Low Emission Farming – a significant step forward to improve the ecological footprint of livestock production

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Abstract
Animal raising and livestock production are major players in global environmental issues. Different players along the value chain must cooperate to lever existing knowledge and move towards more sustainability- based tools to measure the overall progress. The supplementation of feed with amino acids reduces feed consumption and the nitrogen content in feed, waste treatment in a biogas plant brings methane emissions to energy production, purification of methane offers new alternatives for improved energy provision and finally, specific treatment of digested residues provides new fertilizer applications. The combination of these different aspects of nutrient management, waste management, emissions management and finally fertilizer treatment enables new ecological measures to improve the nutrient cycles in livestock production especially for nitrogen compounds. Advanced LCA methodologies following the standards of DIN EN ISO 14040/44:2006 display the material flows and help to identify the losses impacting the soil and water due to eutrophication and acidification caused by nitrogen based emissions and thus, offering new mitigation options.

Key Words
Amino acids, methane, life cycle analysis, nitrogen, eutrophication, acidification, fertilizer

Introduction
Livestock is the major player in global environmental issues. The huge demand for feed crop production shapes entire landscapes and can reduce natural habitats, causing degradation in some areas, technological improvement, but it is also a key driver of global livestock production. Growing productivity has been achieved through advanced breeding and feeding technology, and through irrigation and fertilizer technology in crop production, leading to higher yields per hectare. Intensification, the vertical integration and up-scaling of production also lead to larger units and larger livestock operations. According to FAO (Gerber 2013), it is important to set up advanced technologies such like feed strategies, manure management practices and energy use efficiency to further reduce livestock production related emissions especially caused by nitrogen based compounds like NO_3, N_2O, NO_x or NH_4. Modern livestock production is characterized by efficient nutrient management to lower feed consumption, waste management to reduce waste volumes and finally emission management to reduce environmental impacts. Based on recently published data on improved feeding technologies (Kebreab 2016), the present paper intends to assess the further mitigation options by combining nutrient management, emissions management and waste management applying LCA methodology.

Methods
Life Cycle Assessments (LCA)
Life Cycle Assessments can be used to display and monitor the specific mitigation option of these measures, but can also help to identify hotspots and further options for improvement. A couple of studies are already in place to show the different scenarios to manage feed, waste or energy, but never before concepts have been developed to bring all the different options together in one holistic solution of low emission livestock production. In general, life cycle assessments describe the complete fate of a product by compiling and evaluating all ecological input and the consequences for the environment during each phase in the life cycle of the product based on international standards (DIN EN ISO 14040/44:2006).For livestock production, the impact categories Global Warming Potential (GWP, expressed in kg CO_2-equivalents/kg Functional Unit), Eutrophication Potential (EP, expressed in kg PO_4-equivalents/kg Functional Unit), and Acidification Potential (AP, expressed in kg SO_2-equivalents/kg Functional Unit) are the most relevant ones.

The Low Emission Farming Concept (LEF)
The concept of the “Low Emission Farming” (LEF) offers the best practice to reduce livestock related emissions to the lowest possible level. The supplementation of feed with amino acids helps to overcome nutrient gaps and reduces feed consumption (Haasken 2015, Kebreab 2016). Thus, leads to a lower nitrogen content in the feed and less nitrogen excreted through manure. Waste treatment in a biogas plant brings

methane emissions to energy production, purification of methane offers new alternatives for improved and independent renewable energy provision by further reduction of nitrogen-based emissions. In addition, a specific treatment of biogas fermentation residues provides new fertilizer applications and brings non-used nitrogen based components back to the nutrient cycle in livestock production. The combination of the different options for nutrient management, waste management, emissions management and finally fertilizer treatment by the LEF concept is shown in Figure 1.

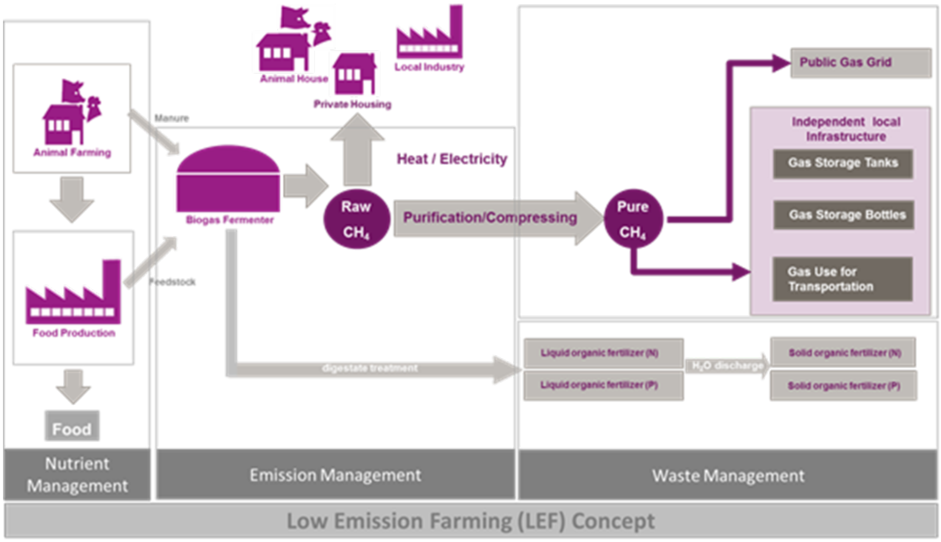

Figure 1: The concept of the Low Emission Farming, which combines Nutrient management, emission management and waste management at farm level

Nutrient management

Improving feed efficiency and reducing the nutrient excretion as the key elements of nutrient management enables mitigation of the overall impact of livestock production substantially. This could already been shown through a life cycle assessment (LCA) (Haasken 2015) for a typical European pig and broiler production scenario supplementing feed with amino acids such like MetAMINO®, Biolys®, ThreAMINO®, TrypAMINO® and ValAMINO®. Thus, soybean meal and corn were replaced and in consequence, the ecological footprint was significantly improved. Another study (Kebreab 2016) described comparable effects of the advanced technology for different feeding regimes in Europe, North America and South America.

Waste and Emission Management

Next to the efficient nutrient management, the emission or waste management represents a further mitigation option realized in the approach of the “Low Emission Farming” concept (LEF) (Binder 2015). As already explained, the supplementation of feed with amino acids as a first measure reduces feed consumption and the nitrogen content in feed. The further waste treatment by managing manure in a biogas plant brings methane emissions to energy production, and thus, additionally reduces emissions normally related to manure disposal. Finally, specific further physical and chemical treatment of biogas fermentation residues provides new fertilizer opportunities allowing more nutrient specific applications in crop production. This helps to reduce the environmental impact and to comply with the more and more strict limitations for nitrogen and phosphorus fertilization of grass- and cropland.

System description

The full study analyzes large-scale pig and poultry production systems in the regions Europe, North America and South America based on the feeding technologies published in the study of Kebreab (Kebreab 2016). Next to this described subsystem for nutrient management, the present study extends to additional subsystems such like the waste management and the emission management including them into the LCA model. In the later subsystem, three different options for biogas processing and usage are compared additionally:

Option 1 (BG CHP, Figure 2) examines the usage of biogas for electricity and thermal energy production in a combined heat and power plant CHP plant, option 2 (BG CH4, Figure 2) includes also purification of biogas to bio-methane and option 3 (BG fuel, Figure 2) the substitution of fossil natural gas or diesel as a fuel. Transportation of feed ingredients and feed mixes in subsystem 1 is included, upstream activities like extraction of crude oil for fuels or energy system are considered as well. For the European alternatives, EU-27 average background datasets are used. The North American scenarios include US-specific datasets and for South American livestock production Brazilian conditions are assumed in the full study, but results will not be shown in the abstract. In this study, the life cycle inventory (LCI) of nutrient management subsystem is based upon the literature data from the sector-wide conducted LCA study on livestock production (Kebreab 2016). The inventory data for background processes like region specific electricity generation, diesel production and crop cultivation are obtained from the GaBi 6 database (PE INTERNATIONAL AG, 1992-2015). All LCA modelling has been done with the GaBi software of thinkstep in its current version.

Results

As already explained above, the full study reflects the LEF concept in three regions for pig and broiler production, whilst the present abstract only shows exemplarily the results in terms of LCA terminology for the eutrophication mitigation potential (EP) in the European broiler production (Figure 2). In total, the implementation of the LEF concept leads to a reduction of 55% for the impact eutrophication potential (EP). The selective addition of required amino acids to the feed mix from broiler lowers the crude protein content in the feed. Thus, less nitrogen is excreted reducing the EP by 42%. Integration of a biogas plant enables control and separation of emerging NH_3 and leads to smaller contributions to EP than conventional storage. Credits for energy, natural gas or diesel show only a small impact on EP as their production and incineration is more relevant for airborne emissions.

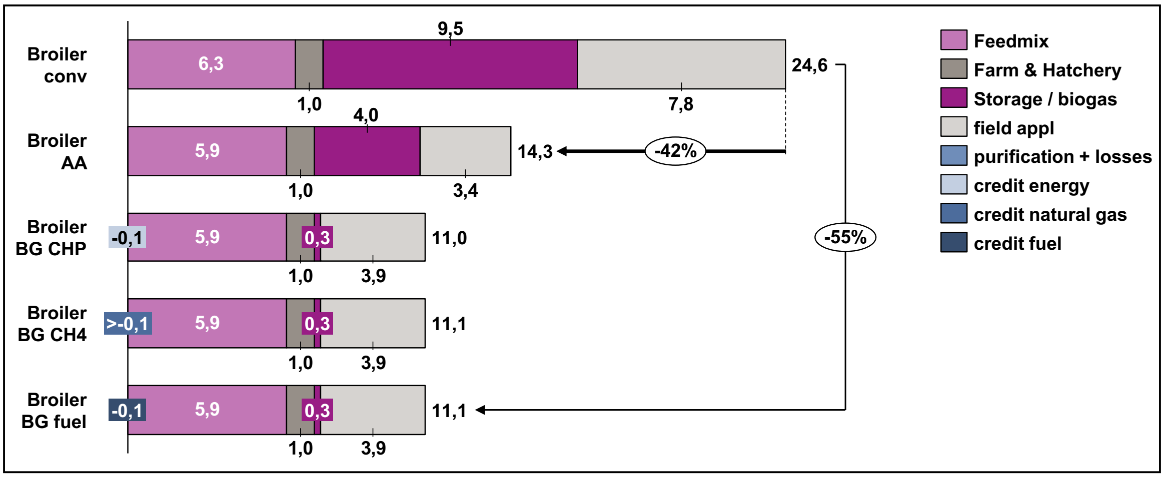

Figure 2: EP [kg PO4e] of broiler production and stepwise integration of the LEF concept per 1,000 kg LW broiler in Europe
(Broiler cov=broiler feed without amino acids; Broiler AA= broiler feed with amino acids; Broiler BG CHP= broiler feed with amino acids and biogas production; Broiler BG CH_4= broiler feed with amino acids and biogas production and purification; Broiler BG CH_4= broiler feed with amino acids and biogas production and purification inclusively credits for fuel replacements)

As already mentioned earlier, in terms of LCA calculations,the Eutrophication Potential (EP) is expressed in kg PO_4-equivalents/kg functional unit, which means in Figure 2 per 1,000 kg of broiler live weight. Following the different calculation factors for N_20, NH_3 and NO_3 contributing to EP, the elementary nitrogen flow can be monitored as well (Figure 3). Beside the improvements of the eutrophication potential shown in Figure 2, the loss of nitrogen along the value chain can also be significantly reduced. The adaption of crude protein content to the nutritional requirements of the broilers from 85.4 kg per 1,000 kg live weight to 52.9 kg leads to reduced nitrogen excretion to the soil from 16.4 kg to 6.8 kg. The implementation of the biogas production slightly increases the nitrogen flow to soil up to 8,0 kg, but improves the nitrogen losses as NH_3 from 12.1 kg (Broiler AA) to 10.3 kg (Broiler BG CHP).

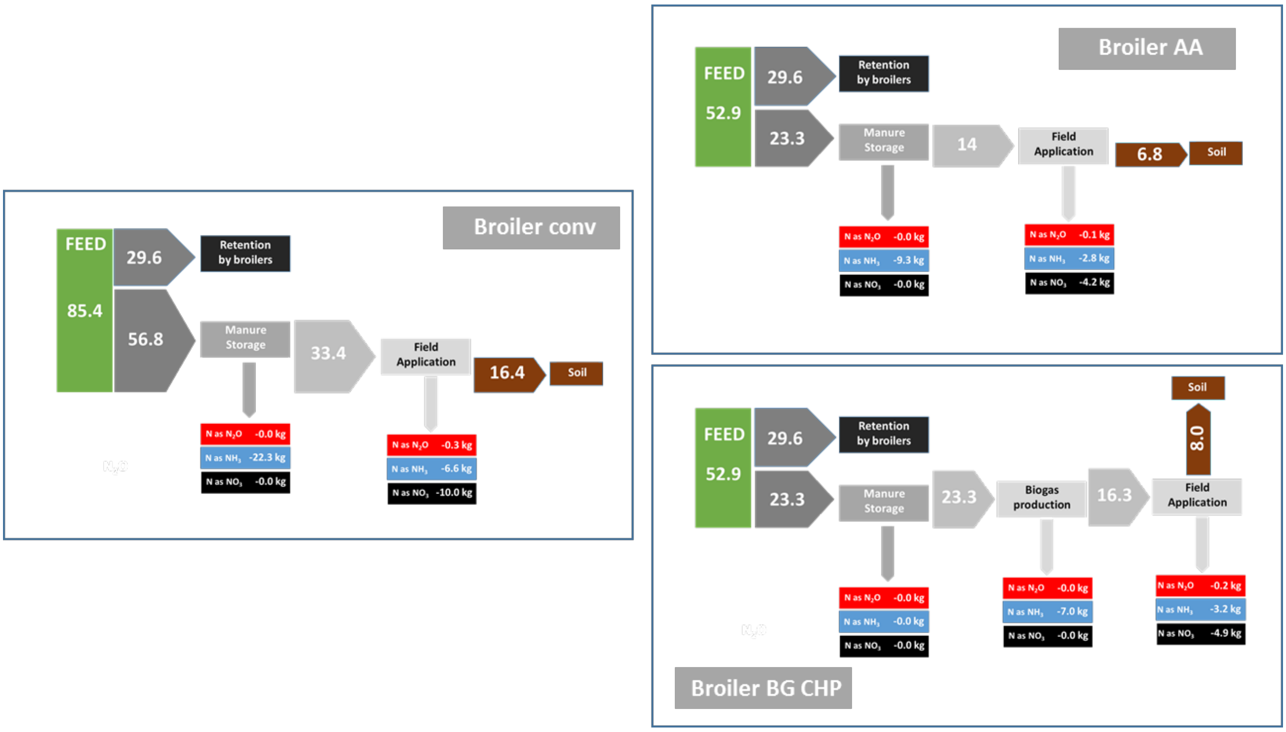

Figure 2: Nitrogen flows [kg N] of broiler production and stepwise integration of the LEF concept per 1,000 kg LW broiler in Europe

Conclusion

Low protein diets contribute to reduce the impact of livestock production especially on climate change in general. Since the reduction of the protein content in feed is closely linked to lower nitrogen amounts excreted, this technology significantly influences the mitigation options specifically for those impact categories of nitrogen based emissions to soil and air, as exemplarily shown for the eutrophication potential in European broiler and pig production. As for current feeding practices, there is still a major potential to mitigate this impact. There is still a considerable gap between the average content of crude protein in standard diets compared to scientifically proven low protein diets.

Additionally to an improved nutrient management further measures such like the LEF concept on a farm level are leading to significantly improved ecological performance of livestock production associated and reduced losses of nutrients such like nitrogen. These applications not only reduce the ecological impact, but also open new business opportunities for renewable energy production, energy self-provision or advanced organic fertilizer use adapted to specific recommendations as best practice with regard to sustainable agriculture.

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