EFFICIENT POULTRY INDUSTRY WASTE MANAGEMENT APPROACH IN THE BIOECONOMY FRAMEWORK

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In order to ensure EU's transition to a climate-neutral energy environment, in accordance with the Paris Agreement, enhanced energy efficiency of waste utilization emerges as an important tool to achieve carbon neutrality goals. Several technologies for renewable waste treatment are investigated lately, researches worldwide focusing on exploiting their energy potential and diminishing the environmental impact. It is remarkable that, solid renewable waste is suitable to supply in particular grate or layer combustion plants. This energy valorization solution reached the technical maturity, experimentally and numerically proven. Further, to support regional development incentives implementation, local utilization of different wastes is strongly encouraged. Considering the fairly uniform territorial spread of poultry farms in Romania, this paper presents a case study aiming to provide a sustainable solution for bird waste management and local energy recovery from it, avoiding significant additional costs, as well as storage and transportation issues. The energy independence level is assessed in two scenarios. To this regard, the energy consumption of a real poultry production hall of 910 m^2 (located in Giurgiu County, having 4650 birds/operating cycle, with a poultry waste flow of 558 kg_{waste}/day) is taken into account. The first scenario analyzes the disposal (for energy recovery purposes) of poultry waste as an individual raw material, while the second scenario investigates a mixture of poultry waste and agricultural biomass residues. It is demonstrated that the electricity and heating requirements of the hall can be partially satisfied in the first scenario and fully in the second one. Therefore, the multi-waste management concept investigated in this paper represents a sustainable solution to reduce industry's carbon footprint, answering multiple requirements in the environmentally friendly energy sector development.

Keywords: multi-waste; poultry industry; regional development.

INTRODUCTION

Regulatory Framework

Following energy demand continuous growth, overlapped with traditional resources availability limitations, the European Commission elaborated an action plan for circular economy unfolding, complying also with the 2030 Agenda for Sustainable Development targets (Directive 2008/98/EC, 2008). In reference to waste management policies, it is remarked that they mainly pursue avoiding and reducing not only their rate of generation, but also the potential environmental impact issued by their toxicity. The most popular methods available to diminish the amount of waste are (Klemeš *et al*., 2019):

- Waste reduction at source;
- Alleviating the waste flows in different sectors by implementing the best available practices;
- Waste valorization by reuse, recycle and energy recovery;

https://doi.org/10.24264/icams-2020.IV.12

- Waste disposal through standardized incineration methods and warehouse storage.

EU legislation regarding waste management imposes different treatment approaches depending on the sustainability level of the regarded waste fount. The highest priority is given to prevention and recycling, as evident also in Figure 1 (Law 211/2011). In order to integrate waste management targets in a low carbon society and support circular economy development, it is necessary to promote innovation and investments in new waste treatment capacity while mitigating the losses determined by the standardization shortcomings (Closing the loop — An EU action plan COM, 2015). As a consequence, waste-to-energy conversion technologies are thoroughly investigated lately, researchers worldwide focusing on sustainable solutions, with high potential in the circular economy framework (Klemeš *et al*., 2019).

Figure 1. Waste management hierarchy.

Depending on the type of waste, achieving the best outcome in terms of environmental impact starts from the priority order given in Figure 1. Further, considering technical feasibility, ecologic aspects and economic viability the treatment approach is selected (Krajačić *et al*., 2016).

Waste-to-Energy Conversion Technologies

A key step enabling the transition towards circular economy is to lay down a set of ranked priorities that reduce the environmental impact, while achieving the optimal resource efficiency in waste prevention and management (Duić and Rosen, 2014). The following waste treatment technologies emerge as having top integration potential:

- co-incineration of waste in combustion plants (e.g. power plants, cement and lime production facilities);
- waste incineration in dedicated facilities;
- anaerobic digestion of biodegradable waste;
- production of waste-derived solid, liquid or gaseous fuels;
- other processes including indirect incineration following a pyrolysis or gasification step.

It is highlighted that classification of these technologies according to the ranking in Figure 1 takes into account many criteria and is actually complex. For instance, waste-to-energy processes such as anaerobic digestion resulting in the production of biogas

https://doi.org/10.24264/icams-2020.IV.12

and digestate are regarded as a recycling operation. However, waste incineration with limited energy recovery is considered disposal.

Considering the poultry industry development, poultry manure became lately an important issue to be addressed. Land application may be sometimes restricted by logistical limitations or over-application risks (Sarfaraz *et al*., 2020). The energy recovery approach applied to the poultry industry waste encourages poultry producers to integrate it within their own facilities, cutting the outsourcing related expenses. Furthermore, biochar (secondary product in the energy recovery process) employment as fertilizer can absorb excess nutrients if applied properly, even if the environmental risks associated are similar to straight poultry litter landfill spreading (Hidalgo *et al*., 2019).

Anaerobic digestion of poultry manure is used for biogas (with over 50% CH_4 content) production. This resulting fuel can be further employed in heat and electricity generation facilities. The remaining digestate could be used as crop fertilizer, but high ammonia concentration in the raw waste and residual bacteria in the digestate represent an important concern (Kelleher *et al*., 2002).

Direct combustion is not a very effective waste-to-energy conversion technology using poultry manure, because of its high moisture content (which represents a drawback is exceeds 10%) (Mihaescu *et al*., 2019). However, dry poultry litter has good calorific values. Additional concerns are linked to the ammonia, potassium and sodium fractions, posing problems not only in the actual burning process, but also from the harmful emissions perspective (Lazaroiu *et al*., 2018). Other important factors influencing combustion efficiency refer to fuel supply chain, moisture content and temperature of the poultry litter, as well as the duration of outdoor storage. Investigations reported in the literature estimate a net electricity production through poultry manure direct combustion in the range 0.75 to 1.15 kWh/kg_{manure} (Cavalaglio *et al*., 2018).

Another technology employed for poultry manure treatment is pyrolysis. In this process, the waste is heated up to high temperatures, in an environment lacking oxygen. The direct products (biogas or biofuel) are suitable for electricity generation, while the secondary biochar can be used as fertilizer (containing high phosphorus and potassium contents per mass unit, enabling a net zero economic value in the bioeconomy framework) (Mihaescu *et al*., 2018). Although both direct products issue greenhouse gases during combustion, the resulting environmental impact is much lower compared to fossil fuels, due to net CO_2 neutrality. Although pyrolysis is a feasible solution, both from environmental and technical points of view, the mass processing infrastructure for medium to large scale applications is not yet available (Hadroug *et al*., 2019).

Aims of Research

This paper introduces a multi-waste management concept, representing a sustainable solution to reduce industry's carbon footprint, answering multiple requirements in the environmentally friendly energy sector development. More in detail, the paper presents a case study aiming to provide a sustainable local poultry waste management solution by means of energy recovery approaches. The energy independence level is assessed in two scenarios. To this regard, the energy consumption of a real poultry production hall of 910 m^2 (located in Giurgiu County, having 4650 birds/operating cycle, with a poultry waste flow of 558 kgwaste ⁄day) is taken into account. The first scenario analyzes the disposal (for energy recovery purposes) of poultry waste as an individual raw material,

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while the second scenario investigates a mixture of poultry waste and agricultural biomass residues. It is demonstrated that the electricity and heating requirements of the hall can be partially satisfied in the first scenario and fully in the second one.

WASTE CHARACTERISTICS

From the point of view of the classification of waste used experimentally, poultry manure and / or by-products of crops and forests, depending on its nature it is from the category of household and assimilated waste, and depending on its origin it is from the category of agricultural and food waste, organic waste, which requires collection procedures and particular treatments.

In the analysis of the optimal waste treatment chain with energy recovery, the results obtained from the environmental impact analysis, the energy analysis and the economic analysis, respectively, will be taken into account.

As a result of increased demand, poultry production has expanded in Romania, creating the need to properly manage wastes generated by this industry. The most common method over time has been to apply poultry manure to the field as nutrients.

Based on the large amount of poultry manure generated, we have advanced a case for the construction of a small power plant, which will be supplied exclusively with farm-generated poultry manure (scenario 1), or farm-generated poultry manure mixed with forest biomass (scenario 2).

Analysis of the properties of raw chicken manure, pre-dried and mixed with wood pellets confirms that the drying process is necessary for the self-sustaining combustibility of chicken manure. The use of mixtures should significantly facilitate the thermal transformation of chicken manure, regardless of the form of animal waste. The heating value of the samples is evaluated based on the elemental composition, according to equation (1) (Mihaescu *et al*., 2019):

$$Hi = 2.336 \cdot [145 \cdot C + 610 \cdot (H - 0.125 \cdot O) + 40 \cdot S + 10 \cdot N] \text{ [kJ/}kg\text{]} \quad (1)$$

where C, H, O, S and N represent the wight percentage of each element.

As expected, the biomass composition differs significantly. Wood pellets have higher organic matter and a lower ash content, resulting in a higher calorific value than that calculated for chicken manure. The results are listed in Table 1.

Table 1. Elemental analysis results

	C	H	O	S	N	H^i [kJ/kg]
Poultry manure	35.81	1.72	58.53	0.08	3.86	4 252.78
Wood pellets	52.45	6.81	40.55	0.04	0.15	20 254.32

ENERGY CONSUMPTION OF A POULTRY HALL

The bird farm Buturugeni, Giurgiu (Figure 2) is considered in this study. It is located in the southern region of Romania, where solar irradiation reaches 1400 kWh/m^2·year, corresponding to 160 W/m^2 incident direct radiation (https://solargis.com/maps-and-gis-data). The poultry farm considered in this study consists of 18 meat poultry production

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halls identical in terms of their sizing. The assessment presented here is made for an individual hall, but the results can be conveniently multiplied to include more, providing relevant information about the energy independence capability of the entire farm.

The specific production parameters vary depending on the age of the birds, from 32.5℃ and 50-70% relative humidity, to 21℃ and 60-70% relative humidity. it is considered a herd of 4650 birds/operating cycle. The heat flow generated by the birds is of 0.12 $kW/$bird, and the manure flow reaches M = 558 $kg/$day.

Figure 2. Details of Buturugeni poultry farm

Poultry Hall Geometry

The geometric characteristics of each hall are the following: Length: L = *76.9 m*; Width: W = *11.84 m*; Height: H = *3.8 m*; Roof surface: A_{roof} = *1 138.12* m^2. The surface of the side walls is determined as: A_{walls} = *674.42* m^2.

Electricity Consumers

Each hall is illuminated by 26 fluorescent tubes, with a power of *58 W*/fluorescent tube. Heating, ventilation and other requirements are satisfied as follows:

- 2 radiators, with a rated power of *12 kW/radiant*;
- 4 motors of *0.55 kW/motor*, with reducer and power supply sensor, ensure the feeding of the bird supply coils with fodder;
- 1 motor *1.5 kW* for feeding the outer hopper;
- 6 fans/hall, of *35* m^3/h per fan, with a rated power of *1.5 kW/fan*;
- 1 variable front fan/hall, with a power of 0.55 *kW*.

RESULTS AND DISCUSSIONS

Based on the geometry characteristics and electricity load and consumption data, the inlet heat flows (1 – radiative flux, 2 – ventilation airflow, 3 – birds body heat, 4 – internal misting flow), the heat losses and accumulated heat are determined. Then, considering the manure flow, the possible amount of energy to be generated in both scenarios (taking into account a global waste-to-electricity conversion efficiency of *0.4*) is evaluated.

In scenario 1, the energy independence level ensured by exploiting the exclusively the poultry manure reaches 25%. Regarding scenario 2, a sensitivity analysis is performed in reference to the share of biomass (having the properties in Table 1). According to Figure 3 it is noticeable that a full energy independence level is achieved

https://doi.org/10.24264/icams-2020.IV.12

for a biomass share of 80%. Depending on the biomass supply conditions, a tradeoff between the energy independence level and biomass costs has to be accepted.

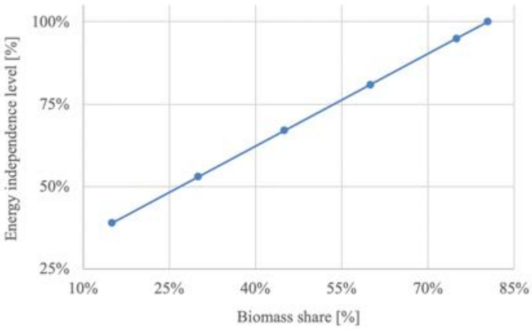

Figure 3. Sensitivity analysis in reference to the biomass share in scenario 2

CONCLUSIONS

In the field of zootechnical production, waste recovery is required by the extension of concentration and specialization by species and products. Continuous reduction of specific consumptions and improvement of production technologies, storage and treatment of zootechnical residues are the main trends in the field. Agriculture can become the main user of all livestock waste, thus ensuring a renewable energy supply while providing high quality production and protecting the environment. In conclusion, energy recovery in a multi-waste approach is a viable solution to reduce industrial energy consumption, but also to optimize the costs of managing and disposing of wastes. Specifically, the energy independence level can be increased from 25% up to 100% by mixing the poultry manure with a higher calorific value biomass residue.

Acknowledgments

This work was supported by a grant from the Romanian Ministry of Research and Innovation, CCCDI—UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0404/31PCCD/2018, within PNCDI.

REFERENCES

Cavalaglio, G., Coccia, V., Cotana, F., Gelosia, M., Nicolini, A., and Petrozzi, A. (2018), "Energy from poultry waste: An Aspen Plus-based approach to the thermo-chemical processes," *Waste Manag.*, 73, 496–503, https://doi.org/10.1016/j.wasman.2017.05.037.

Duić, N. and Rosen, M.A. (2014), "Sustainable development of energy systems", *Energy Convers. Manag.*, 87, 1057–1062, https://doi.org/10.1016/j.enconman.2014.08.046.

European Commission (2008), "Directive 2008/98/EC of The European Parliament and of the Council of 19 November 2008 on Waste and repealing certain Directives".

Hadroug, S. *et al.* (2019), "Pyrolysis process as a sustainable management option of poultry manure: Characterization of the derived biochars and assessment of their nutrient release capacities," *Water (Switzerland)*, 11(11), 1–18, https://doi.org/10.3390/w11112271.

Hidalgo, D., Martín-Marroquín, J.M., and Corona, F. (2019), "A multi-waste management concept as a basis towards a circular economy model", *Renew. Sustain. Energy Rev.*, 111, 481–489, https://doi.org/10.1016/j.rser.2019.05.048.

Kelleher, B.P., Leahy, J.J., Henihan, A.M., O'Dwyer, T.F., Sutton, D., and Leahy, M.J. (2002), "Advances in poultry litter disposal technology - A review", *Bioresour. Technol.*, 83(1), 27–36,

https://doi.org/10.24264/icams-2020.IV.12

https://doi.org/10.1016/S0960-8524(01)00133-X.

Klemeš, J.J., Varbanov, P.S., Walmsley, T.G., and Foley, A. (2019), "Process Integration and Circular Economy for Renewable and Sustainable Energy Systems", *Renew. Sustain. Energy Rev.*, 116(October), https://doi.org/10.1016/j.rser.2019.109435.

Krajačić, G., Duić, N., Vujanović, M., Kılkış, Ş., Rosen, M.A., and Al-Nimr, M.A. (2016), "Sustainable development of energy, water and environment systems for future energy technologies and concepts", *Energy Conversion and Management*, 125, 1–14, https://doi.org/10.1016/j.enconman.2016.08.050.

Lazaroiu, G. *et al*. (2018), "Experimental Investigations of Innovative Biomass Energy Harnessing Solutions", *Energies*, 11(12), 3469, https://doi.org/10.3390/en11123469.

Mihaescu, L., Lazaroiu, G., Pisa, I., Ciupageanu, D.-A., and Berbece, V. (2018), "Energy valorization of poultry manure through products resulted in a pyrolysis process", in: *18th International Multidisciplinary Scientific GeoConference SGEM2018*, 349–355, https://doi.org/10.5593/sgem2018/4.1/S17.046.

Mihaescu, L., Lazaroiu, G., Pisa, I., Negreanu, G.-P., Berbece, V., and. Ciupageanu, D.-A. (2019), "Thermal conditions required for poultry manure combustion in furnace boilers", in: *19th International Multidisciplinary Scientific Geoconference SGEM2019*, 19(4.1), 569–576, https://doi.org/10.5593/sgem2019/4.1/S17.073.

Sarfaraz, Q. *et al*. (2020), "Characterization and carbon mineralization of biochars produced from different animal manures and plant residues", *Sci. Rep.*, 10(1), 1–9, https://doi.org/10.1038/s41598-020-57987-8.

Solargis, Solar resource maps and GIS data for 200+ countries, https://solargis.com/maps-and-gis-data.

*** (2011), "Waste regime", Romanian Law 211/2011.

*** (2015), "Closing the loop — An EU action plan for the circular economy, COM(2015) 614 final. A circular economy is one in which the value of products, materials and resources is maintained for as long as possible, minimising waste and resource use."

https://doi.org/10.24264/icams-2020.IV.12

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