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Editorial: Sustainable livestock systems for high producing animals

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For an expected global population of 9.7 billion by 2050 (United Nations, 2019), major constraints and challenges to our ability to satisfy the food demand for animal proteins can be identified. The geographic heterogeneity in animal production, as well as in populations, are well documented in the literature. At the present time, according to the FAO *Global Livestock Environmental Assessment Model* (GLEAM 2.0 and GLEAM-*i*; See http://www.fao.org/gleam/resources/en/), the East, South and Southeast Asia regions produce a high amount of animal proteins, similar to that produced by the Americas plus Europe together (approx. 29 and 33 million tonnes, respectively), while all other parts of the world produce approx. 13 million tonnes.

Protein production from animals is supported by different livestock systems, which all have significant environmental impacts, e.g., greenhouse gas emissions from animals and manures, air and water pollutants and a high energy demand for food and feed production. This constitutes a major problem in the context of emerging planetary boundaries and sustainability thresholds, and it is necessary to think about how to reduce these impacts within the intensive and semi-extensive systems that will likely remain a strong basis for future production.

Existing systems have been progressively developed from the second half of the last century, mainly in Europe and North America, where the protein production now exceeds human demand. They have been able to dramatically increase productivity in these regions, providing food security and safety at a relatively low economic cost and with reasonable "quality" (organoleptic traits and nutritional content). This food abundance, allied to socioeconomic development of human populations and threats of adverse global climate change, has progressively raised consciousness related to the animal welfare and environmental impact of animal production. Currently, these aspects influence the governmental policies of the different countries in seeking to find feasible solutions at national and global levels, while ensuring feed availability to populations.

The environmental impacts can be mitigated by controlled changes in these production systems: intensification of specialised lines of animals maintained under well-controlled conditions are among the future solutions. Genetic selection of animals for improved production and disease resistance using genomics tools, larger farms, improved feed efficiency, husbandry and disease management in confined areas are also among the tools for these intensive and semi-intensive systems of production. Animal welfare has also become important as a requisite constraint in these systems, not only to maximise animal health status, but also to satisfy consumer and societal demand for an ethical approach to livestock production. However, meeting environmental, welfare and productive objectives will require a holistic approach to system optimisation across a number of simultaneous constraints.

This special issue seeks to identify and describe the scientific and technical approaches that may contribute to reduce the footprint of intensive and semi-intensive livestock systems of production in the high producing species (mainly for meat, milk and eggs), as well as the challenges and trends over the next 2–3 decades.

Sustainably producing animal-sourced foods to supply sufficient protein to meet the requirements of a healthy diet of a growing global population, while respecting planet boundaries, is a challenge. Henchion et al. (2021) highlight the importance of having regional-specific strategies to ensure sustainable livestock production and consumption, with a requirement to consider the impact of actions in one region on others. Clearly, the challenge is not merely one for science and technology, but also one based on a wider conceptualisation of the food system and its diverse stakeholders.

Global agro-food trade is currently dominated by regional blocks, with the European Union (**EU**), the United States, Oceania and Brazil the top five exporters, and China and Japan the two largest importers. As noted by several papers in this collection, the health, animal welfare and environmental impacts of meat production and consumption are coming into sharper focus as market sustainability challenges (Chatellier, 2021).

In some regions, like the EU, animal production is highly regulated, whereas their consumption is unregulated. Many of the

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negative and positive effects are public goods and, thus, there is legitimacy and scope for public policies to reduce the damage and increase the benefits of animal production and consumption (Guyomard et al., 2021). In fact, consumer demand and wider public preferences for public goods and for controlling environmental externalities are becoming more influential in animal production decisions (Moran and Blair, 2021). Consumers progressively choose protein-based foods which also incorporate intangible assets such as the impact of production systems on animal health and welfare, human health, environmental impact, and many others.

Actions to promote sustainability include (1) more research and use of remote sensing technology associated with artificial intelligence as collaborative economic, including international trade, and ecological tools to manage greenhouse gas emissions from livestock (Gilla et al., 2021); (2) nutrient (e.g., nitrogen, phosphorus) conservation and recycling in agricultural systems as a primary key to sustainable semi-intensive and intensive livestock production, e.g., fertiliser recycling from waste streams, precision agriculture technology, and the integration of cropping, multi-trophic and integrated animal production systems with agroecology and industrial ecology (Kronberg et al., 2021); (3) reducing stress in animals to improve welfare, health and productive performance (Orihuela, 2021); (4) improving individual, herd and production system resilience to infectious diseases, e.g., vaccination in addition to biosecurity measures and selective breeding for animal robustness to infection (Doeschl-Wilson et al., 2021).

For poultry production, Maharjan et al. (2021) consider the metabolic challenges and potential management solutions posed by the progressively more feed efficient and fast-growing broilers due to genetic selection. Dietary nutrient intervention strategies regarding metabolic health and market demands, mainly focusing on amino acids and energy, need to be adapted to the broiler production cycle. Free-range farming, sexing of eggs to avoid killing of male chicks, and extending lay to produce more than 500 eggs in the laying hen's lifetime are strategies to enhance bird welfare and health, while development of dual-purpose poultry strains for specific markets may also be promoted in the coming years (Gautron et al., 2021).

Beef production systems should target appropriate genotypes and high productivity relative to maintenance, both for the breeding herd and for growing and finishing cattle. This maximises income and limits input costs, particularly feed costs. Digital and other technologies that enable rapid capture and use of environmental and cattle performance data, even within extensive systems, should enhance beef industry productivity, efficiency, animal welfare and sustainability (Greenwood, 2021). Moreover, Pethick et al. (2021) propose improvement of the sensory, health attributes and yield of beef and lamb meats. To maximise value across the supply chain, accurate carcass grading systems for yield and eating quality can be used to target consumers' needs at given price points, and then to tailor appropriate production and genetic strategies. Also, there is an increased use of cross-breeding and even of traditional dual-purpose breeds that deliver higher milk solid concentrations and carcasses more appropriate for beef production.

The dairy cattle industry has more than doubled milk production over the past five decades. Less than 20% of the world's dairy cows now produce about half of the world's milk. However, it is now clear that the genetic progress in this characteristic tends to reach its limits and needs to be re-focused towards the development of a robust and long-term sustainable dairy industry that maximises animal welfare and productive efficiency, while minimising its environmental footprint. Three main clusters, i.e., improving crop production, water and manure management, were identified to reduce this environmental footprint for future years, and at global level (Britt et al., 2021). Furthermore, management and dietary solutions to reduce enteric methane (**CH4**) emissions are extensively researched as ruminants contribute substantially to global anthropogenic greenhouse gases. De Haas et al. (2021) show that CH4 production is heritable and correlated in a desirable way to milk lactose, protein and fat, as well as DM intake. Simulations show that breeding could make a valuable contribution to the mitigation strategies that could be applied to achieve the EU goals for 2050 (Brito et al. 2021).

As in other species, nutrition, reproduction and health management are the three pillars of flock efficiency, production and sustainability of the intensification of production in sheep and goats (Simões et al. 2021). Nutrition is the major cost for flocks and strongly interacts with the other two pillars, while seasonality of reproduction remains as a strong constraint for a regular production over the year. Developing new feeds and feeding strategies to improve nutrient capture by ruminant livestock is one of the most relevant challenges in the coming years. Engineering and technical innovations to improve forage digestibility, preservation and adaptation of crops to new climatic conditions, and new protein feed sources (e.g., insects), are being refined to achieve the aforementioned purpose (Moorby and Fraser 2021).

The fourth agricultural revolution of digital technologies has started, where sustainable food production is supported by collection of data useful for farm and supply chain improvement, along with automation and compliance. Responsible Animal Agriculture 4.0 (and, also, 5.0) innovation requires public–private collaboration of innovation system stakeholders to enable development of transition pathways from a systems' perspective. The use of responsible innovation processes to support critical reflection on technological trajectories and related innovation system consequences, both desirable and undesirable, should also be built into future strategies (Eastwood et al., 2021).

Worldwide food access and food safety is ensured by semi-intensive and intensive livestock production systems, even though extensive livestock can also play an important socioeconomic and environmental role for humanity. This special issue offers a collection of current knowledge from specialist and experimental scientists linked to livestock production and bringing a multidisciplinary approach to mitigate adverse impacts on animal welfare and the environment. Numerous threats, challenges and solutions are identified in the 18 reviews. We hope that together these contribute to a reflective scientific collection of new ideas to promote sustainable animal proteins in the coming years.

The primary production sector is only one piece in the whole jigsaw of global sustainability. However, its attempts to promote efficient production, to manage the land and water resources, avoiding desertification, to fine-tune production to demand and to promote a responsible global trade are all important in contributing to human welfare. Changes in recent times have seen the newest generations in developed countries living in relative peace and economic abundance, while rural populations have become increasingly more urban. With a growing disconnection between livestock producers and consumers, the perception of animal production of the newest generations can be strongly influenced by (social) media which can often promote images of animal humanisation and animal exploitation. As scientists and animal production professionals, we need to research and support the best practices to ensure a secure supply of nutritious food for all people, using humane and environmentally responsible methods.

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Not applicable.

Data and model availability statement

Not applicable.

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J. Simões, P. Chemineau: Conceptualization, J. Simões, D. Moran, S. Edwards, C. Bonnet, A. Lopez-Sebastian, P. Chemineau: Writing, Reviewing, Editing.

Declaration of interest

Phillipe Chemineau is past president of EAAP and president of WAAP. The remaining guest editors declare "None Interest".

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