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ENVIRONMENTAL EVALUATION OF PORK MEAT CHAIN: A ROMANIAN CASE STUDY

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Abstract. *The aim of this paper was to establish the environmental impacts of pork meat chain using life cycle assessment (LCA) methodology. For this study the system boundaries included: pig farm, slaughterhouse, meat processing, transport and waste treatment, which represent the main and secondary activities of a Romanian pork meat producer. All inputs and outputs data necessary for the inventory analysis were collected from this producer, GaBi database and other sources. The impact assessment phase was performed with GaBi software which includes LCA methods like CML2001 - Jan. 2016, ReCiPe 1.08, UBP 2013 and EDIP 2003. The results showed that pork meat chain has negative impact on the environment mainly contributing to the Acidification Potential (AP), Photochemical Ozone Creation Potential (POCP), Eutrophication Potential (EP) and Global Warming Potential (GWP 100 years). According to the results obtained with CML2001 - Jan. 2016 method, the main activities that contribute to global warming potential are manure storage (67.10%), central heating system (13.56%) and intensive pigs growth (9.59%). Similar results were obtained by applying of UBP 2013 method which indicated also that the manure storage is the main contributor to GWP (66%) followed by central heating system (14.33%) and intensive pigs' growth (9.43%). Wastewater treatment is obvious the main contributor to 'water pollutants' category, while water consumption has a significant impact on 'water resources' according to UBP 2013 method. Resources like water and energy are necessary in very large quantities in meat production from which solid waste and wastewater result, thus increasing the environmental impacts of this process.*

Keywords: *food industry, global warming potential, life cycle assessment, waste*

1. Introduction

Food commodities such as meat and dairy products have significant impacts on the environment [1, 2]. From all activities included in the life cycle of meat products, starting from farming stage until final waste disposal, there result environmental emissions [1]. Pork meat is the most popular meat in the world according to [3], the larger producer is China followed by Europe [1]. Approximately 22.2 million tonnes of this meat was produced in Europe, in 2014 (Fig. 1). In the same year 13 million tonnes of poultry meat, 7.3 million tonnes of bovine meat and 0.8 million tonnes meat from sheep and goats were produced and processed [4]. Most slaughtered pigs in the EU in 2014 were in Poland, over 1000 tonnes, followed by Romania with 800 tonnes and Hungary with about 500 tonnes (Fig. 2).
At global level the average pork meat consumption is of 15 kg/capita/year, while in Europe is of approximately 40 kg/capita/year [5]. In Romania, there was a continuing decline in the production of meat for consumption [6]. Between 2001 and 2013 the largest meat production in Romania was in 2003, namely 710 thousand tonnes, and the smallest production of 553 thousand tonnes in 2010.

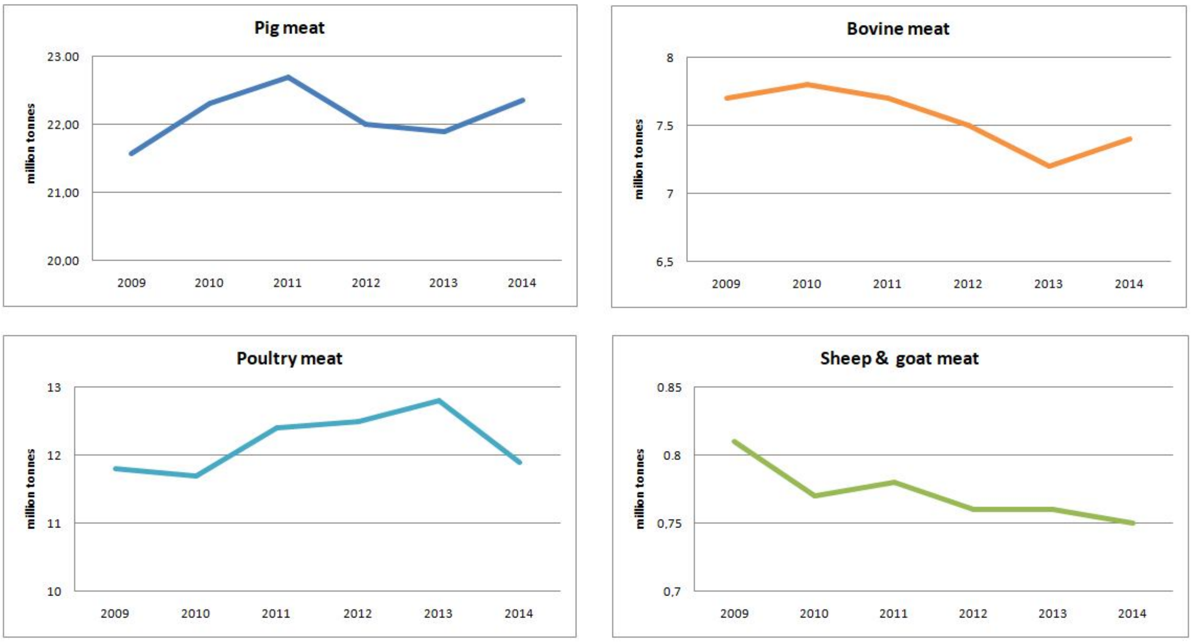


Fig. 1. Meat production by species, EU-28, 2009-2014 (million tonnes) (according to [4])

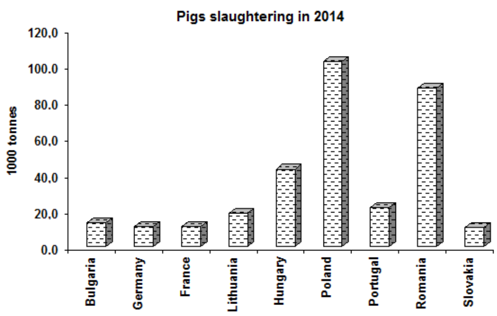


Fig. 2. Pigs slaughtering in 2014, in Europe (adapted from [4])

Life cycle assessment (LCA) is a useful tool which can be applied in the determination of environmental impacts resulted from complex food systems. LCA was applied in various studies to evaluate agricultural and food processing activities (among them: production of rice, fruits, bread, milk, beef, pork meat etc.):

- all life cycle from paddy field to the supermarket of rice production system were evaluated by [7]. They showed that the production of 1 kg of rice produces 2.9 kg of CO_2;
- Ghinea [10] evaluated the production, consumption and loss of apple fruits from the environmental point of view; Vinyes et al. [11] investigated the production, distribution and consumption of fruits like apple and peach in the Mediterranean area, while Longo et al. [12] compared the environmental impacts of organic and conventional apple production from Italy;
- 0.97 to 1.24 kg CO_2 eq. per loaf of bread (800 g) are the results obtained by [8] after evaluation of bread produced and consumed in the UK;
- the environmental impacts of 1 kg of packaged ultra-high temperature (UHT) milk were determined by [9] and for the global warming potential, these authors obtained a value of 0.73 kg CO_{2eq};
- Beauchemin et al. [13] investigated greenhouse gas emissions (GHG) from beef production and estimated the intensity of GHG at 22 kg CO_2 equivalent (kg carcass)$^{-1}$;
- Gonzalez-García et al. [1] calculated the environmental impacts of Portuguese pork meat production and reported a value of 3.3 kg CO_2 eq kg^{-1} pig carcass weight;

- McAuliffe et al. [14] compared the environmental performances of intensive pig production units and estimated a value of 3.5 kg CO_2-eq per kg carcass weight.

In this study LCA was applied in order to establish the environmental impacts of pork meat chain considering the main activities of a Romanian pork meat producer: pig farm, slaughterhouse, meat processing, transport and waste treatment.

2. Materials and methods

2.1. Goal, scope and functional unit

The main aim of this study was to determine the environmental impacts resulting from a Romanian pork meat producer by applying LCA methodology. One tool namely GaBi software, which includes LCA methodology [15-17], was used for the modelling of the considered system. The system boundaries established for this evaluation are illustrated in fig 3. The functional unit considered was the amount of meat products obtained in one year by one Romanian pork meat producer. Table 1 presents the potential emissions which may result from the investigated activities.

2.2. Inventory analysis

Activities included in the evaluated system were: growing and fattening of pigs, preparation of hot water, fresh water supply, meat products manufacturing, primary treatment of wastewater and manure management, organic waste incineration and other related activities. It is considered that for pigs growing from 25 kg up to 110 kg of live weight, about 260 kg of feed is consumed [18]. Also, from pig breeding and fattening are resulting 14000 kg/day of manure.

The main raw materials used in the production of meat products are: pork, beef and poultry, organs and edible by-products of slaughterhouse, bacon and other animal fats. The auxiliary materials are composed of: spices and food additives, membranes and coating materials, packaging materials.

It was considered a production level of 14,000 heads/year and 7700 maximum accommodation capacities (for pig breeding and fattening); 350 pigs (weighing between 95 and 105 kg each) slaughtered daily and 10,000 t/year meat products - processed under normal operating conditions of the target. The annual quantities of raw materials, auxiliaries and fuels used to obtain pork meat products are presented in Table 2. Within the outputs of the process besides the meat products can be mentioned: organic waste - 475 tonnes, plastic waste - 25 tonnes, wood waste - 100 tonnes, bones - 30 tonnes, paper and cardboard waste - 7 tonnes, ash from the incinerator – 16 tonnes and others. The utilities necessary for the technological process are: groundwater captured from the underground, electric energy taken from the national system, thermal energy obtained in its own plant, sawdust for the production of smoke in its own generators, ammonia and gas butane. Annual energy consumption is approximately 3600 MWh (2013-2014) and specific consumption is within the limits recommended by [18]. This consumption is represented by: slaughterhouse - approx. 1875 MWh; the food factory - approx. 1492 MWh; zoo-technical complex - approx. 250 MWh. Chemical substances used (annual consumption) or owned: NaOH - 8500 kg (for wastewater treatment), H_2SO_4 8 L; CH_3COOH 2 L; HCl 1 L; $(C_2H_5)_2O$ 2L; petroleum ether 15 L; naphthylamine 25 g; K_2CrO_4 1 kg; acetone (C_3H_6O) 1L; $NaNO_2$ 1 kg. Other chemicals used for different purposes: detergents (280 L/month), descaler (230 L/month), disinfectants (115 L/month), degreasers (218 l/month), liquid soap (210 L/month), $Fe_2(SO_4)_3$ (4 tonnes/month for wastewater treatment) polyacrylamide (125 kg/month for wastewater treatment). Emissions of gaseous pollutants from the process and the heat and power plant are: CO_2, CO, NO, NO_2, NOx, SO_2 and particulate matter. Ammonia (NH_3) is emitted in air from animal housing, storage of manure and land spreading of manure. Methane (CH_4) comes from animal housing, storage of manure and manure treatment. From animal housing, manure storage and land spreading is also emitted nitrous oxide (N_2O) and odour (e.g. H_2S) [18, 19].

The mass emissions of pollutants from the thermal plant registered in one year are: 1242 t of CO_2, 46.2 kg of CO, 2712 kg of NOx, 1627 kg of SO_2 and 172 kg of particulate matter. The determined and admitted values by the legislation are presented in the Table 3 [20]. From smoking cells are emitted approximately 76.25 mg/Nm^3 CO. In the case of the incinerator the air emissions established were: NO_2 (56 mg/Nm^3), SO_2 (47 mg/Nm^3), CO (0.12 mg/Nm^3). These values fall within the permissible limits [20]. The total average water requirement is 681.5 m^3 and the maximum total water demand is 723 m^3. The daily water consumption was 380 m^3 and the specific consumption of water for pigs was calculated at 31 L/head/ day. The values of the emissions in the water are below the limits allowed by the Romanian legislation (Table 4, [21]). Also, the concentration of nitrate (N - NO_3), ammonium (N-NH_4), total nitrogen (N), total phosphorus (P), chlorides and synthetic detergents falls within the limits set by NTPA 001/2005 [21]. From land spreading and manure storage are emitted in soil in groundwater: nitrogenous compounds, phosphorus, K and Na, heavy metals and antibiotics [18].

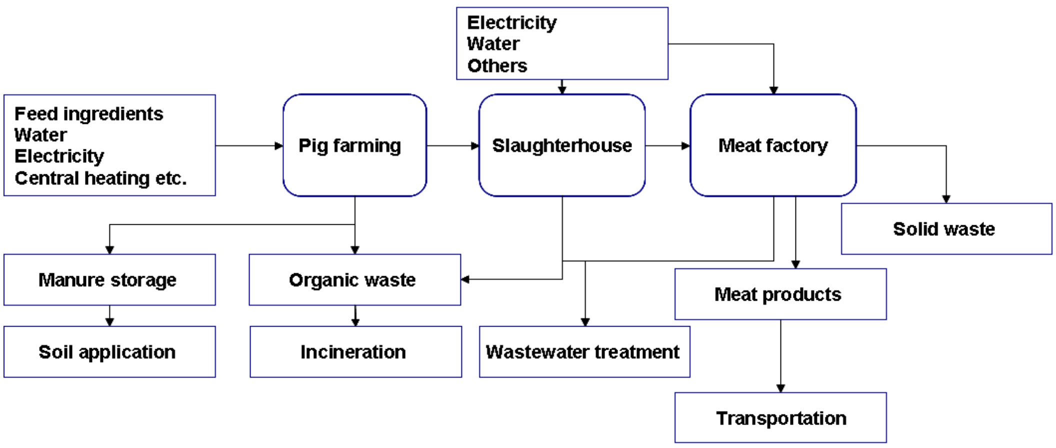


Fig. 3. System boundaries

Table 1.

Potential emissions of activities included in the evaluated system [18, 19]

Activities	Potential emission
Housing of animals	Air emissions, odour, manure, dust, noise, wastewater
Storage of feed and feed additives	Dust
Storage of manure	Air and soil emissions, odour
Storage of other residues	Soil and groundwater emissions, odour
Storage of carcases	Odour
Manure landspreading	Emissions to air, soil, water and groundwater, odour, noise
Incineration of residues	Air emissions, odour

Table 2.
Raw materials, auxiliaries and fuels used for producing of meat products

Raw materials, auxiliaries and fuels	*Unit*	*Annual quantity*
Pork, beef and poultry meat	t	7000
Spices and additives	t	500
Membrane	m	7500
Flexible plastic packaging	t	25
Wood sawdust	t	20
Fuels	t	450
Detergents and hygienic substances	t	10

Table 3.
Emissions from the thermal plant admitted and determined values

	Emissions concentration, mg/Nm^3			
	CO	**NO_2**	**SO_2**	**Particulate matter**
Determined values	8.8	311	189	32.8
Admitted values, alert threshold according to the order MAPPM 462/93 [20]	119	315	1190	35
Admitted values, intervention threshold according to the order MAPPM 462/93 [20]	170	450	1700	50

Table 4.
Wastewater emissions admitted and determined values

Wastewater	**Cu^{2+} (mg/L)**	**Ni^{2+} (mg/L)**	**Zn^{2+} (mg/L)**	**Cd^{2+} (mg/L)**	**Pb^{2+} (mg/L)**
HG 352/2005-NTPA 001 [21]	0.1	0.5	0.5	0.2	0.2
Determined value	0.02	0.021	0.32	0.007	0.015

Soil analysis has shown that emissions fall within the limits imposed by current legislation (Order 756/1997): Cd (0.13 mg/kg determined – 3 mg/kg admitted), total Cr (7.52 mg/kg determined – 100 mg/kg admitted), Cu (13 mg/kg determined – 100 mg/kg admitted), Ni (26 mg/kg determined – 75 mg/kg admitted) [22]. For transportation stage of meat products were calculated the air emissions (CO_2, CO, NO_x, N_2O, PM10, CH_4, SO_2 and hydrocarbons) considering the emissions resulted from burning 1 kg of diesel. Based on the values presented above (and others) were calculated, determined and estimated all the necessary inputs and outputs for each activity included in the system (Fig. 3).

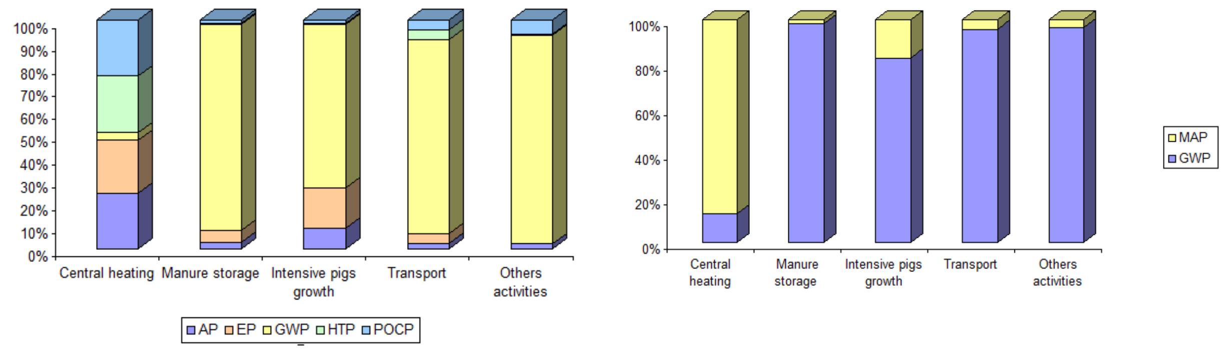
2.3. Life cycle impact assessment, results and discussion

In the impact assessment stage the data obtained in the inventory phase were modelled with GaBi software. The values for impact categories such as: acidification potential (AP), eutrophication potential (EP), global warming potential (GWP), human toxicity potential (HTP), photochemical ozone creation potential (POCP), main air pollutants (MAP), aquatic eutrophication (AE), terrestrial eutrophication (TE), stratospheric ozone depletion (SOD), climate change - ecosystems (CchE), climate change - human health (CcHh) were determined by applying LCA methods like CML2001 - Jan. 2016, ReCiPe 1.08, UBP 2013, EDIP

2003. The emissions which contribute to these impact categories are presented in [15-17]. In Fig. 4 are illustrated the main contributors to the environmental impacts. It can be observed that the main activities that contribute to global warming potential are manure storage (67.10%), central heating system (13.56%), transport (%) and intensive pigs' growth (9.59%).

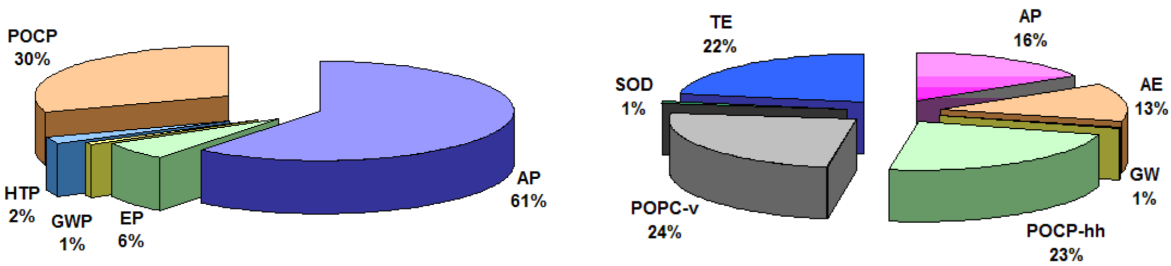
The environmental impacts of pork products obtained by applying CML 2001 - Jan. 2016 and EDIP 2003 LCA methods are presented in Fig. 5. The results obtained with CML method indicate that the manufacturing of pork products contribute mainly to AP (61%), followed by POCP (30%) and to a lesser extent to the other impact categories (Fig. 5a). The results obtained with the second method (EDIP 2003) indicate that production of pork products mainly influences photochemical ozone formation potential (impact on human health (POCP – hh) and impact on vegetation (POCP-v)) and terrestrial eutrophication (Fig. 5b).

With ReCiPe method were obtained the normalised values (in PE = person equivalents) for climate change impact category (CchE, CcHh) (Fig. 6). Three cultural perspectives: egalitarian (E), hierarchist (H), individualist (I) were considered for the evaluation. It can be observed that the pork meat chain has negative impacts on the environment since all the values are positive. For the climate change impact on human health were registered the highest values. Also, Fig. 6 shows that the individualist perspective provides the higher values compared with the other two.



a) b)

Fig. 4. Contribution to the environmental impacts of central heating, manure storage, intensive pigs growth and transport a) CML 2001 - Jan. 2016 and b) UBP 2013 methods



a) b)

Fig. 5. Environmental impacts of manufacturing of pork products obtained by applying: a) CML 2001 - Jan. 2016 and b) EDIP 2003 LCA methods

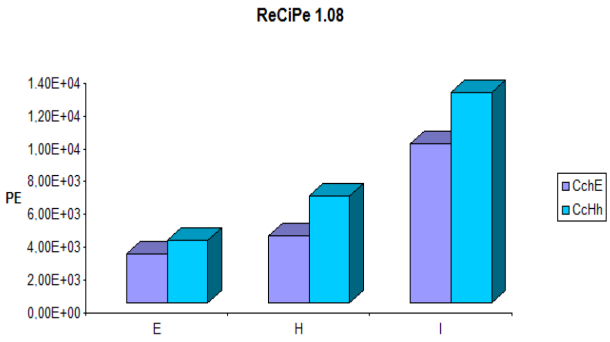


Fig. 6. Impact on climate change of pork meat supply chain (CchE- Climate change Ecosystems; CcHh- Climate change Human Health)

According to [19] the greenhouse emissions for pig production in EU27 there were estimated at 7.55 kg CO_2-eq./kg of pork meat produced (including CH_4 – 0.74 kg CO_2-eq./kg of pork meat produced, N_2O – 1.71 kg CO_2-eq./kg of pork meat produced, CO_2 related to energy consumption – 2 kg CO_2-eq./kg of pork meat produced, CO_2 related to land use – 3.1 kg CO_2-eq./kg of pork meat produced).

3. Conclusions

The environmental impacts of the main and secondary activities of a Romanian pork meat producer (pig farm, slaughterhouse and meat processing, transport and wastewater treatment, incineration of organic waste) were investigated in this paper. Determination of these impacts was performed by applying LCA methodology.

The results showed that the central heating is the main emitter of pollutants contributing to all impact categories. Manure storage, transport and intensive pig growth are the activities which contribute significantly to GWP. Also, intensive pig growth has a major contribution to EP. The main air pollutants come from central heating and manufacturing of pork products contributes mainly to AP and POCP.

4. Acknowledgments

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