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A STUDY OF TRENDS IN PRODUCTIVITY OF RAW AND OTHER MATERIALS IN THE POLISH WOOD PROCESSING INDUSTRY IN 1970–2015

Abstract. In the wood sector, rational management of wood (whether in the form of roundwood, production residues or post-consumer wood) and wood materials (i.e. consumption optimization), is an important factor of sustainable sectoral development. With static indices of raw material intensity and material intensity per production unit, it is possible to balance the mix of resources of wood and wood materials. In turn, dynamic indices enable the assessment of changes in resource levels and structure. This paper presents the results of research on the productivity of raw and other materials in the Polish wood processing industry in 1970–2015. The research was primarily based on the results of a direct survey administered to wood companies. Other sources of information include previous research in this field carried out in the Wood Technology Institute, a literature review, professional magazines, thematic reports and online research. As observed in this study, the time trends in indices of raw wood materials consumption per production unit of wood materials and in indices of unit consumption of raw wood materials in the manufacture of final wood products suggest that the indices primarily depend on the nature and sophistication of technological processes and on the type and quality of raw or other materials used.

Keywords: raw material intensity, material intensity, raw wood material, wood materials and products, productivity indices for raw and other materials

INTRODUCTION

The Polish wood sector comprises interdependent and interacting industries characterized by specific production processes, product ranges intended for different consumers, and a variety of more or less sophisticated techniques and technologies. As a natural and renewable raw material, wood is a significant distinctive feature of

the wood sector and its sub-industries. A rational use of wood at all processing stages brings considerable economic and ecological benefits, contributes to environmental protection and human life quality, and eventually becomes a basis for sustainable development of the wood sector and the entire economy.

The operation of the wood sector is based on roundwood or “mixed” raw material, i.e. roundwood, production

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residues¹ and post-consumer wood² (which are an alternative to roundwood). Also, it relies on wood materials and wood-based materials derived from this raw material. The processing of wood (in different forms) into wood materials and, eventually, into final wood products, is generally a multi-stage process. Every stage involves certain losses which finally determine the raw material and material productivity of the process, i.e. raw material intensity and material intensity of wood materials and products. Therefore, sustainable management of wood resources means rational reduction of wood consumption in the manufacture of materials and products without detriment to their quality or technical and functional parameters.

For the wood sector, it is vital and important in practical terms to know the productivity of raw and other materials. With static indices of raw material intensity and material intensity, reflecting the consumption of wood/wood material per production unit of final product, it is possible to balance the mix of resources of wood (in various forms) and wood materials, whereas dynamic indices enable the assessment of changes in resource levels and structure (Kowalska, 1993; Ratajczak et al., 2003; Szostak et al., 2016). The indices may be determined for a production process, a company, a group of companies or a sector (Hruzik, 2006). They are also useful in benchmarking, e.g. at international or other level. In this case, it is important to know the technological processes in place in different countries and to be aware of the impact of “surroundings” on the production process (Strykowski and Szostak, 1999; Szostak, 1999). Constant monitoring of the indices of raw material intensity and material intensity of the wood sector enables analyses and assessments of:

- the consumption of various types of raw wood materials (roundwood, production residues, post-consumer wood) at successive stages of processing,
- changes in the consumption level of wood materials,
- future demand for wood, wood materials and final wood products,
- the importance of the wood market and of the balance on different submarkets for the development of the wood sector and the entire economy,

¹ Leftovers from successive stages of wood processing in the production process of wood materials and products.

² From worn-out, depreciated or obsolete final wood products.

- the production technology of wood materials and products, and improvement opportunities.

Nevertheless, it should be noted that although raw material and material intensity of production in the wood sector is an important aspect for the national raw material policy and forest policy (and for the assessment of economic effectiveness of the entire wood sector and its different companies and sub-sectors), there is a notable information gap in this respect. Official data from Central Statistical Office reports is very limited, and basically Poland lacks a comprehensive system of professional information on this matter.

The purpose of this study was to capture and present long-term trends in the development of raw material indicators and material intensity per production unit of wood materials, and to show some examples of final wood products in Poland.

RESEARCH METHODOLOGY

There is lack of complete, reliable information on raw material intensity and material intensity of the wood sector; this is especially true for information on the manufacture of products with higher added value. Also, the data cannot be compared over time. Filling this gap is primarily possible through direct surveys of the producers of wood materials and products.

A survey on the consumption of raw wood materials, wood materials and wood-based materials per production unit of basic wood materials and products was carried out by the Wood Industry Economics Department of the Wood Technology Institute in 2016 within the framework of an analysis of the Polish market for wood production residues (Szostak et al., 2016). The survey was administered to 477 respondents selected using non-random (non-probability) sampling: producers from the sawmilling industry, wood-based panel industry (particleboards, OSBs, wet- and dry-process fiberboards, plywood and veneers, LVL panels), furniture industry, packaging industry (pallets), builder's carpentry and joinery industry (windows and doors), pulp and paper industry (wood pulp), and from outside the wood sector, i.e. producers from the chemical industry (match industry). The survey was based on dedicated questionnaires consisting of closed and half-open questions with the possibility to pick one or more answers. The questionnaires were e-mailed to the respondents. The response rate was at a level of ca. 13%.

The research also relied on previous achievements of the Wood Technology Institute in the area of raw material and material management in the wood sector. Additionally, the authors reviewed the relevant literature, professional magazines and thematic reports, and searched through online sources relating to the matter in question. Previously, the indices of raw material intensity and material intensity were most often used as a part of wood market research, especially in the context of managing raw wood material and wood materials (Czemko, 2011; Czemko and Szostak, 1999; Gotycz and Hruzik, 1996; Hruzik 2006; Hruzik et al., 2005; Jakowski, 2005; Malowaniec, 2005; Miński, 1999; Nitka, 2005; Ratajczak et al., 2006a; 2006b; Szczawiński, 2005; Szostak et al., 2004; Wieruszewski, 2017).

RESEARCH RESULTS

The research suggests that the main determinants of raw material and material productivity of wood processing in the wood sector are as follows (Strykowski and Szostak, 1999; Ratajczak, 2001):

- technical progress, manifested in modern technologies, new/modified materials etc.,
- raw material quality, including its dimensions,
- raw material type (substitution between raw materials and other materials),
- prices of raw materials/basic materials and prices of substitutes,
- technical and organizational factors (e.g. normalization and standardization level of materials and products).

It is recognized that changes in the raw material and material productivity of wood processing are primarily stimulated by technical progress, which generally increases productivity and thus decreases raw material intensity and material intensity of wood materials and products. The quality and dimensions of raw materials also have a direct influence on the raw material intensity of wood materials. This is because productivity is lower in the processing of wood of lower quality or smaller dimensions. The substitution between raw materials and other materials is also important. In some cases, raw material intensity of the materials production process may increase due to increased share of a raw material which is an alternative to forest raw materials (production residues, post-consumer wood), if the machinery and tools are not upgraded at the same time. In the case of value-added

products, the unit material intensity may be reduced through the introduction of new/improved materials.

Raw material intensity of basic wood materials/products

The research reveals both short- and long-term variation in levels of raw material intensity of production of wood materials in Poland. A constant increase in unit consumption of roundwood is observed in the production of (both coniferous and deciduous) sawnwood, plywood and furniture panels. The index of raw material intensity in the production of coniferous sawnwood was at an average level of $1.47 \text{ m}^3/\text{m}^3$ in 1970–1980, and went up to $1.64 \text{ m}^3/\text{m}^3$ in 2015, i.e. 12% (Table 1). The corresponding index for deciduous sawnwood increased from $1.35 \text{ m}^3/\text{m}^3$ to $1.59 \text{ m}^3/\text{m}^3$, i.e. by 18%. In the production of plywood and furniture panels, the unit consumption of roundwood increased from $2.22 \text{ m}^3/\text{m}^3$ in 1970–1980 to $2.49 \text{ m}^3/\text{m}^3$ in 2015, i.e. by more than 12%.

In the case of wood materials which involve the processing of large-size raw material for general and specialized uses (saw-logs, peeler logs), the indices of raw material intensity follow a visible upward trend (especially in the long-term). The main reason for the above is the deterioration in the quality and size of wood. Usually, this offsets the positive effects of changes in technological processes. Therefore, in the processing of roundwood, two opposite trends may emerge: an increase in productivity resulting from technical progress, and a decrease in productivity resulting from the deteriorating quality or smaller dimensions of wood.

In the case of agglomerated boards (particleboards, OSBs, wet- and dry-process fiberboards), the consumption structure of wood considerably affects the raw material intensity of production. Hitherto, this structure was dominated by (medium-size and small-size) roundwood but in the case of some boards (especially particleboards and wet-process fiberboards), the share of production residue and post-consumer wood has considerably increased in recent years. As regards particleboards, wood which does not originate from forests already accounts for 90% of raw materials. In wet-process hardboards and softboards, the corresponding ratios are ca. 10% and 15%, respectively (Fig. 1). As shown by research, in the 1970–2015 period, raw material intensity of wet-process hardboards decreased from $2.80 \text{ m}^3/\text{m}^3$ to $2.20 \text{ m}^3/\text{m}^3$, i.e. by as much as 21%. In the case of particleboards, it went down from $1.70 \text{ m}^3/\text{m}^3$ to $1.60 \text{ m}^3/\text{m}^3$,

Table 1. Indices of raw material intensity of wood materials/products in Poland in 1970–2015

Detailed list	Unit of measurement	1970–1980 (yearly average)	1981–1990 (yearly average)	1991–1997 (yearly average)	2003	2010	2015
Sawnwood:							
coniferous	m ³ /m ³	1.47	1.47	1.55	1.61	1.56	1.64
deciduous	m ³ /m ³	1.35	1.36	1.40	1.54	1.54	1.59
Veneers	m ³ /m ³	–	–	–	1.95	1.95	1.95
Plywood	m ³ /m ³	2.22	2.24	2.49	2.35	2.45	2.49
LVL panels	m ³ /m ³	–	–	–	–	–	3.00
Matches	m ³ /t	–	–	–	4.92	–	4.55
Particleboards	m ³ /m ³	1.70	1.78	1.73	1.60	1.80	1.60
OSBs	m ³ /m ³	–	–	–	1.85	1.85	1.85
Wet-process fiberboards:							
hard	m ³ /m ³	2.80	2.76	2.70	2.65	2.55	2.20
soft	m ³ /m ³	–	–	–	0.68	0.68	0.68
Dry-process fiberboards:							
	m ³ /m ³	–	–	–	2.00	2.00	2.00
Wood pulp:							
cellulose	m ³ /t	5.62	5.40	5.26	4.70	4.30	4.50
mechanical wood pulp	m ³ /t	2.75	2.76	–	2.70	2.70	2.70

Source: Ratajczak, 1999, p. 24; Strykowski and Szostak, 1999, pp. 7–11; Szostak et al., 2003, pp. 31–34; Ratajczak et al., 2011, pp. 89–91; Szostak et al., 2016, p. 53, 74; *Gospodarka...*, 1996, p. 66; *Gospodarka...*, 2000, p. 43; *Gospodarka...*, 2004, p. 42; direct surveys of wood sector producers; opinions of industry experts and specialists from the Wood Technology Institute in Poznań.

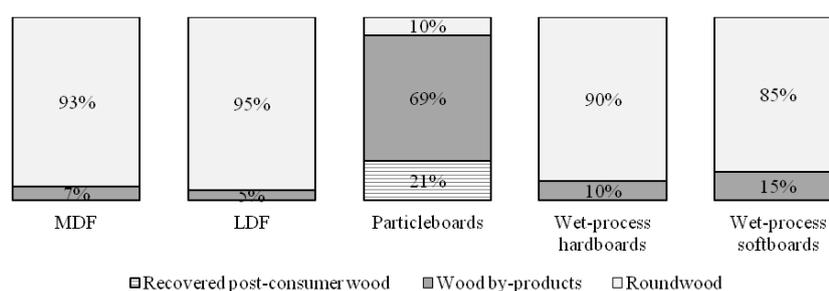


Fig. 1. Approximate structure of raw wood materials used in the production of wood-based panels in Poland

Source: survey of wood companies (Szostak et al., 2016).

i.e. by 6%. The raw material intensity of other types of agglomerated boards (OSBs, wet-process softboards, dry-process fiberboards) remained stable over that period. As regards agglomerated boards, it is assumed that

the increase in the productivity of wood processing was primarily driven by technical progress in production technologies, although smaller pieces of wood or even lower-quality wood was used.

Wood pulp production was also characterized by a constant decrease in raw material intensity over the study period. In the case of cellulose, the index of wood consumption (mainly including roundwood and, to some extent, production residues) per production unit went down from 5.62 m³/t in 1970–1980 to 4.50 m³/t in 2015, i.e. by 20%. When it comes to mechanical wood pulp, a reduction from 2.75 m³/t to 2.70 m³/t (by 2%) was recorded. Especially in last decade, those changes presumably resulted from the implementation of modern techniques and technologies for wood pulp production (highly-productive wood pulp).

Note that although the productivity of wood processing into wood materials in Poland has changed, this is generally a medium- and long-term evolution rather than rapid changes.

Material intensity of value-added wood products

Wood materials and wood-based materials are a basis for the production of final wood products, including

furniture, wooden windows and doors or wooden packaging (further processed products with high value added). These may have a homogeneous (e.g. pallets, windows) or heterogeneous (e.g. door leaves, furniture) composition. Material intensity for products of homogeneous composition can be determined using the indices of wood material consumption per production unit. In turn, when it comes to products of heterogeneous structure, it can be determined based on the mix of wood materials used.

The research suggests that in recent years, the greatest changes have occurred in the structure of materials used for furniture production in Poland (Table 2).

The share of particleboards in the mix of materials used in the manufacture of furniture decreased considerably (from 62% in 2003 to 49% in 2015, i.e. by 13 percentage points), whereas an increase was observed in the share of semi-finished sawnwood (from 15% to 21%, respectively, i.e. by 6 percentage points) and fiberboards (mainly dry-process boards; from 19% to 26%,

Table 2. Material intensity of production of selected final wood products in Poland in 2003, 2010 and 2015

Detailed list	Unit of measurement	Material structure	2003	2010	2015
Furniture:					
semi-finished coniferous sawnwood		%	10	15	21
semi-finished deciduous sawnwood		%	5		
particleboards		%	62	67	49
fiberboards		%	19	16	26
plywood		%	4	2	3
honeycomb boards		%	–	–	1
Wooden windows and doors:					
windows	m ³ per item		0.16	0.09	0.06
exterior doors	m ³ per item		–	0.07	0.40
interior doors	m ³ per item		0.07	0.07	0.06
frames	m ³ per item		0.06	0.06	0.03
Wooden packaging (pallets)					
Euro	m ³ per item			0.04	0.04
industrial	m ³ per item			–	0.03
disposable	m ³ per item			0.03	0.02

Source: Szostak et al., 2003, pp. 35–37; Ratajczak et al., 2011, pp. 90–91; Czemko, 2011; Szostak et al., 2016, p. 55, 74; direct surveys of wood companies, opinions of industry experts and specialists from the Wood Technology Institute in Poznań.

respectively, i.e. by 7 percentage points). Those changes (especially over the 2010–2015 period) presumably resulted from the increased use of high-quality, highly functional modern materials in furniture production.

In recent years, relatively large changes in the consumption of wood materials were also observed in the production of windows. It is assumed that the decrease in the material intensity of window production (from 0.16 m³ per item in 2003 to 0.09 m³ per item and 0.06 m³ per item in 2010–2015) resulted primarily from substituting traditional sawnwood with solid glued elements. A similar situation is observed in the production of frames: the consumption of wood materials dropped from 0.06 m³ per item in 2003 to 0.03 m³ per item in 2015. On the other hand, there was a considerable increase in unit consumption of wood materials in the production of exterior door leaves over the 2010–2015 period. Presumably, this was largely caused by structural changes (increased resistance to deformation and other factors) and by a great variety of sizes combined with product modernization, improvement of functional properties and better usage safety.

On the other hand, material productivity of pallet production remained unchanged for years. Depending on pallet type, it varied in the range of 0.02 m³ per item to 0.04 m³ per item. This is because pallets are a product that uses homogenous materials (sawnwood), adds relatively little value and relies on a basically invariable production technology.

CONCLUSIONS

1. The indices of raw material and material intensity of wood materials and products are analytic measures which specify the input of raw wood materials necessary for the production of one unit of wood material; or the input of wood materials necessary for the production of one unit of final wood product with defined technical and functional parameters. The indices are based on natural units and mainly used at meso- and microeconomic level. They need to be properly interpreted, especially in the case of final products and the necessity to include in them technical-functional parameters of those products (comparability context). The issue to be addressed in constructing those indices, especially the ones referring to material intensity of final products, is the wide variety of materials the products are made of.
2. The indices of raw wood material consumption of wood materials and the indices of wood material and wood-based material consumption in the production of final wood products vary significantly across Poland. This is primarily because of the nature of technological processes. Raw material and material productivity in the wood sector is commonly believed to be the combined effect of: the sophistication of wood processing techniques and technologies; the type of raw or other materials; and quality features.
3. As shown by this study, unit consumption of raw wood materials in the Polish sawmilling industry followed an upward trend, averaging at 1.62 m³/m³ in 2015. In the wood-based panel industry, raw material intensity of production fluctuated (depending on the type of panels) from 0.68 m³/m³ (wet-process softboards) to 3.00 m³/m³ (LVL panels). In turn, a significant decrease in wood consumption per production unit was observed in the case of wet-process hardboards (a 25% decrease in 1970–2015). The productivity of wood processing in the production of wood pulp also increased: in the case of cellulose, the index of raw material consumption per production unit decreased to 4.50 m³/t in 2015, and in the case of mechanical wood pulp to 2.70 m³/t. In recent years, the raw material intensity of match production also decreased to reach 4.55 m³/t in 2015.
4. As regards the processing of large-size raw materials (in the production of sawnwood and plywood), the indices of raw material intensity observed in recent years in Poland demonstrate a decline in the quality and size parameters of that raw material. The indices can also be indicative of a relatively slow modernization of technical equipment in the sawmilling and plywood industries. On the other hand, raw material productivity of the processing of smaller pieces of wood or even lower-quality wood, and of wood-based panels and cellulose is primarily determined by technical progress.
5. Material intensity of production of final wood products varies strongly across Poland. In the case of wooden windows and doors, material intensity basically followed a downward trend. In 2015, it was 0.06 m³ of wood materials per production unit of interior windows and doors, and 0.03 m³ for frames (however, for exterior doors, the index of material intensity increased to 0.40 m³). In the production of pallets, sawnwood consumption depended

on product type and varied in the range of 0.02 m³ to 0.04 m³ per item as at 2015. In recent years, the relatively greatest changes occurred in the material mix used in furniture production. In 2015, the mix was dominated by particleboards and fiberboards accounting for 49% and 26%, respectively, of all wood materials used.

ACKNOWLEDGEMENTS

This paper presents the results of “Resources of wood by-products created in the wood sector,” a research project carried out at the Wood Technology Institute in Poznań, financed with the statutory subsidy granted the Institute (www.itd.poznan.pl) by the Ministry of Science and Higher Education.

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BADANIE TENDENCJI WYDAJNOŚCI SUROWCOWO-MATERIAŁOWEJ PRZEROBU DREWNA W POLSCE W LATACH 1970–2015

Abstrakt. W sektorze drzewnym racjonalne gospodarowanie drewnem (nie tylko w postaci okrągłej, ale również drzewnymi produktami poprodukcyjnymi i drewnem poużytkowym) i materiałami drzewnymi, a więc optymalizacja ich zużycia, jest ważnym wyznacznikiem jego zrównoważonego rozwoju. Wskaźniki surowco- i materiałochłonności jednostkowej produkcji w ujęciu statycznym umożliwiają bilansowanie zasobów drewna i materiałów drzewnych, w ujęciu dynamicznym pozwalają natomiast na ocenę zmian ich poziomu i struktury. W artykule przedstawiono wyniki badań dotyczących wydajności surowcowo-materiałowej przerobu drewna w Polsce w latach 1970–2015. Wykorzystano przede wszystkim wyniki badania bezpośredniego firm drzewnych, a także dotychczasowy dorobek Instytutu Technologii Drewna w tej dziedzinie; dokonano również przeglądu literatury, czasopism branżowych i raportów tematycznych oraz kwerendy źródeł internetowych. Obserwowane na przestrzeni lat tendencje w kształtowaniu się wskaźników zużycia surowca drzewnego na jednostkę produkcji materiałów drzewnych oraz wskaźników jednostkowego zużycia tychże materiałów w produkcji drzewnych wyrobów finalnych wskazują, że zależą one przede wszystkim od charakteru i stopnia nowoczesności stosowanych procesów technologicznych, a także od rodzaju wykorzystywanego surowca lub materiału oraz ich cech jakościowych.

Słowa kluczowe: surowcochłonność, materiałochłonność, surowiec drzewny, materiały i wyroby drzewne, wskaźniki wydajności surowcowo-materiałowej