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METHODOLOGICAL BARRIERS OF MONITORING AND RESEARCH OF FOOD LOSSES AND WASTE (FLW)

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Abstract: The subject of the paper is to perform a review and analysis of the methods and approaches to the problem of quantitative determination of the level of generating the food losses and waste in the food chain in the context of the application of quantitative methods for measurement of food waste generation. In the article, there have been reported the key needs, conditions and problems connected with the quantitative measurement of the food waste and the results of the key studies in this respect, including the definition problems and the results of big research projects, undertaken on a global level by FAO and on the level of the EU. The methods of quantitative determination and assessment of the food waste, including the life cycle analysis (LCA) have been presented. The application of the mentioned method allows satisfying the aims connected with the monitoring of a flow of the resources throughout the whole agri-food chain for the needs of creating a circular economy.

Keywords: food losses and waste, food waste, quantitative methods, food chain, life cycle analysis (LCA)

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INTRODUCTION

Food losses and waste (FLW), being also defined as food waste constitute a current, serious global problem and apart from a threat to the food safety of the world, they mean also wasting of the resources such as water [Duchin 2005], energy [Cuellar, Webber 2010] and other resources of natural environment and potential raw materials to be utilised in food economy in the future [Krajewski et al. 2016]. Generation of considerable quantities of the food waste is a symptom of a society being based upon the non-sustainable consumption which gradually with the increase in consumption and production generates higher and higher level of waste.

The assessment of the size of food losses and waste on the national level as well as in the particular branches and in the whole food sector has not been – until now – the subject of the complex studies in Poland, similarly as it refers to evaluation of the consequences of the phenomena relating to food waste. The mentioned problems cover a wide research area, being not undertaken until now due to a lack of available and reliable information, lack of appropriate documentation and source data. It restricts a scope of the studies and requires firstly, development of the method for quantification of the arising food waste on the macro level. Then, in the successive stage of the studies, the developed method may be verified and applied in relation to the national waste data in order to create the first analysis of quantitative definition of the food waste level in Poland.

The real scale and the level of the currently produced food waste are not known to the institutions of the state administration and to the societies, including also Poland. Apart from a lack of the verified methodology, the barrier comes from the fact that the entities which produce and utilize the discussed waste have not perceived until now the need of collecting the information where the waste were generated, where they were coming from and how they were processed [Beretta et al. 2013]. Only since the moment of appearance and application of life cycle analysis (LCA) method and material flow analysis (MFA), the mentioned data have become available what allowed mapping the streams of waste and monitoring of the mentioned phenomena in perspective of food products and chains [Corrado et al. 2017]. In such situation, the assessment of losses caused by food waste and of the potential resources when recovering the products became possible; the background for management of the discussed processes has been created. The process of food losses and waste management in the food chains should be treated as development of the process of food management, raising the level of effectiveness of managing the resources of food, water and energy [Krajewski et al. 2018] in food sector and in relation to the principles of a circular economy.

According to the scale and necessary accuracy in assessment of the level of food losses and waste, there are two main schools of thinking in respect of the methods for estimating and forecasting data on food wastes [Beigl, Lebersorger,

Salhofer 2008]. The first, bottom-up micro-approach assumes determination of indicator of waste generation (per capita, per plant, for particular products, for household, geographical area, etc.) which is then extended to the economy as a whole [Karadimas, Loumos 2000]. The exact estimation of the quantity of waste in micro-approach has many weak points due to difficulties in estimating of waste flows in the food chains and due to a huge amount of the data required to development of the estimate for each industrial branch. The second approach is a macro approach [Joosten et al. 1998] where is it assumed that the generated waste are proportional to manufacture in each sector and are analysed as a part of significant material flows in the economy.

THE AIM AND RANGE OF THE WORK

The studies on the food losses and waste, not only under the conditions of Polish food sector, meets important barriers of the lack of coherent definitions of the analysed phenomena, lack of adequate research methodologies and lack of data availability in economic documentation of the enterprises and institutions and in national statistics. It makes the processes of the studies and comparative analyses in the world scale difficult, limits the possibilities of monitoring the discussed phenomena for economic and administrative needs, running the national statistics and management of the processes.

Therefore, the aim of the considerations, as discussed in the present paper, will include the definition of the mentioned restrictions and evaluation of the research methodologies for estimating the food losses and waste, with a special reference to the possibilities of gaining and availability of the indispensable information. In the first stage of the work, it will be necessary to perform, therefore, the comparative analysis of the definition of key terms connected with the problems of food losses and waste in the context of the process of estimating the level of the discussed phenomena. Also, the comparative evaluation of the intentionally chosen research methodologies in relation to gaining information, modelling and quantification of the phenomena will be carried out. The obtained information will become a basis for conducting further studies within the frames of the research project, with acronym PROM, as implemented by the team within the frames of the competition NCBR "Gospostrateg"[1].

[1] The project entitled „Development of the System of Monitoring the Wasted Food and of the Effective Programme of Rationalization of Food Losses and Limitation of Food Waste". Acronym PROM. Gospostrateg No 1 1/385753/1/NCMR/2018 dated 10.10.2018.

PROBLEMS OF DETERMINATION OF FOOD LOSSES AND WASTE IN FOOD CHAIN

The review of definitions of food losses and waste and of food waste for the needs of developing the methodology of the studies

The significant methodological problems, connected with the measurement of the level of food losses and waste in the food chain include a lack of clear and coherent definitions of basic categories of the subjects relating to the discussed problems, and, especially the subjects of food wastage and food waste [Bilska, Kołożyn-Krajewska 2016] and lack of common and harmonized methodology of quantitative measurement of generated losses and food waste. The report of the European Commission (EC) includes here also the delineation of the borders of the particular elements of the supply chain (food chain) and determination of the sources of data gaining [Caldeira, Corrado, Sala 2017]. The adequate methodology of the measurement requires, according to the European Commission, the following formulations:

- Appropriate definitions and terminologies, in particular of such categories as: edible/inedible parts of food; avoidable/unavoidable food waste [2];
- Borders of the particular stages and links of the supply chain of raw materials and agri-food products;
- Measurement units, so as the existing data between the regions, countries and types of the products could be comparable.

Until now, any legal definition of food losses and food waste has been adopted, neither in the EU food legislation, nor in the law concerning the waste[3]. The first work being conducted with the aim to make a complex examination of the mentioned problem in the EU included the preparatory study concerning food waste in EU 27 countries[4]. As a result of it, food waste were defined as a part of bio-waste, consisting of raw or processed food substances, including food products, being discarded at any time across the chain between agricultural farm and consumption, especially produced in the households before, during or after preparation of meals. The food waste may be classified into edible and inedible ones.

We should mention here a wide study on the European level, i.e. the Report of the European Project FUSIONS where a similar approach was adopted, with the definition of food waste as substances removed from the food chain. According to

[2] The studies of the food losses and waste with the application of categories „avoidable" and "unavoidable", especially during the final stages of the supply chain, are conducted especially in Great Britain within the frames of the Initiative WRAP (2013). Household Food and Drink Waste in the United Kingdom, WRAP.

[3] Ibid., p.12.

[4] Preparatory study on food waste across EU 27 (2013) European Commission, BIOIS.

the mentioned approach, food waste is referred to as "any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)"[5]. The reference definition on a global level has been generated as a result of the studies ordered by FAO; the mentioned studies consider all flows of substances which may be food, irrespectively of their destination but they treat food waste only as the edible parts of food, destined for human consumption which became losses or waste[6].

In the Report of FUSIONS Project, dedicated to definitional framework for food waste, a comprehensive review of literature and definition of the terms connected with the problems of food losses and food waste for each stage of the food chain was carried out[7]. From the above mentioned review it is followed that the key terms may be differently defined in the particular stages of the chain and by its different participants and stakeholders (producers, processors, distributors, gross and retail trade, gastronomic units, households) and according to a given sector and branch. It is a significant factor of incoherence and methodological risk in the studies on losses, wastage and food wastes which should be appropriately estimated and managed. The results of the FUSIONS Project confirmed also a problem with the availability and quality of the data[8].

In the English-language literature, there is conventionally employed term "Food loss and waste" – FLW, covering food losses and waste in total. In Polish language convention, there is adopted application of formula "food losses and wastage". The univocal settlement of mutual overlapping of the semantic group of terms "losses" and "waste' and "wastage", including their context scope, exceeds the frames of the present paper. It is, however, postulated that – following the definitions, adopted on the EU and global level – the wastage should be relating to generation of the waste and should be monitored via measurement of their amounts, i.e. the substances excluded from the food chain.

In the EU level, the food waste means all food, as defined in art. 2 of the Regulation (CE) 178/2002, that became the waste in accordance with art. 3 par.1 of the Waste Framework Directive[9]. It means that the food waste do not include either substances excluded from food definition (e.g. plants before harvesting, live

[5] Food waste quantification manual to monitor food waste amounts and progression (2016), FUSIONS.

[6] Global Food Losses and Food Waste: Extent, Causes and Prevention (2011), FAO.

[7] FUSIONS Definitional Framework for Food waste Full Report, 2014, Annex C. Pp. 78-100.

[8] Due to this reason, the data for the particular Member States were not published but only an estimate for the whole EU27 for each stage of food supply chain was given.

[9] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste.

animals if they are not prepared to introducing to turnover for human consumption), or substances excluded from waste definition (e.g. agricultural material used in agricultural farm, or by-products, employed in further industrial processes).

The data collected on the grounds of the Regulation (CE) 2150/2002 on waste statistics do not allow precise identification of food wastage within the scope of the generally collected data concerning production of waste. Similarly, the list of the waste as mentioned in art.7 of the Directive, and established in Annex to the Commission Decision 2000/532/EC9, does not allow, in many cases, the univocal identification of food losses. The measurement of food waste should however concern the material recognised as waste in accordance with the Directive. In connection with this fact, neither material excluded from the scope of the Directive, i.e. agricultural material as covered with art. 2.1 f) of the Directive, nor food destined for animal feed (as covered with art.2 par.2. e of the Directive), nor by-products of animal origin (as specified in art.2 par.2 b) should be monitored. Similarly, by-products coming from food production (as mentioned in art.5 of the Directive) should be not considered as food waste. The mentioned limitations should be, however, also estimated.

In the European Union countries, the temporary limits of the waste flows for the need of their measurement are designated by one-year period (since 1st January until 31st December) and the spatial limits – by territory of a given country. The problems of the possibility of classifying the arising food waste as possible to avoid or impossible to avoid are left by the European Commission to be settled on the level of country, region or sector (branch). Food wastes, in the current approach, constitute a separate category of waste, requiring the appropriate classification. It is not possible to obtain information of food waste exclusively on the grounds of the data, collected in within the frames of the European waste statistics WStatR, although the statistics of waste remain the main source of the available information on food wastage[10].

In the Resolution of 16 May 2017 *On initiative on resource efficiency: reducing food waste, improving food safety* the European Parliament recommends the application of the following definition by the Commission and the Member States: "food waste means food intended for human consumption, either in edible or inedible status, removed from the production or supply chain to be discarded at primary production, processing, manufacturing, transportation, storage, retail and consumer levels, with the exception of primary production losses"[11].

[10] According to WStatR, the data on food waste should be supplied in item 09 Animal and vegetal waste which are then divided into following sub-items: 09.1. Animal and mixed waste and 09.2. Vegetal waste. The second category of food waste is category 10. Mixed waste, in particular 10.1. Waste coming from households and similar. https://rod.eionet.europa.eu/instruments/528.

[11] Official Journal of Laws of the EU. C.2018.307.25.

In global (FAO, FLW Standard) and the EU (FUSIONS) definitions there is marked a tendency to consider the food losses and waste in total (FLW) and treating the wastage as generation of unnecessary food waste. There is a visible tendency to situate the losses on the production-supply side of the agri-food chain and the wastage on the demand-consumer side, being eventually considered totally as losses and waste.

In PROM Project, the definition obligatory on the European level (EU) was adopted in relation to food and food products. By-products are not defined as food because they are not intended for consumption but they are utilized for other purposes. If they are not utilized, they become waste but they are not food waste. Food waste is understood in conformity with the Directive on waste and means all food that is consistent with the definition specified in art. 2 of the Regulation (EC) 178/2002 of the European Parliament and of the Council and that became waste. According to the definition, adopted by the Polish Association of Food Technologists (PTTŻ) within the frames of MOST Project [Bilska, Kołożyn-Krajewska 2016], the term food losses and waste, as understood together, should be treated as food raw materials and products, manufactured for consumption purposes that have not been consumed by the people, so they have not been utilized in accordance with the primary destination of food in every stage of the food chain, from primary production, via processing and distribution to the final consumption in households. Such definition was also adopted in PROM Project. In the Project, the losses and waste are therefore defined and due to this fact, they are monitored and analyzed in total.

Identification of losses and waste in food chain

The processes of food management should be identified in a specific economic chain – in food chain, being also defined as the chain "*from farm to fork*". The idea and definition of food chain is now the basis for ISO Standard 22 000[12], settling the processes of health safety and quality assurance in food management. A justified cooperation in this respect, as occurring within the frames of the food chain, contains also a principle of sharing information; it ensures significant advantages for the companies - participants of the food chain, including limitation of waste and losses. Functioning of the chains of the particular food products is determined by many factors what will have an influence on processes of identification of the sites of generation of food losses and waste, monitoring of the level of the discussed phenomena and management of the processes.

On order to gain information of qualitative and quantitative nature in respect of the food losses and waste in the food chain, it is necessary to carry out the identification of the appropriate sources and ways of their obtaining. The data

[12] PN-EN ISO 22000:2006 Food safety management systems. Requirements for any organization in the food chain 2006, Polish Committee for Standardization (PKN), Warsaw.

sources in the qualitative methods may have a primary (direct) or secondary (indirect) nature. The direct measurement methods include: analysis of the composition of the waste, weighing or counting of the waste, evaluation of volume, surveys, diaries, records or observations. The indirect methods cover modelling, mass balance, food balance, use of the data from proxy servers and literature data. The direct obtaining of the data requires considerable expenditure. They are therefore usually employed in the particular stage of the supply chain, with the participation of a limited number of entities taking part in data collection.

The indirect measurements which use secondary data include a wider scope of the analysis and may ensure representativity in a higher scale, e.g. on the level of region or country. Most of the research described in literature is based upon the quantitative approach and data obtained from direct measurements, being based mainly or exclusively on the literature data. The so-far existing studies show that there are no universal methodologies for gaining the data and their choice depends on the specificity of a particular stage or link of the agri-food chain[13]. To estimate food losses and waste, the data obtained and collected primarily for other purposes may be also utilized, for example confirmation of the receipt of food waste, physical inventories or storehouse books. The presentation of direct and indirect methods is given in Table1.

Table1. Characteristics of direct and indirect methods in studies on food losses and waste

Direct methods	
Waste Composition Analysis (WCA)	It consists in physical separation of the waste constituents, their weighing and categorization. The method may be used to separate the fractions of food waste from the waste, containing other types of materials and substances as well as to get to know different substances which constitute food waste, including their types and sorts, as well as quantities of edible and inedible parts
Weighting	Use of weighing scales enables obtaining information on food waste mass (it may also include waste composition analysis)
Counting	Determination of the number of components of food waste with the application of counting methods, scanning, or use of visual scales in order to estimate the weight of the waste
Assessing volume	It consists in determination of the space, taken up by the food waste. The method is recommended for measurement of liquid waste but also, for solid and semisolid substances, including the determination of the waste amount, suspended in a liquid.
Garbage collection	Separation of fractions of food waste from other types of waste in the waste container in order to determine the weight

[13] Kwasek M. (Ed.): Analysis of Food Losses and Waste in the World and in Poland. The Studies on Socially Sustainable Agriculture (37), Institute of Food Agriculture and Economy, State Research Institute, Warsaw (2016), p. 16.

	and proportion of food waste. It may or may not include waste composition analysis
Surveys	Gaining information from individual persons or entities on attitudes, beliefs and behaviours in relation to food waste via surveys (questionnaires)
Diaries	Gaining information on the waste on the grounds of daily records concerning the quantity and types of the generated food waste in the specified time intervals
Records	Determination of the quantity of the waste from the data coming from different documents, collected primarily for purposes different then recording of food waste (e.g. storehouse books)
Observation	Estimation of the waste volume, using comparative scales in order to determine visually the content of particular food residues
Indirect methods	
Modelling	It consists in estimation of the quantity of food waste, with the application of mathematical modelling methods based on the factors that determine generation of the waste
Mass balance	Estimation of the quantity of the waste by measurement of the outlays (e.g. raw materials and components in manufacturing plant) and the results (e.g. manufactured products) in the single stages of processing and related change in weight (e.g. water evaporation during boiling)
Use of Proxy data	Estimation of the quantity of waste on the grounds of the data obtained from enterprises or public entities. The method is often utilized for scaling of the data or gaining the aggregated data
Use of literature data	Gaining the data directly from literature or estimation of the quantity of food waste based upon the data from different publications

Source: C. Caldeira, S. Corrado, S. Sala (2017) Food Waste Accounting. Methodologies, Challenges and Opportunities. JRC Technical Reports, European Commission, 16-17

In the case of the studies reporting FW on the European level, the following approaches have been observed:

- Statistics concerning the waste, as based upon the Eurostat data in which the waste data contain classification into categories of waste according to three-digit European classification of the waste for statistical purposes and in conformity with the statistical classification of activity in the European Union (*Nomenclature Statistique des Activités économiques dans la Communauté Européenne,* **NACE**) where they are generated. EWC-Stat (*European Waste Catalogue*) is a substances-oriented classification and is connected with the administrative classification of waste list;
- Data from the national studies being extended to the European level;

- Combination of different data sources such as FAO, Eurostat, the European Food Safety Agency (EFSA) and scientific literature (Corrado, Sala 2013).

METHODOLOGIES FOR STUDIES ON FOOD LOSSES AND WASTE – GAINING INFORMATION, MODELLING, QUANTIFICATION

Methodologies of the studies on food losses and waste acc. to FAO – the case study: the EU countries

The studies conducted by Bio Intelligence Service (BIOIS) for the European Commission and the studies of Swedish Institute for Food and Biotechnology (SIK) for FAO belong to the major European and world data sources on food wastage. BIOIS conducts the studies on generation of the food waste on all stages of the food chain in the whole EU-27 but excluding agricultural production and without consideration of different product groups. SIK study concerns generation of food waste in all stages of the food chain, including agricultural production and with the classification into groups of the products. Unlike BIOIS, the studies of SIK have a global scope[14].

In the methodology employed by FAO, the estimated level of losses and wastage for each of the analysed groups of products is determined using a mass flow model for each stage of the agri-food chain, in which the so-called food balance sheets coming from FAOSTAT database are utilized. Food Balance Sheets – FBS show a mass flow of food production in the country across a specified time interval. The following stages of the chain are considered: agricultural production, service and storage after harvesting, processing and packing, distribution and consumption. It should be mentioned that definition "consumption" covers domestic consumption as well as consumption outside the house i.e. in restaurants, coffeehouses, canteens, takeaway consumption, that is individual and collective consumption what results from the specificity of FBS which does not allow further differentiating[15].

Food Loss and Waste Accounting and Reporting Standard – FLW Standard has been developed by organization Food Loss & Waste Protocol Partners, in order to determine the requirements and guidelines for governments, enterprises and other stakeholders, interested in identification of the sources of food losses and waste generation, their quantification, monitoring and appropriate management

[14] Bräutigam K.-R., Jörissen J., Priefer C. (2014) The Extent of Food Waste Generation across EU-27: Different Calculation Methods and the Reliability of their Results. Waste Management & Research, 32(8), p. 684.

[15] The method of mass balance to estimate food losses and waste is discussed in the report by J. Gustavsson et al. Global Food Losses and Food Waste – Extent, causes and prevention (2011), FAO, Rome.

with the aim to decrease their generation and reduce their impact on the environment.

The aim of the mentioned system is to facilitate measurement and monitoring of particular substances in the food chain and tracing their destination – target place. FLW Standard may be utilized on the level of a single enterprise as well as of the whole country in determination of the sites and scale of generating food losses, waste and wastage. The Standard consists of ten stages, from the definition of the aim of estimating the losses to the establishment of the way of monitoring the effectiveness and tracing the progress in time. Within the frames of the Standard, there were formulated the guidelines concerning the methods for quantification of food losses and food waste, including their direct measurement, composition analysis, calculation of mass balance and survey studies[16].

According to FLW Standard methodology, the following items are excluded from the definition of waste: not harvested crops, food destined for animal feed, generation of bio-materials. Food waste include such food waste which will be utilized in aerobic (composting) or anaerobic (fermentation) processes, incineration, fertilization and storage, and also, the substances being discarded or disposed to sewer. The losses before harvesting are not included to the stream and weight of the waste. Similarly, composting of biomass in agricultural farm or its anaerobic fermentation for the needs of biogas production (agricultural biogas-producing plants) is not included – according to FLW methodology – to the stream of food waste. The destination and the way of disposal of a given waste play therefore a key role in its qualifying as food waste or not. It should be constantly monitored in order to preserve the representativity of the collected statistical data concerning the stream of the waste, losses and wastage. The mass of food packaging in not included to waste.

On a global scale (FAO), there are also being developed indicators aimed at facilitation of monitoring of the level of food losses and wastage, including food waste. The indicator, which is recommended to be used on the national level, is the index of food losses and waste *per capita*, covering the whole population of a given country; it is expressed in kg/person/year. It consists of two sub-indicators. The first one covers the losses resulting on the stage from agricultural farm to distribution points of the agri-food chain (Food Loss Index). The other one concerns the losses, generated on the stage from trade to households (Food Waste Index)[17].

[16] Food Loss and waste Accounting and Reporting Standard, Version 1.1, (2016), World Resources Institute.

[17] State-of-play on the Global Food Loss Index to monitor SDG 12.3. 2017 https://ec.europa.eu/food/sites/files/safety/docs/fw_eu-platform_20171107_sub-fd_pres-03.pdf .

Methodology of the studies on food losses and wastage in the EU acc. to FUSIONS

On the level of the European Union, we should mention the FUSIONS Project, as implemented under the 7.Framework Programme of the European Commission in the years 2012 – 2016. It was a comprehensive research project dedicated to the development of the methodology for measurement and targeted counteracting food losses and wastage in the EU countries. In its methodological assumption, the mentioned FUSIONS Programme did not separate edible and inedible fractions of food but it covered the whole flow of the resources removed from the supply chain[18]. Redistribution, operation of transferring the food surpluses for charity purposes is treated equally as other targeted sites. FUSIONS considered the redistribution as a part of the food supply chain until the moment of its consumption. FUSIONS encouraged all entities, collecting the data on food wastage, to perform this activity in accordance to the FUSIONS guidelines in order to ensure the comparability of data, gained in all stages of the food supply chain in all EU-28 countries[19].

According to FUSIONS, wastage includes food products which are still suitable for consumption but do not meet the specified criteria for becoming suitable for sale. Such food products are represented by seasonal articles, warehouse surpluses, food which is improperly labelled or was damaged during transport. The results of the project have demonstrated that there is no one universal method allowing obtaining the representative data, and for gaining their representativity, it is recommended to utilize few research methods in parallel[20].

Methodology of the studies and modelling with the application of LCA method

Life Cycle Assessment (LCA) is one of the methods and techniques of environment management, being recommended in many EU documents, *inter alia*, in *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste* – in aspect of the choice of the methods and hierarchy of proceeding. LCA enables identification and assessment of potential environmental risks in the whole life cycle of the products and wastes across the supply chain. Its aim is to deliver the exhaustive information of the impact of a given waste or of a group of waste on the environment throughout the whole supply chain, so from the stage of production until the moment when a product become a waste and is subjected to the disposal processes, including recycling and utilization.

[18] FUSIONS Definitional Framework, op.cot. p. 24.

[19] Ibid., p. 9.

[20] FUSIONS. Report on review of (food) waste reporting methodology and practice. FUSIONS reducing food waste through social innovation, 2014.

LCA facilitates identification, quantification and hierarchization of organizational, logistic, technical and technological solutions from the viewpoint of their influence on the environment and developing the methods for its minimization.

The developed LCA methodology is defined in ISO standards (ISO 14001, 14041, 14044) and is aimed at increase of transparency in the application of LCA method and increase of the comparability between the studies of this type. The guidelines, as contained in the mentioned above standards are general and do not include detailed guidance concerning LCA use in the specified areas and economic sectors. LCA method, as being employed in the area of food waste management covers technical as well as biological processes. The features of the food waste differ from many other waste fractions as they are subjected to biological processes during the whole process of flow through single stages (links) of the supply chain. It has an impact on environment as well as on the potential ways of utilizing such type of the waste to minimize their level and by this, to counteract the losses and wastage. LCA covers such sectors as agricultural production, food economy, waste and sewage management and it requires a close definition of the particular borders of the system. For example, the studies limited to a company's door may omit certain important aspects (e.g. choice of package) which may, in turn, affect the generation of the losses in the successive stage of the agri-food chain [Bernstad, la Cour, Jansen 2012]. The available studies indicate the purposefulness of employing LCA method in the context of qualification of given categories of food losses and waste as being possible to be avoided or impossible to be avoided. Instructive experiences in this respect are available in British studies [Langley, Yoxall 2010].

Food losses occur in every stage of the supply chain. In global approach, as postulated by FAO, in edible parts of food are not treated as losses. In the context of LCA application, the mentioned parts may be recognized as agricultural or processing residues and may be disposed by the defined methods of waste processing (e.g. aerobic or anaerobic fermentation). The possibility of modelling food losses within the frames of LCA approach has a fundamental meaning for complex and detailed assessment of the burden on the environment connected with the food economy. It has a key importance in the case when the results of the studies are to be utilized in the determination of policies and initiatives aiming at reduction of the impact of agri-food system and the sustainable supply chains on the environment and climate [Corrado et al. 2017].

SUMMING UP AND RECOMMENDATIONS TO BE USED IN DEVELOPMENT OF METHODOLOGY OF THE STUDIES ON FOOD LOSSES AND FOOD WASTE

The conducted analyses confirm the thesis that there is no one universal method for gaining the quantitative data concerning food losses and wastage and the resulting food waste. The mentioned problems are of a complex nature and have their theoretical dimensions connected with the choice of the appropriate method of

gaining the quantitative data in the particular stages and links of the food chain. The discussed methods may be direct or indirect. From the performed review, it is followed that each method has a defined scope of applications what is indicated by the cited results of comprehensive research projects, undertaken on global (FAO) and European (FUSIONS Project) level. Life cycle analysis (LCA) is a complex research method, enabling gaining the data being appropriate for the process of implementation the principle of sustainable development and the resulting conception of circular economy. In the discussed model, food losses and wastage are eliminated at the source via optimization of management system in the food chain, including product management.

The key element of correct research methodology, facilitating gaining the data appropriate for the research needs is, therefore, an understandable and transparent system of definitions, concepts and basic descriptive, analytical and operational categories. The present paper, as implemented within the frames of PROM Project, will be used in the process of developing the adequate methodology of monitoring the losses and wastage for branches of food sector in the particular stages of the food supply chain.

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REFERENCES

Beigl P., Lebersorger S., Salhofer S. (2008) Modelling Municipal Solid Waste Generation: A Review. Waste Management, 28(1), 200-214.

Beretta C, Stoessel F., Baier U., Hellweg S. (2013) Quantifying Food Losses and the Potential for Reduction in Switzerland. Waste Management, 33(3), 764-773.

Bernstad A., la Cour Jansen J. (2012) Review of Comparative LCAs of Food Waste Management Systems – Current Status and Potential Improvements. Waste Management, 32(12), 2439-2455.

Bilska B., Kołożyn-Krajewska D. (red.) (2016) Model ograniczenia strat i marnowania żywności z korzyścią dla społeczeństwa (MOST). Wyd. Nauk. PTTŻ, Kraków, 8-9 (in Polish).

Borkowski B. (2003) Systemy informacyjne w rolnictwie na potrzeby Wspólnej Polityki Rolnej. Wydawnictwo SGGW, Warszawa, s.15 (in Polish).

Bräutigam K.-R., Jörissen J., Priefer C. (2014) The Extent of Food Waste Generation across EU-27: Different Calculation Methods and the Reliability of their Results. Waste Management & Research, 32(8), 683-694.

Caldeira C., Corrado S., Sala S. (2017) Food Waste Accounting. Methodologies, Challenges and Opportunities. JRC Technical Reports, European Commission, p. 10.

Corrado S., Ardente F., Sala S., Saouter E. (2017) Modelling of Food Loss within Life Cycle Assessment: From Current Practice towards a Systematisation. Journal of Cleaner Production, 140, p. 850.

Duchin F. (2005) Sustainable Consumption of Food: A Framework for Analyzing Scenarios about Changes in Diets. Journal of Industrial Ecology, 9(1-2), 99-114.

Dyrektywa Parlamentu Europejskiego i Rady 2008/98/WE z dnia 19 listopada 2008 r. w sprawie odpadów (in Polish).

FAO (2011) Global Food Losses and Food Waste: Extent, Causes and Prevention.

Food Loss and Waste Accounting and Reporting Standard (2016), Version 1.1, World Resources Institute.

FUSIONS (2014) Report on Review of (Food) Waste Reporting Methodology and Practice, FUSIONS Reducing Food Waste through Social Innovation.

FUSIONS (2014) Definitional Framework for Food Waste Full Report. Anex C, 78-100.

FUSIONS (2016) Food Waste Quantification Manual to Monitor Food Waste Amounts and Progression.

Gustavsson J. et al. (2011) Global Food Losses and Food Waste – Extent, Causes and Prevention, FAO, Rome.

Household Food and Drink Waste in the United Kingdom (2013) WRAP.

Joosten L. A. J., Hekkert M. P., Worrell E., Turkenburg W. C. (1998) STREAMS: a New Method for Analysing Material Flows through Society. Resources, Conservation and Recycling, 27(3) 249-266.

Karadimas N. V., Loumos V. G. (2008) GIS-based Modeling for the Estimation of Municipal Solid Waste Generation and Collection. Waste Management & Research, 26(4), 337-346.

Krajewski K., Lipińska M., Wrzosek M., Bilska B., Kołożyn- Krajewska D. (2016) Food Waste - Four Dimensions of Security Economic, Social, Energy and Environmental. INTERCATHEDRA, 32/2, 47-53.

Krajewski K., Świątkowska M., Łaba S., Szczepański K. (2018) Losses and Waste in Meat Supply Chain, and the Needs of Product Management and Market Communication. Proceedings of the SUM2018 / 4th Symposium on Urban Mining and Circular Economy (21-23 may 2018) Bergamo, Italy, https://www.urbanmining.it/.

Kwasek M. (red.) (2016) Analiza strat i marnotrawstwa żywności na świecie i w Polsce. Z badań nad rolnictwem społecznie zrównoważonym, 37, Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej, Państwowy Instytut Badawczy, Warszawa (in Polish).

Langley J., Yoxall A. and others (2010) Food for Thought? – A UK Pilot Study Testing a Methodology for Compositional Domestic Food Waste Analysis. Waste Management & Research, 28(3), 220-227.

PN-EN ISO 22000:2006 Systemy zarządzania bezpieczeństwem żywności Wymagania dla każdej organizacji należącej do łańcucha żywnościowego (2006) PKN, Warszawa (in Polish).

Preparatory Study on Food Waste Across EU27. European Commission, BIOIS, 2010.

State-of-play on the Global Food Loss Index to monitor SDG 12.3. 2017.