Towards an Environment-Friendly Animal Feed Industry: The Role of the Nutritionist

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Abstract

Feed production is right at the heart of the animal feed supply chain. This supply chain is part of a dynamic global agricultural sector expanding rapidly due to the increasing demand for animal-sourced food, such as meat, dairy products, and eggs. This increasing demand for animal-sourced food results in the increased demand for animal feed, which uses raw materials, i.e., crops, by-products of the food industry, slaughter and processing of livestock, the marine industry, and biofuels, putting greater pressure on natural resources. The animal nutritionist, a major decision-maker in compound feed production systems, takes center stage in selecting and using feed materials, processing, and applying feed products in livestock production systems. This paper identifies the most significant environmental impacts of the feed supply chain and describes the role of the nutritionist in making decisions that could affect these impacts. Improving feed quality through formulation accuracy, increasing crop and animal by-products with the help of exogenous enzymes, and using alternative raw materials with lower life-cycle emissions and impacts were described as strategies nutritionists should adopt to help achieve a more environmentally friendly animal feed industry.

Keywords: animal feed supply chain, environmental impacts, nutritionist

Introduction

Feed production is right at the heart of the animal feed supply chain. This supply chain is part of a dynamic global agricultural sector expanding rapidly due to the increasing demand for animal-sourced food, such as meat, dairy products, and eggs. This increasing demand for animal-sourced food results in the increased demand for animal feed, which uses raw materials, i.e., crops, by-products of the food industry, slaughter and processing of livestock, the marine industry, and biofuels, putting greater pressure on natural resources (FAO, 2016). Life cycle assessment (LCA) studies have shown that feed production primarily contributes to livestock systems' environmental impact (Middelaar et al., 2019).

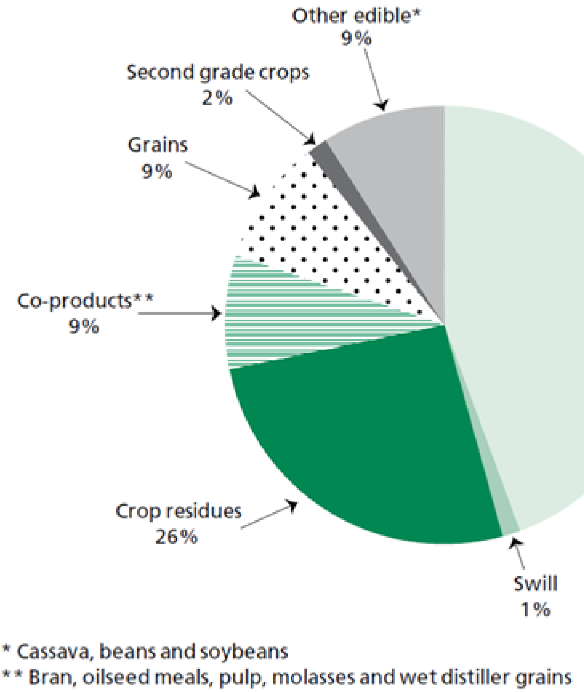
LCA is a method to quantitatively assess the environmental impacts of goods and processes from “cradle to grave”. It identifies and counts all impacts occurring throughout the entire value chain (supply chain plus use and disposal phases), avoiding burden shifting from one environmental impact to another, thereby identifying the most effective improvement strategies (Hellweg & Canals, 2014). FAO (2016) uses LCA in its recommended guidelines for assessing the environmental performance of animal feed supply chains, amidst the many different methods used to assess environmental impacts and performance of livestock products.

The animal nutritionist, a central decision-maker in compound feed production systems, takes center stage in selecting and using feed materials, processing, and applying feed products in livestock production systems. This paper identifies the most significant environmental impacts of the feed supply chain and describes the role of the nutritionist in making decisions that could affect these impacts. Strategies in diet formulation and feeding systems will be discussed, suggesting how today’s nutritionist could make decisions toward an environment-friendly animal feed industry that supports the increasing demand for safe, sustainable, and affordable animal-sourced food for the growing population.

The Animal Feed Supply Chain and its Environmental Impacts

The world’s livestock consumed 6.3 billion tons of feed (on a dry matter basis) in 2005 (Gerber et al., 2013), with ruminants consuming the bulk of feed (4.9 billion tons compared with 1.4 billion tons for pigs and poultry). Grasses and roughages comprise about 44 percent of the feed used by livestock, followed by crop residues (28 percent). Grains, by-products from processing, and other edible crops each comprised 9 percent of the feed used by the livestock sector, while swill and second-grade crops comprised 2 percent and 1 percent, respectively (Figure 1).

Figure 1
Feed Utilization by the Livestock Sector in 2005 (adapted from FAO, 2016)



Different feedstuffs are used to produce different livestock products. Most feed grain (69 percent) is fed to pigs and poultry; the rest is used in ruminant production, particularly in dairy and beef production. Fibrous feeds (grass, leaves, fodder, and crop residues) are of key importance in the diets of ruminants, which consume as much as 99 percent of fibrous feeds; the remainder is used in backyard pig production (FAO, 2016).

The structure of animal feed supply chains is diverse, ranging from simple production units or small-scale farms producing their feed or depending predominantly on local feed resources, to more complex and integrated production units where a variety of producers and industries contribute to the production, mixing, and distribution of feed ingredients and complete feed products. Feed raw material use also differs considerably among livestock production systems. Large industrial pig and chicken systems primarily use grains and other by-products from processing. In contrast, in small to medium-sized mixed livestock systems, where most ruminant livestock (73 percent) are raised, 69 percent of the animal feed supply comes from fibrous feeds (Gerber et al., 2013).

As large-scale, intensive livestock production methods have become the predominant model, animal feeds have been modified to include

include ingredients ranging from crop products and co-products from the processing and food industry to rendered animals, antibiotics, and additives. Feed also needed to be supplied more uniformly throughout the year, with its high-density nutritional content becoming the main priority. As a result, crop production and specialized feed processing plants have emerged to ensure a steady supply of high-quality feed to these large-scale livestock production units worldwide.

In 2013, the world's livestock and poultry used about 35 percent of total cropland and about 20 percent of green water for feed production (Opio et al., 2013). Feed-related greenhouse gas (GHG) emissions from the livestock sector, including those associated with land-use change, account for about 3.3 gigatons of carbon dioxide equivalent (CO2e). This represents about half of the total emissions from livestock supply chains (Gerber et al., 2013). The feed sector is aware of this, and there is a growing interest in measuring and improving the environmental performance of the feed-to-food supply chains because the demand for livestock products is projected to grow 1.3 percent per annum until 2050, driven by global population growth and increasing wealth and urbanization (Alexandratos & Bruinsma, 2012).

GHG emissions from the production, processing, and transport of feed account for about 45 percent of global livestock sector emissions in 2013 (Gerber et al., 2013). Feed production for pork and chicken supply chains contributes 47 percent and 57 percent of emissions, respectively (MacLeod et al., 2013). For cattle, small ruminants, and buffalo, feed production accounts for 36 percent, 36 percent, and 28 percent of the total emissions (Opio et al., 2013). In ruminant production systems, methane from feed digestion is the most significant contributor of GHG emissions.

Fossil carbon dioxide (CO2) and nitrous oxide (N2O) are the dominant GHGs emitted in animal feed production. The fertilization of feed crops and the deposition of manure on pastures generate substantial amounts of nitrous oxide emissions, representing about half of the emissions from feed (one-quarter of the sector's overall emissions). Carbon dioxide emissions result primarily from fossil fuels, particularly diesel in tractors and harvesting machinery, oil in dryers, and natural gas in manufacturing mineral nitrogen fertilizer. In the post-farm stages, carbon dioxide is emitted in conjunction with various feed processes and is associated with the processing, mixing, and distributing feed ingredients (FAO, 2016).

Among feed materials, grass and other fresh roughages account for about half of the emissions, mainly from manure deposition on pasture and from direct land-use change. Crops produced for feed account for an additional quarter of emissions, and all other feed materials (crop by-products, crop residues, fishmeal, and supplements) for the remaining quarter (Gerber et al., 2013).

Feed links livestock to land use, directly via grazing and indirectly via traded feedstuffs. Global changes in how land is managed and the appropriation of natural habitats, such as forest land, have been partly driven by the need to feed animals for animal production. Global croplands for feed and pasture areas have expanded in recent decades, accompanied by significant increases in inputs, such as energy, water, and fertilizer, resulting in considerable losses of biodiversity. In addition, land use and land-use change account for many GHG emissions in animal feed production (FAO, 2016).

About one-quarter of the emissions related to the feed supply chain (about 9 percent of the livestock sector's emissions) are associated with land-use change (Gerber et al., 2013). Land-use change could result in distinct or drastic changes in land quality, such as decreased biodiversity, increased soil compaction, loss of nutrients, and impacts on water availability and quality. These quality losses constitute the ecological damage from land-use change (FAO, 2016).

Role of the Nutritionist in the Feed Supply Chain

The role of the nutritionist in feed supply chain analysis would be better understood through the flow chart showing the step-by-step approach proposed by FAO (2016) in the life cycle modelling of the feed supply chain (Figure 2).

The cultivation stage analyzes the environmental impacts of the cultivation or production system where crops or animals (and their by-products) are grown for feed production. The processing stage is the analysis of the system where the crops and animals (and their by-products) are processed before use in feed production. These products (or by-products) are often further processed as a dry, tradable feed ingredient. These processes may include purification and concentration of the feed ingredients. Products can also be further processed to increase digestibility or may involve mixing with other raw materials, originating from the same process (e.g., adding soybean hulls to soybean meal or adding molasses to the pulp) or external processes (FAO, 2016).

Compound feed production is the stage after processing. In compound feed production, many feed materials from primary production (plant, animal, and non-biogenic origin) or the processing stage are brought together in a factory to produce compound feed as a final product.

Compound feed can consist of different fractions of various feed materials. Feed materials are added based on their nutritional characteristics and the specific requirements for the animal type and its production phase. Some incoming products are treated (e.g., grinding, toasting) before mixing. After the mixing process step, the product can be pelleted or left as a meal. Emissions and resource use counted in the analysis of a compound feed production system are shown in Figure 3 (FAO, 2016).

Figure 2

FAO Recommended Flow Chart to Analyze the Feed Supply Chain (adapted from FAO, 2016)

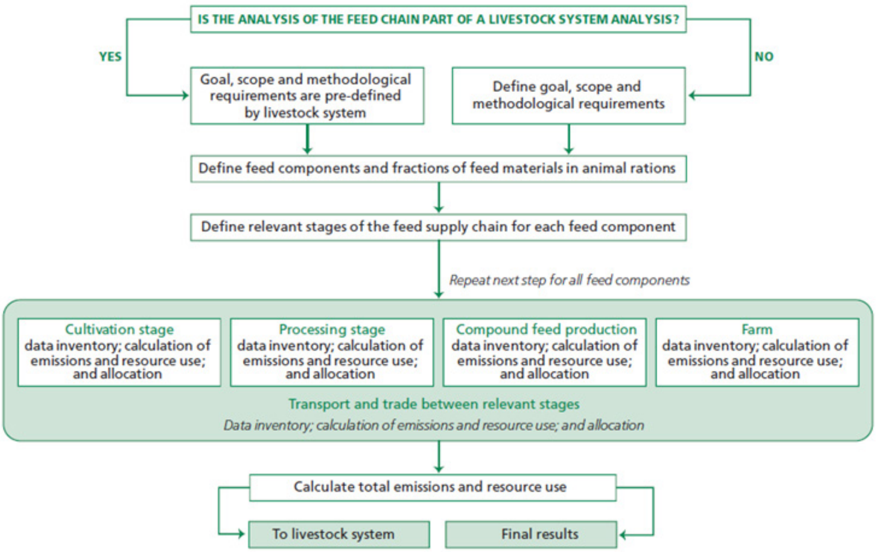
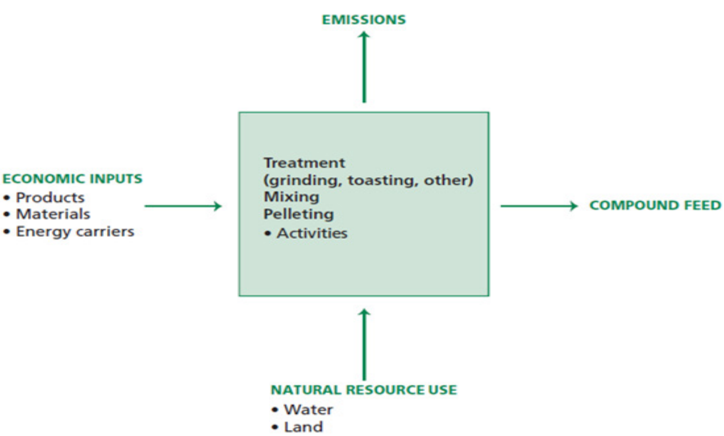


Figure 3

Emissions and Resource Use in Compound Feed Production (adapted from FAO, 2016)



A compound feed factory often produces dozens of different feed types. It is in this system where the nutritionist is a major decision-maker. Aside from deciding what products and materials from the cultivation and processing stage are to be used in feed production depending on the availability and the prices of raw materials, the nutritionist also decides on the composition of the feed types to be produced, depending on the animal's nutritional requirements, or sometimes depending on feed regulations and laws. In addition, the nutritionist may also wish to change what kind of treatment or processing activity should be done in the factory based on the animal type to be fed and the performance target. Product developments targeting better feeding performance or a bigger market could also result from product developments.

The animal on the farm is the final collection point of all feed materials. In massive industrial livestock operations, large quantities of feed are bought, produced, and stored for use at the right moment. Other feeds, such as fresh grass, are harvested and fed immediately, without storage. In the case of grazing, the feed chain ends with the product standing in the field, ready to be consumed by the animal (FAO, 2016). Unless raw feed materials are combined, manually or mechanically, to form a total mix of rations on the farm, the nutritionist has a minimal role in the farm stage of analysis (Figure 2).

Strategies to Reduce Environmental Impacts

Improving the production efficiency of crops and animals has been a significant focus for reducing environmental impacts related to livestock products because crops and animals that grow faster and produce more yield have less environmental impact (Middelaar et al., 2019). However, the best strategy to achieve efficiency rests on plant and animal geneticists who select and breed crops and animals for efficiency. On the other hand, the animal nutritionist could only improve the nutritive value of feed raw materials from crops and combine them effectively in compound feed so that the animal (when fed properly) could achieve its genetic potential—improving the quality and digestibility of feed results in reduced manure emissions and better animal performance (Gerber, et al., 2013).

This can be done in many ways, but the first is by formulation accuracy. Accuracy here is meant to be the correct estimation of the nutrient contents of raw materials used in feed production. It is not enough to use, for example, values of ileal digestible amino acids or net energy content of feedstuffs when formulating diets. What is more important is where and how this digestible amino acid and the net energy content of feedstuffs are calculated and determined. Reliable energy and amino acid estimates require methods promoting accuracy and applicability. For example, an NE system based on a validated prediction equation is now available. It can be easily implemented from DE or ME values of feeds without the need for any further sophisticated measurement of NE values (Noblet et al., 2022). Improving the accuracy of nutrient content values of feedstuffs will result in more efficient utilization of raw materials and help produce high-quality feed.

Another way to improve the quality of animal feed is the addition of exogenous enzymes in feed formulations to improve raw material digestibility. These exogenous enzymes can also reduce nutrient excretion and the environmental impacts of pig and poultry feeding programs. For example, phosphorus excretion in manure can be reduced by adding the exogenous enzyme phytase (Madrid et al., 2013). Another such exogenous enzyme is β-mannanase. For pig feeds, β-mannanase supplementation was found to have mitigated both climate change and eutrophication impact up to 8.5 and 1.4% (45 kcal of ME/kg of feed) or up to 16.2 and 2.7% (90 kcal of ME/kg of feed) compared to control diets formulated without the enzyme. These impacts were mitigated up to 5.6 and 1.1% (45 kcal of ME/kg of feed) for broiler feeds, respectively; β-mannanase supplementation could also reduce the amount of soybean oil used in pig and broiler formulations. Soybean oil has high environmental impacts (Hickmann et al., 2021).

Related to endogenous enzymes is the increased use of by-products from arable production or the food processing industry to reduce livestock production's environmental impact. These two are related because using by-products, such as wheat bran, can only be increased significantly by adding the endogenous enzymes cellulase and xylanase. The environmental impacts related to the processing of by-products (e.g., wheat bran) are usually allocated to the main product (e.g., wheat flour), so using more by-products in the feed formula results in a lower inventory of environmental impacts (Middelaar et al., 2016).

Understanding not only the nutritional characteristics of feed raw materials but also the environmental impact of each is key in helping the nutritionist decide on how to effectively combine raw materials to result in a high-quality feed with less environmental impact. Several life-cycle inventory (LCI) databases for feed are now available online: Agri-footprint, EC Feed LCI database, GFLI database, and Feedprint NL/International, to name a few. Nutritionists may use these databases in combination with feed optimization software to ensure that nutritional and economic requirements are fulfilled, while aiming for a reduced environmental impact (Middelaar et al., 2019).

This methodology of formulating diets using LCI databases to consider both the cost and environmental impacts of the resulting compound feed is called multi-objective (MO) feed formulation. In 2018, Garcia-Launay et al. investigated how MO formulation could effectively reduce the environmental impacts of feed. MO-formulated feeds had lower (−2 to −48 %) environmental impacts in all feed formulations for pig, broiler, and young bulls studied than baseline feeds. They concluded, however, that the ultimate potential for this method to mitigate environmental impacts is probably lower than this, as animal feed supply chains may compete for the same low-impact feed ingredients. This method may only complement other strategies, and ways to optimize the entire animal production system should be explored to decrease the associated impacts substantially.

Another strategy worth mentioning in this review is precision feeding. Several studies have been done by Andretta et al. (2016, 2018, and 2021) to show how precision feeding programs in pig production can be another strategy to decrease environmental impacts. This innovative feeding system, however, is not done by the nutritionist at the feed factory but at the farm. Precision animal nutrition or precision livestock feeding involves the use of feeding techniques that allow the proper amount of feed with the suitable composition to be supplied promptly to a group of animals (Parsons et al., 2007; Cangar et al., 2008; Niemi et al., 2010) or to individual animals in a group optimizing the use of dietary nutrients which results in less nutrient excretion. The practical application of precision livestock feeding to improve profitability was studied first, before its ability to reduce emissions. The on-farm application of precision livestock feeding, however, requires the design and development of measuring devices (e.g., to determine the animal's feed intake and weight), computational methods (e.g., estimating promptly nutrient requirements based on the actual animal's growth), and feeding systems capable of providing the required amount and composition of feeds that will generate the desired production trajectory (Pomar, et al., 2019). Thus, precision feeding could be challenging even in the most modern livestock facilities.

Choice feeding, which allows animals to choose and regulate their feed intake between diets differing in nutrient density, has been around for more than 25 years and could offer some potential in reducing emissions in livestock systems. Recently, Pichler et al. (2020) revisited choice feeding and studied its effect on the feeding behavior and fattening performance of pigs. For pigs offered a choice, they observed that the ratio between a low nutrient density (LND) feed and a high nutrient density (HND) feed consumed by growing pigs changed during the growing period toward a higher percentage of HND. No difference in growth performance between pigs and those not given a choice was observed. They concluded that pigs of modern genetics can still cover their nutrient requirements by choosing between diets differing in nutrient density without impairing performance. It would be interesting to know if emissions (in manure) from pigs on choice feeding and those without would differ.

Conclusion

The global feed supply chain is vast and complex, and its contribution to global emissions can be reduced only by changing practices in all stages of the supply chain system. Although the nutritionist is at the compound feed production stage, several strategies can be taken to reduce the environmental impact of feed production. Decisions made by nutritionists today could pave the way for a more environmentally friendly animal feed industry in the future.

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