

Food Waste in the Organic Recycling System and Sustainable Development

Odpady żywności w systemie recyklingu organicznego a zrównoważony rozwój

Joanna Kostecka, Mariola Garczyńska, Grzegorz Pączka

*Department of Biological Basis of Agriculture and Environmental Education, Faculty of
Biology and Agriculture, University of Rzeszów, M. Ćwiklińskiej 1A, 25-601 Rzeszów, Poland
E-mail: jkosteck@ur.edu.pl*

Abstract

According to the FAO report, nearly one-third of products manufactured for food purposes is wasted every year (1.3 billion tons per year) in the world. That is of great importance for all the aspects of sustainable development: natural, social and economic. More educational actions should be introduced in order to avoid and minimize the household organic waste. When it cannot be avoided, those who produced it – average consumers, but at the same time very important elements of the sustainable system of waste management, shall recognize food leftovers as a raw material for organic recycling. They should be composted, that results from a constant need of nutrient supplementation in soils of Europe.

The aim of this study was to bring attention to the importance of activities concerning the organic waste segregation by each citizen. In the study, three possible methods of management were proposed (co-creation of food sharing, conducting earthworm ecological boxes and simply segregation of kitchen organic waste according to the currently effective law), every one of which becomes a part of building strategically explained waste management organization.

Key words: waste management, food waste, segregation, food sharing, earthworm ecological box

Streszczenie

Na świecie, zgodnie z raportem FAO, mniej więcej jedna trzecia produktów wytwarzanych w celach spożywczych marnuje się co roku (1,3 miliarda ton żywności rocznie). Ma to ogromne znaczenie dla wszystkich aspektów zrównoważonego rozwoju (przyrodniczych, społecznych i ekonomicznych). Należy wprowadzać więcej działań edukacyjnych na rzecz unikania i minimalizacji domowych odpadów organicznych. Gdy nie uda się ich uniknąć – ich wytwórcy – przeciętni konsumenci, ale niezwykle ważni jako elementy ogniwa zrównoważonego systemu gospodarki odpadami, powinni rozpoznawać resztki żywności jako surowiec dla recyklingu organicznego. Należy je kompostować, co wynika ze stałej potrzeby uzupełniania składników pokarmowych w glebach Polski i Europy.

Celem pracy było zwrócenie uwagi na istotność działań z zakresu segregacji odpadów organicznych przez każdego obywatela. W opracowaniu zaproponowano rozważenie 3 możliwości postępowania (współtworzenie jadłodzielni, prowadzenie dżdżownicowej skrzynki ekologicznej i segregowanie organicznych odpadów kuchennych zgodnie z obowiązującym obecnie prawem), z których każda wpisuje się w budowanie strategicznie uzasadnionej organizacji gospodarki odpadami.

Słowa kluczowe: gospodarka odpadami, odpady żywności, segregacja, jadłodzielnia, dżdżownicowa skrzynka ekologiczna

Introduction

In the XXI century, in the anthropocene epoch, Earth's technosphere weighs over 30 billion tons. It is a mass larger than 50 kilograms per each square metre of our planet's surface and the number of human products (*technofossils* that will remain on Earth for a long time after us and will be a proof of our civilization) is higher than the number of species on Earth (Zalasiewicz et al., 2016; Zalasiewicz, Williams, 2017). The presence of technorubbish disturbs the functioning of ecosystems and ecosystem services (Mazgajski, Stępniewska, 2012).

Among the main megatrends (demographic, globalization, scientific progress, new industrial and technical revolution, disappearing of nation states), also a megatrend of ecological threats is demonstrated. Environment, including the soil one, is exposed to many anthropogenic degradation factors. Apart from a directly negative improper agricultural economy, indirectly the soil quality is influenced by pollution associated with the development of industry, urbanization, transport or improperly conducted management of waste – including the organic one.

Improperly abandoned and accumulated organic waste poses a danger of, for example, eutrophication of surface and underground waters and is also dangerous for biological diversity (Krempa et al., 2018). On the other hand, lack of organic matter in soil is one of the most important reasons of its degradation (Framework Directive on Soil Protection, 2008). Thus, treating organic waste as a valuable raw material for processing into fertilizers supplementing humus content in soil, is a crucial point in the development of ecological culture in the society, and this culture is an important, but equal to the economic and social, element of building sustainable development, which nowadays is evolving in the direction of permanent and responsible development both in terms of nomenclature and understanding.

According to the report of the Food and Agriculture Organization (FAO) of the United Nations, approximately one-third (1.3 billion tons per year) of food production is thrown into bins (Food Loss and Food Waste ...). Food production burdens ecosystems and is important for all the aspects (natural, social and economic) of sustainable development.

This paper brings attention to the importance of activities in the scope of economical food management and segregation of organic waste done by every citizen. In this study, three possible ways of management are proposed for consideration, every one of which becomes a part of building strategically explained organization of waste management in a different way.

Study method

When investigating the issues of the subject, the selected items of literature were considered. Elements

of the SWOT analysis were applied and strengths and weaknesses associated with taking actions by the citizens to prevent food waste, such as: co-creation of foodsharing facilities, conducting earthworm ecological boxes and simply home segregation of kitchen organic waste according to the currently effective law, were taken into account.

Organic waste in the structure of municipal waste in Europe

The overriding objective of the European Union in terms of waste management for the nearest years, written in the union's guidance documents (programs and strategies), is to separate the rate of increase in the amount of produced waste from the pace of economic growth. Requirements and targets leading to the implementation of the main provisions were described in the following UE documents:

- *Directive of the European Parliament and of the Council 2008/98/EC of 19 November on waste* (the so-called framework directive/waste directive),
- *Directive of the Council 1999/31/EC of 26 April 1999 on the landfill of waste* (the so-called Landfill directive),
- *Directive of the European Parliament and of the Council 94/62/EC of 20 December 1994 on packaging and packaging waste* (the so-called Packaging directive).

In 2009, a statistical inhabitant of the EU-11 countries produced on average less waste (370 kg) than a statistical inhabitant of the entire EU-27 (512 kg). Among the EU-11 countries, the largest amount of waste was produced by an inhabitant of Bulgaria (470 kg/year), whereas the least amount was produced by an inhabitant of Poland and the Czech Republic (approximately 316 kg/year each). In 2014, an inhabitant of Romania and Poland still produced the least waste (comparably to an inhabitant of Romania) (table 1).

In 2009, in all the EU-11 countries about 42 million tons of waste were produced, but it constituted only 16% of all the waste produced in the EU-27. In 2014, the situation slightly changed (Municipal waste statistics ...).

Additionally, despite the noticeable improvement of the situation, illegal rubbish dumps are still reported. Among the municipal waste, both in illegal rubbish dumps and in landfills, numerous resources are wasted, including organic waste resources (table 2). According to the EU policy, Member States should ensure waste management in line with the principles of sustainable development, which means the introduction of a waste management hierarchy as defined in the EU *Framework Directive* (Directive 2008/98), which includes:

prevention – therefore, in civic education should be promoted such management and measures whose implementation will stop the transformation of substances, materials or products into waste, and

Table 1. Waste produced in the EU-11 and the EU-27 in 2009 and 2014 [kg/inhabitant], *source*: based on the data of *Municipal waste statistics... 2010,2015, 2016*

Bulgaria	Greece	Slovenia	Hungary	Romania	Lithuania	Estonia	Latvia	Slovakia	Czech Republic	Poland	UE-11	UE-27
reference to 2009												
470	457	448	430	396	361	346	334	322	316	316	370	512
reference to 2013* and 2014												
442	506*	432	385	272*	433	357	325	321	312	283		474

Table 2. The amount of biodegradable municipal waste directed to landfills in 2010 in the EU-11 [millions of tons]

32*	17.7*	14.2	3.5
landfilled municipal waste	landfilled biodegradable municipal waste	EU target for 2010	excess of landfilled biodegradable waste

*Estimated based on the data from 2009

which will reduce the amount of waste and its negative impact on the environment and human health;

preparation for reuse / waste minimization – consists in, for example, cleaning or repair, thanks to which products or components of products that have previously become waste can be re-used without any other pre-processing actions;

recycling – it is a recovery process in which waste materials are reprocessed into products, materials or substances used for the original purpose or for other purposes (it does not include energy recovery, which causes the final disappearance of the resource);

other recovery methods – these are the processes other than preparation for re-use and recycling, whose main result is that the waste serves a useful purpose by replacing other materials that would otherwise be used to perform a given function;

disposal – including non-recovery processes, even if the secondary effect of such a process is the recovery of a substance or energy. Waste disposal consists in subjecting it to the processes of biological, physical or chemical transformation in order to bring it to the state that does not pose any danger to human life or health as well as to the environment. This should be done when waste formation could not be prevented and it was impossible to subject it to recovery.

Figure 1 presents how these principles can be applied in case of food leftovers that are organic waste.

As it was mentioned before, the organic part of municipal waste is a valuable raw material to be processed into fertilizers. This is important because soils used for agriculture in the world lose the organic matter content that negatively affects their fertility. That causes a decision of its urgent supplementation. The EU *Strategy for Soil Protection* (IP/06/1241 of 22 September 2006) contains, among others, the conclusion that the use of the Earth in areas where organic matter content in soil is lower than 2% must necessarily be combined with activities aiming to stabilize the soil or, even indispensably, gradually increase the content of organic substances in it. In

Europe, even in case of optimal organic waste management in all the EU countries and using the full potential of biowaste, the content of humus in these areas can be increased by only 1-2% (Gościński, 2007). In such a situation, not only due to a threat of EU penalties, organic municipal waste must be very carefully managed as a potential source of a good quality fertilizer.

Careful management with this type of waste is also forced by a concept of *circular economy*. This economy is supposed to be a resignation from the existing *take – use – discard* linear model in favour of a circular model. Most of the waste should be recycled, because storing it has been recognized for a long time as very burdensome for the environment, and additionally, waste removal from ecosystems disturbs their stability. Therefore, regulations concerning the methods of waste collection in households, enterprises and other places where it is generated will be very important. Recycling specialists point out that if waste recycling is to be effective, it must take place only in special installations dedicated to recycling and be based on participation of every citizen in the system. Once again, the foremost issue is a problem of effective and urgent education in the discussed area (Kostecka et al., 2016).

Kitchen organic waste include not only fruit or vegetable peelings, coffee or tea grounds. It also consists of light-heartedly treated leftovers of cooked food whose production leaves an important carbon and water footprint. Therefore, it is necessary to return to the habit of not allowing people to throw them away, that used to be common until recently. If shopping is strategically appropriate and thoroughly done, and the content of the refrigerator is checked, such behaviour is simple and easy. In addition, when it is not possible to effectively plan the rational use of purchased or produced food, there is still another action – sending excess food to a foodsharing facility, that is increasingly popular in many European and world countries (Nadolski, 2014; Food sharing ...).

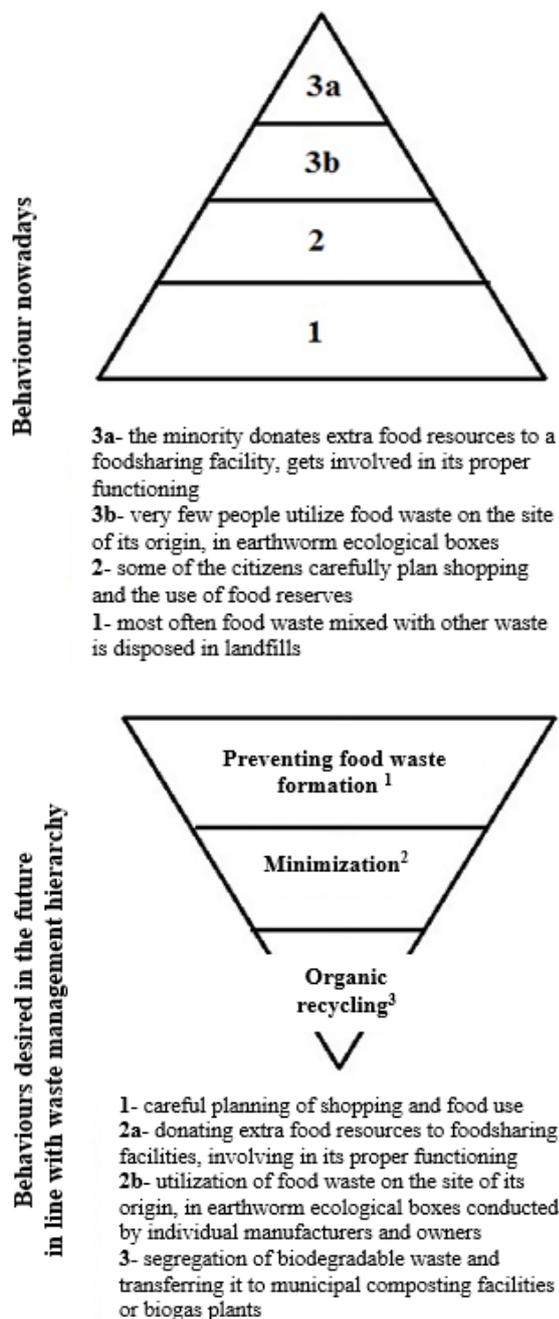


Figure 1. Present and future participation of citizens in the subsystem of household biodegradable waste management, source: authors' own study

Segregation of biodegradable waste is now a civic obligation but disposal of carefully segregated organic residues can also be carried out on the site of their origin, using the biotechnology of earthworm ecological boxes. It can take place in home gardens, basements and even on the balconies of flats or in the kitchens. Such handy earthworm ecological boxes are known in some countries of Western Europe and also in the United States and Canada (Appelhof, 1982; Hogan, 1997; Selden et al., 2005; Kostecka et al., 2011; Pishaheb et al., 2013). Functioning of earthworm ecological boxes has been tested in Polish conditions for many years. The possibilities of using

them on different levels of education for sustainable development and waste management were also considered (Kostecka et al., 2018).

According to the ERNST & YOUNG company report (Gabrys et al., 2011), in 2010 none of the EU-11 countries, except Romania, did not achieve the EU goal concerning the reduction of biodegradable municipal waste directed to landfills, and in the whole EU-11 the acceptable level of landfill designated for 2010 was exceeded by approximately 3.5 million tons (25% of the upper limit determined by the EU – 14.2 million tons). Deliberations contained in the present publication may help escape heavy fines for not fulfilling the obligations (an economic element of sustainable development). As it was demonstrated below, the proper behaviour of the citizens (a choice between 3 possibilities of participating in managing food leftovers) will also contribute to implementation of sustainable development on economic and social level. Table 3 presents the selected elements of influence of these actions on building sustainable social organization.

In case of failure of educators promoting the economic management of food and segregation of organic waste by every citizen, the potential benefits of efficient reduction of the negative impact of organic waste on the socio-economic life of humans in contact with ecosystems will be threatened (table 4).

Education for waste reduction

Obviously, education for sustainable development includes also education on waste management and shall consider it as one of the basic elements creating socioeconomic harmony in nature. Important issues raised by educators should include building respect for limited nature's ability to regenerate that is threatened e.g. by improper waste management. Formation of a group of more responsible beliefs may include indicating the conviction of the sense and urgency to match the needs of local communities to the endogenous resources that are at their disposal. The rational and slow use of resources is associated with avoiding and minimizing waste, that in turn may help implement the principles of retardation of resource transformation by waste (Kostecka, Koc-Jurczyk 2010; Kostecka, 2013; 2017).

An issue of waste management education must apply to all the stages of education. If we want to protect the environment from waste, protect its resources, understand its mechanisms, it is necessary to create new models of teaching scientific subjects that include a holistic approach of understanding the environment of human life. Lack of a holistic system of teaching the environmental phenomena is the main cause of a lack of understanding the principle cause-and-effect phenomena occurring in the natural environment. Selby (2017) regrets that earlier such words as: ash, beech, bluebell, buttercup, cowslip, dandelion, mistletoe, willow used to be important in

Table 3. Identification of the role of co-creation of foodsharing facilities, conducting earthworm ecological boxes and segregation of kitchen waste by citizens in building sustainable development divided into natural, social and economic plane

Participation in the action	Strengths for building sustainable development on the following planes		
	natural	social	economic
Segregation of biodegradable kitchen waste to a brown container ¹	relieving ecosystems of threats; possibility of supplementing the level of humus in the soil, improving fertility, improving the conditions of functioning of trophic chains and the life of soil inhabitants	participation in the organization of the waste management system, in accordance with legal requirements, favours order and neatness; landscape components are improving	delaying the threat of high fines for failing to meet the EU commitments; improvement of ecosystem services of soil, that also has a measurable financial value
Co-organization or delivery of food leftovers to foodsharing facilities ²	reduction of the ecological footprint; more effective management of natural resources, slowing down the transformation of ecosystems, the chance for their regeneration	better use of already produced food, whose ecological print burdens the planet, also important for people needing help	lower losses of financial resources at present, and benefits, also financial, from the recovered ecosystem services in the future
Segregation of biodegradable kitchen waste and conducting an earthworm ecological box ³	segregation of organic waste and neutralizing it at the site of its origin, reduction of the ecosystem burden	participation in the socially explained pro-environmental action	savings in the transport of waste and other elements of the waste management system, including disposal and storage
all forms of activity relieve ecosystems, limit financial investments and have a positive impact on rebuilding or conservation of ecosystem services, which is of strategic ecological, social and economic importance			

¹ since July 2017 compulsorily in accordance with the Regulation on the detailed manner of selective of 29 December 2016

² the action fits the European idea of foodsharing that has been present for a long time in the UK, Germany, Austria, Canada and is becoming more popular also in Poland (Food sharing ...).

³ earthworm ecological box is a small-scale pro-environmental vermiculture conducted in home conditions: in the kitchen, on the balcony, in the basement or in the garden and in the allotment

Table 4. Identification of weaknesses for 3 proposals of participation in food leftovers management, divided into planes important for building sustainable development

Participation in the action	Threats on the plane		
	natural	social	economic
Segregation of biodegradable kitchen waste to a brown container	the threat of not using the opportunity to easily relieve the environment from the pressure of poorly located organic waste	with poor organization, the energy and enthusiasm of citizens may be wasted	there is a risk of failure, if economic profits are placed over not entirely measurable social and ecological profits and long-term development strategy
Co-organization or delivery of food leftovers to foodsharing facilities	in the absence of promotion and low acceptance of participation, if there are not any similar proposals for the management of unusable food, waste is produced and there is a risk of wasting food and presence of a still growing ecological footprint during its production, a threat to other ecosystems and their services	the problem of further food waste still exists; people in need of help are not taken into consideration	there are known consequences of dishonest actions of some people, companies and pseudofoundations damaging social trust, that also translates into financial losses
Segregation of biodegradable kitchen waste and conducting an earthworm ecological box	In case of poor organization, the threat of wasting the possibility of using small-scale vermicomposting, which could also be one of the stimuli for rebuilding the relationship with nature and earthworms – <i>the youngest domesticated animals in the world</i>	lack of support for this unconventional method of action, not taking it into account in the activities of pro-environmental educators	insufficient promotion of the phenomenon, lack of access to information and exchange of experiences concerning vermicomposting products may be a reason for not taking up or abandoning breeding, that will waste the chance of reduction of recycling costs
all types of action relieve ecosystems, therefore not presenting them with paying attention to a possibility of choosing in accordance with possibilities and willingness of each citizen or each family individually, poses a threat			

Table 5. The degree of transposition of the EU regulations to the national legislation in Poland, *source: Elaboration by Ernst & Young (Gabryś i in. 2011) revised*

1. A hierarchy of waste management	met
2. Definitions of recovery, recycling, reuse, disposal	partially met
3. A requirement for the development of waste management plans,	met
4. A requirement for the development of waste prevention programs,	not met
5. A requirement for the organization of a selective collection system,	met
6. Goals for recycling and recovery of secondary raw materials and construction waste,	met
7. Goals for recycling and recovery of packaging waste,	met
8. Other regulations regarding packaging waste management (e.g. labelling),	met
9. A reduction of the amount of landfilled biodegradable municipal waste,	met
10. Provisions regulating operation of landfills.	met
Estimated degree of transposition	85%

All the criteria were assigned the same weight. The fulfilment of each criterion was evaluated as follows: *included in the national legislation*, not included in the national legislation.

young person's life. Nowadays, a young man withdrew a long list of words describing nature. These words are not considered significant for contemporary childhood – they are replaced with the words of hidden and virtual worlds (e.g. blog, broadband network, copy and paste) as well as voicemail. That has the effect on breaking emotional bonds with nature and improper development of resource management. Nowadays, the proper functioning of human civilization involves not only taking and processing resources from environment, that usually means consumption, but also the actions leading to minimize the enormous amount of waste.

Among other urgent tasks, it is needed to develop and introduce more educational programs on avoidance and minimization of household organic waste. When it cannot be avoided, those who produced it – average consumers, but at the same time very important elements of the sustainable system of waste management, shall recognize food leftovers as a valuable raw material for organic recycling. The leftovers should be also selected from a stream of household waste, because they will constitute a good quality raw material for the production of fertilizers. A need of constant fertilizer production results from the need of nutrient supplementation in soils of Europe.

The degree of transposition of the EU regulations in the field of waste management to the national legislation of the individual EU-11 countries was assessed by Ernst & Young (Gabryś at al., 2011) on the basis of transferring the elements of the EU directives to the national provisions. In terms of the implementation of the EU legislation, the EU-11 countries can be divided into three groups:

- a) full implementation – Lithuania, Latvia and Romania,
- b) partial implementation (non-implementation of the *Directive 2008/98/EC on waste*) – Czech Republic, Poland (table 5), Estonia, Slovakia, Slovenia and Hungary,
- c) implementation of the selected requirements only – Bulgaria and Greece.

In terms of reducing the amount of municipal waste sent to landfills, the group of 27 Member States of

the European Union is headed by Germany, Austria, the Netherlands and Sweden. According to the Eurostat data (Municipal waste statistics...), already in 2009 less than 2% of the collected municipal waste was deposited in landfills in these countries.

The waste management system operating, for example, in Sweden is based on the principle of minimizing the amount of waste going to landfills and maximizing the recovery of raw materials and energy from waste. Local governments there have a duty to organize collection and transport of all municipal waste, as well as its processing and disposal. They are also responsible for the part of municipal waste that is not subject to manufacturer's liability (such as, for example, packaging waste).

Collection and transport of waste in Sweden is handled by companies belonging to local governments and by private enterprises with which municipalities have signed contracts. Services related to the further waste management are usually carried out by enterprises owned by municipalities. A small part of installations belonging to private entities is strongly controlled by local government authorities.

Education gives results if it is long-term and multi-dimensional. For example, in German schools issues concerning environmental protection have already appeared in the 1950s between the subjects (introduction of information in this field concerned several selected subjects). In 1980, at the conference of ministers of education of the individual lands, a need for greater involvement of schools in raising the ecological awareness of children and young people was confirmed. It was pointed out that ecological education should be more comprehensive and that students should know the relationships between social problems, environmental protection and economics (Pawul, Sobczyk, 2011). The federal Minister of Education and Research as well as universities and research institutes played a large role in formal education. In informal education, a leading role has been and still is played by Internet.

The implementation of a *circular economy* concept package can be a chance for consecutive stages of introducing new and more effective ways of saving resources to human behaviours. It is an important el-

ement of sustainable development and should also involve thoughtful and effective education, convincing the society to a necessity of urgent departure from the linear model *take – consume – uncritically discard* in favour of the circular model. This requires careful treatment by all members of the society. Most of the waste (when it cannot be avoided and minimized) should be recycled, because its storage is, firstly, burdensome for the environment and secondly, re-use of waste protects the remaining 40% of the ecosystems of our planet that have not been changed by humans yet (*Millenium Ecosystem Assesment...*).

When recycling organic waste, we limit the number of *five-star hotels* for unwanted vertebrate and invertebrate animals that find comfortable hiding places and unrestricted access to food in landfills throughout the year. Biomass selected from household waste can also be very easily processed into fertilizers at the place of its origin. In the recycling of household organic waste, the most effective is processing it at the place of its formation. Thus, a particular role is played by small-scale vermicomposting in earthworm ecological boxes (Kostecka 2000).

The term *vermiculture* is known among ecologists, biologists and farmers in many countries: in the USA and Canada, in German-speaking countries and English-speaking countries as well as in the Czech Republic, Slovakia, China, Sweden, India or Spain (Dominguez, 2004; Dominguez, Edwards, 2004; Garg, Gupta, 2009; Edwards et al., 2011; Manaig, 2016; Kostecka, 2015; Kostecka et al., 2011; 2018). It consists in using dense earthworm populations for accelerating the decay of different types of organic matter. It enables to derive a name that explicitly describes the product of earthworms' work as a vermicompost (natural fertilizer). Another product of vermiculture is a valuable earthworm biomass, and currently the actions and research on vermiculture that are conducted in the world have two main objectives:

- transformation of various types of organic waste (animal and vegetable) into useful fertilizers – vermicomposts, which can be introduced into soils to improve their structure and fertility, or have horticultural use as a substrate for plant growth or an ingredient of fertilizer blends,
- production of a protein-rich biomass of earthworm musculocutaneous sacs, with a possibility of treating it as a feed additive in fish, poultry, and pig farming as well as a cost-free feed for animals in the zoo or aquarium fish.

Conclusions

In addition to shaping the competencies of proper participation of entrepreneurs and private investors in the waste management system, the competence and standards of conduct of every citizen – an individual consumer, are equally important in building

sustainable development. Therefore, it is necessary to undertake further and effective educational activities aiming to change the previous behaviour of residents in the sphere of consumption and waste management, including food leftovers.

Information about the necessity to limit consumption, possibilities and ways of management of food leftovers, and subsequently food waste, in a responsible way should be introduced not only into traditional forms of formal education integrating various fields of knowledge both in lower-education schools and colleges and universities; the activities of informal education initiating the effective actions that encourage the society to useful and socially important activities are also vital.

Reducing the mass of the generated waste and its selective collection must also apply to organic waste, especially to food leftovers. As soon as possible, every citizen should be informed and convinced about the benefits of e.g. *foodsharing* and the obligation to segregate the organic waste as well as about ecological, social and economic threats resulting from non-compliance with obligations and legal regulations in this area.

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