LIFE CYCLE ASSESSMENT OF PIG PRODUCTION - A CASE STUDY IN MEXICAN FARM

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ABSTRACT

The porcine mexican sector has an important participation worldwide, dynamics of growth has positioned it inside the principal producing countries, in such a way that, not only competes in satisfying the needs of the market, also in the creation of social value. The answer to environmental problems is for companies an indicator of competitiveness. The aim of this study was to evaluate the environmental burdens associated with pig production in a full-cycle farm, using life cycle assessment methodology. All activities carried out in the pig farm were evaluated (breeding, lactating, weaning, rearing-start, growth, development and finishing pig). The inventory integrates data on livestock feed, water and electricity consumption, as well as manure emission factors. The inventories were processed in the OpenLCA software version 1.7. The characterization factors of the ReCiPe Midpoint method were used. The results present impacts in the categories Agricultural land occupation, Climate change, Freshwater

eutrophication, Marine eutrophication, Particulate matter formation, Photochemical oxidant formation, Terrestrial acidification and Water depletion.
Keywords: *environmental burdens, pig, sustainability*

1. INTRODUCTION

The market dynamics of pork production has presented a trend of productive growth and consumption during the last decade, Mexico is positioned in the tenth place among the main producers worldwide (USDA, 2018). Associated with productive growth, pig farming is considered as direct and indirect cause of environmental impacts, generated in the different stages that make up the productive system, from cultivation of fodder grains, production of food for livestock, animal production, to slaughter. (González et al., 2015). One of the main challenges for this sector is to achieve the reduction of the emissions generated to the environment and at the same time to be able to satisfy the market demand (MacLeod et al., 2013). The competitiveness of swine companies depends on their efficiency in the economic, environmental and social fields. Buxel et al. (2015) explains the need for the use of tools that provide elements for understanding the environmental aspects involved in production and that allow the identification of critical points that require strategies to improve processes and products. Life Cycle Analysis (LCA), is considered a tool that allows identifying and prioritizing areas of intervention to reduce emissions generated in a productive activity (McAuliffe et al., 2016). The aim of this study is to identify and evaluate the environmental burdens associated with the production of 110 kg of live weight pig, from a Life Cycle Analysis approach.

2. METHODOLOGY

For the environmental evaluation of the present study, it was used in the Life Cycle Analysis approach, in accordance with the phases established by ISO 14040 and 14044 (ISO, 2006a, 2006b).

2.1. Goal and scope definition

The goal of this study is to identify and evaluate the environmental burdens associated with pig production in a full-cycle farm located in Temascaltepec, State of Mexico (Central Mexico). Was performed through a gate-to-farm gate perspective, only stages of pork production are considered. The functional unit was defined as 110 kg live weight of pig at farm gate, which is the weight that the pig must reach before being sent to slaughterhouse.

2.1.1. Description of the system

The LCA in this study is limited to the productive cycle of 110kg of live weight pig. The flow diagram (figure 1) shows the processes carried out in the full-cycle pig farm (production of piglets that are raised and fattened until obtaining 110 kg of weight required for slaughter).

Figure following on the next page

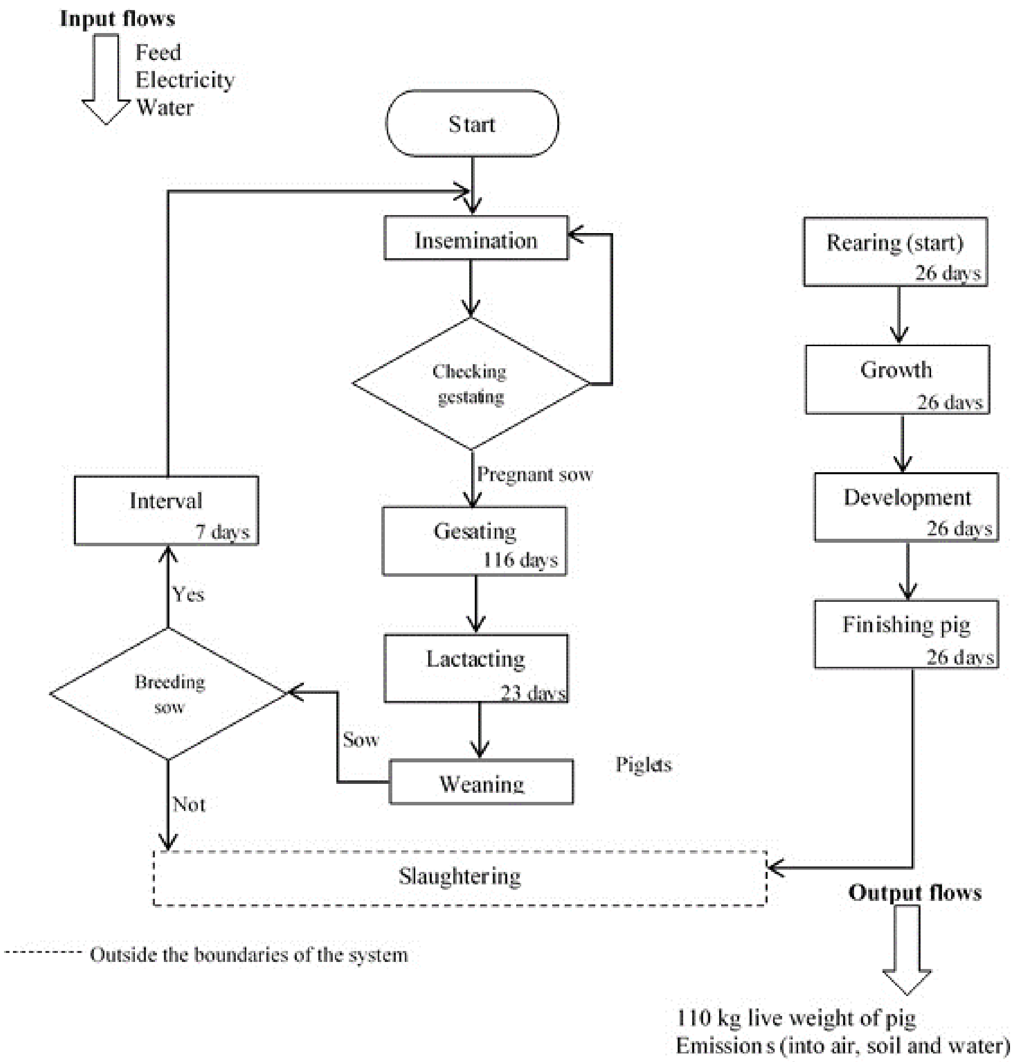

Figure 1: System boundaries of the pig production. Shaded box corresponds to processes excluded from the assessment

The pigs are housed in a total confinement system, are separated according to their productive stage. In the breeding phase the sows are inseminated, once the fertilization is certified, they are taken to the gestation area where remain for 116 days, one week before delivery are transferred to the maternity ward where will remain for 23 days, which is the period of lactation; for each litter an average of 12.5 piglets are born, there is a mortality of 16%, that is, at the end of the phase 10.5 piglets are weaned, the piglets must have an average weight of 7.37kg at weaning. The sows return to the service area and wait 7 days before being inseminated to start a new cycle. The weaned piglets are moved to the breeding sheds where they are fed with pre-initiators for 26 days to reach a weight of 19.28 kg and be taken to the start area whose period is 26 days until achieving a weight of 35.45 kg. Finally, are transferred to the fattening area for a period of 78 days, 26 days are fed a diet of growth to have a pig of 55.78 kg, 26 days with a diet of development to achieve a weight of 80.27 kg and 26 days with a finishing diet until reaching 110 kg. The water supply for the pigs is carried out by means of pacifier drinking troughs, installed in production facilities. In the service, gestation and lactation sections, daily cleaning is carried out with drag chain and in the weaning and fattening sections cleaning is done weekly with system based on high pressure water. The consumption of electricity is required in all areas of the production system, in the lactation and weaning area is used mechanical ventilation and infrared lamps as a heating system.

2.2. Inventory analysis

The data for the inventory analysis of the porcine system under study were obtained from primary information through a survey applied to the owner and visits to the production facilities. The farm has an extension of 0.51 ha, divided into: breeding area (insemination and gestation), lactating area, rearing area (weaning and start) and fattening area (growth, development and finishing). The inputs for livestock feeding are acquired in a food factory located 40 km from the farm. The water consumption calculations were made according to the physiological state of the pig (Boulanger, 2011). The electricity consumption was provided in the survey. The inventory data corresponding to the functional unit are described in table 1.

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Table 1: Inventory data by functional unit (Production 110 kg live weight of pig)

	Breeding	Lactating	Weaning	Rearing (Start)	Growth	Development	Finishing pig	Unit
Inputs								
Breeding feed	27.65	-	-	-	-	-	-	kg
Lactating feed	-	9.86	-	-	-	-	-	kg
Pre-initiator	-	-	12.29	-	-	-	-	kg
Starter feed	-	-	-	32.5	-	-	-	kg
Growth feed	-	-	-	-	49.92	-	-	kg
Development feed	-	-	-	-	-	65	-	kg
Fattening feed	-	-	-	-	-	-	78	kg
Water	221.53	90.27	86.78	116.68	146.58	183.95	290.10	L
Transport of feed	27.65*40	9.86*40	12.29*40	32.50*40	49.92*40	65.00*40	78.0*40	Kg* km
Electricity	2.71	0.89	1.16	1.16	1.16	1.16	1.16	kWh
Outputs								
Pig live weight	1.50	7.37	19.28	35.45	55.78	80.27	110	Kg
Manure								
Mass	16.59	6.75	7.37	19.50	29.95	39.00	46.80	Kg
Nitrogen	0.25	0.18	0.11	0.29	0.45	0.59	0.70	Kg
Phosphorus	0.12	0.01	0.05	0.14	0.21	0.27	0.33	Kg
Potassium	0.28	0.03	0.13	0.33	0.51	0.66	0.80	Kg
Air emissions								
CH_4								
Enteric fermentation	16.59	6.75	7.37	19.50	29.95	39.00	46.80	Kg
Manure management	11.52	4.69	5.12	13.53	20.79	27.07	32.48	Kg
N_2O (nitrus oxide)	0.08	0.03	0.04	0.10	0.15	0.20	0.23	Kg
NH_3 (ammonia)	0.17	0.07	0.07	0.20	0.30	0.39	0.47	Kg
NOx (nitrogen oxides)	0.17	0.07	0.07	0.20	0.30	0.39	0.47	Kg
Water emissions								
NO_3^- (nitrate leaching)	0.12	0.05	0.06	0.15	0.22	0.29	0.35	Kg
PO_4^- (phosphate leaching)	0.17	0.07	0.07	0.20	0.30	0.39	0.47	Kg

The emissions of this system: methane (CH_4), nitrus oxide (N_2O), ammonia (NH_3) y nitrogen oxides (NOx), come mainly from enteric fermentation and manure management, were calculated considering the emission factors with the methodology of the Intergovernmental Panel on Climate Change (IPCC), calculated for the livestock sector in Mexico (FAO-SAGARPA, 2012).

2.3. Impact assessment

The modeling of the inventory data was performed in OpenLCA Software Version 1.7 (OpenLCA, 2018), to obtain the relative contribution of the inventory data to the different impact categories, the characterization procedure established by ISO 14040 was used (Rosembaum et al., 2018), with the method ReCiPe Midpoint E (Goedkoop et al., 2009) which deals with 18 categories described in table 2.

Table 2: Impact categories evaluated by the method Recipe Midpoint E (Acero et al., 2017).

Category	Description	Unit
Agricultural land occupation (ALO)	Loss of land as a resource. Amount of land not available for another activity.	m^2*a
Climate Change (CC)	Emissions of greenhouse gases generated by anthropogenic activities.	kg CO_2 eq
Fossil depletion (FD)	Extraction of reserves of natural gas, oil and coal at a rate greater than nature replaces it.	kg oil eq
Freshwater ecotoxicity (FEC)	Impact of heavy metals on freshwater ecosystems. Your reference unit is kg 1,4-dichlorobenzene equivalent.	kg 1,4-DB eq
Freshwater eutrophication (FEU)	It refers to the excessive growth of aquatic plants or algae blooms, due to the high levels of nutrients in freshwater ecosystems such as lakes, reservoirs and rivers.	kg P eq
Human toxicity (HT)	Impacts on health due to heavy metal emissions. Its reference unit iskg 1,4-dichlorobenzene equivalent.	kg 1,4-DB eq
Ionising radiation (IR)	Related to the damage to human health and ecosystems that are linked to radionuclide emissions throughout a product or life cycle.	kg U235 eq
Marine ecotoxicity (MEC)	Impacts of heavy metals on the ecosystem.	kg 1,4-DB eq
Marine eutrophication (MEU)	It refers to the excessive growth of aquatic plants or algal blooms, which causes severe reductions in water quality and animal populations.	kg N eq
Metal depletion (MD)	Depletion of abiotic resources.	kg Fe eq
Natural land transformation (NLT)	Impact on land due to agriculture, anthropogenic settlement and resource extractions.	m^2
Ozone depletion (OD)	Decrease in the stratospheric ozone layer due to anthropogenic emissions of substances that deplete the ozone layer.	kg CFC-11 eq
Particulate matter formation (PMF)	Extremely small suspended particles originated by anthropogenic processes such as combustion, extraction of resources, etc..	kg PM10 eq
Photochemical oxidant formation (POF)	Type of smog created from the effect of sunlight, heat, volatile organic compounds other than methane (NMVOC).	kg NMVOC
Terrestrial acidification (TA)	Reduction of pH due to the acidifying effects of anthropogenic emissions. Increase soil acidity.	kg SO_2 eq
Terrestrial ecotoxicity (TE)	Toxic effects of chemical products in an ecosystem.	kg 1,4-DB eq
Urban land occupation (ULO)	Activities carried out in a specific place and its level of spatial accumulation.	m^2*a
Water depletion (WD)	Decrease in water availability.	m^3

3. RESULTS (INTERPRETATION OF LIFE CYCLE IMPACT)

The evaluation allowed identifying the main impacts in the categories ALO, CC, FEU, MEU, PMT, POF, TA y WD. Table 3 shows the results of characterization in each phase of the productive cycle of 110 kg of live weight pig. The phases of growth, development and completion present the greatest environmental burdens in the impact categories.

Table 3: Results of the impact evaluation by functional unit (Production 110 kg live weight of pig).

Impact category	Breeding	Lactating	Weaning	Start	Growth	Develop-ment	Finish-ing pig	Total	Avg	sd
ALO (m^2*a)	12.23	8.75	0.45	0.45	0.83	0.83	0.83	24.37	3.48	4.53
CC (kg CO_2 eq)	180.68	73.54	80.31	212.34	326.16	424.69	509.62	1807.34	258.19	155.57
FEU (kg P eq)	0.59	0.24	0.26	0.69	1.06	1.38	1.65	5.86	0.84	0.50
MEU (kg N eq)	0.15	0.06	0.06	0.17	0.26	0.34	0.41	1.46	0.21	0.13
PMT (kg PM10 eq)	0.09	0.04	0.04	0.11	0.16	0.21	0.25	0.90	0.13	0.08
POF (kg NMVOC)	0.45	0.18	0.20	0.53	0.81	1.06	1.27	4.50	0.64	0.39
TA (kg SO_2 eq)	0.60	0.24	0.27	0.70	1.08	1.40	1.68	5.97	0.85	0.51
WD (m^3)	0.22	0.09	0.09	0.12	0.15	0.18	0.29	1.14	0.16	0.07

Avg=average
sd= standard deviation.

The occupation of soil of the ALO category, in this case is associated with the facilities of the farm, the production of 110 kg of live weight pig requires a space of 24.37 m^2 per year. The ReCiPe method considers the loss of biodiversity as an effect of the occupation of land use (Goedkoop, et al., 2009). For the farm, the facilities represent an asset of main importance in the development of its activities, in such a way that, the optimal use of this resource will reflect its productive, environmental and economic efficiency. The emissions generated in the farm have a significant impact in the CC category, generate 1807.32 kg de CO_2 eq greater extent in the growth phase (18%), development phase (23%) and Finishing pig phase (28%). The gases that contribute most to this category are CH_4 and N_2O related to enteric fermentation and manure management. During the fattening period (growth, development and finishing), the consumption of feed and the amount of manure generated is greater, which may explain the greater impacts in these phases. Impacts were identified in the categories related to eutrophication, associated with the amount of manure generated during the confinement of pigs with emissions of 5.86 kg P eq in the FEU category, and 1.46 kg N eq in the MEU category. Increases in phosphorus and nitrogen concentrations have effect on water resources, affecting the quality of water and species, so that the results indicate the importance of evaluating the storage, transport and application of manure. Manure management has an impact on PMT category, the functional unit evaluated generates 0.90 kg PM10 eq by NH_3 and N_2H emissions to the atmosphere. Emissions to the atmosphere are also generated in the POF category by 4.50 kg NMVOC coming from diesel combustion. The TA category presents environmental loads of 5.97 kg SO_2 eq by the generation of NH_3 and N_2O gases coming from the storage and management of manure. Finally, the WD category expresses the amount of water used in the system. The results of this evaluation indicate that the production of 110 kg of live weight pig requires 1.14 m^3 of water for feeding livestock and cleaning the productive facilities.

4. CONCLUSION

The results of the environmental evaluation in the productive cycle of 110 kg of live weight pork allowed to identify that the environmental burdens are associated with enteric fermentation, storage and management of manure during the confinement of the pig in the farm. The greatest environmental burdens are produced in the phases of growth, development and finishing, are related to the amount of food consumed and manure generated. The study allows to identify that one of the main processes to be evaluated in the farm is the storage, transport and application of manure, although the environmental burdens can´t be avoided, if can contribute to the reduction of these. In this case study, the results are considered an important element for the creation of value in the swine company, by integrating environmental sustainability using the life cycle assessment.

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