwood sawdust and 10-12%of softwood sawdust from the input material. This value was comparable to the data noted in research on other sawmills, which processed similar amounts of wood [Ratajczak et al. 2011]. As the amount (volume) of hardwood sawn within a separate batch (order) increased, so did the share of sawdust. The opposite tendency was observed in softwood processing. This situation may have been caused by the increasing use of thinner hardwood in the production. In consequence, the amount of hardwood by-products increased. It also indicated that the cross-section of softwood was used better and that the production increased.

There are continuous attempts to completely minimize loss in the sawing process. However, it is assumed that part of sawn material may be lost during storage and transport. This situation is caused both by the process of depreciation and decomposition of the structure of wood by-products and by the mixing of fractions formed during sawing.

Larger wood by-products: wings, slaps and edgings

During the sawing of round wood larger pieces of wood by-products, i.e. wings , slaps and edgings are also formed. They are mostly by-products formed during the production of unedged timber. Further wood processing generates other pieces of waste, which are usually used for heating.

The research was based on primary data concerning the sales volume during the period under study, including production fluctuations. On average, the processing of round hardwood generated 6.2% of larger pieces of wood waste. The share of these by-products resulting from softwood processing was minimal and it did not exceed 2.5%. Wings and slaps were predominant – they made about 73% of the total weight of larger pieces of wood waste. Table 3 shows detailed data on the amount of larger wood by-products. Volumetric measurement units, i.e. steres (st), are used in trade in larger pieces of wood waste. For comparative analysis the data were standardized, using the conversion factor 1 st = 0,65 m^3.

Table 3. The amount of larger wood by-products generated by the wood-processing enterprises between 2013 and 2017 (1 st = 0.65 m^3)

Specification	Type of wood	Measurement unit	Year				
			2013	2014	2015	2016	2017
Average volume processed per annum	hardwood	m^3	24,362	23,131	22,156	26,340	25,482
Wings and slaps		m^3	1,175	931	740	1,547	1,125
Edgings [m^3]		m^3	457	319	345	507	379
Total volume of larger wood by-products		m^3	1,632	1,249	1,086	2,055	1,503
		st	2,511	1,922	1,671	3,162	2,312
Share in weight of material sawn		%	6.7	5.4	4.9	7.8	5.9
Average volume processed per annum	softwood	m^3	31,283.37	30,222.82	27,950	30,719.46	29,780.58
Wings and slaps		m^3	16	15	6	28	164
Edgings [m^3]		m^3	9	659	31	200	500
Total volume of larger wood by-products		m^3	25	674	36	227	664
		st	385	10,369	559	3,497	10,217
Share in weight of material sawn		%	0.08	2.23	0.13	0.74	2.23

Source: the authors 'compilation

Woodchips

Larger pieces of wood waste, including wings, slaps and edgings (products of primary processing) are shredded into woodchips for easier storage and transport. Woodchips may be contaminated with bark or they may be bark-free, depending on the debarking operation. Those with bark are defibrillation and heating woodchips, which are used to manufacture boards or as a fuel for heating. Bark-free wood chips, which are made from 'clean 'pieces of wood waste, are used to produce paper and pulp chips. They are a valuable raw material for boards and for the cellulose industry (except oak-wood and ash-wood chips).

The data on the sales volume between 2013 and 2017 were used to calculate the amount of hardwood and softwood chips. During the period under study the processing of round hardwood and softwood generated 14% of woodchips. Table 4 shows detailed data. The conversion factor 1 st = 0.42 m^3 was used to convert the measurement units. The share of defibrillation woodchips (with bark) amounted to 67%, whereas the share of paper wood chips (without bark) amounted to 33%.

As far as the weight of wood sawn at the enterprises is concerned, during the period under study the share of industrial wood chips was similar in individual years. Hardwood processing generated 11-16% of wood chips, where as soft wood processing generated as much as21-24% of woodchips. Deviations from the volume did not exceed 3%.

Table 4. The amount of industrial woodchips formed as a result of wood waste shredding at the enterprises between 2013 and 2017 (1 st = 0.42 m^3)

Specification	Type of wood	Measurement unit	Year				
			2013	2014	2015	2016	2017
Average volume processed per annum	hardwood	m^3	24362	23131	22156	26340	25482
The amount of industrial woodchips		m^3	3459	3678	3301	3372	2879
		st	8237	8757	7860	8027	6856
Share in the volume of sawn raw material		%	14,2	15,9	14,9	12,8	11,3
Average volume processed per annum	softwood	m^3	31283	30223	27950	30719	29781
The amount of industrial woodchips		m^3	7580	7214	6387	6525	6689
		st	18048	17177	15206	15535	15926
Share in the volume of sawn raw material		%	24,2	23,9	22,9	21,2	22,5

Source: the authors 'compilation

Bark

Due to qualitative and technological reasons related with the optimization of production, round wood is debarked before further processing. At present it is a standard procedure applied to raw material before it is sawn at sawmills. However, full debarking (the removal of bark and phloem with outer bark) is rare due to the limitation of debarking devices, the dimensions of wood and its curvature. Round wood assortments with a high share of outer bark are usually subjected to the debarking procedure. As far as medium-sized wood and logs from tree tops (about 8% of round wood sawn) are concerned, even smaller amounts of outer bark are removed during debarking.

So far research has shown that the average share of bark in hardwood (Table 4) ranged from 6% to 21% (8% on average) of the volume of the tree trunk with bark (the bark density is about 300 kg/m^3). Beech bark is smooth in young trees. It tends to flake slightly in older trees and its share amounts up to 6% of the volume of the tree trunk with bark. Its density is about 340 kg/m^3. The share of bark in oak wood or alder wood is larger and amounts to over 20%. Its density reaches 335 kg/m^3.

The actual amounts of bark acquired during wood processing were calculated on the basis of primary data acquired from the enterprises under study, allowing for the share of different species and dimensions of round wood (Table 5). It was assumed that apart from medium-sized thin wood (8%), all the purchased raw material was debarked. As a result, the share of bark in round beech-wood amounted to 4.5%, whereas the share of bark in round oak-wood amounted to 14.6%.

The research showed that on average the share of all by-products amounted to 25% of the round hardwood used as raw input material. The value of this indicator varied from 22% to 27% due to the diversified assortment of final products (the demand criterion).

Table 5. The amount of bark generated during raw material preparation at theenterprises between 2013 and 2017

Specification	Year					Total in Year	
	2013	2014	2015	2016	2017	2013-2017	
	[m^3]					[m^3]	[%]
Average volume processed per annum	24362	23131	22156	26340	25482	121471	100
Kora łącznie	2600	2852	2162	3113	3272	13999	11,5
Wartości ustalone dla dominujących gatunków (dąb i buk)							
Oak bark	2171	2340	1826	2600	2954	11890	9,8
Beech bark	340	445	261	433	229	1707	1,4
Bark of other species of deciduous trees	89	67	75	80	89	402	0,3
Average volume processed per annum	31283	30223	27950	30719	29781	149956	100
Total	1411	1206	567	968	1697	5849	3,9
Wartości ustalone dla dominujących gatunków (sosna i świerk)							
Pine bark	1323	1018	480	888	1572	5282	3,5
Spruce bark	53	156	65	60	88	421	0,3

Source: the authors 'compilation

CONCLUSIONS

In view of the considerable diversity of processing on the market of sawmill products, the structure of the forms of by-products generated by the wood sector in Poland may help to develop the cognitive area related with this issue.

The form of wood by-products is closely related with production technology and the selection of tools. Most by-products are generated during primary wood processing in a sawmill. At the stage of further processing – prefabrication (secondary production), the amount of wood by-products can be significantly reduced.

The structure of wood by-products generated as a result of the processing of round hardwood was predominated by larger pieces of wood waste, intended for further use. Woodchips were mostly generated as a result of softwood processing.

Wood by-products are handled at the places of their formation or they are offered for sale. The enterprises used most of the wood by-products generated at the place of their formation for heating.

Woodchips are mostly offered for sale. Sawdust, shavings and other larger pieces of wood waste are processed into heat (for technological and social purposes).

The research confirmed that the structure of wood by-products was mostly affected by production and technological factors. The attempts to shred by-products finely resulted from the possibility to use them for heating. In consequence, the profitability of the enterprises increased.

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Streszczenie: *Udział produktów ubocznych w przerobach średnich przedsiębiorstw tartacznych.* Przerób surowca drzewnego w zakładach tartacznych pociąga za sobą powstawanie produktów ubocznych (towarzyszących). Udział poszczególnych grup tych produktów oraz ich postać zależą od wielkości produkcji i stosowanych technologii. Na rodzaj generowanych pozostałości i stopień ich rozdrobnienia mają też wpływ inne czynniki, między innymi gatunek i rozmiary przecieranego surowca. Czynniki te determinują możliwości racjonalnego zagospodarowania drzewnych produktów ubocznych – biomasy drzewnej o dużym znaczeniu dla przemysłu płyt drewnopochodnych, celulozowo-papierniczego oraz dla producentów materiałów energetycznych. Ze względu na dominację małych i średnich firm w mechanicznym przerobie drewna, największe znaczenie, jako dostawcy drzewnych pozostałości mają średnie przedsiębiorstwa. W opracowaniu określono udział różnych postaci produktów ubocznych, powstających w procesie przetarcia surowca iglastego: sosny i świerka. Zbadano wpływ wielkości przerobu i sortymentacji wytwarzanych materiałów na rodzaj generowanych pozostałości poprodukcyjnych: kory, trocin, zrębków i odpadów kawałkowych, a następnie dokonano analizy wyników opisujących wpływ zmienności rodzajowej, jakościowej i wymiarowej surowca. Weryfikację procesów przeprowadzono w warunkach zakładowych – w tartakach średniej wielkości. Zakresem badań objęto lata 2013-2017.

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