Environmental analysis of organic broiler production in France and improvement options

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Abstract In this study, the Life Cycle Assessment method was applied to organic broiler production in France to identify the main stages contributing to environmental impacts from cradle to farm gate, to suggest improvement options and to contribute to designing innovative production systems. Producing one tonne of broiler live weight required 270 m3 of water, 33GJ of cumulative energy demand and 0.8 ha.year of agricultural land. It resulted in the emission of 2.3 t CO2 eq., 50 kg SO2 eq. and 27 kg PO4 eq. Feed was the main contributor for all impacts except acidification. Feed ingredients transport by road was also a major contributor, heating of the broiler house had significant impacts. This study was part of a project which involved stakeholders of the broiler production chain. Project participants became familiar with the LCA method and its results; this will enable them to better consider environmental issues in the future.

1 Introduction

In France, the demand for organic products has steadily increased over the last decade, but it has not met the national organic product supply yet. Organic farming is therefore considered as a promising asset for the French agricultural sector.Its development is seen as a good way to maintain employement and further economic development in rural areas, as well as to preserve the environment. The question is: how to promote the sustainable development of organic broiler production in France? The national project AviBIO was launched to answer this question. It is based on a participative approach involving farming advisers, researchers, companies and professional unions. Surveys were conducted in Europe and in France to gain a better insight into organic broiler productions and to generate economic, social and environmental data.

The two main organic broiler production areas are the Pays de la Loire region in the West of France and the Aquitaine region in the South-west. Most of organic broiler production takes place in integrated production systems where companies own industrial facilities such as feed factories and slaughterhouses.

Although these regions are also major regions for the production of organic crops, a large quantity of feed ingredients, especially protein crops, are imported from other regions or from abroad. This is because regional feed ingredients are either not sufficiently available or more expensive than imported ones.

French organic broiler production involves the use of slow-growing strains and a long rearing phase (around 93 days), resulting in a high feed conversion coefficient (3.2 kg/kg). Chicken have access to an outdoor run.

In this study, we used the Life Cycle Assessment (LCA) method to produce environmental indicators to identify the main stages contributing to the environmental impacts from cradle to farm gate, to suggest improvement options and to contribute to designing innovative production systems.

2 Methods

2.1 General

We analysed organic broiler production in France's two main production areas (South-west and West). We used the LCA method to assess total cumulative energy demand, climate change, eutrophication, acidification, water use and land occupation. The functional unit is one tonne of broiler live weight at the farm gate. The characterisation methods we used were the CML 2001 Baseline version 2.04 and the CML 2001 version 1.05 for the Total Cumulative Energy Demand. GWP 100 characterisation factors were updated according to IPCC (2007). An economic allocation was performed when a process yielded several co-products.

2.2 Description of the system and life cycle inventories

The production stages included in the system are the production of day-old chicks, the production of crops, the production of the feed, and the broiler rearing phase. The production and maintenance of infrastructure (machines and buildings) were included. End of life of buildings was not included.

2.2.1 Feed production

Feed formulas were based on feed producers' data. Information on feed ingredients' region and country of origin were either collected by questionnaire sent to feed producers or based on interviews or extrapolated if information was missing. In the last case, high uncertainty was associated with transport distances and crop production inventories that can greatly vary depending on the location. Ninety-five % of the feed materials of plant origin are from the organic production methods.

All transport of crops and feed ingredients and was taken into account. Transport inventory was taken from the ecoinvent database v2.1. Feed formulas, transport distances and uncertainty on transport distances are summarized in Tables 1and 2. Data on feed processes such as the production of meals are based on various sources.

Tab.1: Rate of incorporation, transport distances and uncertainty on transport distances for poultry feed ingredients of the Aquitaine region

Feed ingredients	Rate of incorporation (kg/tonne)	Mean distance from the farm to the factory (km)	Uncertainty
Wheat	35	1220	Low
Grain maize	532	248	Low
Triticale	13	170	Low
Pea/ Fababean	83	870	Medium
Soybean grain	0	-	-
Corn gluten meal	40	970	Low
Wheat bran	55	1500	Low
Soybean meal expeller	145	1000	Medium
Sunflower meal expeller	50	1200	Medium
Potato tubermine	7	800	Low
Other ingredients	40	620	Low

Tab.2: Rate of incorporation, transport distances and uncertainty on transport distances for poultry feed ingredients of the Pays de la Loire region

Feed ingredients	Rate of incorporation (kg/tonne)	Mean distance from the farm to the factory (km)	Uncertainty

Wheat	100	150	Medium
Grain maize	390	150	Medium
Triticale	80	150	Medium
Pea/ Fababean	50	150	Medium
Soybean grain	50	150	High
Corn gluten meal	22.5	550	Medium
Wheat bran	30	1000	High
Soybean meal expeller	150	1600	High
Sunflower meal expeller	80	1600	High
Potato tubermine	22.5	500	Medium
Other ingredients	25	250	Medium

Uncertainty classes
Low uncertainty: the origin of the ingredient is well known
Medium uncertainty: the origin of the ingredient directly incorporated in the feed (e.g. the soybean meal) is well known but the origin of the raw agricultural material (e. g. the soybean grain) is not well known.
High uncertainty: neither the raw material's nor the ingredient's origin are well known.

2.2.2 Crop production

Data on organic crop production were collected from extension services in Aquitaine and Pays de la Loire [1,2]. Yield data are 4 year averages (2005-2008). The crop inventory for maize in the SW of France is based on the results of a questionnaire which was submitted to 8 farmers by a grain and poultry production company in 2010. Crop inventories from imported crops were taken from the literature [3,4] and from statistics [5,6].
Nitrate leaching was estimated according to [7]. Ammonia emissions were estimated according to [8], phosphate emissions to surface water and groundwater were estimated according to [9,10].
The environmental inventory for the production of feather meal (a fertilizer) was based [11]. No impacts were associated with the production of raw feathers as they are considered as wastes. The impacts associated with the storage and composting of poultry manure were allocated to these fertilizers and gaseous emissions occurring during the storage and composting phases were based on [12].
Inventory data for agricultural machinery and irrigation were taken from the database ecoinvent v2.1.

2.2.3 Production of one-day-old chicks

The production of one-day-old chicks includes feeding and housing of the broiler breeders, transport of the eggs to the hatchery and the hatching process. Data come from a poultry company.

2.2.4 Broiler rearing phase

The broiler rearing phase includes the construction and heating of the broiler house, bedding material, the delivery of one-day-old chicks and feed, water for drinking and cleaning, electricity. The area occupied by the outdoor range and the building is also taken into account. Data on propane and electricity consumption are taken from [13]. Data on the building materials were taken from [14] and adapted to organic broiler building according to [15]. Technical data concerning the final live weight and the feed conversion rate are taken from a poultry production company in Aquitaine and are taken from [16]; data are summarized in Table 3.

Other data such as the outdoor run and building sizes, amount of bedding materiel used, and transport distances to the farm come from surveys conducted in 2009 in 26 broiler farms.

Tab.3: Technical data of organic poultry production in the main producing regions in France

	Aquitaine	Pays de la Loire
Final live weight (kg)	2.25	2.3
Feed conversion rate (kg/kg)	3.35	3.1

Levels of nitrogen excretion for broilers were estimated from Corpen [12], these are specific to organic broilers. Emissions of ammonia and dinitrogen oxyde from the building and the outdoor run were estimated according to GAC et al. (2006), considering that broilers spend 20% of their time on the outdoor run.

Methane emissions from the building were based on [18].

3 Results

3.1 Environmental impacts

Environmental impacts were quite similar for the two regions, except for the water use impact which was higher in Aquitaine (Table 4). This is due to different irrigation practices and a higher maize content in the feed.

Tab.4: Environmental impacts of one tonne of organic broiler live weight in the two main producing regions in France

Impact category	Unit	Aquitaine	Pays de la Loire
Total cumulative energy demand	GJ eq	32.4	33.9
Climate change	t CO2 eq	2.2	2.4
Acidification	kg SO2 eq	50.5	50.5
Eutrophication	kg PO4 eq	27.6	27
Land occupation	m2.a	0.78	0.74
Water use	m3	343	199

Table 5 summarizes the results of a study for the UK [20]. Although in France and UK rearing systems can be different, our results are in the same order of magnitude for all impacts except energy use.

Tab.5 Environmental impacts of one tonne of conventional, free range and organic broiler live weight according to Williams et al. [20]

Impact category	Unit	Conventional	Free range	Organic
Primary energy use	GJ eq	11.2	11.2	12.4
Climate change	t CO2 eq	1.8	2.0	2.6
Acidification	kg SO2 eq	25.9	30.8	28.8
Eutrophication	kG PO4 eq	14.0	23.5	42.2
Land occupation	m2.a	0.4	0.5	0.9

Note that the functional unit originally used in this study was one tonne of edible carcass weight. We used slaughter yields of 67% for organic and free range and 70% for conventional broilers to convert the results to the fonctional unit one tonne of broiler live weight.

3.2 Main contributors to environmental impacts

Feed production including crop production, ingredient transformation and transport is the main contributor to all environmental impacts except acidification. (Table 6). Indeed, acidification is mainly due to NH3 emissions from the building and the outdoor range and during the storage and composting of manure.

Tab.6: Contribution of the feed production stages to the environment impacts of organic broiler live weight

Impact category	Aquitaine	Pays de la Loire
Total cumulative energy demand	71%	67%
Climate change	76%	74%
Acidification	40%	46%
Eutrophication	75%	74%
Land occupation	88%	93%
Water use	98%	96%

Tab.7: Contribution from several stages to total cumulative energy demand for organic broilers

Life cycle stages	Contribution to total cumulative energy demand (%)	
	Aquitaine	Pays de la Loire
Road transport	22%	22%
Fuel combustion for agricultural machinery	12%	12%
Irrigation	12%	6%
Heating of the broiler house	11%	16%
Broiler house	7%	7%

Tab.8: Main contribution from several stages to climate change impact for organic broilers

Life cycle stage	Contribution to climate change (%)	
	Aquitaine Region	Pays de la Loire Region
Road transport	20%	19%
Fuel combustion for agricultural machinery	12%	12%
Irrigation	4%	3%
Heating of the broiler house	10%	14%
Broiler house	2.5%	2.5%

4 Improvement options

4.1 Feed

Feed production was the main contributor for all impacts except acidification. This in accordance with other studies [19,20]. Therefore reducing feed production impacts is fundamental to reach a substantial decrease in organic broiler environmental impacts as is the improvement of feed conversion

4.1.1 Transport of feed ingredients

In this study, we showed that feed ingredient transportation is a major contributor to total cumulative energy demand and climate change. Imported ingredients especially soybean and sunflower meals and pea as well as mineral and additives are transported over long distances resulting in high total cumulative energy demand and climate change values. Growing feed ingredients locally may be a good way to decrease energy use and climate change. However, this implies to grow protein crops adapted to local conditions. It is important to note that this issue is not specific to organic poultry production. The dependence of European countries towards soybean for feeding animals is well known and has led for instance to European research programs such as GLIP (Grain Legumes Integrated Projects). One aim of these projects was to study the replacement of soybean from North and South America with European grain legumes.
Concerning cereals, an improvement option might be to "grow them home". Indeed, Katajajurri et al. [19] showed that by using more grain grown on-farm a broiler producer would be able to decrease energy use and climate change. However, this caused more eutrophication. This option should be tested in further research.

4.1.2 Data availability

In the course of this study we discovered that information on the origin of imported ingredients was not always available and that companies were not always willing to reveal this information. A feed ingredient (e.g. soybean meal) may be processed in one country with the raw material (soybeans) coming from another. In this study, in case of uncertainty on the provenance of feed ingredients, we made the most optimistic assumption (i.e. shortest distance) regarding the

origin of the crops. In the case of soybean and sunflower meal we had evidence that a major fraction originated from or had at least been processed in Italy. a major organic crop producer in Europe. However, some sources indicated that these ingredients were also imported from much outside Europe. Evidence, in this respect was not sufficient, as we had difficulty obtaining reliable information. We therefore assumed that all soybean and sunflower was produced in Italy. As a result we probably underestimated the impacts of transport of feed ingredients.
This raises the question of the traceability of organic animal products and the feeds used to produce them. The organic supply chain relies on certification procedures for the crops used as feed ingredients, it is unsettling to discover that, despite serious efforts, we have not been able to establish the provenance of all feed ingredients with certainty.

4.1.3 Feed conversion

French organic broiler production usually involves the use of slow-growing strains and a long rearing phase (around 93 days), resulting in a high feed conversion coefficient (3.2 kg/kg). Therefore, shortening the rearing phase to 70 days for instance could lead to substantial improvements. However, there might be some reluctance either from poultry companies or even farmers, because a long rearing phase is associated with a better taste of the meat and with high quality standards. It can be argued, However, that there may be some room on the market for both product types, where 70-day broilers could also be more affordable.

4.2 Crop production

Fuel combustion for agricultural machinery contributed a significant share of the total energy demand and climate change. One way of decreasing the impact of fuel combustion per kg of broiler is to enhance crop yields, e.g. by selecting crop varieties and hybrids more adapted to organic production methods.
Water use is mainly for irrigation, which also contributes to cumulative energy demand. Thus, reducing irrigation will decrease energy demand and water use, which is particularly relevant in areas facing water shortage. However, irrigated crops have higher yields than non-irrigated crops. Therefore life cycle assessment could be used to find an optimum between higher yields and irrigation levels.
We saw that growing feed ingredients locally can decrease climate change and total cumulative energy demand. Therefore, incorporating regional crops that have

the lowest impacts in one given region is an interesting option. Crops and varieties should therefore be adapted to local conditions.

4.3 Point source and non-point source emissions

Ammonia is the main contributor to acidification and has a significant share in eutrophication. It is mainly emitted during the rearing phase and during the storage or composting of manure. Limiting ammonia loss during these phases is therefore necessary. Keeping the litter dry in the broiler building can help decreasing ammonia emissions, as well as covering the compost heaps. This last option may affect on the emission of other gases such as N2O.
Non-point source emissions such as field emissions of nitrate and phosphate can be reduced as well. The use of intercrops is an efficient mean of decreasing nitrate leaching, for instance. Reducing soil erosion could limit phosphate losses

4.4 Heating of broiler building

Heating of the broiler building had a significant contribution to total cumulative energy demand and climate change. Propane consumption can be reduced by improving the insulation of the roof, for instance. Using new and more efficient heating devices and ensuring their maintenance can further reduce propane consumption [17]. As heating the building is required only during the first weeks of the broiler’s life, energy savings can be obtained by dividing the building in two parts and heating only one of them [17].

4.5 Life cycle management and the AviBIO project

The AviBIO project is a national project involving a large number of stakeholders in the organic broiler production system: researchers, farming advisers, poultry and feed production companies, professional unions, and consumers. Its aim is to promote the sustainable development of organic poultry production. It is based on a participative approach. All stakeholders were given a questionnaire asking them to rank principles and criteria of sustainable development from most to least important. A sub-group of participants was asked to select a set of principles and criteria and to associate them with a limited number of points in order to calculate a global score. They selected indicators associated with each criterion. LCA impact indicators were integrated among other environmental indicators. Although they did not result of a selection process by the participants, participants ranked them. This process that took place over a long period of time enabled participants to better understand the LCA method and the meaning of its results. This process raised stakeholders' awareness of the environmental impacts of the poultry productions. This will enable them to implement their decision to reach more sustainable production systems.

5 Conclusion

As other studies on broiler production, we showed that feed production was the main contributor to all impacts except acidification. It is therefore necessary to focus on this stage to decrease the overall environmental impacts. Point source emissions such as ammonia as well as direct energy use such as heating of the broiler house can also be reduced. We discovered that data concerning the origin of the feed ingredients were not easily available. We think that this information should be more transparent, especially for organic production systems which claim to be environmentally-friendly. In the Avibio project, the participative approach enabled stakeholders to better understand the LCA method and the meaning of its results. This will help them to better cope with environmental issues in the future.

6 Reference

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