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HARMONIZATION OF CRITERIA AND OPERATIONALIZATION OF SUSTAINABLE DEVELOPMENT INDICATORS IN THE ASSESSMENT OF BIOPRODUCTS

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ABSTRACT: This article analyses sustainable development indicators for the assessment of bioproducts. It also determines criteria for the operationalization of bioproduct assessment on the basis of available literature on the subject and the opinions of entrepreneurs producing packaging made of petroleum derivative materials. The results of literature and questionnaire studies indicate that indicators used for the assessment should accurately reflect the process or state of affairs they present, and be clear for every stakeholder throughout the entire supply chain.

KEY WORDS: bioproducts, assessment, SD indicators, operationalization

Introduction and methodology

The golden age of the plastics industry resulted from the industrial revolution and technical progress. Over time, plastics found a number of applications, including use in construction, electronics, medicine, aviation and many other industries (Piontek, 2019, p. 19).

Over the past 70 years, world plastics production had increased from nearly 0.5 million tons in the mid-twentieth century to over 365 tons in 2016. After China, Europe is the world's second-largest producer of plastics (Dobrucka, 2019, p. 129). In medium- and underdeveloped countries, the share of plastic waste in municipal waste increased by almost 10% from 1960 to 2005 (Geyer, Jambeck, Law, 2017). The reasons for this state of affairs can be traced to three phenomena: an increase in the scale of use of non-natural packaging materials, development of the disposable packaging market and the use of the packaging as marketing materials. In highly developed countries, packaging accounts for over 40% of municipal waste. In Poland, this share amounted to nearly 48% in 2017 (Piontek, 2019, p. 21).

The main advantages of using plastics include, first of all, low costs and high functionality (Piontek, 2019, p. 21). Although the use of plastics has many advantages in comparison to other materials, their disadvantages are becoming an increasing concern. PET is a carcinogen (see Sax), and the annual mass of plastic waste discharged into the oceans by rivers is 1.15-2.41 million tons (Lebreton et al., 2017). Currently, the use of virtually non-decomposable materials for packaging is being reduced (Nampoothiri et al., 2010). The obligation to change the approach to this issue has been forced by the introduction of two European documents: Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste and Directive of the European Parliament and Council (EU) 2018/852 of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste (Dobrucka, 2019).

The European Union does not use the potential arising from the recycling of plastic waste. Only 30% of nearly 26 million tons of plastic waste are recycled annually. One of the main principles of the European Commission's economic policy, adopted to protect the environment and implement the principles of sustainable development, is the circular economy. Closed circulation minimizes resource waste and reduces the scale of resource use (Stahel, 2016). This policy also applies to the packaging industry, mainly in terms of minimizing the amount of packaging waste generated from conventional plastics (Dobrucka, 2019, p. 133).

In 2018 PlasticsEurope formulated the paramount goals of the Plastics 2030 Voluntary Commitment of the Plastics Industry: preventing the release

of plastics into the environment, increasing the scale of recycling and reuse of waste and improving resource efficiency. Poland is an important participant in the European plastics market, being the sixth economy after Germany, Italy, France, Spain and Great Britain in terms of demand for plastics. The demand for plastics in 2017 in Europe was over 51 million tons. Both in Europe and in Poland, plastics are mainly used in the packaging industry (Europe 39%, Poland 34%). However, it would be best to introduce materials that completely ensure the possibility of the circular economy. Therefore, research focused on rational resource management and improving the efficiency of their use (bioeconomy) is being continued. Bioeconomy includes all sectors related to biological resources (Chył, Rzepecka, 2011, p. 3), including bioproducts.

In the 2020 Strategy, the European Union strongly supports the development of bioproducts. The importance of bioeconomy for smart and ecological growth in Europe is emphasized in this strategy. Changes in the bioeconomy will not only contribute to saving natural resources and to protecting the climate, but it is also expected that bioeconomy "is able to stimulate and maintain economic growth and create jobs in rural, coastal and industrial areas; reduce dependence on fossil fuels and contribute to improving the economic and environmental sustainability of primary production and the processing industry" (Communication from the Commission…, 2019). "The essential element of sustainable economic development in the EU and the country will be the production of products and services in a manner that ensures constant restitution of the natural environment" based on raw materials of biological origin. However, even bioproducts have an environmental impact and should be part of not only the bioeconomy but of the wider circular economy (Gołaszewski, 2013, pp. 51-54). In order to control the environmental impact of bioproducts, assessment is required throughout the entire life cycle using properly selected sustainable development indicators. In addition to the proper selection of indicators, it is necessary to operationalize them, i.e. bring the indicators and variables to a form that can be precisely expressed. Despite the huge number of indicators proposed in literature and documents of the European Union, Borychowski et al. (2016) indicate the lack of data to produce relevant aggregate indicators as the basic problem in operationalization. This is the main obstacle observed in the implementation of the concept of sustainable development (Sahely et al., 2005) at the practical level. Recommendations for current standards for sustainable development of bioproducts in the European Union require interoperability, which is a key factor in enabling digital transformation. In the case of bioproducts, it is a process of increasing information comparability by introducing a uniform set of sustainable development indicators based on common assumptions and

concepts. The problem involves the harmonization of the entire process and their proper selection to ensure the quantitative measurement and qualitative assessment of a given bioproduct and its environmental impact. Therefore, the question arises: how should sustainable development indicators used in the assessment of bioproducts be characterized, so that they can be a practical tool at every stage of the life cycle?

The article is aimed not so much at preparing a finished list of indicators as it is at indicating the path of their selection. It is an attempt to determine the criteria for the operationalization of bioproduct assessment based on available literature and opinions of entrepreneurs who are producers of packaging made of petroleum derivative materials.

Due to the nature of pilot studies, the analyses were narrowed to one voivodeship. In the first stage, using the search engine – Panorama Firm – companies registered in the Warmia and Mazury Voivodeship were identified, whose common feature was the production of packaging from petroleum derivatives. In this way, 35 enterprises were selected. Surveys were conducted among decision-makers in these enterprises.

In the next stage, verification was carried out by interviewing the decision-makers in the enterprises to obtain consent to send the questionnaire. Twenty-four enterprises returned correctly completed questionnaires, which constituted 68% of the identified enterprises.

This was a representative sample for the studied area. The survey consisted of four closed questions and a metric that took into account the length of business operations on the market and activity in introducing innovations. Among the surveyed enterprises, eleven had been operating for over 20 years. One company had been operating for the longest time (47 years) and one company for the shortest (3 years). It should be noted that although the survival rate of companies on the Polish market is growing, the Warmia and Mazury Voivodeship is one of those voivodeships (only Kuyavian-Pomeranian Voivodeship is lower in the ranking), where young companies are doing the worst. Research shows that the third year of operations is the most difficult one, during which the funds to start up a company are often exhausted. Companies often ended their activities between the 25th and 36th month (CRIBIS.pl). Considering the length of functioning of the surveyed companies, it can be stated that they are companies with an established position and are long-term operators on the market as per Polish conditions. This may bode well in terms of the possible implementation of innovations. In addition to intellectual effort and financial resources, innovation always requires industry experience. Among the surveyed enterprises, over 90% made innovative changes in the field of technology. One of them made such changes twice in 2008 and 2018, which is worth emphasizing in this case, as the enterprise –

as the only one – started production based on oxy-biodegradable materials, and then biocomposites. This result is much higher than the average in Poland. In Poland, between 2015-2017, only 20.2% of industrial enterprises showed innovative activity. Industrial enterprises most often introduced new or significantly improved methods of manufacturing products.

The results of the survey were developed, and the structure of indications was given.

Place of bioproducts in constant and sustainable development

According to the European Standard EU (European Standard EN 16575: 2014 'Bioproducts-Dictionary), bioproducts are products made in whole or in part from biomass, i.e. biomaterials, with the exception of materials embedded in geological or fossil formations (Communication from the Commission…, 2019) On the other hand, biomaterials (in the utilitarian concept) are materials used in technology, e.g. for the production of packaging materials. According to, i.e. Malinowski (2015, pp. 215-231), three criteria for the division of biomaterials are listed: methods of obtaining them, the structure of the polymer chain, physicochemical properties and application technologies.

At the same time, the definition officially adopted by European Bioplastics defines bioplastics as biodegradable materials and/or plastics from renewable sources, indicating the biodegradability criterion and sources of extraction (European Bioplastics, 2019) From the point of view of operationalization of the environmental impact assessment of a bioproduct, the adoption of such a definition is fully justified. The definition constructed in this way indicates that biomaterials are not necessarily degradable. According to it, biomaterials also include materials that are not biodegradable, but which are made from renewable and non-renewable resources. Out of six possibilities, only one is not a biomaterial (figure 1). It is a material from fossil resources that are not degradable (non-biodegradable).

From the point of view of environmental protection, the most beneficial material is a biomaterial produced from renewable resources and, at the same time, a biomaterial that is biodegradable which, in consequence, means that the bioproduct produced is also biodegradable. Błędzki and Fabrycy (1992, pp. 343-350), Trznadel (1995, pp. 485-492) have written about it for a long time, as well as – more currently – Peneczek et al. (2013, pp. 835-846) (figure 3). The materials most commonly used in the production of bioproducts are based on starch, polylactic acid (polylactide, poly (lactic acid), PLA), polyhydroxyalkanoates, alkanoates (PHA's: PHB, PHBV etc.), aliphatic-aromatic polyesters, cellulose (cellophane, etc.) and lignin.

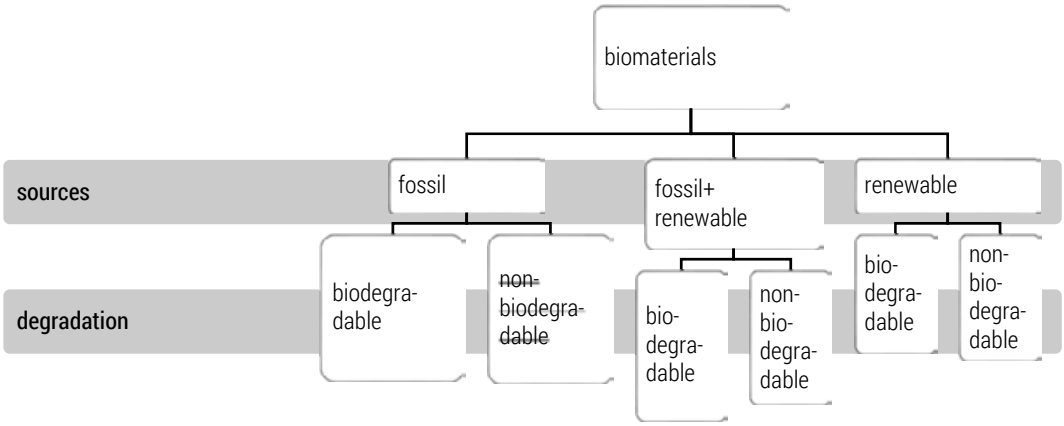

Figure 1. Division and interrelationships of biomaterials by their source and biodegradability
Source: European Bioplastics, http://european-bioplastics.org [17-09-2019].

The best solution for environmental protection and an alternative to petroleum derivative materials would be to introduce biomaterials into large-scale production and, as a consequence, bioproducts. However, in Poland, the biomaterial market is practically non-existent, despite its intensive development in the EU. EU experts expect that by 2021, the EU will be able to boast a quarter of the world's biomaterial production. At the same time, the global market is recording 20-100% growth on an annual basis. However, it should be added that the world's production of biomaterials produced from renewable and/or biodegradable raw materials is at the level of 1% (Malinowski, 2015, pp. 215-231). Malinowski (2015, pp. 215-231) indicate the reasons for low production: high costs of testing of these materials, insufficient promotion, as well as manufacturers' concerns about new, alternative products from materials with a predetermined lifetime. However, their development is inevitable. Biomaterials constitute an important element of the circular economy, which is to replace the linear economy.

It should be added that nature produces about 170 billion tons of biomass annually. Of this, 3.5% (6 billion tons) is used, of which about 62% is intended for food production, 33% for energy and paper production and 5% is processed into chemical compounds (Malinowski, 2015 after Shen et al., 2007). All of these circumstances indicate the problem of insignificant production of bioproducts. Biomaterials can be an alternative to petroleum derivative materials, although the lack of organized collection and the possibility of effective separation of waste is a significant problem. Currently, bioproducts offered on the market are in an insignificant quantity, or there are none. However, their introduction to the market is inevitable in the shaping

of the environment towards constant and sustainable development. To quote Gołaszewski (2013, pp. 51-54), *it is estimated* (OECD, 2009; The bioeconomy to 2030: Designing and Policy Agenda) *that products obtained from renewable biological resources (biomass) will gradually replace products produced from fossil fuels today, creating a new bioprocess market and, as a result, a new market for bioproducts and services – they constitute 25% of the world market*.

Problems with the proper selection of indicators for assessing the impact of bioproducts on the environment

General guidelines for the selection of indicators

Assuming the introduction of bioproducts on a larger scale in the future, it seems necessary to measure their environmental impact. Sustainable development goals related to sustainable consumption and production are only achievable if well-monitored. Babbie (2001) indicates conceptualization and operationalization among the pillars of any measurement. Conceptualization involves the specification and refining of abstract concepts, while operationalization involves the creation of specific research procedures that will allow for empirical observations corresponding to these concepts in the real world. Although the concept of sustainable development has many definitions and indicators, it is still difficult to choose the right one for its assessment. In the multitude of definitions of sustainable development, Borychowski et al. (2016) detect problems with the conceptualization of this concept, which translates into a high number of measures and sustainability indicators. The International Institute for Sustainable Development indicates the existence of 173 alternative sustainable development indicators used in various countries, and there are even more to be found in the scientific literature (Borys, 2005). However, Borychowski et al. (2016) indicate the lack of data to produce relevant aggregate indicators as the basic problem in operationalization. This is the main obstacle that is observed in the implementation of the concept of sustainable development (Sahely et al., 2005) at a practical level. There are also gaps in indicating the direction of preferences for many proposed indicators, and even contradictions depending on the component (order) that is being analysed. An indicator may take a positive direction due to, e.g. social needs, but a negative direction due to environmental protection. Therefore, it is extremely important not only to know but also understand, the direction of preferences. In current systems, this direction is not always defined, which may cause misunderstandings or misinterpretation. It must, therefore, be clearly determined whether a given parameter is a stimulus conducive to sustainable development, or on the contrary, a destim-

ulant. While in the case of the economic sphere, the highest possible values of indicators describing it are most often desirable, in the ecological sphere – the minimum environmental burden associated with production. Even for bioproducts, this burden occurs. Operationalization means bringing indicators and variables to a form that can be precisely expressed. In addition, it is also important to be able to use digital technology to assess achievements. Especially since interoperability is required in the European Union, which is a key factor in enabling digital transformation. Interoperability should be understood as the ability of a system or product to fully cooperate with other systems or products. This enables the exchange of relevant information in a way that can be understood by all parties (The new European Interoperability..., 2017) However, the adopted general principles of interoperability should be emphasized: subsidiarity and proportionality, openness, transparency, reuse, technological neutrality and data portability, user orientation, inclusion and accessibility, security, privacy and multilingualism.

Additionally, it is assumed that it should be legal, semantic, organizational and technical interoperability. This, therefore, requires harmonization. For the assessment of bioproduct indicator compliance with the principles of sustainable development, harmonization at the level of coordination, communication and monitoring of progress is necessary.

Harmony means the right order, arrangement, complementarity of elements, objects, phenomena etc. that make up a whole (Polish dictionary). The act of adapting different people, plans, situations, etc. to each other is the result of this process (https://dictionary.cambridge.org/pl/dictionary/english). Harmonization is the way to achieve the right order. In accounting, it is a process of increasing the comparability of financial statements by introducing a common set of templates based on common assumptions and concepts. This can also refer to operationalization.

Harmonization is required for cooperation in the field of bioproduct assessment criteria and operationalization of sustainable development indicators, which can thus be used by all stakeholders and at all stages of the product life cycle. They should be constructed in such a manner that they can be used to achieve purposes for which they were created and, thanks to the established uniform system, they can be fed with data at subsequent stages of the supply chain. Indicators can provide a quantitative measurement and qualitative assessment of a given bioproduct and its environmental impact (Delzeit, Holm-Müller, 2009). Indicators should be clearly worded and relatively simple to use. Goldschmidt et al. (2013) emphasize the need for indicators to have basic features. They should:

- accurately reflect the process or condition they represent,

- be sensitive enough to capture changes over time and between bioproduction and traditional systems,
- be applicable to measures in terms of time, expenditure and level of skills required,
- be clear and relevant to users at every stage of the supply chain and to end-users.

Practical tips resulting from the analysis of surveys

Due to the insignificant share of producers of biomaterial packaging in Poland, entities producing packaging made of petroleum derivative materials were selected for analysis, as potential producers. In the systemic approach to the sustainable management of natural resources, industries based on raw materials of biological origin will be a significant impulse for the development of the innovative economy (Gołaszewski, 2013, pp. 51-54). Due to this, enterprises have been characterized in terms of introducing innovation in production technology since 2005. This may indicate the openness of these enterprises to innovative solutions. Most of the respondents introduced innovations in 2005 just after Poland joined the EU and in 2015 when new funding for 2014-2020 was available, but only one innovation concerned the introduction of the production of bioproducts (figure 2).

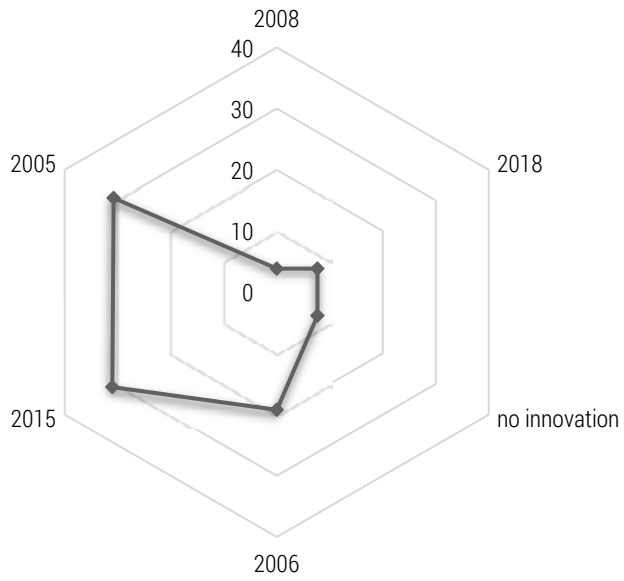

Figure 2. Structure of indications for introduced innovations between 2005-2018

Source: author's work based on a survey.

However, it should be noted that the scale of Polish bioplastics production is far behind world plastics production (Malinowski, 2015, p. 16). Among the 2,658 patents granted in 2015 in the field of biotechnology in the world, less than 2% were Polish patents. The United States, with a 37% share, is a powerhouse in this field. It should be noted, however, that approximately 2/3 of Polish patents applied for were granted (Twardowski, Woźniak, 2016, p. 158).

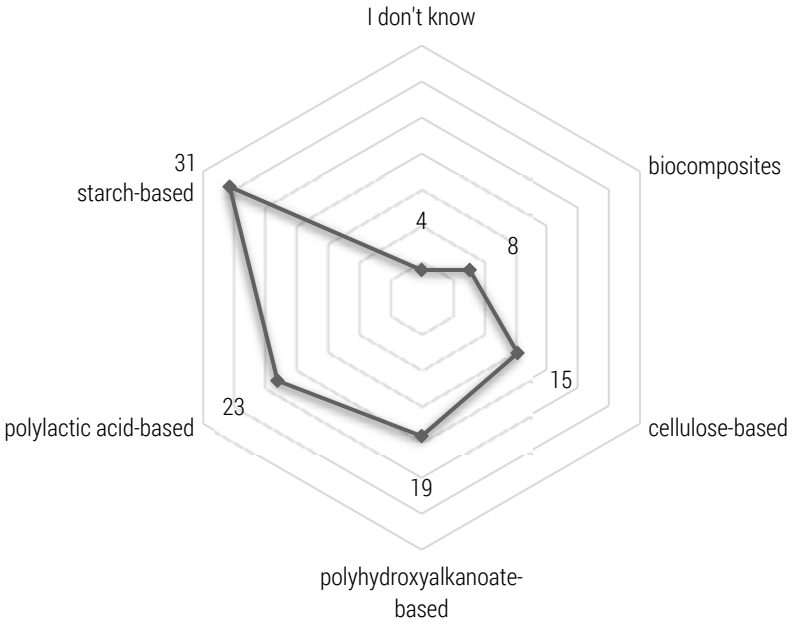

Figure 3. Structure of responses for the knowledge of biomaterials by the decision-makers [%]
Source: author's work based on a survey.

One of the biggest problems (and perhaps the reason) for resisting such innovations is poor detailed knowledge of the types of bioproducts and biomaterials among decision-makers in companies. This is revealed by the structure of the indications (figure 3). Asked about knowledge of biomaterials, entrepreneurs most often listed starch (31%) and polylactic acid 23%; only 4% of indications concerned biocomposites. It is worth adding that the company operating on the market for the shortest time gave the answer "I do not know". This is a disturbing phenomenon, given that in the near future these materials may become the most commonly used packaging materials (Dobrucka, 2019, p. 133), and the scale of their use is scarce. Of the approximately 170 billion tons of biomass produced annually by nature, only 3.5% is used by people (Malinowski, 2015, p. 219). Dynamic production, a variety of

applications and competitive performance properties can make bioplastics a material of the 21st century. Research on innovation (the propensity and the company's ability to innovate) (Stanisławski, 2015, p. 119) of enterprises shows that the main reason for moderate innovation is the lack of motivation.

Innovations constitute a priority in the socio-economic development of the European Union. In Polish conditions, innovations may be related to the implementation of the concept of the circular economy, which, by closing the product cycle and reusing it, contributes to the competitive growth and economic development of the economy due to low emissions, sustainability and competitiveness of the economy (Twardowski, Woźniak, 2016, p. 158). The theoretical foundations of the circular economy should be sought in endogenous theories of economic growth, according to which economic growth occurs as a result of introducing innovations. An intelligent, sustainable and innovative plastics sector should be shaped, based on recycling and reduction of greenhouse gas emissions. Safe consumption patterns should be created, and the use of plastics should be reduced (Piontek, 2019, p. 24).

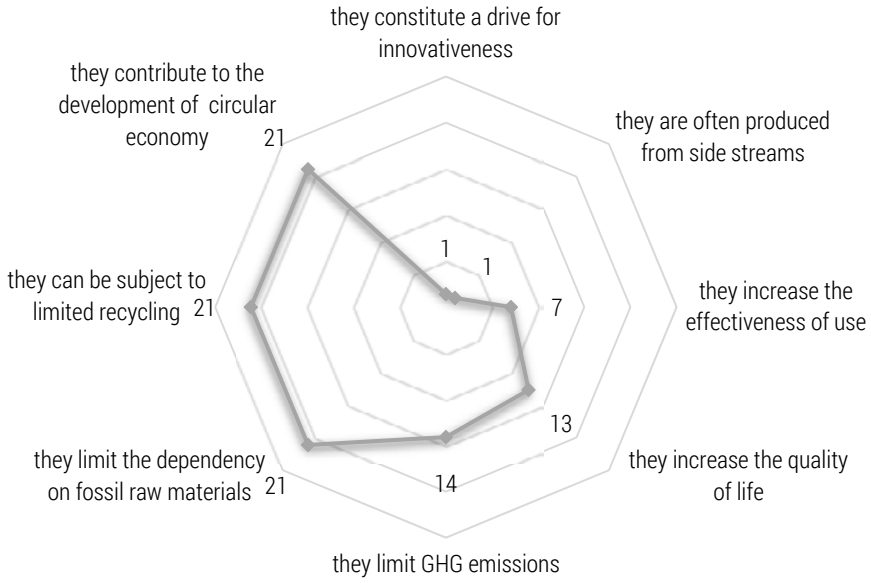

Figure 4. Number of indications of the greatest benefits resulting from the introduction of bioproducts to the economy

Source: author's work based on a survey.

Respondents were also asked to comment on the benefits resulting from the introduction of bioproducts to the economy. They were asked to indicate the three greatest benefits resulting from the introduction of bioproducts to

the economy. Despite the poor detailed knowledge, the respondents showed fairly good general knowledge about the benefits of using bioproducts (figure 4). The global economy faces numerous social challenges of a global nature. These include food security, depletion of resources and climate change (Czernyszewicz, 2016, p. 49). A further increase in the use of plastics will move humanity away from achieving these goals. The concept of sustainable development should be implemented. The goal should be to reduce the scale of the negative impact of humanity on the natural environment. Entrepreneurs mainly pointed to the features associated with the circular economy, that they can be subjected to organic recycling and emphasized the impact of bioplastics on reducing dependence on mining raw materials.

Knowledge of the benefits of using bioproducts with experience in the packaging production industry, allowed features of potential indicators to assess the environmental impact of bioproducts to be indicated. The respondents were asked to indicate the most important feature of indicators used to assess bioproducts (figure 5).

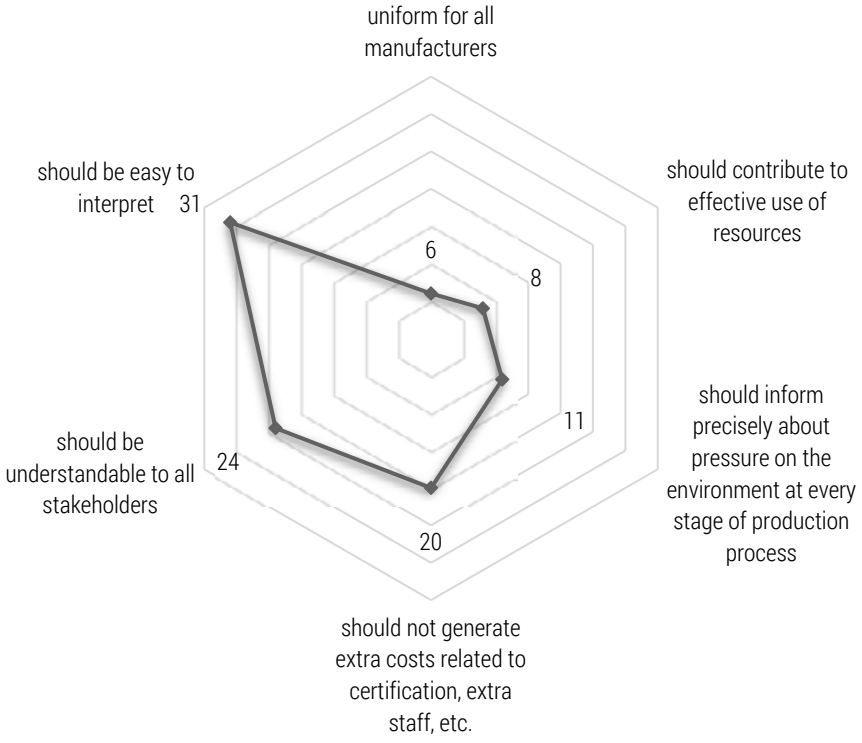

Figure 5. Structure of responses for the most important feature of the indicators used to assess bioproducts [%]

Source: author's work based on a survey.

Most indications concerned the ease of interpretation of an indicator and its understandable formula for all stakeholders. They also emphasized the need for certification costs associated with the assessment not to be high.

Conclusions

In Poland, plastics are mainly used in the packaging industry, and packaging accounts for 48% of municipal waste. The need to abandon the use of virtually non-decomposable packaging materials encourages the search for alternative solutions and including enterprises in the circular economy.

The surveys conducted among manufacturers of petroleum-based plastic packaging in the Warmia and Mazury Voivodeship showed that these enterprises implement innovations in the field of introducing bioproducts to the market to a small extent. The introduction of innovations related to the implementation of the concept of circular economy and the use of bioproducts, which are an important element of socio-economic development of the 21st century, are inevitable.

Despite little knowledge about the diversity of bioplastics, entrepreneurs are able to precisely determine the benefits resulting from their use: reducing dependence on mining raw materials, the possibility of their recycling and indicate them as important factors in the development of the circular economy. The use of bioproducts may become a source of competitive advantage of 21st-century enterprises, innovative enterprises that are socially responsible and caring for the environment. It will be possible when an efficient bioproduct assessment and control system is combined with entrepreneurs' motivation. Then there will be a chance to achieve economies of scale in the bioproduct market. The economy of scale is a measure of the change in production occurring in connection with a reduction in production costs and an increase in the consumption of resources. It is the main factor affecting long-term average total costs. In companies where there are economies of scale at the production level, the number of units produced has a significant impact on changing the long-term average cost" (Encyklopedia zarządzania, 2019). Taking into account theoretical considerations and suggestions of entrepreneurs, it should be emphasized that the indicators used must fully reflect all the environmental impacts of bioproducts indicated by the European Union: greenhouse gas emissions, water consumption, soil protection (acidification, changes in land use, use of marginal land). It would be desirable to have the environmental impact clearly visible in relation to the use of a bioproduct instead of its "traditional" counterpart. Users at subsequent stages of the supply chain and final consumers should be able to make an informed choice about a product based on such indicators. The costs related

to the assessment were also an important issue postulated by entrepreneurs. The cost of introducing an index assessment should not exceed the benefits of the assessment. Since there is already an extensive certification system for other reasons, the indicators should comply with the requirements of certification bodies (they are not superfluous, do not overlap, their significance is marginal). It is also important to know whether the data for the construction of indicators is obtainable and whether it is possible for the participants to widely use the data at every stage of production.

Indicators used for assessment ought to ensure both quantitative measurement and qualitative evaluation of a bioproduct and its impact on three pillars of sustainable development (environment, economy, society), as well accurately reflect the process or state of affairs they present. The indicators should be sensitive enough to capture changes over time and in the various biological production systems and standard production systems and relate to measures/funds in terms of time, expenditure and level of skills required. They must be understandable and relevant for users at every level of the supply chain and final customers.

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The contribution of the authors

Mirosława Witkowska-Dąbrowska – 80% (concept, methodology, literature review, conclusions).

Natalia Świdyńska – 10% (conducting a survey).

Agnieszka Napiórkowska-Baryła – 10% (development of study results).

Literature

Babbie, E., 2001. The practice of social research. Wadsworth/Thomson Learning, 139-172.

Błędzki, A., Fabrycy, E., 1992. Polimery degradowalne – stan techniki (Degradable polymers – state of the art). Polimery, 37, 343-350.

Borychowski, M., Staniszewski, J., Zagierski, B., 2016. Problems of the measuring of the sustainable development on the examples of selected indicators. Roczniki

Ekonomiczne Kujawsko-Pomorskiej Szkoły Wyższej w Bydgoszczy, 9, 28-43, http://kpsw.edu.pl/nauka-i-rozwoj/roczniki-ekonomiczne-kpsw.

Chyłek, E., Rzepecka, M., 2011. Biogospodarka – konkurencyjność i zrównoważone wykorzystanie zasobów (Bioeconomy – competitiveness and sustainable use of resources). Polish Journal of Agronomy, 7, 3-13.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Innovations for sustainable growth: bioeconomy for Europe, https://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX:52012DC0060&from=EN [02-09-2019].

CRIBIS.pl [17-04-2019].

Czernyszewicz, E., 2016. Uwarunkowania i perspektywy rozwoju biogospodarki w Unii Europejskiej. Zeszyty Naukowe SGGW w Warszawie – Problemy Rolnictwa Światowego, 16(31) (3), 49-56.

Dobrucka, R., 2019. *Bioplastic packaging materials in circular economy*. LogForum, 15(1), 129-137.

Encyklopedia zarządzania, https://mfiles.pl/pl/index.php/Efekt_skali [08-07-2019].

European Bioplastics, http://www.european-bioplastics.org [17-04-2019].

Geyer, R. et al., 2017. Production, use, and fate of all plastics ever made. Science Advances, 3(7), doi: 10.1126/sciadv.1700782.

Gołaszewski, J., 2013. Odnawialne źródła energii w biogospodarce. Odnawialne źródła energii obecnie i w nowej perspektywie po 2013 roku (Renewable energy sources in the bioeconomy. Renewable energy sources now and in the new perspective after 2013), Płońsk, http://mazowieckie.ksow.pl › MODR ›konferencja_oze_listopad › modr_oze.

https://dictionary.cambridge.org/pl/dictionary/english [17-04-2019].

Komunikat Komisji do Parlamentu Europejskiego, Rady, Europejskiego Komitetu Ekonomiczno-Społecznego i Komitetu Regionów. Innowacje w służbie zrównoważonego wzrostu: biogospodarka dla Europy (Communication from the commission to the European Parliament, the council, the european economic and social committee and the committee of the regions Innovating for Sustainable Growth: A Bioeconomy for Europe), https://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX:52012DC0060&from=EN [02-09-2019].

Lebreton, L. et al., 2017. River plastic emissions to the world's oceans. Nature Communications, 15611, doi: 10.1038/ncomms15611.

Malinowski, R., 2015. Biotworzywa jako nowe materiały przyjazne środowisku naturalnemu Bioplastics as a new environmentally friendly materials). Inżynieria i Ochrona Środowiska, 18(2), https://docplayer.pl/13640312-Biotworzywa-jako-nowe-materialy-przyjazne-srodowisku-naturalnemu.html.

OECD, 2009. The bioeconomy to 2030: Designing a Policy Agenda.

Penczek, S., Pretula, J., Lewiński, P., 2013. Polimery z odnawialnych surowców, polimery biodegradowalne (Polymers from renewable resources. Biodegradable polymers). Polimery, 58.

Piontek, W., 2019. The circular plastics economy and the instruments to implement it. Ekonomia i Środowisko, 3, 18-33, doi: 10.34659/2019/3/32.

Fundacja PlasticsEurope Polska, Raport roczny 2017, https://www.plasticseurope.org/pl/resources/publications/540-raport-roczny-plasticseurope-polska-2017 [08-07-2019].

Sahely, H., Kennedy, C., Adams, B., 2005. Developing sustainability criteria for urban infrastructure systems. Canadian J Civil Eng, 32(1),72-85, doi: 10.1139/l04-072.

Sax, L., 2009. Polyethylene Terephthalate May Yield Endocrine Disruptors. Environmental Health Perspectives, 118(4), 445-448, doi: 10.1289/ehp.0901253.

Shen, L., Haufe, J., Patel, M.K., 2009. Product overview and market projection of emergingbio-basedplastics. Raport.

Słownik Języka Polskiego.

Stahel, W.R., 2016. The circular economy. Nature News, 531(7595), 435-438, doi: 10.1038/531435a.

Standard Europejski EN 16575:2014, Bioprodukty-Słownik.

Stanisławski, R., 2015. Skłonność do innowacji wśród małych i średnich przedsiębiorstw (A propensity for innovation among small and medium-sized enterprises). Zeszyty Naukowe Politechniki Łódzkiej, 1196, Organizacja i Zarządzanie, 59, 119-132.

The new European Interoperability Framework (EIF) for IT is part of the Communication (COM(2017)134) from the European Commission adopted on 23 Marc.

Trznadel, M., 1995. Biorozkładalne materiały polimerowe (Bio-degradable polymeric materials). Polimery, 15.

Twardowski, T., Woźniak, E., 2016. Bioekonomia wokół nas. Nauka, 3, 147-160.