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Editorial: The 10th international Workshop on Modelling Nutrient Digestion and Utilization in Farm Animals (MODNUT)

A. Cannas [a,*], V.E. Cabrera [b], H.C. Dougherty [c], J.L. Ellis [d], A. Gallo [e], P. Huhtanen [f], I. Kyriazakis [g], M. McPhee [h], K.F. Reed [i], N.K. Sakomura [j], J. van Milgen [k]

[a] Department of Agricultural Sciences, University of Sassari, Italy
[b] Department of Animal and Dairy Sciences, University of Wisconsin, Madison, Madison, WI, United States
[c] Department of Animal Science, University of New England, Armidale, NSW, Australia
[d] Centre for Nutrition Modelling, Department of Animal Biosciences, University of Guelph, Ontario, Canada
[e] Dipartimento di Scienze animali, della nutrizione e degli alimenti (DIANA), Facoltà di Scienze Agrarie, Alimentari e Ambientali, Università Cattolica del Sacro Cuore, Piacenza, Italy
[f] Natural Resources Institute Finland (LUKE), Production Systems, Jokioinen, Finland
[g] Institute for Global Food Security, Queen's University, Belfast, United Kingdom
[h] NSW Department of Primary Industries, Armidale Livestock Industries Centre, University of New England, Armidale, Australia
[i] Department of Animal Science, Cornell University, Ithaca, NY, United States
[j] Department of Animal Science, School of Agricultural and Veterinary Sciences, São Paulo State University (UNESP), Jaboticabal, São Paulo, Brazil
[k] Pegase, INRAE, Institut Agro, Le Clos, Saint Gilles 35590, France

This supplement is based on research presented at the 10th Workshop on Modelling Nutrient Digestion and Utilization in Farm Animals (**MODNUT**), held in Alghero (Sardinia, Italy) on 18–21 September 2022.

The 10th MODNUT featured seven invited speakers, 33 oral presentations and 47 posters and was attended by researchers, professionals, and students coming from 16 different countries.

For the first time, the workshop was held both physically and online. A satellite course on methodologies for modelling in nutrition was held on the last day of MODNUT.

This was the 10th edition of the workshop, which started in 1979, when animal researchers and mathematical modelers around the world, led by Dr. Lee Baldwin, proposed a workshop to their respective fields. The first workshop was held in Hurley, United Kingdom. Since then, researchers from across the globe have gathered quinquennially, and more recently every three years, at this scientific workshop to discuss modelling as a research approach and its application across multiple nutritional areas of animal science. After the first pioneering event, MODNUT has been held across the world in seven editions: California 1984; New Zealand, 1989; Denmark 1994; South Africa, 1999; The Netherlands, 2004; France, 2009; Australia, 2014; Brazil, 2019. Its next edition will be held in Switzerland in the year 2025.

The workshop has greatly evolved over its 33 years of life, in terms of scope and modelling approaches, and it has been influenced by the recent developments in digital and sensor technologies, and the availability of very large datasets. Fortunately, it has maintained its original informal style and the rich after hours, as well as maintaining a vivid memory of its founders and former participants. During the workshop, an informal but touching commemoration of Prof. Daniel Sauvant was held. He was an invited speaker of this edition and the organizer of the French 2009 edition.

This Supplement includes 21 papers, four of which are reviews, which have been grouped into four main sections.

Modelling methodology and advancements

In this section, the review of Tedeschi (2023) examined the paradigms of mathematical models, with a critical in-depth classification of the main type of models used in biological sciences and of their evaluation. He also discussed and exemplified the potential of model hybridization, with important reflection on the role of mathematical modelling in supporting the advancement of sustainable animal production, and of the need to introduce mathematical modelling in animal science education programs, thus avoiding the disconnection between nutritionist and pure modelers. These issues were further examined by the review of Leishman et al. (2023), who focused on the evolution of empirical and mechanistic models in poultry production systems, discussing how these models might be integrated with new digital tools and technologies in the development of automation and precision feeding technologies, based on machine learning and big data algorithms. Large datasets might have several missing data. In this regard, You et al. (2023) compared 13 different methods to input the data and replace missing data, showing that the Random Forest method outperformed all other methods tested. Among the various modelling approaches, system dynamics certainly represents one of those most suited to understand the nature of interactions among variables and to account for their feedback and loops. Atzori et al. (2023) highlighted the potential of using system dynamics to overcome the limitations of current whole farm

* Corresponding author.
E-mail address: cannas@uniss.it (A. Cannas).

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models and presented a system dynamic model to predict future pattern of herd composition and milk delivery.

Nutrient intake, digestion, utilization, metabolism, and requirements – Ruminants

The review of Muñoz-Tamayo et al. (2023) highlighted the need to develop rumen models able to go beyond the current correlation-based approaches, with a focus on rumen genomics and on the models potentially suited to account for causative relationships in the rumen microbiome, mechanistically integrating currently available omics data. Two papers proposed precision feeding mathematical approaches to optimize diets and DM intake for individual and for the pen average of dairy cattle, considering the distribution of their requirements (Campos et al., 2023; Lucey and Rossow, 2023).

Precision nutrition was also the goal of Cavallini et al. (2023), who developed, through machine learning algorithms applied to dairy cow individual data, a prediction equation to estimate total-tract potentially digestible NDF digestibility, and of Hruby Weston et al. (2023), who developed a metabolic model to understand, in lactating dairy cows, how total plasma glucose entry was affected by dietary starch and rumen undegraded protein. Nonlinear feedback mechanisms were considered in the system dynamics model of Cresci et al. (2023), to quantify the animal response of lactating dairy cows subjected to heat stress and to distinguish heat-sensitive cows from heat-tolerant cows. Prediction models to predict feedlot bloat were developed by Macias Franco et al. (2023), who highlighted that parametric models both outperformed and generated more easily implementable models compared to machine learning algorithms. Empirical models for predicting the reticulorumen passage rate of particles and solutes in growing goats, the first ever published for this goat category, were developed and evaluated by Gindri et al. (2023). This topic was further explored, by studying between-individual variability of reticulorumen passage rate of solutes and particles in goats, and its relationship to total NDF digestibility (Gindri and Teixeira, 2023). While the rumen passage rates showed meaningful between-individual variance, NDF digestibility was unrelated to the inherent characteristics of reticulorumen particles.

Nutrient intake, digestion, utilization, metabolism, and requirements – Non-ruminants

Souza et al. (2023) proposed a review and metaanalysis on the efficacy of three free methionine sources and their efficiency of utilization in postweaned piglets, suggesting that the utilization efficiency for protein deposition of different free methionine sources did not differ. More precise nutrition of growing pigs can be achieved if nutrient digestion kinetics, and diet vs animal interactions are considered, as done by the SNAPIG model (Schop et al., 2023).

Three simulation models were proposed for poultry. The first one is a whole animal mechanistic and stochastic model, named Egg Production Model, aiming to simulate the amino acid and energy requirements of laying hens. The evaluation of the model carried out in this study suggested good precision and accuracy in predicting the performance of laying hens (Reis et al., 2023b). The second one was named Broiler Growth Model. It was developed for estimating feed intake, growth, body composition of broilers. It also includes an economic optimizer. As demonstrated in the paper, the model can predict the feed intake and BW of broiler chickens with good accuracy, accounting for the variations in the diets used (Reis et al., 2023c). The third model focused on broiler metabolism and requirements of calcium and phosphorus, with the aim of optimizing their dietary concentration and limiting their excretion in the environment. This mechanistic model predicted the dietary effects of Ca and P on broiler chicken responses with low error (Reis et al., 2023a). The effect of Eimeria maxima infection on protein requirements of boilers was studied with a monomolecular model by Freitas et al. (2023), showing that the infection modified the use of dietary protein, altering body composition and impairing broiler performance.

Livestock and the environment

Two studies analyzed important environmental issues associated to animal production. The first one proposed a system dynamics methodology to conceptualize the water footprint for beef cattle, going over to some of the limitations of current prediction models, where the lack of fundamental ruminant nutrition equations and the fact that time delays and feedback mechanisms that influence water consumption rates, nutrient absorption, and growth are not considered (Menendez et al., 2023).

A multiphase diet feeding strategy for intensive beef cattle fattening, based on adjusting the diet dynamically according to the change of nutritional requirements, was simulated and modeled by Guarnido-Lopez et al (2023). This strategy reduced feeding cost and nitrogen excretion, but increased methane emissions, due to the increased use of fiber-rich diets.

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Not applicable.

Data and model availability statement

Not applicable.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors did not use any artificial intelligence-assisted technologies in the writing process.

Author ORCIDs

Victor E. Cabrera: https://orcid.org/0000-0003-1739-7457.
Antonello Cannas: https://orcid.org/0000-0001-6297-1556.
Holland C. Dougherty: not available.
Jennifer L. Ellis: https://orcid.org/0000-0002-0180-5084.
Antonio Gallo: https://orcid.org/0000-0002-4700-4450.
Pekka Huhtanen: https://orcid.org/0000-0001-7855-7448.
Ilias Kyriazakis: https://orcid.org/0000-0001-7703-3626.
Malcolm McPhee: https://orcid.org/0000-0003-2645-3369.
Kristan F. Reed: https://orcid.org/0000-0003-1766-4148.
Nilva K. Sakomura: https://orcid.org/0000-0001-5707-4113.
Jaap van Milgen: https://orcid.org/0000-0002-6131-5255.

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A. Cannas: Conceptualization, Writing – original draft. **V.E. Cabrera:** Writing – review & editing. **H.C. Dougherty:** Writing – review & editing. **J.L. Ellis:** Writing – review & editing. **A. Gallo:** Writing – review & editing. **P. Huhtanen:** Writing – review &

editing. **I. Kyriazakis:** Writing – review & editing. **M. McPhee:** Writing – review & editing. **K.F. Reed:** Writing – review & editing. **N.K. Sakomura:** Writing – review & editing. **J. van Milgen:** Writing – review & editing.

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