Environmental Impact Evaluation of Beef Production in Veracruz Using Life Cycle Assessment

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ABSTRACT

Life-Cycle Assessment (LCA) was utilized to compare the potential for climate change, acidification and human toxicity associated with the production of boneless beef sold to the consumer through two chains of production in Veracruz, Mexico. An intensive method based on feedlot finishing and highly technified transformation and marketing procedures was analyzed and compared to an extensive livestock-farming model up to the finishing period and adopting low technology transformation and marketing procedures. The potential impacts on every category studied were greater in the intensive chain. More methane from enteric fermentation was generated in the extensive chain due to lower quality feed compared to feedlot finishing, however the latter is associated with greater impact within the intensive chain because of production and processing of the feed raw material.

Keywords: LCA, beef , climate change, supply chain, environmental.

1. Introduction

Beef production worldwide has increased more than threefold between 1970 and 2009 (FAO 2012). The beef production supply chain has a significant impact on the environment, at every level of production (Steinfeld et al., 2006) such as the degradation of natural resources as a result of cattle feeding, land use in primary production, fossil fuel consumption, water usage and greenhouse gas emissions.

Life-Cycle Assessment has been applied in different world locations to identify the beef production environmental impact and define key points for its environmental sustainability improvement (de Boer et al., 2010). A Life-Cycle perspective provides also a useful framework to study the links between social needs, natural and economic processes related to food production, and their environmental consequences (Heller and Keoleian, 2003). In Mexico a full study to calculate the impact of the beef production chain on the environment has yet to be carried out. Therefore in this paper we used the Life-Cycle Assessment approach to evaluate two beef production chains in the state of Veracruz, Mexico. A production system involving animal growing on pasture and successively fattened in feedlots where modern technologies are adopted in the transformation and commercialization stages is analyzed, has been compared to another production system based on livestock exclusively bred in pastures and adopting low-level technologies in the transformation and commercialization stages. The objective of this study was to quantify and compare the two systems environmental impact related to both the beef production and the other stages in their supply chains and to identify windows of opportunity for improvement in their sustainability.

2. Methods

The Life-Cycle Assessment (LCA) was carried out according to the ISO 14040 standard. The aim was to compare potentials for climate change, acidification, and human toxicity associated with the two beef production chains above described, characteristic of the North-Central region of the state of Veracruz, Mexico. They will be named *intensive production chain* and *extensive production chain*.

2.1. Goal and Scope Definition

2.1.1. System boundary

The LCA covered the stages from the production of fodder and grain used as cattle feed up to the final consumer. This included manure-handling impact, manure use as farmland fertilizer, transport between the different production stages including transport to the consumer's home, the use of fertilizers, energy, organic residue disposal and packaging material in the transformation and commercialization procedures.

2.1.2. Functional Unit

The functional unit in this LCA is 1 kg of boneless, skinless beef without fat, produced in Veracruz for processing and consumption.

2.1.3. System Description

The study scenarios were put together based on literature review, national and state-level statistics and data collected from producers, beef association representatives, researchers, academics and extension specialists. The production chains studied are made up of five process units: growth and development (G & D), pre-fattening (PrF), fattening (Fat), transformation (Tr), marketing (Market). In the intensive chain G & D and pre-fattening livestock are kept on pasture, fattening is carried out in feedlot, transformation in highly technified slaughterhouses and marketing in supermarkets. In the extensive chain G & D, pre-fattening and fattening are on pasture, transformation takes place in slaughterhouses of low technology and finally, marketing is done by local butchers. The life-cycle inventory is based on average data from 2011 to 2013 for each life cycle, all-representative of Mexico. The production processes of each supply chain, and related parameters are described below:

2.1.4. Growth and Development

The growth and development process is the same in both production chains. Cattle are a mix of Brown Swiss-Zebu and Holstein-Zebu in different proportions. Feed is pasture based with a supplement of 14% raw protein. The model adopted is representative of the North-Central region of Veracruz and consists of 72 production cows, 20 calves and 2 bulls. Fertility in the reproductive cattle is 58.5% and mortality rate is 2%. Calves at birth weight 37 kg and are weaned at 167 days, after that they are pasture fed with a supplement of 14% raw protein feed. 93 hectares of prairie are used, and fertilized with ammonium sulphate (150 kg/ha/year). 44 calves weighing 225 kg and 12 months of age are sold annually. Cattle are transported 10 km to the pre-fattening sites.

2.1.5. Pre-fattening

In the intensive chain, livestock enter the pre-fattening stage weighing 225 kg. They are fed on pasture and 76 days before they are sold they are also given 1 kg/head of raw protein supplement at 15 %. This stage lasts 190 days. Per year 270 head are sold for fattening, each weighing 336 kg. The livestock is transported 10 km.

In the extensive chain pre-fattening takes place on pasture with no supplements. Cattle are received weighing 225 kg and spend 243 days until they weigh 348 kg. The area used measures 240 ha. Per year 362 head go on to fattening. Pre-fattening and fattening are carried out in the same place therefore no transport is necessary in these stages.

2.1.6. Fattening

In the intensive chain fattening is carried out in pens. Animals start this stage weighing 333 kg. Feed is composed of maize, sorghum, and soybean meal. Distiller dried grains (DDG), bran, poultry manure, mineral premix and molasses. This stage lasts 107 days with cattle weighing 514 kg. Per year 5,880 head are processed in highly technified slaughterhouses 138 km away from fattening enclosures.

On the other hand the fattening stage in the extensive chain takes place on pasture supplemented by a ration of 2 kg/head of 15% raw protein for the last 120 days. The stage lasts 213 days. Cattle at the end weigh 455 kg and are processed in low technology slaughterhouses 80 km away.

2.1.7. Transformation

Beef are slaughtered in modern and highly technological plants at 508 kg, a carcass yield of 59% is obtained. Organic residues, bone and tallow are turned into meal in a rendering plant and the manure is supplied to local farms. Residual water from the slaughterhouse is processed in a water-treatment plant. Carcasses are sectioned and deboned and vacuum-packed in polypropylene bags and placed in cardboard boxes. 12.1 tons of meat per year is transported to supermarkets distant on average 350 km.

In low technology slaughterhouses (extensive chain) livestock is processed at 450 kg. The carcass yield is 52%. Manure, blood, hooves and horns are thrown away into municipal dumps. Residual water is flushed into the local drainage system and bones and tallow are sold to a rendering plant. Fresh carcasses are taken to local butchers distant on average 7 km. 753,064 kg of carcasses are sold at the butchers' every year.

2.1.8. Marketing

Supermarkets receive a total of 278,351 kg of cut, packed meat. This is carved into beef cuts and sold to the final consumer. The packing consists of a polystyrene tray, a layer of PVC and a coated paper label. Supermarkets sell 24,818.3 kg of organic residue, which they sell to a rendering plant 15 km away. Meat is exhibited in refrigerated showcases. The power consumed in conservation, exhibition and cutting procedures was measured. Power used for lighting the sales-floor was not. Consumers cover 2.3 km (presumably in their own vehicle) to buy meat.

On the other hand, local butchers receive half carcasses, which they keep in cold storage and exhibit in refrigerated showcases. Loss through cut and deboning is 45%. Meat is sold in biodegradable poly-paper bags. 5,698 kg of organic residue is generated every year and sold to a rendering plant. The market is a local one and consumers walk to the butcher shops or take public transport.

2.1.9. Estimation of Greenhouse Gas Emissions

In the growth and development, pre-fattening and fattening stages on pasture no housing is necessary; therefore all manure is assumed to end up directly on the ground. The manure produced by livestock in the fattening process in pens is collected and spread on farmland belonging to pre-fattening farms, part of the intensive chain, 15 km away. The nitrogen excretion was estimated in order to calculate amounts of direct nitrous oxide, ammonia and nitric oxide emissions from the manure as well as indirect emissions of nitrous oxide through volatization and lixiviation, IPCC (2006).

2.1.10. Evaluation of Impact in LCA

Impact evaluation in LCA involved calculating the contributions of materials and fuels and the output at inventory phase in each of the environmental impact categories. The aforementioned categories are: climate change, acidification and human toxicity, all considered relevant in evaluating the environmental behaviors of obtaining animal products in a production chain. Impact evaluation was estimated using the CML 2000 method (Guinée et al., 2002), and SimaPro 7.3 LCA software from Pré Consultants. Greenhouse gas emissions, expressed in CO_2-eq units were quantified using the IPCC (2006) method and considering a temporal horizon of 100 years. Acidifying emissions are expressed in SO_2-eq and human toxicity in 1,4-DB-eq.

3. Results and Discussion

3.1. Evaluation of Life-Cycle Impact Results

In the intensive chain and in order of magnitude, the G & D herd used up more resources and produced more emissions in the categories of climate change impact and human toxicity. Pre-fattening demonstrated more acidification emissions in this chain. In extensive production the G & D stage is the greatest contributor to the impact categories. In both production chains enteric methane is the main contributor to climate change, followed by a substantial contribution from nitrous oxide obtained from manure biodegradation. In both chains, the fattening process is the one that least contributes to acidification and to climate change. This data coincides with reports from Pelletier et al. (2010), who compared three cattle production scenarios from G & D to finalization and observed the fattening process as the one, which impacts the least. In both chains, terms of acidification during the fattening stage showed the lowest levels. Pre-fattening shows the lowest impact for human toxicity in both production chains. In the intensive production chain, fattening is second to G & D for human toxicity emissions. In the extensive production chain G & D comes first and commercialization second in terms of human toxicity emissions (Figure 1).

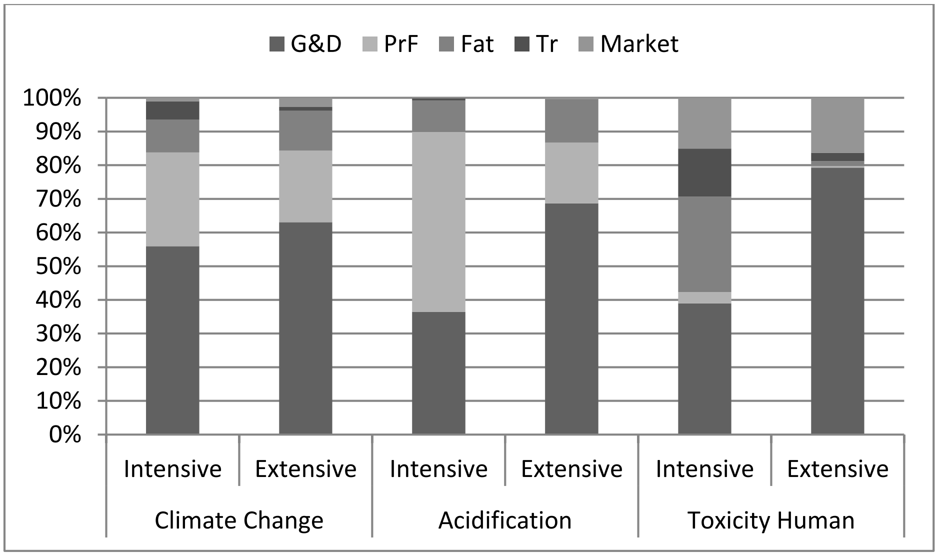

Figure 1. Total impact values shown in individual procedures by production chain.

3.2. Climate Change

Our results suggest that 1 kg of meat from Veracruz, Mexico produced in a chain based on intensive finishing systems and adopting modern technologies in the transformation and marketing stages has the potential to produce higher greenhouse gas emissions (17.80 kg CO_2-eq) than 1 kg of meat from an extensive beef production chain, including more traditional technologies in the transformation and marketing procedures. The main emissions are shown in Figure 2 where methane is the main contributor to climate change, with extensive productions emitting more methane (10.0 kg CO_2-eq) contributing to 63.3% of the total GHG when compared to the extensive chain (9.0 kg CO_2-eq) contributing to 50.7% of the total GHG. This result is consistent with another research showing that a higher quality diet for ruminants produces lower methane levels and increases the growth rate of livestock, therefore reducing methane emissions in the meat production life-cycle (Cederberg et al., 2009; Pelletier et al., 2010; Peters et al., 2010). Likewise, the higher levels of nitrous oxide in the intensive production chain are associated with manure management and production and processing of feed components in drylot-fed livestock.

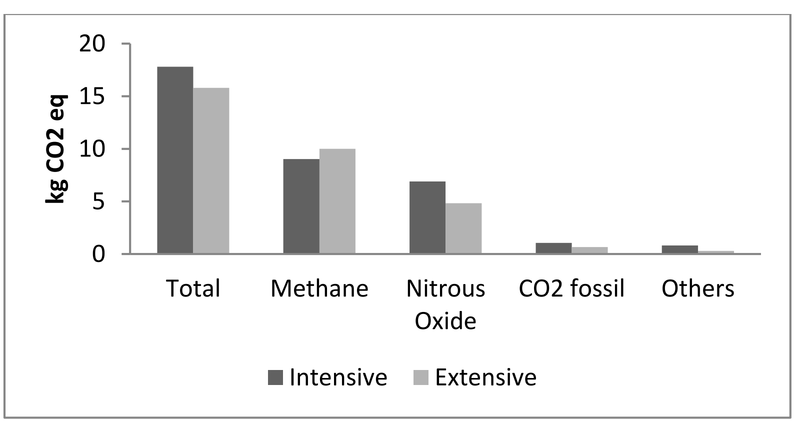

Figure 2. Comparison of greenhouse gas emissions by production chain.

3.3. Acidification

The potential for acidification in the intensive production chain was estimated to be greater than the extensive one (0.24 vs 0.13 kg SO_2-eq). This is directly related to the amount of ammonia produced when manure is accumulated in the confinement corral and then distributed over farmland; this result in greater ammonia volatilization as opposed to livestock on pasture (see Figure 3). The values obtained are consistent with those found by Roer et al. (2013) who used LCA to examine 1 kg of meat off the carcass from double purpose livestock. The higher emission of sulphur dioxide in the intensive production chain is a result of production and processing methods in the making of the feed during the feedlot stage. However, processing and marketing provide a smaller contribution compared to the production stages. This is in agreement with Meneses et al. (2012) who compared the milk production stage to the transport and packing.

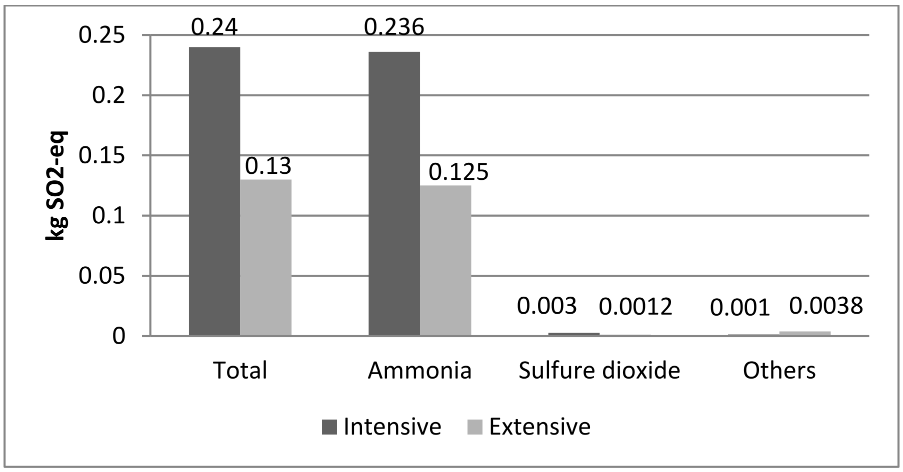

Figure 3. Contributing emissions to the acidification impact category by production chain.

3.4. Human Toxicity

Once again the intensive production chain shows higher potential for impact on human toxicity. In the case of the total potential emissions in both chains, polycyclic aromatic hydrocarbons show the highest potential emissions, 22.3% (0.13 kg 1,4-DBeq) in the intensive chain and 22.1% (0.06 kg 1,4-DBeq) in the extensive chain, as seen in Figure 4 due to the use of grain in drylot feed and food supplements during pre-fattening. This feed requires greater amounts of pesticides and fossil fuels for its production as well as more electricity during transformation and packing materials in the transformation and marketing stages. These results agree with Röös et al. (2013) who puts forth that an intensive beef production system has higher environmental impact potential due to greater quantities of agro-chemicals used.

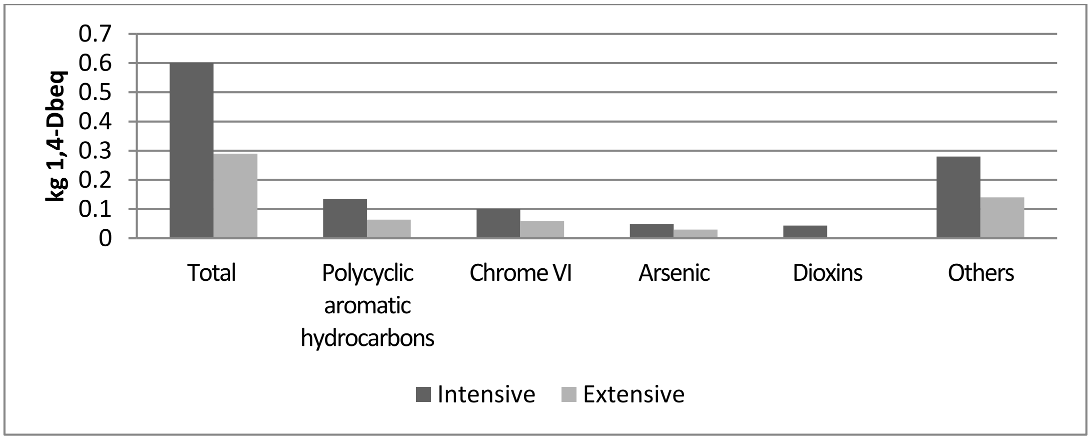

Figure 4. Contributing emissions to the human toxicity impact category by production chain

4. Conclusions

It was found that regardless of what systems of finishing, transformation and marketing are used, G & D is the main stage that contributes to the impact categories. This support the results of previous studies (Beauchemin et al., 2010; Pelletier et al., 2010) and is strongly related to the low fertility in bovine livestock compared to other species. In the present study cows produce one calf every 20 months and the maintenance of bulls and replacement calves must also be considered. However considering that calves come from double-purpose systems (milk production and veal production) the emissions generated were shared amongst both products, thus reducing the impacts from calf production which would be greater if the emissions were assigned solely to calf production; this coincides with other authors' findings (Roer et al., 2010).

The higher consumption of forage of livestock exclusively grown on pasture, for each kg of boneless meat produced, leads to higher methane emissions as a result of enteric fermentation; this is due to their lower feed conversion rate associated to the feeding system. However, it is important to consider the resources used to feed pasture-finished beef cattle are not competing with human nutrition, thus reducing the impact on the food and nutrition security due to cereals and legumes used in drylot finishing. Therefore, from an anthropocentric perspective, it is beneficial to obtain beef from pasture production chains.

The transformation stage carried out in slaughterhouses adopting modern technologies implies higher electricity requirements in order to process and store meat. In addition packing materials have an additional impact on beef production. However these systems allow for a much larger scale of production and transport of beef thus allowing satisfying the increasing demand for food, particularly in large urban settlements.

LCA has the potential to support decision making from a production chain perspective. This is extremely useful in the case of foodstuffs that involve relevant consequences on the environmental, economic and social necessities of the different stakeholders. Therefore further studies should integrate the social and economic dimensions of sustainability and the best way to effectively communicate the results to the consumer and other end users of researches on beef sustainability.

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