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Perspective

Animal nutrition in a 360-degree view and a framework for future R&D work: towards sustainable livestock production

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Abstract. As a result of a growing population, national economies and urbanisation the consumption of animal products has risen sharply and will also rise substantially in the future, leading to a huge demand for animal feed. This paper illustrates that feed impacts almost all sectors and services of the livestock sector and its sustainability hinges on how feed is produced and fed. A 360-degree view of animal nutrition is presented, illustrating linkages between animal nutrition and various other domains of the livestock sector, for example productivity, reproductive efficiency, environment including biodiversity, land degradation and land-use change, animal welfare and health, food-fuel-feed competition, product safety and quality, among others. Based on the 360-degree view a framework for future research and development work in animal nutrition is presented. This framework has three components: the first one seeks better knowledge and in-depth analysis of the impact of feed and feeding on various domains of the livestock production system; the second one focuses on the impact of ongoing changes such as climate change, increases in cost of and volatility in feed prices, decreases in water and arable land availability, global trade of feedingstuffs, and high food losses; and the third one deals with providing solutions to challenges through technology, policy and institutional development measures. A multi- and trans-disciplinary approach is suggested for implementation of the framework. Application of the framework would contribute towards producing adequate, safe and nutritious food in a humane way in the face of rapid population growth; reducing impact on the environment and biodiversity; and promoting social equity.

Additional keywords: feed and feeding, holistic animal nutrition, R&D framework, sustainable livestock production.

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Introduction

The Food and Agriculture Organisation of the United Nations (FAO) estimates that there will be a 73% increase in meat and egg consumption and a 58% increase in dairy consumption worldwide by the year 2050 (taking the base values of 2011). The increase in population, likely to be 9.4 billion in 2050 would put additional pressure on the availability of land, water and energy. As a result, feed production in order to meet the increasing demand of animal products will be a challenge in the context of the three pillars of sustainability (*Planet* – environment, *Profit* – economy, and *People* – society; Makkar and Ankers 2014*a*).

In a conventional sense animal nutrition is the science of feed preparation (or formulation) and feeding i.e. how feeds should be prepared and fed to animals to produce adequate and safe food and non-food articles such as wool or manure. Availability, in a sustained manner, of desired type and quantity of animal feed and its feeding is the foundation of livestock production systems. Animal feed availability and animal feeding is a multi-faceted theme. It influences all livestock sub-sectors across production systems. It also has far reaching impacts on human nutrition, poverty, food prices and the global economy. It impacts almost every sector of the livestock production – from animal reproduction, health and welfare – to farm economic viability, environment, animal product safety and quality (FAO 2014).

The post-1800 period laid the foundation of modern animal nutrition. Some of the major milestones being: Magendie (1816) developed methods for animal feeding experiments, separated foods into protein, fat, and carbohydrate components and showed that food nitrogen (N) was essential. Boussingault (1839) proposed the concept of basic elements [carbon, N, phosphorus (P) and oxygen] balance studies, to study nutrition and physiology of lactation; during the late 19th century and early 20th century roles of proteins, carbohydrates, fats, vitamin and micronutrients in animal and human nutrition were broadly established (Bergen 2007); in the 1920s and 1930s the concepts of digestible energy, metabolisable energy and net energy were developed (Johnson 2007), which formed the basis for determining the nutrient requirements of various animal species; and publication of the nutrient requirement tables from the 1940s onwards [e.g. US National Research Council

[1]The views expressed in this publication are those of the authors and do not necessarily reflect the views or policies of FAO.

published the first edition of tables for swine and poultry in 1944 and those for beef and dairy in 1945 (Applegate and Angel 2014)]. Over the past 25 years, considerable progress has been made in increasing our understanding of metabolism in domestic animals, at levels of biological organisation, including the whole animal, organ systems, tissues, cells, and molecules. The birth of molecular biology and systems biology including 'omics' offer exciting opportunities in better understanding fundamental nutrition (Kore *et al*. 2008; Zhang *et al*. 2008; Zduńczyk and Pareek 2009), the strategic and applied research in the future should focus on a better understanding of interactions and dynamics between how feed is prepared and fed and other components such as the environment, welfare, biodiversity, product quality and safety, among others.

Traditionally, the issues of environment, animal health, animal welfare, product safety and quality have been debated separately for each domain. In this paper, efforts have been made to weave strands from these domains with animal nutrition to present a 360-degree view. This view enables better appreciation of the role of feed and feeding in livestock operation. Based on the 360-degree view a framework for future research and development (R&D) work has also been presented. Using this framework, synergies and trade-offs of managing various domains and sustainability of livestock system can be established in more integrated and more meaningful ways. This framework could be the basis for providing guidance for the future R&D work; and because this framework addresses feed and feeding in a holistic manner, it is expected to further the sustainability of livestock production systems.

Interactions of animal nutrition with other domains of the livestock operation

Animal nutrition interacts with almost all sectors and services of the livestock sector. These interactions are illustrated below by giving some examples. The purpose here is to demonstrate interactions and therefore examples are not exhaustive.

Animal nutrition and farm economics

Feed is financially the single most important element of animal production in most production system, irrespective of species. Feed costs can account for up to 70% of the total cost of production of an animal product (Makkar and Beever 2013). High feed costs and/or high volatility in feed costs can wipe out a livestock rearing operation. As a result of global financial and economic crisis in 2008 high cost of feeds decreased supply of animal products and increased prices. Optimisation of feed-use efficiency (i.e. producing more with less feed) decreases feeding costs and increases economic viability of the livestock operation (Makkar and Beever 2013).

Animal nutrition and productivity

Poor feeding decreases productivity of the animal. A vast array of literature on the nutrition-production nexus shows that nutritionally balanced feeding increases milk production of lactating animals. It also enhances growth rate and efficiency of meat-producing animals. Good nutrition also has the potential to increase reproductive efficiency, reflected in a higher cyclicity, lower age at first calving, lower inter-calving interval, higher productive life and higher profitability to farmers (FAO/IAEA 2002). Furthermore, an increasing body of evidence now exists showing that *in utero* nutrition has impact on productivity of offspring later in life (Bell and Greenwood 2013; Mossa *et al*. 2015).

Animal nutrition and the environment

Livestock production is resource demanding: it occupies 30% of the world's ice-free surface and consumes 8% of global human water use, mainly for the irrigation of feed crops (FAO 2009*a*). The area dedicated to feed-crop production represents 33% of total arable land. In addition, animal products generally have much higher water and carbon footprints than plant-based foods (Mekonnen and Hoekstra 2012; Ripple *et al*. 2014) and the livestock sector contributes ~14.5% of all anthropogenic greenhouse gas (GHG) emissions (7.1 gigatonnes of CO_2-equivalent per year). Globally, the production, processing and transport of feed account for ~45% of the GHG emission from the livestock sector. At a species level, feed production constitutes 47% and 57% of emissions from pork and chicken supply chains, respectively. For cattle, small ruminants and buffalo, feed production contributes 36%, 36% and 28% of the total emissions, respectively (Gerber *et al*. 2013). Feed nutrients (55–90% of N and P) are lost into the environment through manure, which if not managed properly can lead to environmental pollution. The emission of methane (CH_4) and nitrous oxide from manure also to some extent depend on the nature of feed being fed to livestock (Gerber *et al*. 2013). Livestock contribute 37% of anthropogenic CH_4, mostly from enteric CH_4 (FAO 2009*a*), which is feed dependent. Feed production and use also impact on land use and land-use change (Gerber *et al*. 2013), which leads to loss of sequestered carbon and biodiversity. Use of good quality feeds with high digestibility decreases emission intensity of animal products (Opio *et al*. 2013). Disruption of the global N cycle due to exports of soybean from Latin America to Europe and China, and associated N depletion from the place of export and N concentration at the place of soybean use is giving rise to environmental challenges including water pollution. Another effect of this practice is the loss of biodiversity. Both environment and biodiversity degradation have linkages with ecosystem and human health. Smart feeding practices, especially the balanced ration approach would reduce N, P and CH_4 release in the environment and biodiversity loss (FAO 2012*a*; Garg *et al*. 2013). Tannin- and saponin-containing diets have the potential to decrease enteric CH_4 (Goel and Makkar 2012). Additives and other dietary manipulations have also been shown to decrease enteric CH_4 production, and CH_4 and nitrous oxide emission from manure (Hristov *et al*. 2013; Montes *et al*. 2013). The use of locally adapted feed resources is also expected to conserve biodiversity. In the past five decades, over 75% plants have become extinct, largely because of these were not being utilised (FAO 2010*a*).

Animal nutrition and product safety

The safety and quality of the food chain can be affected because of the close link between feed and food-borne pathogens such as *Escherichia coli* O157, *Salmonella*, *Listeria* and *Campylobacter*. Animal food products can become contaminated with these pathogens as a result of their presence in feed. The mycotoxins, heavy metal, radionuclides, pesticides, dioxin, dibenzofurans, and other contaminants present in feed get transferred into animal products, potentially affecting animal and human health and product safety. Therefore, animal feed safety and quality can affect animal health, welfare and productivity as well as the safety of the human food supply and the livelihood of farmers (FAO 2012*b*). Microbial species such as *Salmonella immune*, which is pathogenic for humans, is also found in fresh food plants (Franz and van Bruggen 2008). Further, survival of these pathogenic bacteria in soil was found to be affected by both the ways in which manure is managed (Franz *et al*. 2008) and the composition of the diet fed to cattle that produced the manure (Franz *et al*. 2005). Feed constituents have been shown to increase shedding of *E. coli* O157 in faecal samples (Keen *et al*. 1999; Gilbert *et al*. 2005; Jacob *et al*. 2008), enhancing the risk of their presence in animal products.

Safe feed helps to reduce production costs, maintain or increase food quality and reduce feed and food losses and wastes. Contaminated feed has often resulted in food of animal origin being recalled and/or destroyed with significant economic losses for the livestock industries and a negative impact on food security. Feed is an integral part of the food chain, and feed production must therefore be subject, in a similar manner as food production, to the quality assurance of integrated food safety systems.

Animal nutrition and product quality

Several studies (e.g. Butler 2014; Vazirigohar *et al*. 2014) present opportunities to improve final product quality including increases in conjugated linoleic acid, omega-3 fatty acids, minerals in animal products, and product shelf life through manipulation of animal feeding. Many of these changes elicit positive effects on human health (Ip *et al*. 1991; Belury 2002; Bauman *et al*. 2006). Recently, there has been interest in the use of dietary polyunsaturated fatty acids, specifically the omega-3 (n-3) fatty acids α-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid, to improve sow and piglet performance. Feeding specific n-6 and n-3 fatty acids from either fish (Mateo *et al*. 2009; Leonard *et al*. 2010) or flax (Farmer and Petit 2009) to sows also transfer these fatty acids to their offspring via milk. Feeding cattle with flax-based feeds can increase concentrations of n-3 fatty acids in beef, which is considered to have human health benefits (Drouillard *et al*. 2004). Likewise, meat from pasture-finished lambs had higher n-3 polyunsaturated fatty acids than from those finished indoors on commercial pellets (Kitessa *et al*. 2010). Addition of tannins and saponins in the diet has been shown to change colour and increase shelf life of meat. Increase in antioxidation potential in milk has also been shown by phenolic-rich diets (Vasta *et al*. 2011).

Animal nutrition and food-fuel-feed competition

In 2012–2013, 795 million tonnes of cereals (one-third of total cereal production) were used globally in animal feed and by 2050 an additional 520 million tonnes would be required for feeding livestock to meet the anticipated increase in demand of animal products. In 2000, 78% of feed grains were fed to pigs and poultry in regions where industrial intensive systems dominate (FAO 2013*a*). According to an estimate, taking the energy value of the meat produced from all livestock into consideration, the loss of calories by feeding the cereals to animals instead of using the cereals directly as human food represents the annual calorie need for more than 3.5 billion people (Nellemann *et al*. 2009). In the past 20 years, there has been an increased interest in forage-fed beef for multiple reasons (health related, environmental concerns, and welfare issues; Scaglia *et al*. 2014). Use of smart feeding options such as a decrease in the level of grains in the concentrate by using agro-industrial by-products, an increase in green fodder use, use of chopped forages, and increase in digestibility of crop residues could contribute to decrease in grain in ruminant diet.

About 10% (~120 million tonnes) of global production of coarse grains are used for bioethanol production (FAO 2012*c*). The International Food Policy Research Institute estimates that under a scenario of drastic biofuel expansion up to 2050 would lead to the number of undernourished pre-school children in Africa and South Asia being 3 and 1.7 million higher than would have been otherwise the case (FAO 2009*b*). Efficient use of alternate novel feed resources such as biofuel co-products, for example glycerol, dried distillers grains, gluten meal, cassava residue, *Camelina sativa* meal, sweet sorghum residue, kernel meal from the non-toxic Jatropha, pongamia meal, castor meal, palm kernel meal, and algae residue (FAO 2012*c*) are expected to decrease food-feed competition. Likewise, other novel emerging feed resources such as insects (Makkar *et al*. 2014), seaweeds (Makkar *et al*. 2016) and other lesser known quality feeds such as moringa and mulberry (Foidl *et al*. 2001) would also decrease competition between food and feed.

Animal nutrition and animal welfare

When ruminants are fed to sustain high production levels, nutrient deficiency or excess can lead to metabolic disorders such as acidosis and lameness causing welfare issues whereas breeding monogastric animals, which are restrict-fed to optimise health and production, may suffer from chronic hunger. Freedom from hunger is the first of the five freedoms that are widely acceptable as a fundamental principle of animal welfare (FAO 2010*b*). The feeding of poor quality feeds elicits several welfare problems in ruminants. A properly balanced diet free of undesirable substances and water supplied in adequate amounts avoid physical and psychological suffering from hunger and thirst. Furthermore, correct nutrition is crucial for sustaining optimal fitness and wellbeing. The adverse impact of improper animal nutrition on animal welfare and the corrective measures are detailed in FAO (2012*b*).

Animal nutrition and animal health

Improper nutrition (unbalanced diet: under- or overfeeding) can impact adversely health, both directly as well as indirectly by making animals more prone to diseases (Berthon and Wood 2015). Furthermore, in case of disease, corrective measures in the form of medicines may be less or not effective. Vaccination done during the period of improper nutrition might also not properly protect the animals (Saker 2006). Correct nutrition can reduce infectious diseases by enhancing cell-tissue integrity and optimising defence mechanisms of the immune system (FAO 2012*b*). Feeding of a balanced ration has been shown to increase immune-globulin levels in blood, suggesting higher immunity (FAO 2012*a*). Supplements such as minerals, antioxidants and amino acids such as methionine also play a role in immune stimulation (Celi *et al*. 2014; Jankowski *et al*. 2014). Influence of nutrition on the aging process and ultimately lifespan in pet animals has recently been highlighted (Butterwick 2015). Even, maternal nutrition during pregnancy has an impact on animal health of offspring later in life (Bell and Greenwood 2013; Mossa *et al*. 2015). Better nutrition could also be a biosecurity measure to control zoonotic and infectious diseases.

Animal nutrition and global security

Increased food-feed-fuel competition can lead to food shortages, high food prices and high volatility in food prices. This could adversely impact global food security and possibly trigger civil unrest and conflict among masses and between people and government. Government stability and governance could be affected, resulting in global insecurity. This has happened in the recent past in many countries (Lagi *et al*. 2011; Bellemare 2015). Animal nutritionists have a role as a peacemaker also by manipulating the feeds and feeding in a manner that there is least food-feed-fuel competition and the feed efficiency is optimised to achieve more animal products from less feed and grain.

It can be surmised from the above that the choice of feed constituents and their consumption affect animal productivity (including reproductive efficiency), GHG, animal health, product safety and quality, and animal health and welfare. The production of those dietary constituents has an impact on water quality, GHG and land use. The animal wellbeing and possibly human wellbeing may be influenced by animal diets.

A 360-degree view of animal nutrition and a framework for future R&D work in animal nutrition

A 360-degree view that emerges from the previous discussion is presented in Fig. 1, Component 1. Feed impacts not only on the environment, animal product quality and safety, land use and land-use change, reproductive efficiency and life time productivity, animal health and welfare and feed-food-fuel competition, but also on the profitability of the livestock enterprise, which is the main driver of a livestock operation and the prime objective of keeping livestock in many production systems. Interactions of feed with various domains listed above and presented in the 360-degree view are complex – also there are synergies and trade-offs between them. Based on this view, a framework for future research and development work in animal nutrition is presented below. This framework has three components. Component 1 seeks a better understanding of the various interactions between feed and feeding and other domains, including trade-offs and synergies. Furthermore, there are several ongoing changes, for example climate change, increases in the cost of and volatility in feed prices, increasing demand for animal products especially from developing countries, decreases in water and arable land availability, high global trade of feedingstuffs, and high food losses (Fig. 1, Component 2), which raise concerns and challenges for the livestock sector and threaten its sustainability. So Component 2 of the framework focuses on getting a better insight into the impact of these ongoing changes on the interactions between feed and feeding and other domains listed in Component 1. The third component of the proposed framework deals with providing solutions through technical, policy and institutional building measures including capacity

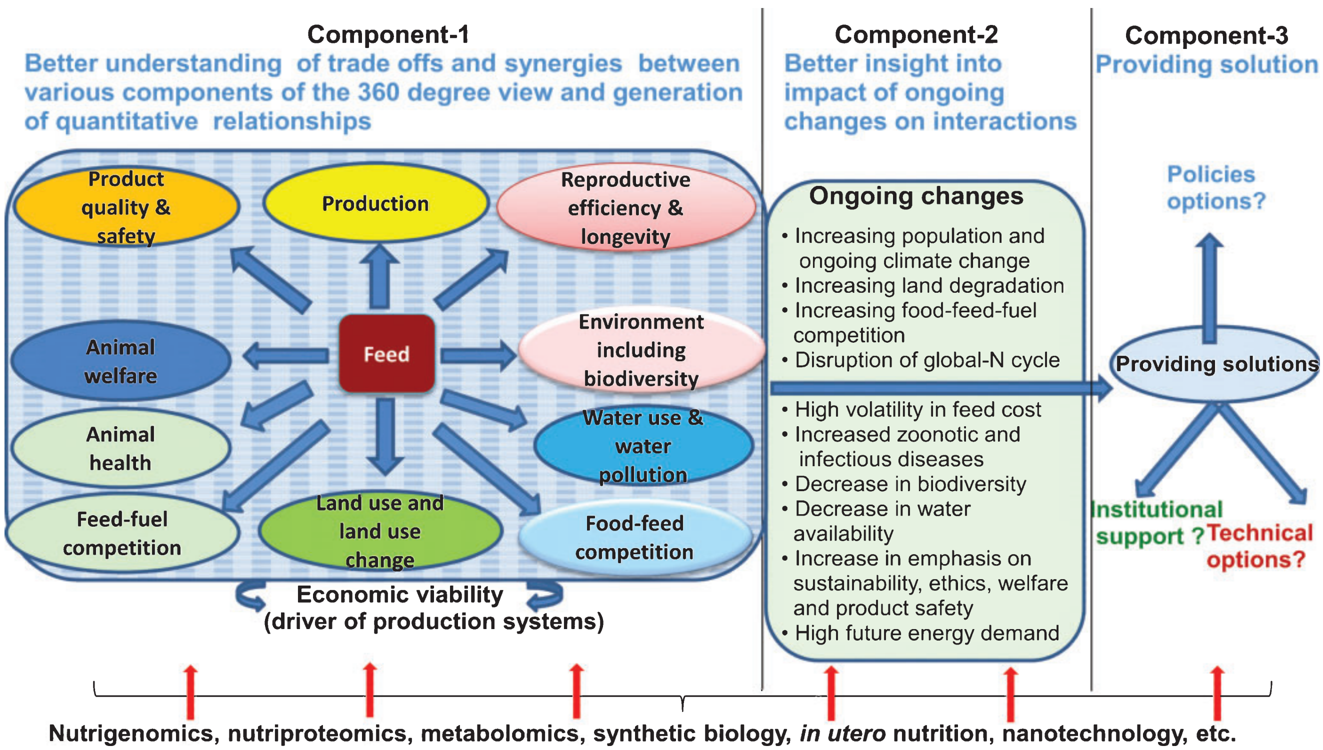

Fig. 1. A 360-degree view of animal nutrition and a framework for future research and development work.

development measures to the challenges that emanate from Components 1 and 2. The three components of the framework are mentioned separately in Fig. 1 for the sake of clarity, but in practice, they run simultaneously. This framework also integrates the important role of fundamental science, especially through Component 3 by providing solutions to various challenges. There are several examples where molecular biology including other biotechnologies, nanotechnology and systems biology, and *in utero* nutrition have contributed and will increasingly contribute to making animal agriculture more efficient and sustainable (FAO 2011*a*, 2013*c*; Ruane and Sonnino 2011; Bell and Greenwood 2013).

Some research is currently underway to understand these relations; however, there are knowledge gaps and quantitative relationships are lacking. Much research is directed towards GHG emissions in the livestock sector (Gill 2013; Hristov *et al*. 2013) and some towards quantifying GHG emissions as a result of feed production (land use and land-use change) and feeding (Gerber *et al*. 2013). However, these studies use several assumptions and are short-term and based on individual animals or herds with less emphasis on impact at system level (Gill 2013). Little attention has been given to the interactions of 'feed and feeding' with other domains listed in Component 1. Also much research needs to be conducted to understand the impact of various ongoing changes depicted in Component 2 of the framework. Although sporadic research, focusing on effect of climate change, particularly, increase in temperature beyond optimum temperatures of crops, and decrease in water availability and weather extremes on: (1) feed availability (in most situations decrease; Kang *et al*. 2009); (2) feed quality (a likely shift from C_3 to C_4 plants and increase in lignin and decrease in digestibility; Milchunas *et al*. 2005); and (3) feed safety (increased prevalence of mycotoxins; Kovalsky 2014) has been carried out. Nevertheless, systematic research integrating all the domains impacted by feed and feeding is required to meet future challenges. Furthermore a point worth noting in relation to Component 3 is that for generating large impact, technologies alone are not sufficient. It is imperative to have conducive policy environment, appropriate mechanisms and adequate institutional infrastructure including human capability that facilitates wide adoption and application of the technologies.

This proposed framework could be the basis for guiding the future R&D work, and investment options. Generation of better knowledge and quantitative relationships between animal nutrition and other domains and sectors of livestock production will enhance sustainability of the livestock production systems because the interactions (Fig. 1) impact society, environment, economic and ethics.

For translating the framework into action, as an example, some of the challenges and issues pertaining to sustainability of the livestock sector that hinges substantially on how feed ingredients are produced, and feed is prepared and fed are being addressed through the FAO's initiative: Towards Sustainable Animal Diet. A Sustainable Animal Diet may be defined as the diet that has the core traits, i.e. balanced in all nutrients, free from deleterious components, meet production objective, generate animal products that are safe for human consumption and integrates the *Three-P* dimensions of sustainability. The *Three-P* dimensions, *Planet*, *People* and *Profit*, *inter alia*, have been used to describe the term, implying ecological soundness, social equity and economic growth) and also the ethical dimension. Translating the Sustainable Animal Diet concept into action would be beneficial for the animal, the environment and society, and likely to generate socioeconomic benefits (Makkar and Ankers 2014*a*). The strategies that increase nutrient-use efficiency in the animal food chain i.e. enhance the transfer of nutrients from feed to animal products also simultaneously decrease nutrient excretion into the environment, which contribute to decrease in pollution. Furthermore these strategies also enhance animal health, welfare and production (Garg *et al*. 2013; Makkar and Beever 2013). Examination of undesirable constituents in feed, integrated with sound quality control systems (FAO 2013*b*), also contribute to enhancing animal product safety and preventing feed wastage. The channelling of food wastes to feed without compromising feed-food safety nexus would enhance global resource-use efficiency. These are some examples of the synergies between different domains (stated above in Component 1) that interact with feed. Generation of sound data on availability of feed resources, mapping of feeding systems at regional and national levels and correct analysis of feed ingredients for their nutritional value by feed analysis laboratories (Makkar and Ankers 2014*b*) are overarching and pre-requisite to better understand interaction between feed and feeding and other domains of the livestock sector.

The implementation of this framework would demand multi-dimensional efficiency measurements. For example, for the environment dimension, in addition to taking emission intensity (GHG emission as CO_2 equivalent per unit of animal product) as the unit of efficiency (Gerber *et al*. 2013). Arable land use, water use, P use, water pollution or disruption of global N cycle per unit of animal product are important (Gill 2013) and need to be considered. Furthermore, efficiency should also be determined based on lifetime productivity of an animal (Zehetmeier *et al*. 2014; Garg *et al*. 2016) and not only per year or per animal lactation basis (Gerber *et al*. 2013; Hristov *et al*. 2013). Other units of efficiency in the social dimension of sustainability could be employment generated, the number of women empowered or people brought out of poverty per unit of animal product. Food security is a high profile global priority. The efficiency measured as human edible protein or energy output (in animal product) per unit of human edible protein or energy input (in animal feed; Bradford *et al*. 1999; FAO 2011*b*) has food security dimensions and reflects net contribution to food security. This unit of efficiency has trade-off with another unit of efficiency, namely the emission intensity. The values for both these parameters are higher for forage-fed ruminants (Bradford *et al*. 1999; Hristov *et al*. 2013). Higher emission intensity is a reflection of greater adverse effects on the environment whereas higher human edible protein or energy output per unit of human edible protein or energy input represents greater contribution to food security. A holistic system view needs to be taken, dictated by multi-dimensions of sustainability that respects diversity in local and regional conditions, and aimed at optimisation rather than maximisation of production. In many situations: (a) the quest for maximisation of production to meet high global demand of animal products and associated economic gains; and (b) heavy reliance of livestock production on high global trade of feedingstuffs, overlook the overexploitation of natural resources.

Conclusions

Achieving high production is not only sufficient – high animal productivity, animal product safety and quality, animal welfare and health and protection of environment and biodiversity are also being increasingly demanded. Increasing awareness and emphasis on animal welfare, environment, product safety and quality have become a priority in food production systems involving animals. Transition towards a more sustainable path must consider sustainability in its full complexity encompassing all its pillars – economic, ecological, and social and recognising the interface function of agriculture between human and natural systems. Partial solutions will not produce the desired results. For example, any effort towards conservation that ignores the need for economic development, food security and livelihoods is unlikely to succeed. Conversely, socioeconomic development will not be sustainable if it does not maintain the ability of the ecosystem and society to adapt to short- and long-term changes. This complexity necessitates consideration of sustainability as a societal issue and requires integrated efforts by a wide range of stakeholders to capitalise on the strength of livestock production systems and to minimise the potential negative impact of rapid growth in demand and supply of animal products. It is also imperative that such efforts be realistic, equitable, and conscious of ecological, socioeconomic and cultural dimensions. In this changing landscape animal nutritionists could influence most of the activities of the livestock sector. Animal nutritionists are at the crossroads where almost all sectors and services of the livestock industry meet, as illustrated in the 360-degree view. They are in the driver's seat for taking the livestock sector towards sustained development following the principles of sustainable animal diets and using the proposed framework based on the 360-degree view (Fig. 1) as a guiding tool for future research and development. To make meaningful impact, a multi-disciplinary approach in which animal nutritionists work with experts from the fields of environment, economics, social sciences, public health, among others is required. The proposed framework could exploit the complimentary expertise and knowledge of these specialists to deliver a livestock industry that contributes more to global food security while conserving the environment and biodiversity and promoting social equity. Also a paradigm shift from maximisation of animal production to optimisation of animal production by thinking efficiency in multi-dimensions is required.

Equally important is the role of appropriate policies and institutional support and therefore scientists also need to work with policy makers, the private sector, civil societies and farmers to help identify the options that are environmentally, socially and economically sustainable. Application of the framework and the approaches suggested in this publication could make substantial contributions towards producing adequate, safe and nutritious food in a humane way in the face of rapid population growth; saving the environment, biodiversity and the way of life of pastoralists and ranchers. Besides, implementation of the framework could play an important role in bringing smallholder livestock farmers out of poverty; promoting industrial growth, alleviating malnutrition especially in pregnant ladies and growing children that is related to inadequate vitamins, minerals and amino acids consumption; safeguarding public goods including human health; and promoting global security.

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