

BOARD INVITED REVIEW

ASAS-NANP SYMPOSIUM: Mathematical modeling in animal nutrition: training the future generation in data and predictive analytics for sustainable development. A Summary

Luis O. Tedeschi,^{†,1} Dominique P. Bureau,[‡] Peter R. Ferket,^{||} and Nathalie L. Trottier^{\$}

[†]Department of Animal Science, Texas A&M University, College Station, TX 77843-2471, [‡]Department of Animal Biosciences, University of Guelph, Guelph, ON N1G 2W1, Canada, ^{||}Department of Poultry Science, North Carolina State University, Raleigh, NC 27695-7608, ^{\$}Department of Animal Science, Cornell University, Ithaca, NY 14853

¹Corresponding author: luis.tedeschi@tamu.edu

ORCID number: 0000-0003-1883-4911 (L. O. Tedeschi).

Introduction

Data analytics and mathematical modeling (MM) are essential to understand complex systems related to science and society (National Academies of Sciences, Engineering, and Medicine, 2019). Mathematical modeling can be defined as an abstraction and simplification of reality to capture and integrate interactions within a system. It has been a vital tool in animal nutrition for over 100 yr (France and Kebreab, 2008). In animal nutrition, MM is essential to make decisions that can be applied in the real world, such as balancing diets, dietary supplementation responses, and excretion of nutrients given a specific diet (Tedeschi and Fox, 2020). However, despite MM's importance, there are few opportunities for students and researchers to receive training in modeling principles. Recent advancements in data and predictive analytics (Tedeschi, 2019a), including artificial intelligence (AI), make this lack of training an even more daunting challenge for further developing MM. Hence, the main goals of the Modeling Committee of the National Animal Nutrition Program (NANP; <https://animalnutrition.org>) are to 1) raise awareness of the needs and methods for quantitative MM approaches for data and predictive analytics and 2) develop MM skills for future generations in animal science programs.

Symposium Overview

The first symposium was held at the annual meeting of the American Society of Animal Science (ASAS) in Vancouver, Canada, on July 8, 2018, and it was titled "The Future of Livestock Research: Knowledge Gaps, Data Collection and Quality, and the Role of Supporting Tools for Sustainable Production." The second symposium took place in Austin, TX, on July 8, 2019, and it was titled "Mathematical Model Building and Evaluation, and Data Analyses." The third symposium was held virtually on July 19, 2020, and it was titled "Mathematical Modeling in Animal Nutrition: Training the Future Generation in Data and Predictive Analytics for a Sustainable Development." Four presentations and two hands-on training sections occurred during the third symposium. Given the animal science community's interest in MM, the third symposium's central theme was to reinforce data visualization, AI, and modeling techniques.

The adoption of cloud-based decision support systems is steadily growing in many scientific disciplines (Li, 2020), specifically to assist group policy making, given their ability to manipulate large amounts of data and expedite interconnectivity and accessibility among scientists. During the third symposium, Morota et al. (2021) advocated the use of interactive and dynamic graphics in Animal Science disciplines

for enhancing human–computer interaction and exploratory data analysis. They provided a basic understanding of data visualization and then covered the benefits of interactive visualization and statistical graphics within the big data concept, using modern tools, such as the Plotly R (<https://plotly.com/r>) for interactive graphics and R Shiny (<https://shiny.rstudio.com>) for web applications, among many others. The authors pointed out that although interactive statistical graphing has recently been used as a visual tool to facilitate human and graphic interaction, the conceptualization likely started in the mid-1970s when John Tukey proposed the PRIM-9 system at Stanford Linear Accelerator Center (<https://www.youtube.com/watch?v=B7XoW2qiFUA>). Morota et al. (2021) further discussed the use of interactive graphics to assist web-based decision support tools and contemporary data-driven technologies, such as computer vision and precision livestock farming. The authors made the R code available so that readers can reproduce the graphics presented in the paper.

Subsequently, Tulpan et al. (2021) addressed the strengths and weaknesses of the latest technologies to indirectly estimate biometric and morphometric measurements of livestock, including 1) computer vision based on contactless electro-optical sensors such as 2D, 3D, and infrared cameras and 2) computer vision associated with AI algorithms, such as machine learning and deep learning, to calculate the body weight of animals for commercial applications. The authors discussed the three stages necessary to obtain these measurements when using computer vision: detecting an animal in the image, segmenting (or separating) the animal from the background, and extracting the measurements from the animal's segmented image. The authors concluded that the current technology shows promising results but must overcome many hurdles before the scientific community embraces it, including small sample size, lack of animal diversity (breed and species), inconsistent adequacy measurements of the technology, and different 2D and 3D sensors across studies. Furthermore, AI-based algorithms might not provide additional benefit over commonly used statistical fitting algorithms under specific circumstances (Dong and Zhao, 2014; Li et al., 2019; Tedeschi, 2019b).

Then, a mechanistic modeling technique was presented by Gerrits et al. (2021) to highlight the importance of upcycling agricultural byproducts, food waste, and food processing byproducts. These authors illustrated the shortcomings of conventional, static feeding tables for future feed ingredient evaluation. They proposed combining *in vitro* data and *in silico* simulation to assess diet ingredients' nutritive value for swine production. Mechanistic modeling has frequently been used in animal science to understand the underlying individual elements' mechanisms within complex systems (France and Kebreab, 2008; Tedeschi and Fox, 2020). Gerrits et al. (2021) demonstrated the modeling of digestion kinetics, how to develop dynamic models using differential equations, and how to acquire insights from MM to simulate the impacts of digesta transport and hydrolysis kinetics on the nutritive value of feedstuffs. The authors provided a comprehensive, step-by-step instruction for developing a simplified model that meets these objectives, also ready to use for education at graduate student levels.

Finally, Stephens (2021) discussed systems thinking's epistemology and how the Animal Science community can apply it to improving research. Systems thinking is a way to see the world as a complex entity in which everything is connected (Sternman, 2000); thus, changes applied to one variable will

affect another variable's behavior. In the social sciences, system dynamics became the preferred methodological approach in developing models using systems thinking concepts (Forrester, 1961, 1973). Stephens (2021) reviewed complementary definitions of systems thinking based on different viewpoints of modeling strategies, including the teleonomic (goal-seeking) and teleologic concepts that, in the past, have influenced the development of many models (Tedeschi and Fox, 2020). The systems thinking approach allows us to acknowledge that the dynamic complexity of models causes some outcomes because of the model structure, existing feedback loops, delays in the transmission of information or material, incomplete information (i.e., the model is lacking essential pieces), path dependency arising from its time-dependent nature, and policy resistance (Stephens, 2021). The systems thinking approach is an underutilized tool by the Animal Science community that could help to solve “wicked problems” and “grand challenges,” including the antimicrobial resistance conundrum, which was addressed by Stephens (2021).

In summary, these four papers examined different modeling techniques to address critical aspects of MM's development phase while providing examples of application for contemporary issues. Future symposia should incorporate fundamental and applied modeling techniques for other animal species and different aspects of the livestock production system.

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Summary of the papers from the ASAS-NANP Symposium: Mathematical Modeling in Animal Nutrition: Training the Future Generation in Data and Predictive Analytics for Sustainable Development at the 2020 Virtual Annual Meeting & Trade Show of the American Society of Animal Science, Canadian Society of Animal Science, and Western Section of the American Society of Animal Science from July 19 to 23, with publications sponsored by the *Journal of Animal Science* and the American Society of Animal Science. This symposium was sponsored by the National Research Support Project #9 from the National Animal Nutrition Program (<https://animalnutrition.org/>).

Conflict of interest statement

The authors declare no real or perceived conflicts of interest.

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