CURRENT CHALLENGES IN ANIMAL NUTRITION

I.M. Pop*, D. Simeanu, C.G. Radu-Rusu, S.-I. Petrescu

"Ion Ionescu de la Brad" Iasi University of Life Sciences, Romania

Abstract

Nowadays, globally we face many important issues related to animal nutrition. The interest is not only in a proper nutrition in terms of animal physiology and valorization of their genetic potential, but also in achieving many other goals. Of course, the efficiency of transforming food into the higher possible animal production with minimal costs remains a basic idea, and is why nutritional requirements are continuously improved, also working to increase digestibility and improving the feeding optimization programs. But aspect such as new raw materials as feed sources, the quality of the obtained products, feed and food safety, soil and water management, reducing environment pollution and influence on climate change, animal welfare and others are also very important. The applied use of modern and new techniques such as biotechnologies and expansion of automatics and robotics, including through the use of AI will certainly be helpful.

Key words: *animal nutrition, challenges, quality, efficiency, safety, sustainability*

INTRODUCTION

Animal nutrition plays a central role both in animal husbandry and animal production, having a great influence on their health, performance, and sustainability of livestock and companion animals.

To meet both human and environmental needs, the animal feed sector faces numerous challenges and is undergoing rapid transformation, driven by various factors such as scientific research and innovation, regulatory changes and market dynamics [1].

The interest is not only in a proper nutrition in terms of animal physiology and valorization of their genetic potential, but also in achieving many other goals.

Animal nutrition research is predominantly targeted toward the commercial production of food and hence, efficiency. The optimization of that efficiency has long been a driving force in the design and implementation of animal nutrition research.

While production efficiency remains a primary goal in animal nutrition research, societal concerns and improvements in the knowledge of animal nutritional physiology drive modern research objectives [2].

The use and evaluation of potential feed sources for livestock is both historical [3] and a critical component of modern livestock feeding and production [4].

Nowadays, a multitude of constantly evolving constraints (environmental, economic, biological, ethical, sanitary-veterinary regulation, etc.) modify the field's paradigms and push it towards new approaches.

The paper highlights some of the main challenges and some ideas about some current strategies and solutions or possible future approaches.

MATERIAL AND METHOD

We reviewed recent information from the specialized literature and from the practice of the field, and on this basis, we tried to identify some of the most important challenges and relevant trends for the field of animal nutrition and feed industry and

* Corresponding author: mircea.pop@iuls.ro
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formulated a series of personal ideas and considerations.

RESULTS AND DISCUSSIONS

Animal husbandry and animal production are of great importance to humans globally, not only as a major source of food and as a valuable business, but also in relation to ensuring the health of the population and a sustainable life while preserving the environment.

The sharp demographic growth inherently determines the increase in the total food requirement and implicitly that of animal origin products. There is a growing demand for animal protein due to continued increase in human population and rising incomes [5] and the animal protein sector (which includes meat, dairy, and fish) is expected to continue to increase (respectively by 12%, 1.6% and 11.2%, by 2033 [6] or by nearly 70 %, 50 % and 90 % by 2050 - FAO estimations).

The contribution of livestock to climate change is estimated between 12-20% [7], mostly in the form of methane from ruminants and carbon dioxide release from cleared forests to create pastures.

Animal feeds play a leading role in the global food industry and feed is the largest and most important component to ensuring safe, abundant and affordable animal proteins, having also the environment in attention.

Global feed production increased to 1.396 billion metric tons in 2024, being valued at US$ 465.1 billion in 2024, and it is projected to reach US$ 638 billion by 2033 [8,9,10]. This data shows the importance of the field both in terms of resources consumed and business value.

As such, animal nutrition and the feed industry face numerous challenges and are undergoing rapid transformation driven by scientific innovation, regulatory changes, and market dynamics.

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Animal nutrition research is predominantly targeted toward the commercial production of food and hence, efficiency. The optimization of that efficiency has long been a driving force in the design and implementation of animal nutrition research.

Of course, the efficiency of transforming food into the higher possible animal production with minimal costs remains a basic idea, and is why nutritional requirements are continuously improved, also working to increase digestibility and improving the feeding optimization programs. But aspect such as new raw materials as feed sources, the quality of the obtained products, feed and food safety, soil and water management, reducing environment pollution and influence on climate change, animal welfare and others are also very important.

In our view, we have identified, systematized and grouped the most important current challenges into five major categories (*Figure 1)*: quality, efficiency, economic aspects, safety and sustainability. These issues cannot be approached separately, simplistically, but are often interdependent, requiring a systemic but at the same time specialized approach.

1. **Quality** - this is a mandatory condition to be also accepted and competitive on the market, but we know that quality is very complex and dynamic. Quality does not only refer to the finished feed product but is currently a systemic concept (Total Quality Management) that takes into account the whole organization and all the processes until the final product and also after his utilization. Several so-called Good Manufacturing Practices ensure the achievement of high, consistent and repeatable quality.

Of course, the quality of feed raw materials or ingredients - in terms of chemical composition and nutritional value,

but also availability - is very important, and modern technology, together with the use of artificial intelligence (AI) tools, helps to quickly and safely perform analyzes, to assess nutritional value and solve logistical problems.

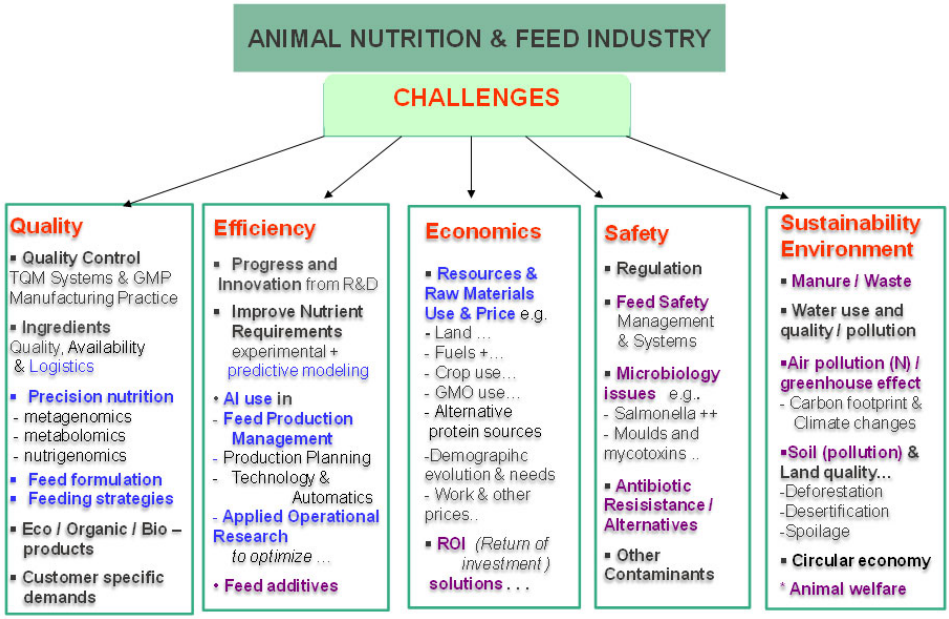

Figure 1. Current and Future Challenges in Animal Nutrition and Feed Industry

Additionally, new or alternative feed resources, including agro-industrial by-products, insect-based proteins, and algal biomass, offer sustainable solutions to feed scarcity and contribute to circular economy practices [11]. By- product often contain valuable nutrients, and can be further enhanced through dehydration, fermentation, or upcycling as dietary substrates for insects, which are then incorporated into diets as alternative protein sources. Examples of common circular feed ingredients include processed and spent fermented grains, as well as bakery, fruit/vegetable, and retail excesses.

2. **Efficiency** - is essential in any activity and combines effectiveness with optimal use of resources in relation to the obtained result. This is always in the attention of the research sector and the practical application of the developed results and innovation represents the main source of progress.

One of the objectives continually refers to improve nutrient requirement using both experiments on live animals but also modelling using artificial intelligence tools.

Also, the AI is or would to be used to solve problems in feed production management such as production planning, technology, automatics, processes optimizations - including feed formulation and others.

Applied of "Precision feeding" - as a part of "Precision animal farming" [12] - utilizes new modern approaches (such as metagenomics, metabolomics, nutrigenomics, mathematical modeling) to optimize nutrient delivery, also by feed formulation and feeding strategies, minimizing waste while maximizing feed efficiency and animal production. Animals differ (genetics, health status, environment) in their nutrient needs and responses. Advances in sensor technology, artificial intelligence, and real-time monitoring

enable precise dietary adjustments tailored to individual animals. A one-size-fits-all diet is inefficient and the precision feeding aims to tailor diets more closely, reducing waste and increasing efficiency [11].

The use of multiple feed additives (vitamins, minerals, amino acids, enzymes, acidifiers and oligosaccharides, biotics, probiotics, ionophores, botanicals and others) also allows for a more efficient use of feed, but also the achievement of other important objectives related to animal health, improving their performance or the quality of the products obtained, reducing pollution and, last but not least, increasing economic efficiency and competitiveness.

3. **Economics**. These problems are strictly related to efficiency aspects, and involve the application of operational research in most processes, starting with the availability, use and cost of various resources (soil, water, equipment, human resources, raw materials, etc.).

Competition for feed ingredients (e.g. soy, maize, fishmeal) between animal feed, human food, and biofuel production drives volatility in ingredient supply and cost; also, climate change seriously influences the production of feed raw materials (especially cereals and soybeans, which often represent over 80% of the structure of feeds for pigs, poultry and more), but also the global situation characterized by insecurity and open or hybrid conflicts, including economic ones, strongly affects the availability and price of feed ingredients.

Finding new feed sources, especially by capitalizing on agricultural or food by-products or by developing new circular agriculture technologies (e.g. using insects, worms, natural fermentation) or new biotechnological applications, are viable solutions of great interest to the feed industry.

Applying the results of the research and development sector, with the ultimate goal of increasing competitiveness and the ROI (Return of Investment) value, respectively the profit of the business. Both AI tools and the use of feed additives, together with quality management may have a significant contribution to achieving these goals.

4. **Food safety** is a mandatory condition and is starting from the feed safety, that is also very important for animal health, impacting animal performances, efficiency and economy. The implementation of a and basic food safety management systems, such as HACCP, is regulated by law throughout the entire food and supply chain, but today there are many other more evolved and more demanding public or private systems, such as ISO 22000, BRCGS, IFS - Food and others that ensure confidence in safe products for consumers. Also, the functioning of a general quality management system like ISO 9001 gives added confidence to producers and users of feed and animal products.

For food safety the usual hazards are physical, chemical and biological; of these, microbiological contamination - such as with Salmonella sp. - or the presence of mycotoxins above acceptable levels are the most common, but other contaminants may also occur. Fungal toxins in feed (e.g. aflatoxin, fumonisin, zearalenone) interfere with digestion, immunity, performance and may carry over into animal products; controlling them across supply chains is necessary and some feed additives use can reduce their negative effects.

As regulatory and consumer pressure pushes to remove or reduce in-feed antibiotics, maintaining gut health (resilience, nutrient absorption, resistance to pathogens) becomes more challenging [13, 14]. Use of feed enzymes, probiotics, prebiotics, biotics, botanicals/phytogenics and microbial engineering to optimize gut microflora offers real benefits, even the responses may be dose -or context-dependent.

5. Sustainability and Environment.

Pollution from animal waste or exhaust gases is a real and major problem. As a

result, possibilities are always being sought to reduce the quantities of manure and their polluting potential, especially its nitrogen and phosphorus content. Mitigating pollutant emissions while maintaining or increasing animal production amount is a major challenge today and for the future.

Excess dietary protein or unbalanced diets increase nitrogen excretion, leading to ammonia release and the air and water and soil pollution. Precisely matching amino acid supply to requirements (especially in monogastrics) helps reduce nitrogen waste and cost. Also, better use of phosphorus or other minerals (zinc, copper, sulfur, selenium..) needed in animal feed (e.g. using exogenous phytases and organo-mineral chelates) is desired to reduce their levels in manure.

Thus, in monogastrics, using a higher dose of phytase and non-starch polysaccharide degrading enzymes (NSPases) when formulating diets, together with using chelates and a full amino acid and energy matrix is a good way to achieve these goals.

Ruminants (e.g. cattle, sheep) in particular contribute particularly to methane emissions through rumen fermentation and there are several ways to manipulate these fermentations, modulating the type of biochemical reactions and thus the proportions of the resulting fermentation products and the impact on gaseous emissions. Since methane is responsible for 44% of livestock-related carbon emissions, methane inhibitors also offer potential in reducing enteric methane emissions from ruminants [15].

Bio-circularity, which increases the use of residues, by- and co-products, or incorporates excess food streams to provide value-added sustainable feedstuffs serves to decrease GHG emissions from landfills/compost and can reduce the risk of commodity crop land conversion [16].

Animal nutrition and feeding have to be also compatible with animal welfare. Heat stress, drought, flooding, or feed quality deterioration (e.g. spoilage) impose nutritional stress; formulating diets resilient to variable feed and climate is challenging.

Animals under disease pressure or environmental stress may respond poorly to standard diets; designing nutrition to support resilience and recovery is an evolving frontier [15].

Ethical and consumer-driven constraints are also current issues. Pressure to reduce intensification, adopt “natural” diets, restrict certain additives, or favor organic systems adds constraints to nutritional design.

CONCLUSIONS

Animal feed sector faces numerous challenges and is undergoing rapid transformation, driven by various factors such as scientific research and innovation, regulatory changes and market dynamics.

By combining precision feeding, microbiome modulation, new sustainable feed resources, several feed additives, good manufactory practices and quality and food safety management, the livestock industry can achieve a more resilient and sustainable future, increasing productivity with minimum environmental impact.

We need today an "**Integrative Systemic Animal Nutrition**" that combines animal genetics, the microbiome, precision nutrition, animal behavior, aspects of sanitary-veterinary prevention and food safety, environmental preservation and economic efficiency in optimized integrated models that can be solved using the advantages of AI.

Animal nutrition and feeding that allows a correct relationship with the natural environment while ensuring a minimum acceptable level of animal welfare can be considered sustainable.

For the future, practicing “Precision animal farming” by integrating “Integrative systemic animal nutrition” with other technological advances and globally adopted good and sustainable practices,

along with consumer education, are truly necessary for a sustainable world.

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