Are there Environmental Benefits from Feeding Livestock with European Grain Legumes?

D.U. Baumgartner[1], T. Nemecek[1], L. de Baan[1], F. Pressenda[2] K. Crépon[3], B. Cottrill[4], Julia-Sophie von Richthofen[5] and Mónica Montes[6]
[1]Agroscope Reckenholz-Tänikon Research Station ART, CH-8046 Zurich, Switzerland; daniel.baumgartner@art.admin.ch
[2]CEREOPA, AgroParisTech, F-75231 Paris, France; [3]UNIP, F-75008 Paris, France;
[4]ADAS, Wolverhampton WV6 8TQ, United Kingdom; [5]proPlant GmbH, D-48147 Münster, Germany;
[6]CESFAC, E-28001 Madrid, Spain

Keywords: life cycle assessment, LCA, grain legumes, soya bean meal, feedstuff, livestock production, Europe

Abstract

Currently the protein supply of the European animal production is mainly covered by soya bean meal from overseas. We assessed the environmental impact of replacing soya bean meal with grain legumes produced in Europe in the feed for pigs, broilers, laying hens and dairy cows in different European regions using the life cycle assessment (LCA) methodology.

There were no overall advantages from the feed alternative containing European grain legumes: While energy demand was reduced by 1% to 9%, eutrophication potential was similar with the exception of pig production in Catalonia, where high NO_3-losses in connection with the cultivation of peas led to a higher impact. For ecotoxicity there was a tendency towards negative environmental impacts.

Conclusively, the use of grain legumes produced in Europe decreased the environmental impact from transport, especially when using locally produced feed, and from land transformation compared with imported soya beans. However, the results are even more influenced by the choice of the replacing feed ingredients. These factors should be considered in formulating the feedstuffs. Measures have primarily to be taken to reduce the environmental burden of the feedstuff production, but also optimising animal husbandry and manure management should be aimed for.

Introduction

An important part of the human diet in Europe consists of products of animal origin. At the same time, animal production is economically the largest branch of European agriculture. In 2002, 37 million tonnes of meat, 33 million tonnes of milk and 5 million tonnes of eggs were consumed in the EU-15 (EUROSTAT, 2007). The large count of livestock needed to supply these products puts pressure on the environment by using non-renewable resources and by emitting nutrients and pollutants to water, soil, and air. Feedstuff production is known to contribute considerably to the environmental impacts of animal production.

Today more than 70% of the protein sources for animal feed for the European Union are imported, mostly as soya bean meal from North and South America. Besides, the adverse environmental impacts of long transport distances, the conversion of rainforests into arable land and the cropping of genetically modified varieties act negatively on consumers' acceptance. Cultivation of more grain legumes in Europe is thus expected to be an interesting alternative to the importation of soya bean meal, particularly since grain legumes, being capable of symbiotic nitrogen fixation, do not need any nitrogen fertilisation.

Life cycle assessment studies on meat, milk, and eggs

Five case studies in four European regions were conducted to analyse the environmental impacts of introducing grain legumes into animal feed: pork production in North-Rhine Westphalia (NRW, Germany) and in Catalonia (CAT, Spain), chicken and egg production in Brittany (BRI, France), and milk production in Devon and Cornwall (DAC, United Kingdom; Baumgartner *et al.*, 2008). The selection of these regions was based on their national importance in producing the respective animal products (Crépon *et al.*, 2005). For all five case studies, a life cycle assessment (LCA) was calculated, comparing different feeding alternatives. In the life cycle approach, all stages of the agricultural production were included: the production of inputs and infrastructure (e.g. production of energy, fertilisers, seeds, machinery, buildings), crop production (e.g. fertiliser and pesticide application, harvesting, crop processing and storage, land transformation), and animal production (e.g. transport of feeds, direct animal emissions, manure management). Finally, the environmental impacts (emissions and resource use) for producing one kg of meat, eggs, or milk were assessed. Slaughtering and processing of the animal products were not considered. The LCA calculations were performed with the Swiss Agricultural Life Cycle Assessment methodology (SALCA) as described in Nemecek *et al.* (2008).

Using an economic optimisation model (Pressenda *et al.*, 2006) the different feeding alternatives were calculated, providing the necessary nutrients for every animal category with a realistic feedstuff composition. The formulas contained five categories of feedstuffs: soya bean meal (origin: Brazil, USA, Argentina), different protein rich feeds (e.g. rapeseed, sunflower and palm kernel meal, maize gluten feed), European peas and faba beans, energy rich feeds (e.g. wheat, wheat middlings, barley, maize, beet and citrus pulp, cassava, oils), and mineral feeds (e.g. limestone, di-calcium phosphate, synthetic amino acids, vitamins). Dairy cows also had roughage feed (fresh or conserved grass) in their ration.

The following feeding alternatives were compared: SOY, standard feed formulas with soya bean meal (and in the milk case study with other protein rich feeds) as the major source of protein; GLEU, alternative feed formulas, where most of the soya bean meal was replaced by grain legumes from Europe (i.e. peas and faba beans) and different protein feeds. As grain legumes provide both protein and energy, a partial replacement of energy rich feeds also took place in those feed formulas. In two case studies additional feeding alternatives were analysed: the FARM alternative in NRW, i.e. simplified feed formula based on GLEU, with fewer feed ingredients, produced on the animal farm; and short-SOY in BRI, a more common chicken production system with a shorter fattening length, where inclusion of peas instead of soya bean meal was not possible for nutritional reasons (Baumgartner *et al.*, 2008).

Results

Feedstuffs contributed greatly to the environmental impact of animal products. In nearly all case studies, feedstuff production (crop production, transport, and processing) accounted for more than half of the energy demand and the eutrophication potential (nutrient enrichment), for about two-thirds of the global warming potential, and for most of the ecotoxicity. For dairy cows, the impact of concentrate feeds on the environmental burden was still high, but was slightly lower because the cows, fed mostly on grass and grass silage, consumed less concentrate feed than other animal categories.

Overall, the environmental impacts of the GLEU alternative ranged from very favourable to very unfavourable compared with the SOY (Table 1). The results are classified in three environmental impact groups: resource use, nutrients and pollutants, as defined by Nemecek *et al.* (2005).

Resource use-driven impacts

Introducing grain legumes into animal feeds reduced the demand for non-renewable energy in all case studies except in NRW, where the GLEU alternative was similar to SOY (Table 1). The favourable effect of the GLEU alternative results from reduced transport and from the fact that pea and faba bean production is less energy intensive than the combination of soya bean meal and energy rich feeds that they are replacing.

Table 1. Environmental impact of feed formulas with European grain legumes (GLEU alternatives) as a percentage of feed formulas with soya bean meal from overseas (SOY) for all five case studies (per kg animal product) in North Rhine-Westphalia (NRW), Catalonia (CAT), Brittany (BRI) and Devon and Cornwall (DAC) (++ = very favourable, + = favourable, 0 = similar, – = unfavourable, – – = very unfavourable; EDIP and CML are two alternative ecotoxicity impact assessment methods.)

	Region	**NRW**		**CAT**		**BRI**		**BRI**		**DAC**	
	GLEU in % SOY	**Pork**		**Pork**		**Chicken**		**Egg**		**Milk**	
Resource use-driven impacts	Energy demand [MJ-equivalents]	99%	0	94%	+	93%	+	94%	+	91%	+
	Global warming potential [kg CO_2-equivalents]	95%	+	98%	0	89%	+	89%	++	96%	0
	Ozone formation [g Ethylene-equivalents]	98%	0	106%	–	97%	0	95%	+	97%	0
Nutrient-driven impacts	Eutrophication [g N-equivalents]	93%	0	117%	–	105%	0	106%	0	102%	0
	Acidification [g SO_2-equivalents]	98%	0	98%	0	98%	0	99%	0	99%	0
Pollutant-driven impacts	Terrestrial ecotoxicity EDIP [points]	96%	0	126%	–	125%	–	124%	–	97%	0
	Aquatic ecotoxicity EDIP [points]	111%	0	127%	–	89%	0	125%	–	82%	+
	Terrestrial ecotoxicity CML [points]	376%	– –	165%	– –	108%	0	116%	–	95%	0
	Aquatic ecotoxicity CML [points]	176%	– –	105%	0	104%	0	110%	0	95%	0
	Human toxicity CML [points]	103%	0	108%	0	100%	0	102%	0	97%	0

This effect is illustrated clearly in the milk case study (Figure 1). In the GLEU alternative, most of the beet pulp and wheat was replaced by faba beans, resulting in a twofold reduction in energy demand: i) reduced use of N fertiliser (its production is energy intensive) and ii) reduced energy inputs for drying and processing crops. Of particular note is the low energy demand of roughage feed, although it accounted for 70% of the feed ration. As in the other case studies, housing (i.e. construction and operation of the buildings) had an important contribution to the total energy demand.

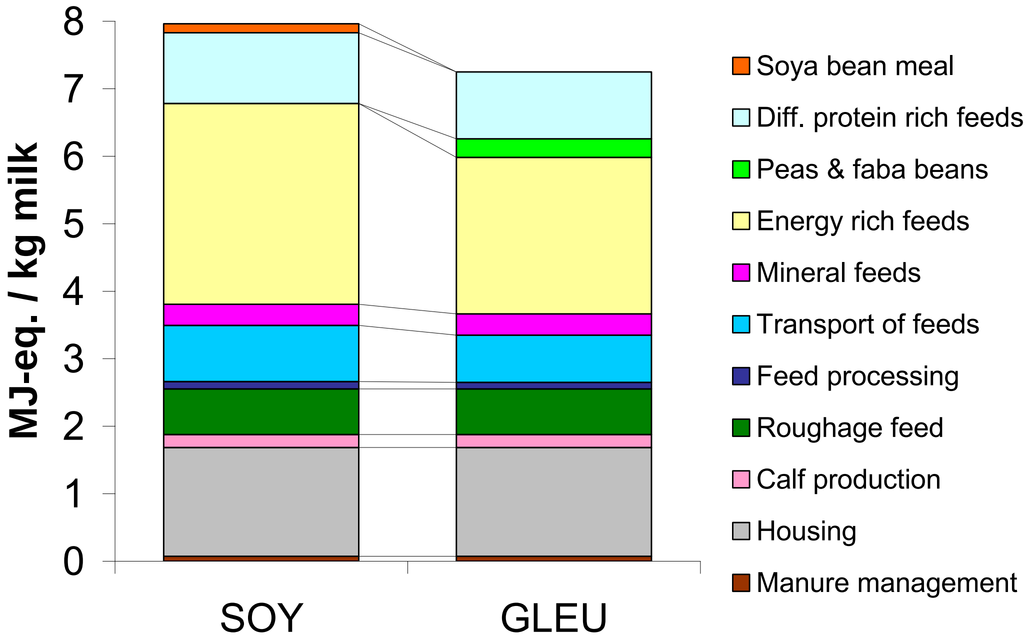

Figure 1. Demand for non-renewable energy resources for producing one kg milk in Devon and Cornwall (UK) with the two feeding alternatives, soya bean meal from overseas (SOY) or European grain legumes (GLEU).

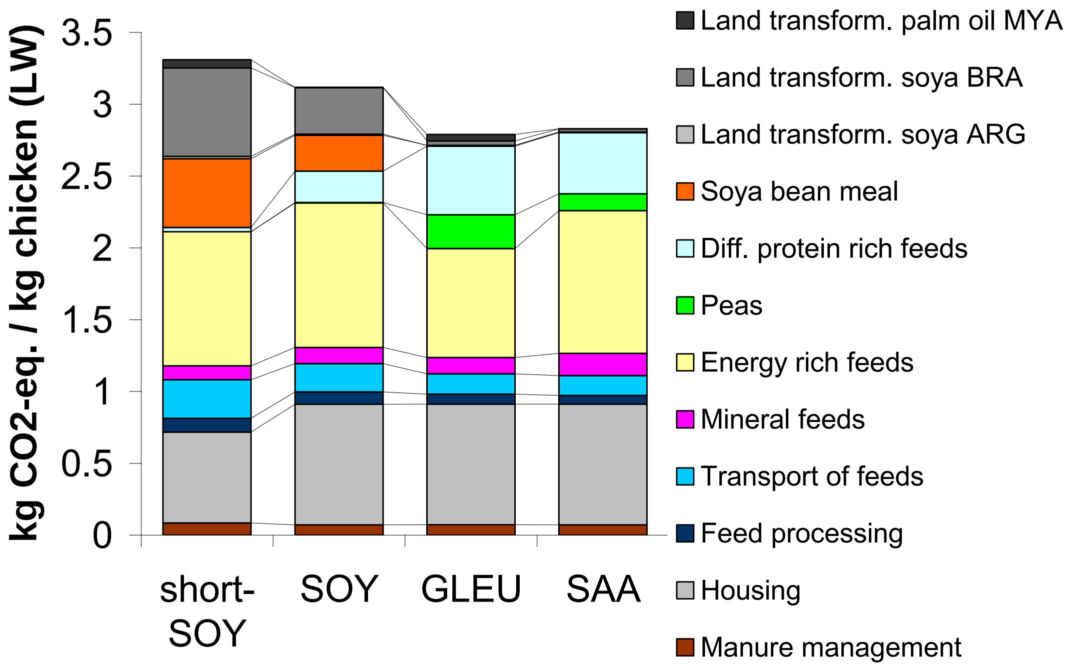

Figure 2. Global warming potential (100a) for producing one kg of chicken (live weight: LW) in Brittany (BRI) with the four feeding strategies SOY (soya bean meal from overseas), GLEU (European grain legumes), SAA (synthetic amino acids), and short-SOY (short fattening length). MYA: Malaysia; BRA: Brazil; ARG: Argentina.

Global warming potential (GWP) was reduced in all case studies except for CAT (Table 1). This was largely due to the high global warming potential of soya beans. The transformation of Brazilian rainforest and Argentinean savannas into soya bean cultivation areas leads to large releases of CO_2 from biomass and soils.

This is exemplified in the broiler chicken case study (Figure 2), where for the overall result on GWP the difference solely lied in the CO_2-release by land transformation, here mainly from the soya bean cultivation in Brazil: There was very little soya bean meal and oil in the GLEU alternative, whereas in the short-SOY alternative there was about double the amount of soya bean meal compared with the reference SOY. In short-SOY there was a smaller GWP from housing and energy rich feeds, due to the higher productivity of the system. Whereas there was more GWP from the process steps transport of feeds and soya bean meal, because of the high share of soya bean meal. The GLEU alternative had a smaller GWP through less transport of feeds and the absence of maize in those formulas. The increase of rapeseed meal and sunflower meal in protein rich feeds as well as peas led to a higher GWP for these process steps, resulting in a similar impact for GLEU and SOY. Finally, the SAA alternative had a diminished GWP from transport of feeds, but a higher GWP from mineral feeds and the protein feeds replacing the soya bean meal. The reasons are an increase of the use of synthetic amino acids for the mineral feeds, the partial exchange of wheat by maize in the feedstuff group energy rich feeds and the introduction of maize gluten as a protein rich feed. Maize has compared with wheat a higher energy demand because of the grain drying after harvest. And maize gluten is in its production much more energy intensive as soya bean meal.

Nutrient-driven impacts

Replacing soya bean meal with grain legumes had little effect on eutrophication (nutrient enrichment) (Table 1). In the pork case study in CAT, the GLEU alternative was unfavourable compared with SOY (Figure 3). This was mainly due to the lower yield levels of Spanish peas, resulting in high nutrient losses per kg of peas. Low yield levels combined with a twofold incorporation rate of peas in the feed formulas explain why producing one kg of pork meat in CAT caused nearly twice as much eutrophication as in NRW. Other reasons are a lower feed conversion rate in CAT, implicating an increased use of feed raw materials and increased losses of nitrogen and phosphorus through excretion, and unfavourable manure management (ammonia emissions from an uncovered slurry lagoon).

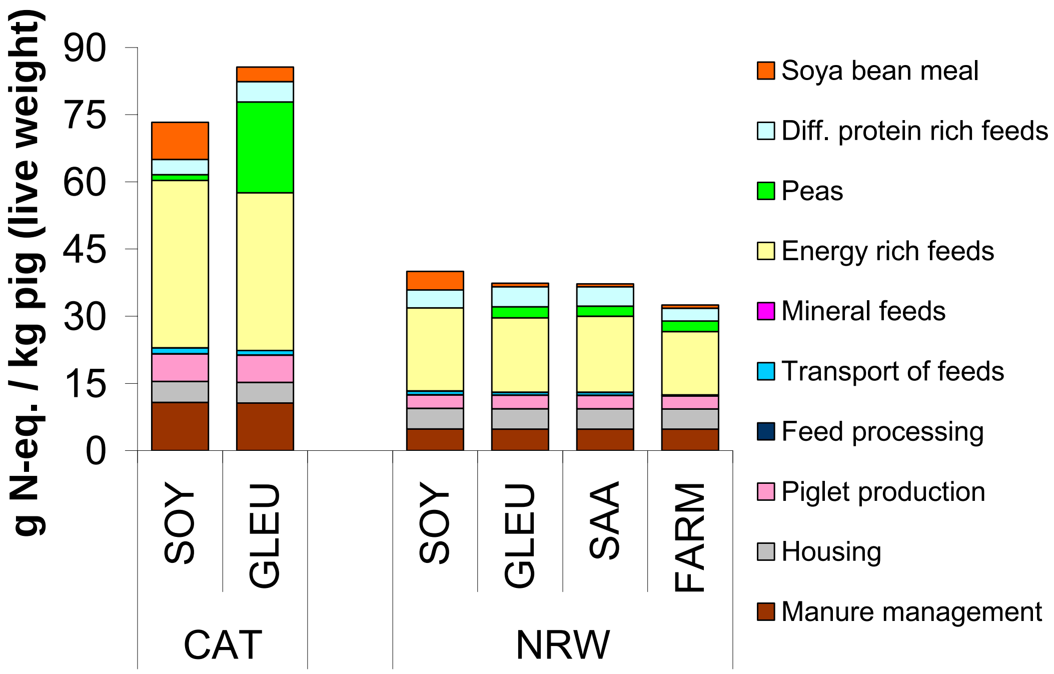

Figure 3. Eutrophication potential per kg pork produced in Catalonia (CAT) and North-Rhine Westphalia (NRW) with soya bean meal from overseas (SOY), European grain legumes (GLEU), or on-farm feed production (FARM).

Pollutant-driven impacts

Throughout all case studies the results for terrestrial and aquatic ecotoxicity ranged between a similar to unfavourable effect of GLEU compared with SOY (Table 1). Only in the milk case study was the ecotoxicity of GLEU slightly reduced.

For the terrestrial ecotoxicity (according to EDIP97 methodology) cereals, rapeseed meal and peas dominated the results, while soya bean meal contributed little to this impact category. The reason lies in the applied active ingredients (pesticides) during the cultivation of the above mentioned crops. The detailed analysis showed that two active ingredients were responsible for the largest part of the terrestrial ecotoxicity according to EDIP97, namely i) the fungicide propiconazole, which is used in cereals and ii) the insecticide lamda-cyhalothrin, which is applied in pea, oilseed rape and cereal cultivation. Since the results for ecotoxicity are very dependent on the applied active ingredients and the method chosen to assess them, a careful interpretation of the results is required.

Effects of on-farm production and of fattening length

By using European instead of overseas protein sources transport can be reduced, especially if feedstuffs and livestock are produced locally, or on the same farm. This option was assessed for the pork production case study in NRW. The results show clearly (Table 2) that, compared with SOY, the FARM alternative had a very favourable effect on resource use-driven impacts, a favourable effect on nutrient-driven impacts, and a similar to very unfavourable effect on pollutant-driven impacts. The reduced non-renewable energy demand and global warming potential were achieved mainly by reduced transport, but also because energy intensive crops such as grain maize were replaced partly by the incorporated grain legumes. This replacement was also the reason for the favourable effect on eutrophication and the unfavourable effect on terrestrial ecotoxicity in the FARM alternative.

The fattening length has an effect on the environmental impacts. The feeding alternatives in the broiler case study were all based on a medium fattening length of 60 days, except for the short-SOY alternative (41 days), which is actually the most common broiler farming system in BRI. The short-SOY alternative was favourable compared with SOY in terms of energy demand and ecotoxicity, but unfavourable in terms of global warming potential (CO_2 releases from clearing of rainforests), ozone formation (due to longer transport distances), and acidification (higher ammonia emissions, because of higher N-content in excretion). Thus, medium fattening length did not improve the overall environmental performance of chicken production, but was favourable for some environmental impacts.

Table 2. Environmental impacts of on-farm feed production (FARM) for pork in North Rhine-Westphalia (NRW) and standard feed formulas containing soya bean meal for the most common fattening length of 41 days (short-SOY) and 60 days (SOY) for chicken in Brittany (BRI), both expressed as a percentage of SOY (the standard feed formula with soya bean from overseas) per kg of animal product. (++ = very favourable, + = favourable, 0 = similar, — = unfavourable, — — = very unfavourable; EDIP and CML are two alternative ecotoxicity impact assessment methods.)

	Region	NRW		BRI	
		FARM in % SOY		short-SOY in % SOY	
Resource use-driven impacts	Energy demand [MJ-equivalents]	81%	++	94%	+
	Global warming potential [kg CO_2-equivalents]	84%	++	111%	−
	Ozone formation [g Ethylene-equivalents]	75%	++	105%	−
Nutrient-driven impacts	Eutrophication [g N-equivalents]	81%	+	102%	0
	Acidification [g SO_2-equivalents]	90%	+	113%	−
Pollutant-driven impacts	Terrestrial ecotoxicity EDIP [points]	124%	−	79%	+
	Aquatic ecotoxicity EDIP [points]	103%	0	102%	0
	Terrestrial ecotoxicity CML [points]	317%	−−	62%	++
	Aquatic ecotoxicity CML [points]	131%	−	65%	++
	Human toxicity CML [points]	97%	0	89%	0

Discussion and Conclusion

Replacing soya bean meal with European grain legumes in feedstuffs was expected to improve the environmental performance of livestock production. The results of the five case studies on meat, egg, and milk production revealed that this replacement did not lead to an overall environmental improvement. Clear benefits could only be found regarding the resource use-driven impacts due to less transport, reduced incorporation of energy rich feeds and absence of land transformation. There was little effect on nutrient-driven impacts, as the positive effects of the reduced use of soya bean meal and energy rich feeds were often (over) compensated by the negative effects of the cultivation of the grain legumes themselves or the accompanying protein rich feeds, especially sunflower and rapeseed meal. For the pollutant-driven impacts, the introduction of grain legumes in feedstuffs tended to be negative. Again the reason lies in the crop production, where the feed ingredients replacing the soya bean meal involve using particularly harmful pesticides. However, these results should be checked with improved ecotoxicity assessment methods, as in some case studies they vary considerably depending on different methodologies.

As a matter of fact, replacing soya bean meal by grain legumes changes the whole composition of the feed formulas not only the part of the protein rich feeds. Consequently, the results are more determined by the whole composition of the feed formulas than by the replacement of soya bean meal by grain legumes.

Having diverging results throughout the different environmental aspects highlights the importance of a holistic approach to the evaluation of the integration of European grain legumes in animal feed. This enables to detect alterations from one environmental problem to another. As the feedstuff production has a major share in the environmental impact of animal products, improvements should target this part of the life cycle. As a possible measure we propose the integration of environmental criteria into feedstuff models, allowing the optimisation of feed formulae in terms of economic and environmental aspects.

The following factors have been identified in helping to improve the environmental performance of livestock production:

- Local feedstuff production is favourable.
- Manure management can be improved (e.g. by covering the slurry lagoon, adjusting the timing of slurry spreading and use of appropriate spreading techniques).
- Feedstuffs that need low levels of inputs for crop production and processing are favourable. Here, it is important to consider inputs in relation to yield levels; lower yields often lead to higher emissions per unit of the commodity.
- Improved feed conversion of animals reduces the consumption of feedstuffs and hence the overall environmental impact of animal products.
- For ruminants a high proportion of roughage in their diet is favourable.

Acknowledgements

This research was supported by the European Commission (grant no. FOOD-CT-2004-506223) and by the Swiss State Secretariat for Education and Research SER, Berne, Switzerland.

We would like to express our thanks to H. Jebsen (Agravis Raiffeisen AG, Münster, Germany), as well as R. Fechler and W. Sommer (North Rhine-Westphalia's Chamber of Agriculture, Münster, Germany) for providing data and information.

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