BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Volumul 67 (71), Numărul 4, 2021
Secţia
CHIMIE şi INGINERIE CHIMICĂ

FOOD WASTE: CURRENT TRENDS, GLOBAL PERSPECTIVES AND IMPACTS

BY

ERSILIA DANIELA COȘBUC[1], ELENA-DIANA UNGUREANU-COMĂNIȚĂ[1,*] and MARIA GAVRILESCU[1,2,*]

[1]“Gheorghe Asachi” Technical University of Iași,
“Cristofor Simionescu” Faculty of Chemical Engineering and Environmental Protection,
Department of Environmental Engineering and Management, Iași, Romania
[2]Academy of Romanian Scientists, București, Romania

Received: October 11, 2021
Accepted for publication: November 30, 2021

Abstract. Food production and consumption have a considerable impact on the environment, since one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tonnes per year. Food waste represents not only a loss of materials, but also a substantial loss of other resources such as soil, water, energy, and workforce. Waste generated during food processing and consumption is becoming increasingly problematic, because it may account over 50% of the total waste produced in different countries, while 60 % contain organic matter.

In this context, an analysis of the current situation of food waste and wastage, continued with the practices possible to be applied to turn food waste in resources as secondary raw materials and energy is very opportune today. This work aims at developing an overview on sources and categories of food waste, their environmental, economic and social impacts, followed by a case study, which addresses the valorization of food waste. Two scenarios were considered: (i) recovery of food waste to obtain compost for the soil; (ii) recovery of food waste for obtaining compost and energy.

[*]Corresponding author; *e-mail*: comanita_elena_diana@yahoo.com; mgav@ch.tuiasi.ro

The evaluation of impacts followed the life cycle strategies and methodology and considered several impacts such as: *Acidification Potential (AP), Eutrophication Potential (EP), Photochemical Ozone Creation Potential (POCP), Human Toxicity Potential (HTP), Terrestrial Ecotoxicity (TE), Photochemical Oxidant Formation (POF), Human Toxicity (HT)*, estimated based on ReCiPe and CML methods (LCA methodologies) included in GaBi software.

The study demonstrated that food waste can be a sustainable resources and energy. This approach can reduce the impacts generated by the food waste in the environment and resources depletion.

Keywords: compost; food waste; impact; energy; life cycle.

1. Introduction

Looking to the future, we realize that food is a major concern worldwide. In 2050, with the same planet, we will have to feed three times as many people as we did a century ago.

The choices we make about food production and consumption already have direct or indirect consequences on the climate, the use of resources, such as water and soil, but also on people's ability to feed and have a healthy diet decent living (Elimelech *et al.*, 2019; Ghinea *et al*., 2015).

Climate change is compounded by pressures on food security, and some regions feel more stressed than others. Droughts, fires or floods directly hamper production capacity (Ungureanu-Comăniță *et al.*, 2020). Unfortunately, climate change often affects countries that are more vulnerable and may not have the means to adapt (Ungureanu-Comăniță *et al.*, 2020).

A significant amount of food is disposed of as waste, especially in developed countries, and this also means eliminating the resources used to produce food (Al-Rumaihi *et al*., 2020). In the European Union, 90 million tonnes of food or 180 kg per person are disposed as waste, every year, much of which is still suitable for human consumption (FAO, 2019. In poor African countries, only six kilograms of food per capita are thrown away at the same time. In Romania, food waste amounts to 6.000 tons per day (Ungureanu-Comăniță *et al.*, 2020). In consequences, about a third of globally produced food is lost or discarded.

In total, this means that 1.3 billion tons of food are not consumed annually. Taken together, this food waste produces 3.6 gigatons of carbon dioxide, according to FAO estimates (FAO, 2019). **The main sources which generate food waste** are represented in Fig. 1.

The magic word that characterizes the particularity of waste in the food industry is "recovery". Food waste should be seen as a raw material for high value-added products, rather than as waste in the sense of the dictionary definition (Al-Rumaihi *et al*., 2020). For example, oligopeptides can be obtained by peptic hydrolysis from whey protein concentrate. Ethanol can be obtained by enzymatic conversion of cellulose-rich waste (Read *et al*., 2020).

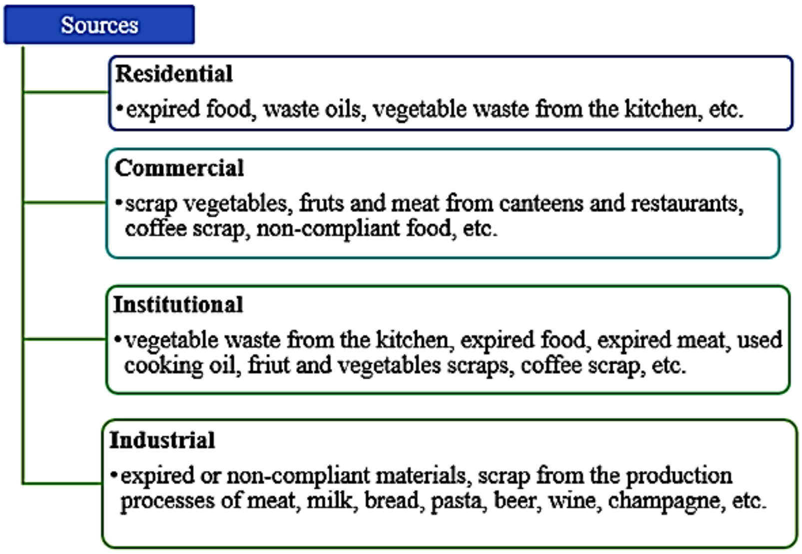


Fig. 1 – Sources of food waste.

Also, the depletion of fossil fuel resources has triggered extensive research programs in the field of fuels obtained from rapidly renewable resources, such as organic biomass from waste.

A lot of treatment processes and technologies are used to generate usable forms of materials and energy and which also reduce the volume of food waste such as: incineration, gasification, anaerobic digestion (from mixed residual waste, often as part of an MBT process (Comăniță *et al*., 2015a,b; Comăniță *et al*., 2016; Comăniță *et al*., 2018; Ghiga *et al*., 2020; Ghinea and Gavrilescu, 2011; Simion *et al*., 2017; Vrânceanu *et al*., 2020).

Also, according to the Waste Management Hierarchy, a series of measures have been applied worldwide in order to reduce the volume of waste and whose benefits are presented in Fig. 2 (EC Directive 98, 2008).

The biochemical production of fuels, from organic by-products, has received special attention in recent years, and recent advances in biotechnology and bioengineering have led to the discovery of new ways of producing fuels (methane, hydrogen, ethanol) by fermentation, from raw materials, renewable (Ekvall *et al*., 2007).

Waste recycling has become a common method to prevent the decline of environmental factors and to meet the growing demand for raw materials (Comăniță, 2016). The benefits that can result from the successful recycling of food waste are enormous. For food industry waste, bioconversion can be applicable either in energy production or in the transformation of waste into raw materials for obtaining market value products (Comăniță *et al*., 2015a,b,c).

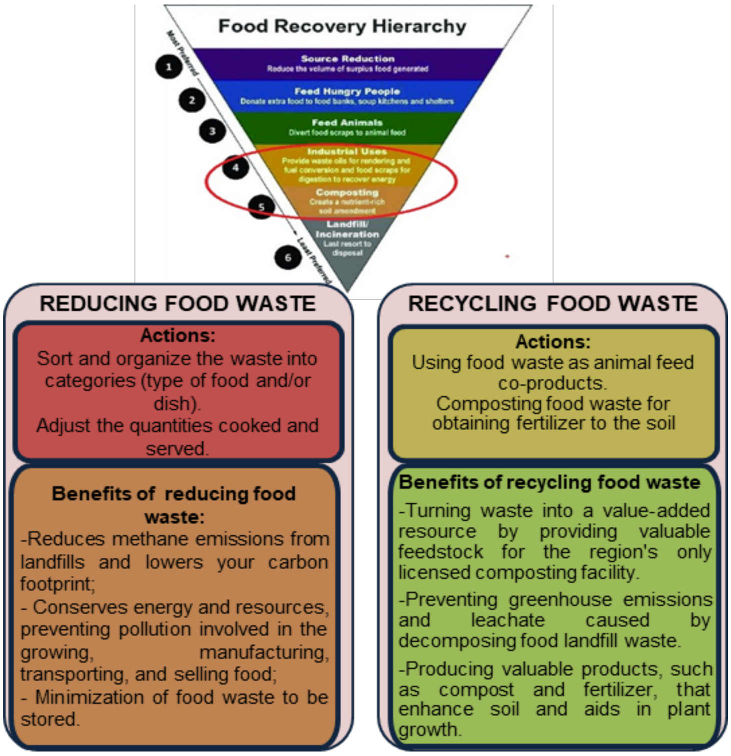


Fig. 2 – The benefits resulting from the application of actions to reduce food waste.

In this context, in order to find the best alternative for the recovery of food waste, we applied the Life Cycle Assessment methodology for to compare two alternatives: (i) recovery of food waste to obtain compost for the soil; (ii) recovery of food waste for obtaining compost and energy.

2. Life Cycle Assessment (LCA) of the Bioconversion of Food Waste into Compost and Energy

2.1. Methodology

LCA according to ISO 14044 (2006), is the method in which energy and raw material consumption, different types of emissions, and other important factors, characteristic of a product, process or activity, are measured, analysed and summed, throughout the life cycle, under environmental impact aspect.

The working methodology for LCA studies includes four interactive phases schematically represented in Fig. 3 (Ghinea *et al.*, 2016).

In this paper, the analysis was assisted by GaBi software.

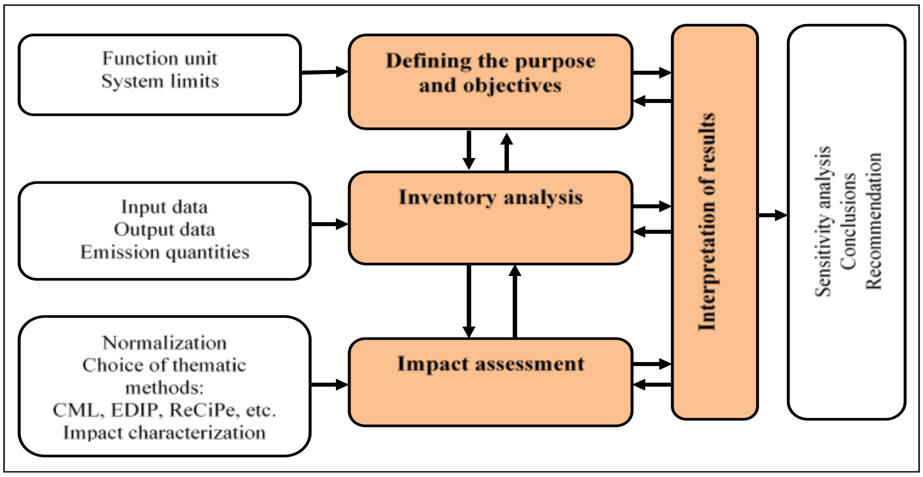
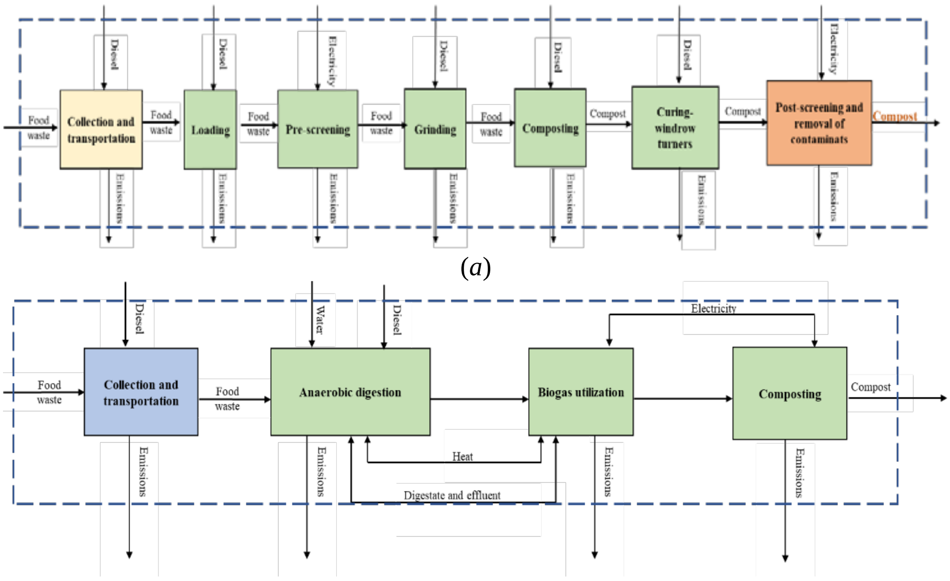


Fig. 3 – Life cycle assessment application stages (adapted upon ISO 14044 2006).

2.2. Goal and Scope of the Study

We applied the LCA methodology to make a comparative evaluation for the environmental performance of two processes: (i) recovery of food waste to obtain compost for the soil; (ii) recovery of food waste for obtaining compost and energy, considering **1 tonne of food waste as the functional unit.**

The limits of the system are shown in Fig. 4.



(*a*)

(*b*)

Fig. 4 − System boundaries for (*a*) composting and (*b*) anaerobic digestion processes.

2.3. Inventory Analysis

The inputs consist in the materials, energy and resources that enter into the unit process whereas, the outputs are represented by the products, waste and emissions resulting from the process. Tables 1-2 represents the LCI referred to 1 tonne of food waste related to the two processes, mentioned in the previous section (2.2.).

Table 1
Composting Inventory

Stages	Input	Amount	Unit	Output	Amount	Unit
Collection and transportation	Food waste	1	tonne	Diesel emissions: CO_2, CO, NOx, SO_2, CH_4, N_2O, PM_{10}, Hydrocarbons	1.04×10^{-1}	kg
	Diesel	14	kg			
Loading	Food waste	1	tonne	Diesel emissions		kg
	Diesel	0.46	kg			
Pre-screening	Food waste	1	tonne	Electricity emissions		kg
	Electricity	1.8	kWh			
Grinding	Food waste	940	kg	Diesel emissions		kg
	Diesel	0.15	kg			
Composting	Food waste	940	kg	Composting emissions: CH_4 N_2O NH_3	9.08×10^{-1} 3.72×10^{-2} 2.01×10^{-1}	kg kg kg
	Diesel	1.07	kg	Diesel emissions		kg
Curing-windrow turners	Compost	330	kg	Diesel emissions:	0.09×10^{-1}	kg
	Diesel	0.11	kg			
Post-screening and removal of contaminats	Compost	330	kg	Electricity emissions		kg
	Electricity	0.9 kWh				

Table 2
Anaerobic Digestion Inventory

Process	Input	Amount	Unit	Output	Amount	Unit
Collection and transportation	Food waste	1	tonne	Diesel emissions: CO_2, CO, NOx, SO_2, CH_4, N_2O, PM_{10}, Hydrocarbons		kg
	Diesel	14	kg			
Anaerobic digestion	Food waste	1	tonne	Biogas	150	m^3
	Energy for feedstock preparation	11.25	kWh	Digestate	0.85	tonne
	Heat for digester	19.25	kWh	Effluent	0.57	tonne
	water	0.5	tonne			
Biogas utilization	Biogas	148	m^3	Emissions from biogas use: NMVOCs, NOx, CO, PM, Sox, HCl, HF		kg
				Electricity	178.1	kWh
				Heat	120. 9	kWh
Composting	Energy from biogas utilization	9.52	kWh	Compost	225	kg
	Air	0.9	tonne			
	Digestate	0.85	tonne	Emissions from composting: CH_4 N_2O NH_3	$9.08x10^{-1}$ $3.72x10^{-2}$ $2.01x10^{-1}$	Kg
	Effluent	0.57	tonne			

2.4. Impact Assessment

The impact assessment stage aims to identify the impact on the environment associated with each stage of the process. The analysis was assisted by GaBi software. Two methods included in LCA methodology and GaBi software were applied: **ReCiPe08** and **CML2001**.

The impact categories resulted considering the application of CML 2001 and ReCiPe08 methods are presented in Table 3.

Table 3
Impact Categories from ReCiPe 08 and CML 2001 Methods Used in the Study

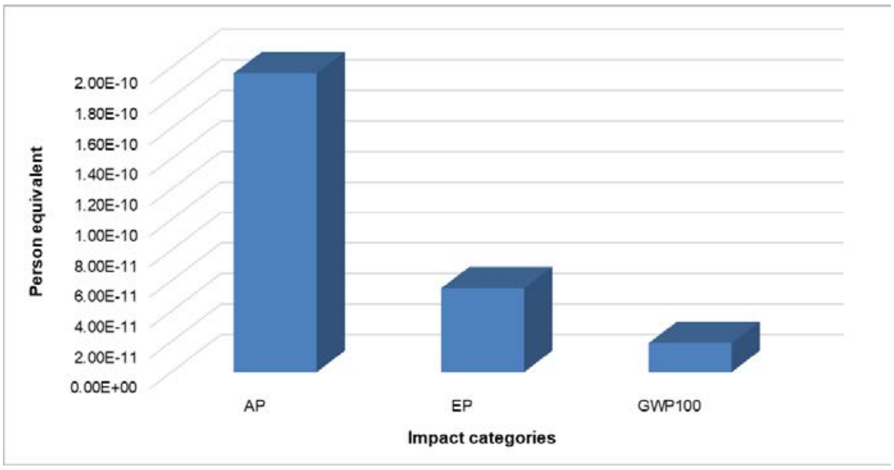
Impact categories	Abbreviation	Methods
Acidification Potential	AP	CML2001
Eutrophication Potential	EP	
Global Warming Potential 100 years	GWP 100	
Climate change Human Health	CcHh	ReCiPe08
Climate change Ecosystems	CcE	
Agricultural Land Occupation	ALP	

The ReciPe and CML 2001 methods were selected due to annually updated data-bases. Because these 2 methods used 3 different algorithms to quantify the impact of the various stages of production, the end-results were normalized in order to obtain a single unit of measure, **person equivalent**.

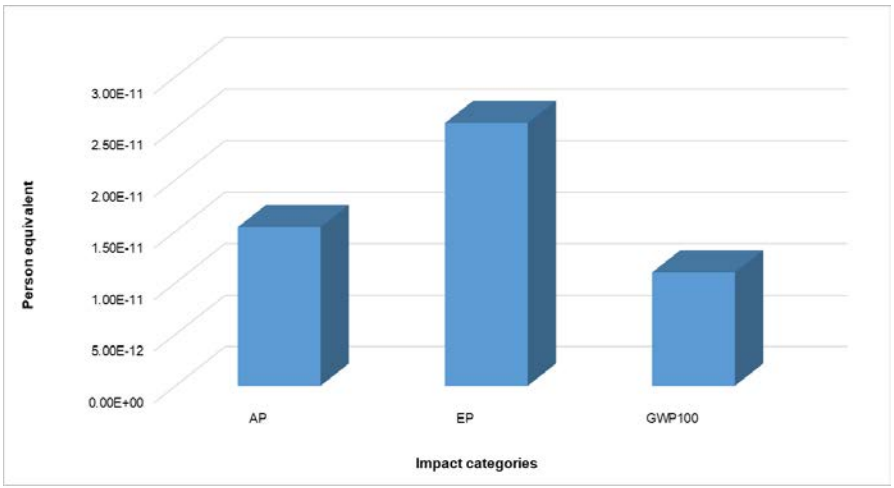
2.5. Interpretation of Results

According to the **CML2001** method, shown in Fig. 5, multiple impact categories are negative, each of them being more severe than the last, in the following order: (a) anaerobic processes - AP> EP>GWP100; (b) composting - EP>AP> GWP100. In scenario (a), the anaerobic mainly affects *Acidification Potential*, its percentage contribution being 86%. Also, the emissions of inorganic substances resulting from the process, influence this category of impact in proportion of 95%. In comparison, scenario (b) shows a fairly large impact on the *Eutrophication Potential* that is attributed to both air and water emissions. Air emissions have a total contribution to the eutrophication potential of about 55%, of which the most representative are NO_2 and NO emissions released during the fermentation stage. Emissions to water (released after wastewater treatment) through COD and BOD emissions have a slightly lower contribution, 15%.

Global warming potential has low values in both scenarios because a number of benefits are obtained: (i) organic waste is transformed into compost that replaces inorganic fertilizers; (ii) biogas is obtained which is an energy source for the process.



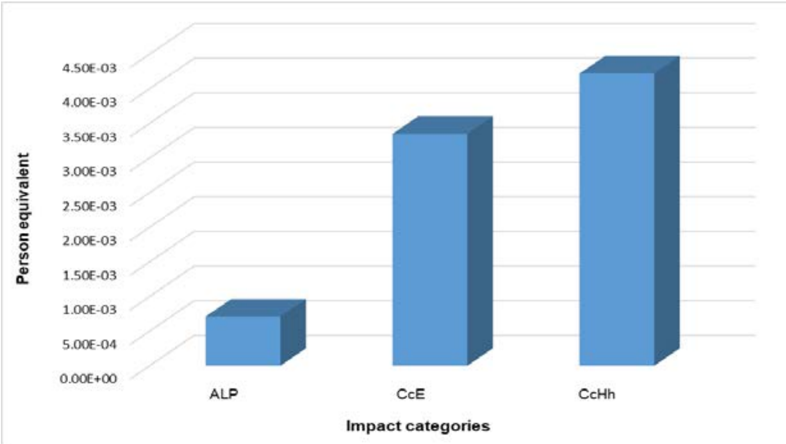
(*a*)



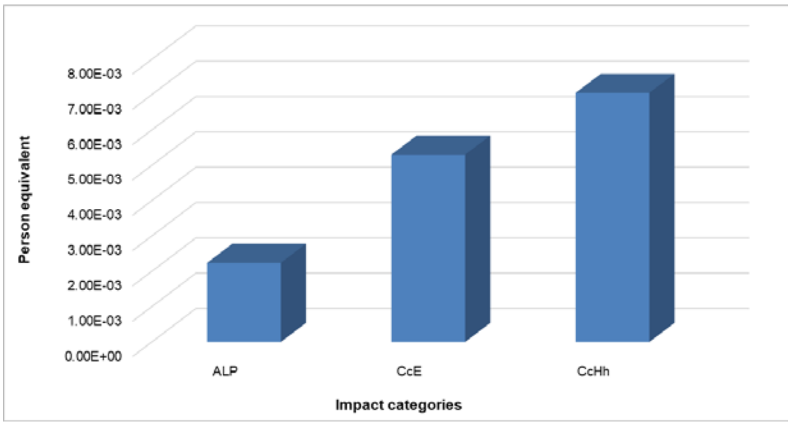
(*b*)

Fig. 5 – Impacts on the environment resulting from the application of the (*a*) anaerobic digestion and (*b*) composting processes, CML2001 method.

Also, according with **ReCiPe08** method can be ranked in the following order: (a) anaerobic digestion processes - CcHh> CcE>ALP; (b) composting - CcHh> CcE>ALP (Fig. 6). Responsible for the impact on human health and ecosystems are air emissions which have a major contribution, especially VOC emissions. All these emissions (VOC, nitrogen oxides ... etc) result from the fermentation process and the use of diesel for waste transport.



(*a*)



(*b*)

Fig. 6 – Impacts on the environment resulting from the application of the (*a*) anaerobic digestion and (*b*) composting processes, ReCiPe08 method.

It can also be seen that *Agricultural Land Occupation* has a minor impact because it considerably reduces the storage area of food waste, which is transformed into compost and energy used in the process.

3. Conclusions

In this study Life Cycle Assessment methodology was applied for the evaluation of environmental performance of two processes: (i) recovery of food waste to obtain compost for the soil; (ii) recovery of food waste for obtaining compost and energy, considering **1 tonne of food waste as the functional unit**.

GaBi software was used in the development of the LCA methodology. Two of the many methodologies specific to Gabi software were used: **ReCiPe08** and **CML2001**.

The results obtained in both methodologies underlined the fact that capitalizing on food waste substantially reduces the waste storage area. A number of environmental impacts are also observed, but much smaller, compared to the fact that they have only been stored so far.

After applying the LCA methodology, as a result of the comparative analysis, it could be observed that the alternative with the highest ecological performances is the anaerobic digestion process which, in addition to reducing food waste, also obtains energy.

Acknowledgements. This work was supported by a grant of the Romanian National Authority for Scientific Research, CNCS –UEFISCDI, project number PN-III-P2-2.1-PED-2019-5239, Contract no. 269PED⁄2020.

REFERENCES

Al-Rumaihi A., McKay G., Mackey H., Al-Ansari T., *Environmental Impact Assessment of Food Waste Management Using Two Composting Techniques*, Sustainability, 12, https://doi.org/10.3390/su12041595 (2020).

Comăniță E.-D, Ghinea C., Roşca M., Simion I.M., Petraru M., Gavrilescu M., *Environmental Impacts of Polyvinyl Chloride (PVC) Production Process*, 2015 E-Health and Bioengineering Conference (EHB 2015), DOI: 10.1109/EHB.2015.7391486 (2015a).

Comăniță E.-D., Ghinea C., Hlihor R.M., Simion I.M., Smaranda C., Favier L., Roșca M., Gostin I., Gavrilescu M., *Challenges and Oportunities in Green Plastics: An Assessment Using the ELECTRE Decision-Aid Method*, Environ. Eng. Manag. J, **14**, 3, 689-702 (2015b).

Comăniță E.-D., Ghinea C., Roșca M., Smaranda C., Favier L., Gostin I., Iordache Ș., Gavrilescu M., *Impact of Climate Change on the Production of Polyvinyl Chloride (PVC) and Polyhydroxyalkanoates (PHAS): A Comparative Approach*, Lucrări Ştiinţifice, Seria Horticultură, **58**, 253-260 (2015c).

Comăniță E.-D, *Tools for Decision Making in the Sustainable Use of Waste as Materials and Energy Resources*, PhD Thesis, „Gheorghe Asachi" Technical University of Iasi, "Cristofor Simonescu" Faculty of Chemical Engineering and Environmental Protection, Iași, Romania (2016).

Comăniță E.-D., Ghinea C., Hlihor R.M., Gavrilescu M., *Occurrence of Plastic Waste in the Environment: Ecological and Health Risks*, Environ. Eng. Manag. J, **15**, 3, 675-687 (2016).

Comăniță E.-D., Cozma P., Simion I.M., Roșca M., Gavrilescu M., *Evaluation of Eco-Efficiency by Multicriteria Decision Analysis. Case Study of Eco-Innovated and Eco-Designed Products from Recyclable Waste*, Environ. Eng. Manag. J, **17**, 8, 1791-1804 (2018).

Ekvall T., Assefa G., Bjorklund A., Eriksson O., Finnveden G., *What Life-Cycle Assessment does and does not do in Assessments of Waste Management*, Waste Manage., **27**, 8, 989-996 (2007).

Elimelech E., Ert E., Ayalon O., *Bridging the Gap Between Self-Assessments and Measured Household Food Waste: A Hybrid Valuation Approach*, Waste Manage., **95**, 15, 259-270 (2019).

Ghiga S.C., David M., Minuț M., Ungureanu- Comăniță E.-D., Cozma P, Gavrilescu M., *Reducing Health and Ecological Risks by Using WEEE as Secondary Sources for Critical Raw Materials*, Proc. of the 8th IEEE Int. Conf. on E-Health and Bioengineering - EHB 2020, Iași, Romania, DOI: 10.1109/EHB50910.2020.9280253 (2020).

Ghinea C., Spranceana A., Comăniță E.-D., Constantinescu G., Gavrilescu M., *Assessment of Environmental Impacts of Municipal Solid Waste Management in Iași, Romania*, Journal of Faculty of Food Engineering, Ştefan cel Mare University of Suceava, Romania, **XIV**, 2, 171-180 (2015).

Ghinea C., Gavrilescu M., *Decision Support Models for Solid Waste Management – An Overview*, Environmental Engineering and Management Journal, **9**, 6, 869-880 (2011).

Ghinea C., Dragoi E.N., Comăniţă E.-D., Gavrilescu M., Câmpean T., Curteanu S., Gavrilescu M., *Forecasting Municipal Solid Waste Generation Using Prognostic Tools and Regression Analysis*, J Environ Manage, **182**, 80-93 https://doi.org/10.1016/j.jenvman.2016.07.026 (2016).

Read Q.D., Brown S., Cuéllar A.D., Finn S.M., Gephart J.A., Marston L.T., Meyer E., Weitz K.A., Muth M.K., *Assessing the Environmental Impacts of Halving Food Loss and Waste Along the Food Supply Chain*, Sci. Total Environ., **712**, DOI: 10.1016/j.scitotenv.2019.136255 (2020).

Simion I.M., Comăniță E.-D., Hlihor R.M., Cozma P., Ghiga S.C., Roșca M., Gavrilescu M., *Life Cycle Assessment of Paper Manufacturing: Environmental and Human Health Impacts*, Proc. of the 6th IEEE Int. Conf. on E-Health and Bioengineering - EHB 2017, Sinaia, Romania, DOI: 10.1109/EHB.2017.7995424 (2017).

Ungureanu-Comăniță E.-D., Coșbuc E.L., Cozma P., Smaranda C., Gavrilescu M., *Human Health Risks Concerning Food Waste Management*, Proc. of the 8th IEEE Int. Conf. on E-Health and Bioengineering - EHB 2020, Iași, Romania, DOI: 10.1109/EHB50910.2020.9280256 (2020).

Vrânceanu T., Ungureanu Comăniță E.-D., Coșbuc E.L., Cozma P., Tudorache D.I., Gavrilescu D.-A., Gavrilescu M., *Sustainable Alternatives for Hazardous Waste Management*, Analele AOSR – Sect. de Șt. Fz. și Ch., **5,** 79-94 (2020).

*** EC Directive 98, *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives*, Official Journal of the European Union, L 312, 3-28 (2008)

*** FAO, *The Food and Agriculture Organization*, on line at: http://www.fao.org/platform-food-loss-waste/flw-data/en/ (2019).

*** ISO 14044, Environmental Management - International Organization for Standardization, *Life Cycle Assessment-Requirements and Guidelines*, on line at: http://www.iso.org/iso/catalogue_detail?csnumber=38498 (2006).

DEȘEURI ALIMENTARE: TENDINȚE ACTUALE, PERSPECTIVE GLOBALE ȘI IMPACTURI

(Rezumat)

Producția și consumul de alimente au un impact considerabil asupra mediului, întrucât la nivel global, o treime din alimentele produse pentru consumul uman se pierd sau devin deșeuri, cantitate care se ridică la aproximativ 1,3 miliarde de tone pe an. Deşeurile alimentare reprezintă nu numai o pierdere de materiale, ci și o pierdere substanțială a altor resurse, cum ar fi solul, apa, energia și forța de muncă. Deșeurile generate în timpul procesării și consumului alimentelor devin din ce în ce mai problematice, deoarece pot reprezenta peste 50% din totalul deșeurilor produse în diferite țări, în timp ce au un conținut de aproximativ 60% materie organică.

În acest context, o analiză a situației actuale a deșeurilor si a pierderilor alimentare continuata cu posibilele practici care pot fi aplicate pentru a transforma risipa alimentară în resurse precum materii prime secundare și energie este foarte oportună în prezent. Această lucrare își propune să dezvolte o imagine de ansamblu asupra surselor și categoriilor de deșeuri alimentare, a impactului acestora asupra mediului, economic și social, urmată de un studiu de caz, care abordează valorificarea deșeurilor alimentare. Au fost luate în considerare două scenarii: (i) recuperarea deșeurilor alimentare pentru a obține compost pentru sol; (ii) recuperarea deșeurilor alimentare pentru obținerea compostului și a energiei.

Evaluarea impactului a adoptat metodologiile și metoda de evaluare a ciclului de viață şi a considerat mai multe categorii de impact, cum ar fi: *Potențialul de acidificare* (AP), *Potențialul de eutrofizare* (EP), *Potențialul de creare a ozonului fotochimic* (POCP), *Potențialul de toxicitate umană* (HTP), *Ecotoxicitate terestră* (TE), *Formarea fotochimică a ozonului* (POF), *Toxicitatea umană* (HT), estimate pe baza ReCiPe și CML (metodologii LCA) incluse în software-ul GaBi.

Studiul a demonstrat că deșeurile alimentare pot fi o resursă de materie și energie durabilă. Această abordare poate reduce impactul generat de deșeurile alimentare asupra mediului și epuizarea resurselor.