Carbon footprint of organic beef meat from farm to fork: A case study of short supply chain

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ABSTRACT

BACKGROUND: Sustainability of food systems is one of the big challenges of humans kind in the next years. Local food networks, especially the organic ones, are growing worldwide and few information is known about their carbon footprint. This study was aimed to assess greenhouse gases (GHG) emissions associated to organic local beef supply chain with a cradle to grave approach.

RESULTS: The study pointed out an overall burden of 24.46 kg CO_2 eq./kg of cooked meat. The breeding and fattening phase accounted 86% of the total emissions and resulted the main hot spot throughout the whole chain. Enteric

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methane emission was the greatest source of GHG at farm gate (47%). The consumption of meat at home was the second hot spot throughout the chain (9%) and cooking process was the main source within this stage (72%). Retail and slaughtering activities accounted for 4.1% and 1.1% on the whole supply chain, respectively.

CONCLUSION: The identification of GHG hot spots associated to organic beef meat produced and consumed in a local food network may stimulate the debate on environmental issues among the actors involved in the network and direct them toward processes, choices and habits less carbon polluting.

Keywords: organic beef meat, local food network, LCA, GHG emissions, climate change

INTRODUCTION

The production of food has been identified as one of the most important factors of environmental pressures.[1] The food system, considering all stages from primary production to waste disposal, contributes from 19% to 29% of global greenhouse gases (GHG) emissions generated by anthropogenic activities.[2]

Food supply will be one of the major priorities for humankind in the 21st century. The human demand for animal proteins is expected to increase over next decades due to the continuous growing of world population and per capita consumption.[3] In order to satisfy the increasing demand of food, it will be necessary to increase production, resulting in a high environmental impact in terms of consumption of resources (e.g. land, water, energy) and release of pollutants in air, water and soil.[4] In this context, bovine meat has been identified as the main source of GHG among the food products.[5]

Carbon footprint (CF), an indicator calculated with a LCA (Life Cycle Assessment) approach, evaluates the GHG associated to the life cycle of a product.[6] The CF takes into account all processesin the production of a product including raw materials, intermediate products, transports and waste disposal. Several studies were carried out to evaluate the environmental impacts of beef system considering all activities up to farm gate[7,8,9] and only few of these included further stages such as slaughtering, processing, retails and consumption.[10,11,12] Mainly, these study were referred to country level or to large scale retail distribution. To the best of our knowledge, no studies were carried out to establish the GHG emissions associated to organic beef production and its consumption in a local food network. There is no clear and simple definition of "local food network" or a "short supply chain".[13] Here we refer as "short" when it is characterized by short distance between producer and consumer (proximity) and the number of intermediaries involved in the supply chain should be as few as possible.[14] The present case study was aimed at investigating the CF of organic beef meat production and its consumption considering a local organic beef supply chain.

MATERIALS AND METHODS

Functional unit and system boundaries

The functional unit was 1 kg of cooked beef including waste disposal evaluated at consumers' home. No distinction was made between different cuts of meat (steak, loin, and fillet).

The burdens associated to the short beef supply chain were evaluated with "a cradle to grave" approach.[6] The system boundaries included the breeding and fattening of animals, slaughtering operations, meat processing including production of packaging, retail activities, transports, home storage, cooking and waste disposal. The boundary system is shown in Figure 1.

Life cycle inventory

Data were referred to the year 2014 and were collected throughout the processes included in the system. When it was not possible data were obtained from international databases which support environmental assessments,[15] calculated using appropriate models indicated by the guidelines for National Greenhouse Gas Inventories[16] or provided from bibliography. A summary of data is reported in Table 1.

Breeding and fattening

An organic cow-calf and fattening Italian farm was considered. The farm bred native Chianina beef cattle and it may be considered as typical organic farming system for beef production in the centre of Italy in terms of animals, land size and management adopted. Chianina breed is characterized by somatic gigantism, long trunk, light-weight skeletal structure, great ease of calving, adaptability to a variety of environments, resistance to harsh environment and to modest feeding conditions. Fattening bulls were slaughtered between 20-24 months old and at 700 kg of live weight (LW). The farm was made up of two phases: breeding of cows and heifers for calves production, and fattening of bulls. All animals were fed a total mixed ration.

Farm cultivated 106 ha and no extra feed was purchased and organic manure (3,268 t) was mechanically spread as organic fertilizer. Slaughtering animals leaving the farm referred to fattening bulls, heifers (those not used for breeding) and culled cows and no distinction between these types of meat was done.

Slaughtering, retail and consumption

Animals were slaughtered in the same abattoir distant 33 km from the farm. The abattoir received different livestock species and total animals slaughtered (2014) were 25,601 heads, including: 3,304 cattle, 8,923 pigs and 13,374 lambs. The primary products were meat carcasses whereas offal, blood and leather were co-products. The carcasses are usually stored at 0-2 °C for two days at plant and then transported to retails for aging and processing operations. The storage system at plant worked with 180 kg R-434a (refrigerant gas as a blend of pentafluoroethane, tetrafluoroethane, triflouroethane and isobutane).

Transports of cattle from farm to plant, energy consumption (electricity and methane), refrigerant gas leak, manure produced by animal while waiting to be slaughtered, cleaners and captive bullets production were considered for slaughtering operations.

The butcher shop received beef only from the farm considered (farm butcher shop). The transport of beef carcass from slaughterhouse to butcher shop, electricity consumption, refrigerant gases leaks and packaging production were accounted for retails activities.

The storage system at butcher shop consisted of a climatic chambers for meat aging and fridge bench for meat exhibition that worked with a total amount of 5.64 kg of R-404a (refrigerant gas as a blend of pentafluoroethane, trifluoroethane and tetrafluoroethane) and 0.4 kg of R-134a (tetrafluoroethane), respectively.

Total meat sold at butcher shop was 13,176 kg/year, which included: 9,536 kg of beef, 1,938 kg of pork, 1,049 kg of lamb, 574 kg of chicken and 76 kg of rabbit. The packaging to pack 1 kg of meat was composed by two sheets, one made of 19 g of paper and 1 g of low-density polyethylene (LDPE), and the other made of 2 g of high-density polyethylene (HDPE). Customers usually used own shopping bags and therefore these were not considered in the study.

A sample of customers (50) was interviewed to acquire data for the analysis of meat consumption. Data acquired with the survey were: amount, frequency and type of meat purchased, type of transport adopted for the shopping of meat (by foot or car), type of car (gasoline, diesel or GPL), distance travelled (km) for the shopping journey, incidence of beef cost on total shopping expense of the day, type (refrigerator and/or freezer) and duration of storage, cooking type (stove and/or oven) and waste disposal (recycling or not). A summary of consumers' habit is reported in Table 2.

It should be noted that the survey was proposed to every consumers that entered in the shop during several days distributed during a year and it was filled out only for who was positive to response and no criteria to select the consumers was used (e.g. the demographic structure of the referent population).

Life cycle inventory analysis

Breeding and fattening

Emission factors associated to the production of seeds and fuel were obtained from Ecoinvent database.[15]

Carbon dioxide (CO_2) emitted for electricity consumption was calculated according to the emission factor of 0.385 kg CO_2/kWh.[17] Emission factors associated to fuel consumed for cropping, animal management and transports were obtained from Ecoinvent.[15]

Farm combined breeding and fattening stages and emissions were calculated for both. Emissions released from cows to produce calves and from heifers to renew the herd were considered for breeding activities. GHG emitted from growing and fattening animals were considered for fattening stage.

Enteric CH_4 emissions were calculated for each category of animal (growing bulls, cows, heifers and fattening bulls) according to tier 2 methodology.[16] This method is based on daily gross energy intake (GEI), digestible energy (DE) and Y_m conversion factor corresponding to the fraction of GEI converted to CH_4. Daily GEI was calculated according to: LW, milk produced for calves, daily LW gain, activity (time at pasture) and cows pregnancy (%).

The value of Y_m adopted was 6.5% for higher forage diet (breeding) and 4.5% for higher grain diet (fattening). The values of DE adopted were 65% and 70% for breeding and fattening, respectively.

Solid manure (no liquid form was produced), volatile solid (VS) and N yield yr^{-1} were calculated considering all category of animals (cows, heifers, beef) and their housing system as reported in Italian guideline for manure management.[18] Country-specific conversion factors of 4.8 g CH_4/kg of VS and 0.02 kg N_2O-N/kg N were used[17] to calculate CH_4 and N_2O (nitrous oxide) from storage manure, respectively. Methane emissions from dugs deposited on pasture by cows and heifers (no grazing for beef) were calculated according to total VS excreted, livestock category and time at pasture/year. Nitrous oxide emitted from soil management was estimated considering 0.01 kg N_2O-N/kg N.[16] The method is based on nitrogen inputs, which include organic fertilizer (land–applied manure), urine and dung deposited on pasture, mineralization of soil organic matter and crop residues decomposition (above and below-ground residues). The potential of soil organic carbon sequestration was not considerate in the analysis.

Slaughtering, retails and consumption

Emission factors for electricity consumption and methane combustion were obtained from Nation Inventory Report and IPCC.[16,17] Emission factors associated to transports (trucks, vans and cars) were considered.[15] The emissions of refrigerant gases used in the storage systems were estimated considering different rate of gas leaks for each type of refrigeration systems, then gas losses of 50%, 25% and 15% on the total capacity of the refrigerant (kg/year) were considered for transport, slaughterhouse, and butcher shop, respectively.[16]

The emissions related to waste disposal, packaging, detergents and captive bullets (iron) were calculated.[15,16]

The electricity consumption for meat storage at home (refrigerator and freezer) was estimated considering the volume of meat, the time stored and the factors of 0.59 kWh/m^3/day and 0.63 kWh/m^3/day for refrigerator and freezer, respectively.[19] The emissions released to cook 1 kg of meat by gas stove or electric oven were calculated considering 15 minutes and 1 hour, respectively.

Allocation

Dealing with multi-stage system allocation of products and co-products may become an issue. There are various way to handle products and co-products data throughout meat supply chain, but not a single established/validated method.[20] We have calculated GHG for each stage and if the stage had more products than we have allocated emissions. We have considered slaughterhouse, retails, transport to home and consumption where allocation occurred. None allocation was done for the breeding and fattening where slaughtering animals were the only product, thus the emissions were allocated to the total live weight leaving the farm and no distinction was made for primary (fattening bulls or heifers) and secondary (culled cows) meat.

The main products at slaughterhouse were beef, pork and lamb carcasses, whereas offal, blood and leather were sold as co-products. Prices provided by plant company were 5.3, 2.9 and 7.5 €/kg for beef, pig and lamb, whereas they were 120, 6 and 12 €/100kg for leather, offal and blood. Considering the economic values the allocation factors were 60%, 29%, 8%, 2%, 0.5% and 0.1% for beef, pork, lamb, leather, offal and blood, respectively.

The emissions for butcher shop were allocated economically between types of meat sold, thus 87%, 8% and 5% were allocated to beef, pork and lamb, respectively.

GHG related to the transport of meat (all types) from butcher shop to home were allocated between meat and other products that were bought in the same shopping trip. The economic allocation was done according to the incidence of beef cost on total shopping expenses (25.5%). At home, the emissions produced from storage and cooking were allocated economically between types of meat (beef, pork and lamb), thus 73% of GHG were allocated to beef.

Impact assessment

Global warming potential (GWP) was evaluated and GHG were converted in unit of CO_2-equivalent according with a time horizon of 100 yr.[21] Considering the kg of CO_2 as reference the GWP factors for kg of CH_4, N_2O, R-134a, R-434a and R404a were 25, 298, 1,430, 3,245, and 3,922 kg, respectively. All emissions were calculated modelling data in excel worksheets.[22]

RESULTS

Table 3 shows processes contribution to CF of short organic beef supply chain. Total CF was 24.46 kg CO_2 eq. for kg of cooked beef.

Breeding and fattening activities, referred to an organic farm that combines breeding and fattening of native Chianina cattle, emitted 20.98 kg CO_2 eq. for kg of live weight leaving the farm and it was the main hot spot (86%) of the total CF.

The emission of methane from enteric fermentation was the greatest source of GHG at farm gate (47%). Carbon dioxide emitted for energy use was the second hot spot (28%), while CH_4 and N_2O from manure management and N_2O from soil management accounted for 16% and 9%, respectively. Transports for farming operations (seeds, fuel, feed, animals) were locally and they accounted less than 1% within stage.

Slaughtering operations, including the transport of animals to slaughterhouse, emitted 0.27 kg CO_2 eq. for kg of beef carcass and accounted for 1.1% of the whole supply chain. Energy use and refrigerant gases leak were the main sources of GHG emissions within slaughterhouse (85%). Transport of animals to slaughterhouse accounted for 10% of GHG emitted at plant, CH_4 and N_2O from manure produced by animals waiting to be slaughtered accounted for about 4%. The GHG associated to the production of captive bullets and cleaners used for slaughtering operations were less than 1%.

The overall GHG emitted at butcher shop were 1.00 kg CO_2 eq. for kg of beef sold and it accounted for 4.1% on total CF. The hot spots identified for this stage were refrigerant gases leaks (50%) and electricity consumption (40%). Minor contribution was associated to transports of carcasses from the slaughterhouse to the butcher shop (7%) and packaging production (3%).

The consumption of meat including transport to home, home storage, cooking and waste disposal resulted in 2.22 kg CO_2 eq. for kg of cooked meat and corresponding to 9% of total CF. Energy use for storage and cooking was the main contributor of GHG for this stage (81.5%). Energy consumed to cook meat (82% as gas stove and 18% as electric oven) was 1.41 kg CO_2 eq., while it accounted 0.4 kg CO_2 eq. for the storage of meat in refrigerator (13%) and freezer (87%). Transport of meat from shop to home (18.1%) was the second source of emissions, while GHG emitted by packaging disposal were lower than 1%.

When transports were considered all together throughout the chain they represented the 2% of total CF and the analysis pointed out a different incidence for the processes evaluated (Figure 2).

Transport of meat from butcher to home was the main source of GHG within the transports of local food network analysed. The incidence of other transports (chilled carcasses from slaughterhouse to butcher shop and animals from farm to slaughterhouse) was lower.

In Figure 3 is reported the GHG emitted considering only the use of fossil energy as a source of emissions. The consumption of fossil energy throughout the local organic beef network emitted 8.22 kg CO_2eq.. Liquid fuel (diesel) used for farming activities (feed production, feeding operation and animal management) contributed to 5.9 kg CO_2 eq. and it represented the main source (71%). The emissions to store and cook meat at home accounted 1.81 CO_2 eq. (22% of total fossil energy consumed) and gas fuel burned for cooking operations was the main source of emissions. The GHG emitted for slaughtering and retails activities accounted 1.5% and 5% of the total GHG emitted for energy use, respectively.

DISCUSSION

Local food networks are important retail systems in Italy as well as worldwide, they are growing and represent a valid alternative of large retail networks. Furthermore, these food systems are important because they may guarantee social and economic sustainability of rural communities. On the other hand, few is known about the carbon polluting of short food supply chains and even less if we consider a local organic beef network. Our boundaries have included a farm, slaughterhouse, farm's butcher shop and its customers. Although the local food network considered is highly representative of the beef produced and consumed in Italy, we have not analysed replicate of this system, then we must be careful not generalizing results. Nevertheless, these results may provide some interesting and useful insights into the GHG emission of local meat networks.

Breeding and fattening

Studies from specialist beef production indicated values of CF between13 and 40 kg CO_2 eq./kg LW.[23,24,25] This huge variability was mainly related to the differences in production systems analyzed (i.e. organic *vs* conventional; suckler cow-calf *vs* dairy bull calf) and/or to the methodological approaches adopted (i.e. functional unit, system boundaries, emission factors and allocation methods).Therefore, direct comparisons between studies are difficult due to substantial differences in the systems evaluated and methods adopted. Our CF at farm gate was in the range indicated above and the incidences of GHG from gut and manure management were conform with the values indicated in bibliography.[26,9] The burden associated to feed production was lower than the range 27-41% described in previous studies.[7,26] In these studies the emissions associated with fuel consumption and soil management for feed production were considered together, whereas we considered separately these sources of gases. The incidence of feed production would rise up to 32% of CF at farm gate if we consider together these two sources of GHG.

The 20.98 kg of CO_2 eq./kg LW evaluated at farm gate, that refers to organic production system with breeding and fattening stages combined in the same farm, was higher (0.6 kg CO_2 eq./kg LW) compared with that calculated for beef destined to large retail system where production system was based on breeding of calves in France and their transport (approximately 1,000 km) to Italy for fattening.[12] Despite the longer distance travelled by animals in the coop's study, the CF was lower of that of our system where calf were born and bred until the slaughtering age in the same farm. The Coop study referred principally to cosmopolitan breeds (Charolais and Limousin) raised in conventional system (personal communication from Coop Italy). Cosmopolitan breeds have higher production efficiency than native breeds. Charolais bulls showed a higher feed efficiency with a reduction of 0.7 kg of dry matter intake for kg of weight gain compared with Chianina bulls.[27] In addition, organic beef cattle systems (18.2 kg CO_2 eq.) are indicated to be more carbon polluting compared to conventional ones (15.8 kg CO_2 eq.).[8] This result was confirmed also when organic and conventional beef production was referred to Italian context. Recent Italian study showed a CF of 24.62 and 18.21 kg CO_2 eq./kg of live weight for organic and conventional beef, respectively.[28] This result could seem to confirm that production efficiency has a stronger effect on total emissions rather than distance travelled by animals during breeding stages.[29]

We did not consider the potential organic carbon sequestration by the soil that may be derive from more conservative practices of the organic system. The estimation of carbon sequestration of soil is difficult for the high variability of the soil characteristic and climate conditions, differences in soil management and missing of certain data. However, when the carbon sink was evaluated in organic and conventional beef system its contribution was limited for both production system.[28] These authors reported how the net carbon sink decreased the CF from 24.62 to 23.32 kg CO_2eq/kg live weight in organic beef system and from 18.21 to 17.71 kg CO_2eq/kg live weight in conventional beef system. The carbon sequestration was two time an half higher in organic system than of that in the conventional one. This suggest a high mitigation capacity of organic practices that should be evaluated and confirmed over a longer period of observation.

In light of what stated above, we may argue that the concept of greater sustainability of organic local beef system because of shorter transports and conservative practices is not completely correct. Behind the contribute of conservative practices to increasing carbon sequestration in the soil, other factors, that may affect the production efficiency of farm, should be considered to define the sustainability of beef.

Several practices are reported to reduce GHG emissions at farm level and the optimum strategy should take into account all processes adopted in the farm, their interactions and the benefit achieved by mitigation measure relative to its cost. In general, we may state that mitigation of GHG at farm level may be achieved by increasing farm productivity. Breeding animals with higher weight gain per unit of feed intake, reducing the unproductive animals on farm, and increasing production (slaughter weight reached at younger age, higher forage yield for unit of land) may contribute effectively to reduce GHG emissions for unit of meat produced. However, in order to maximize the sustainability of beef, the strategies to improve production efficiency should be synergic with those practices aimed to increase the organic carbon sequestration by the soil.

Slaughtering, retail and consumption

The GHG emitted from slaughtering operations resulted lower (0.27 *vs* 2.00 kg CO_2 eq.) of that indicated in the Coop study already mentioned above.[12] The lower distance from farm to slaughterhouse may at least partially explain these differences. The distance between our farm to slaughterhouse was shorter (33 km) compared to 350 km reported in the Coop study. In addition, the Coop study also included, for this stage, the intermediate transports of carcass from the abattoir to processing plant (250 km). Finally, this discrepancy might also be related to different allocation factors adopted for bovine meat and co-products (leather, offal and blood).

Japanese study reported 0.04 kg CO_2 eq. for kg of bulls carcass at slaughterhouse gate.[11] This value was calculated on the basis of total meat yield (chicken, pork and beef) and it included the activities for meat storage and packaging. The lower carbon emission associated to the Japanese slaughtering activities, compared with our result, can be related to different allocation approaches. These authors have allocated emissions based on mass of products and co-products whereas we allocated on economic basis.

The contribute of slaughtering operations to the CF of Canadian beef was 0.18 kg CO_2 eq./kg of carcass.[10] The lower value may be due to the methodological and allocation procedures adopted. Compared to our conditions, Canadian study did not include refrigerant gas leaks, while considered the biogas recovery from manure and waste management. In addition, even if both studies adopted an economic approach to allocate emissions between products (primary meat) and co-products (offal, blood and leather), allocation factors were different on the basis of dressing percentage, cutting yield, rendering yield and prices of primary meat and co-products.

The emissions of butchery activities were higher compared with that indicated for large retail networks.[11,12] The difference is likely to depend on the higher energy efficiency of supermarket compared with local butcher shop.[30]

Improvement of energy efficiency may contribute to mitigate GHG of slaughtering and retail activities. Furthermore, the use of refrigeration systems which contain a smaller amount of refrigerant gas and/or a refrigerant gas with lower GWP such as ammonia, hydrocarbon or carbon dioxide should be preferred.[31] Even the adoption of appropriate operations such as carry out regular checks of the cooling systems and avoid rapid changes in temperature during load and unload of carcasses are indicated to reduce GHG of food networks.[32]

The GHG emitted from home consumption were calculated on the basis of habits for transport, storage, cooking and waste disposal declared by costumers during the interviews. Our value (2.22 kg CO2 eq.) is comprised in the range 0.8-3.3 kg CO2eq./kg of cooked beef indicated in the Coop study[12] or it was higher of 0.34 kg CO_2 eq./kg indicated for beef cooking process for which further information was not provided.[11] Energy consumed for cooking operations was the main hotspot and it reflects the cook habits of the customers interviewed. In general, cooking operations are related to societal, cultural and economic aspects that characterize several societies in the world, therefore the development and/or implementation of more sustainable cooking practices should be done considering these aspects. Taking into account only the cooking devices, evidences indicate that the electrics ones release less GHG compared with devices working with fuel, and between these last ones, the use of solid fuel is more polluting than liquid or gaseous one.[33]

Despite the short distance between shop and home (10 km), the transport of meat to home represented the 20% of the CF for the consumption stage or 80% of GHG emitted by all transports throughout the whole cycle. This aspect seems to be contradictory with the idea that buy food directly from producer is more sustainable in view of the avoided intermediate transports. The GHG of transports for shopping may be an important source of emissions, especially when it refers to local food network where very short distances did not compensate the very small quantity of products transported per vehicle.[34]

When more products are transported with the same vehicle, fewer kilometres are driven per consumer or per kg of meat. Therefore, burdens associated to the shopping trips by private car could be reduced with delivery service offered by retails (e.g. collective orders), especially if combined with remote ordering (e.g. through Internet). Moreover, even without alternative distribution systems, the frequency of shopping, and thereby the overall driven distance, may be reduced by providing better tools for planning of food purchases and through increased shelf life of the products.[29]

In the light of what has been discussed above, as well as evidences already reported,[35] the choice of local products or “food miles” is not sufficient to guarantee consumption of food environmentally sustainable because other processes and activities of the supply chain, including our shopping and consumption habits, should be considered very carefully.

CONCLUSION

Local food networks are growing worldwide and they are considered as a sustainable food system even if their contribute to GHG emissions is not well known yet.

The analysis carried out in the present study permitted to identify hot spots for greenhouse gas emissions associated to a short organic beef supply chain. Farm activities and home consumption were the stages in the chain with the highest global warming potential. These evidences may help to figure out the contribution to climate change of local food networks and facilitate the adoption of practices more sustainable. Their adoption implies farmers, retailers, consumers and policy makers education and a careful evaluation of their benefit cost ratio.

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Tables

Table 1.Data referred to the year 2014 and collected throughout the chain

Process Categories of input	Data
Breeding and fattening	
Seeds	7.4 t
Land use	106 ha
Organic fertilizers	3 268 t
Cows	71
Bulls	2
Calves (0-6 months)	58
Heifers for breeding (6-24 months)	23
Growing bulls (6-12 months)	19
Fattening bulls (12-24 months)	33
Average slaughter weight	700 kg
Slaughtered bulls/year	31
Slaughtered cows/year	6
Fuel	21 684 l
Electricity	56 059
Slaughter house	
Animals transported to plant*	2 442 km
Natural gas	37 060 kg
Electricity	292 433
Refrigerant gas	180 kg
Butcher's shop	
Transports of input	4 584 km
Beef sold	9 536.7 kg
Electricity	11 319
Refrigerant gas	5.6 kg

* The total distance was calculated considering 37 animals leaving the farm, one animal for journey, 33 km from farm to

Table 2. Main findings of the interviews aimed at collecting information on consumer habits for shopping and consumption of meat (average values).

Phases Habits[1]	Data
Meat purchased	
Quantity for each shopping/customer	2 kg
Bovine	72%
Others	28%
Meat transported	
On foot	17%
By car	83%
Diesel	64%
Petrol	28%
NGV[2]	8%
Distance travelled for each shopping/customer	10 km
Meat stored	
Refrigerator	20%
Freezer	80%
Time in refrigerator	2 days
Time in freezer	21 days
Meat cooked	
Gas stove	89%
Electric oven	11%
Packaging disposal	
Recycled	44%
Not recycled	56%

[1]Consumer habits acquired throughout an interview of a sample (50) of butcher's shop customers. [2]Natural gas vehicle

Table 3 Carbon footprint expressed as kg CO_2-equivalent related to processes considered in the short organic beef supply chain.

Process	kg CO_2-eq	% GHG within supply chain
Breeding and fattening	20.98	85.8
Slaughterhouse	0.27	1.1
Butchery	1.00	4.1
Consumption	2.22	9.0
Total	24.46	100.0

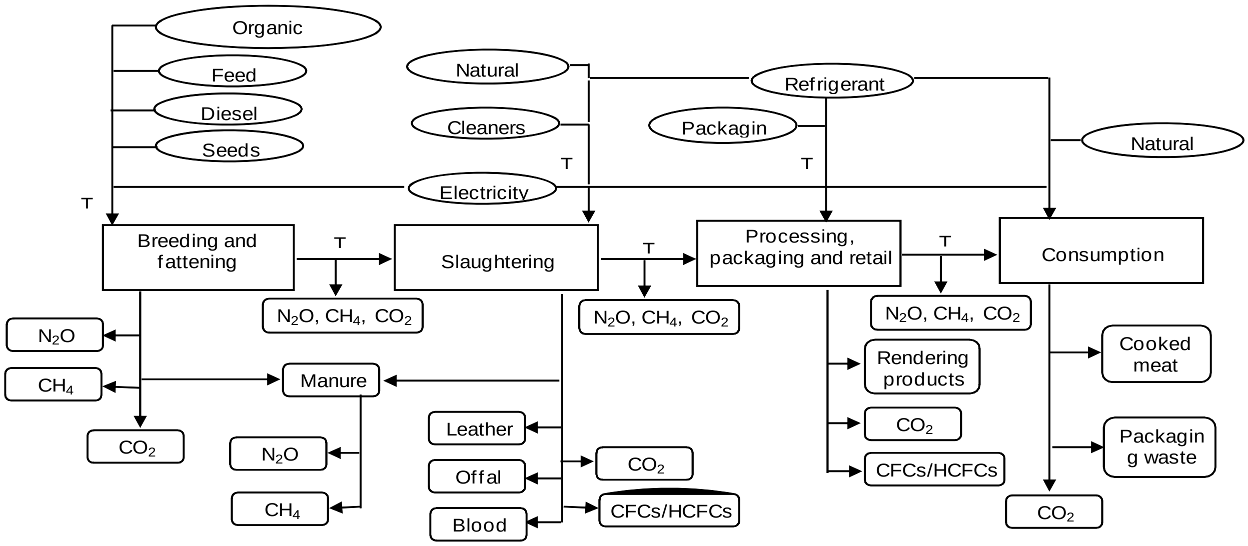

Figure 1. System boundaries of short organic beef supply chain analysed. T indicates the transports between and within processes

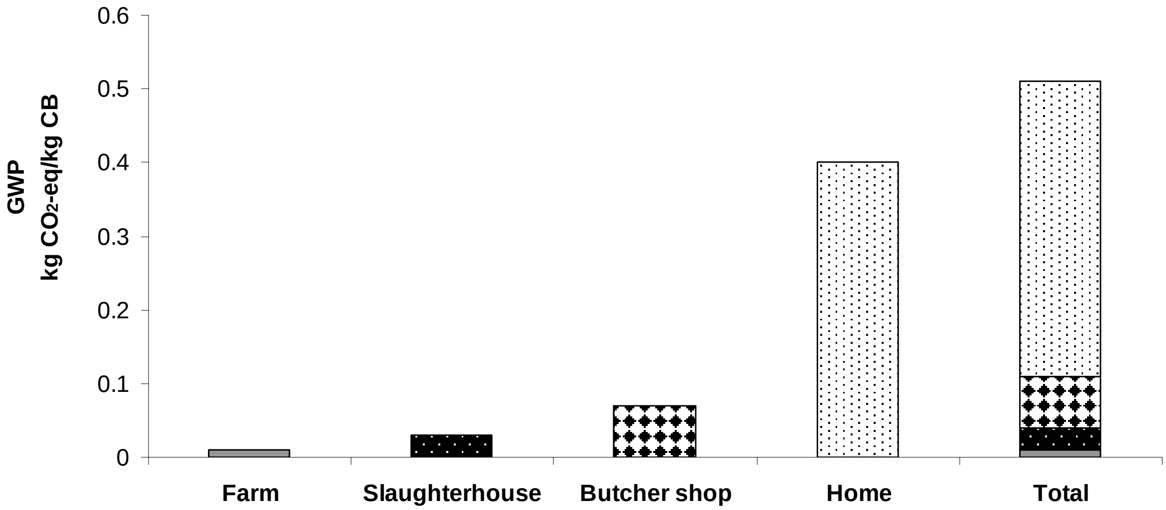

Figure 2. Carbon Footprint expressed as kg CO2-equivalent (CO2-eq.) per kg of cooked organic beef (CB) associated to the transports carried out in the local organic beef supply chain.

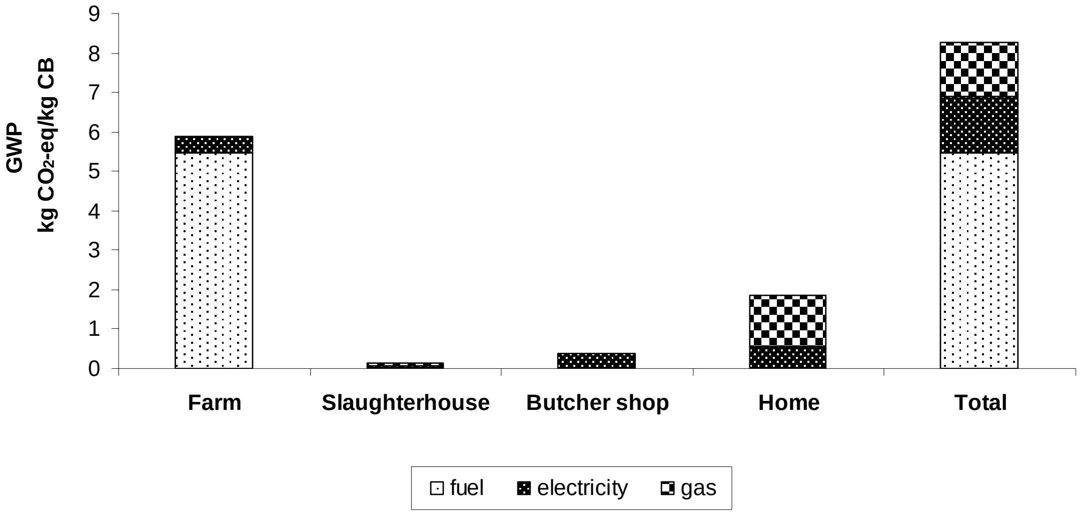

Figure 3. Carbon Footprint (CF) expressed as kg CO2-equivalent (CO2-eq.) per kg of cooked organic beef (CB) associated to the energy consumed in a local short beef supply chain