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FACULDADE DE CIÊNCIAS AGRÁRIAS E VETERINÁRIAS
CÂMPUS DE JABOTICABAL

ASSESSING ENERGY METABOLISM IN BROILER CHICKENS: METHODOLOGY FOR EVALUATION AND DETERMINING THE ENERGY CONTENT OF FEED INGREDIENTS

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IMPACTO POTENCIAL DESTA PESQUISA

A produção avícola no Brasil representa uma das principais atividades econômicas no setor agropecuário. Os resultados desta tese representam um avanço para a implementação de um sistema de energia líquida na formulação de rações, permitindo uma estimativa mais precisa do valor energético dos alimentos e a otimização dos custos de alimentação.

POTENTIAL IMPACT OF THIS RESEARCH

Poultry production in Brazil represents one of the main economic activities in the agricultural sector. The results of this thesis represent a significant advancement towards implementing a net energy system in feed formulation, enabling a more accurate estimation of the energy value of feed ingredients and the optimization of feeding cost.

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CERTIFICADO DE APROVAÇÃO

TÍTULO DA TESE: ASSESSING ENERGY METABOLISM IN BROILER CHICKENS: METHODOLOGY FOR EVALUATION AND DETERMINING THE ENERGY CONTENT OF FEED INGREDIENTS

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Jaboticabal, 11 de março de 2024

CURRICULAR INFORMATION

RONY RIVEROS LIZANA – Natural from Peru, born on September 7th, 1993. Started his undergraduate studies in Animal Husbandry in 2011 at the National Agrarian University “La Molina”– Lima, Peru, obtaining the bachelor’s degree in animal Husbandry in 2016. On the last period of undergrad, started as researcher assistantship collaborating in human nutrition researcher in a project of National Council for Science and Technology (from acronym CONCYTEC, Lima, Peru). During the period 2016-2017 he was recruited by the local company as Jr. Research working elaborating and supervising experiments in poultry nutrition. In 2018, he moved to Brazil to enhance his knowledge, applying and being approved in the top position on the non-ruminant nutrition area to the master’s degree in the graduate program in the Sao Paulo State University “Júlio de Mesquita Filho” (FCAV–UNESP), Jaboticabal Campus, under the supervision of Prof. Dr. Nilva Kazue Sakomura and co-supervision by Dr. Jaap van Milgen from INRAe (France). Throughout his master’s studies, he actively contributed to the development and execution of the thematic project “Net Energy for Poultry” coordinated by Prof. Dr. Nilva Sakomura, funded by the São Paulo Research Foundation (FAPESP). In March 2020, he completed his master’s degree and was subsequently admitted to the Ph.D. program, ranking first in the non-ruminant area, under the supervision of Prof. Dr. Nilva Sakomura. During his Ph.D., he continued to be involved in the thematic project, conducting his doctoral research on the development of equations for net energy in broilers, along with his collaboration on other projects involving calcium and phosphorus modeling for poultry and poultry growth modeling.

To my parents, who anyway, are responsible for myself be here and who I am today.

To my brother, for his guidance, from our shared childhood.

To my dream, that just for me *“make sence”*.

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SUMMARY

UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Câmpus de Jaboticabal

CEUA – COMISSÃO DE ÉTICA NO USO DE ANIMAIS

C E R T I F I C A D O

Certificamos que o projeto de pesquisa intitulado **"Determinação da energia líquida de ingredientes para frangos de corte"**, protocolo nº 5401/20, sob a responsabilidade da Profa. Dra. Nilva Kazue Sakomura, que envolve a produção, manutenção e/ou utilização de animais pertencentes ao Filo Chordata, subfilo Vertebrata (exceto o homem), para fins de pesquisa científica (ou ensino) - encontra-se de acordo com os preceitos da lei nº 11.794, de 08 de outubro de 2008, no decreto 6.899, de 15 de julho de 2009, e com as normas editadas pelo Conselho Nacional de Controle de Experimentação Animal (CONCEA), e foi aprovado pela COMISSÃO DE ÉTICA NO USO DE ANIMAIS (CEUA), da FACULDADE DE CIÊNCIAS AGRÁRIAS E VETERINÁRIAS, UNESP - CÂMPUS DE JABOTICABAL-SP, em reunião ordinária de 10 de dezembro de 2020.

Vigência do Projeto	03/10/2021 a 17/03/2022
Espécie / Linhagem	*Gallus gallus domesticus* / Cobb 500
Nº de animais	1400
Peso / Idade	45 g / 1 dia
Sexo	Machos
Origem	Incubatório Pluma, Descalvado - SP

Jaboticabal, 10 de dezembro de 2020.

Fabiana Pilarski

Profa. Dra. Fabiana Pilarski
Coordenadora – CEUA

Faculdade de Ciências Agrárias e Veterinárias
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ASSESSING ENERGY METABOLISM IN BROILER CHICKENS: METHODOLOGY FOR EVALUATION AND DETERMINING THE ENERGY CONTENT OF FEED INGREDIENTS

RESUMO – Este trabalho visa estabelecer o sistema de energia líquida (EL) para frangos de corte, elucidando o metabolismo energético das aves e os métodos metodológicos empregados na investigação desse metabolismo. Para atingir esse objetivo, realizou-se uma revisão bibliográfica, ensaios de validação do sistema de calorimetria indireta (CI) e ensaios biológicos para determinar o valor de EL dos alimentos para frangos de corte. O sistema de EL para esses animais tem sido pouco explorado, considerando que sua aplicação na formulação de rações comerciais permanece limitada. Nesse contexto, efetuou-se uma revisão bibliográfica abrangente, com foco nos princípios conceituais, na evolução dos estudos sobre metabolismo energético em aves e nas diversas metodologias utilizadas para a sua avaliação. Os ensaios experimentais foram realizados utilizando-se seis câmaras de respirometria, fundamentadas no sistema de CI de circuito aberto com pressão negativa, equipadas com gaiolas metabólicas, bebedouros e comedouros do tipo calha, configurados para acomodar grupos de frangos de corte. O sistema de fluxo foi monitorado por uma bomba de pressão negativa com fluxômetro integrado para controle do fluxo. Os gases foram mensurados por um analisador paramagnético de O_2 e um analisador infravermelho de CO_2, integrando um conjunto de componentes característicos da linha Classic Line da Sable System. Adicionalmente, conduziu-se um ensaio para implementar e avaliar o sistema de CI por meio de procedimentos estatísticos e simulações, considerando a dinâmica dos gases atmosféricos. Desse ensaio, desenvolveu-se uma planilha em MS Excel para automatizar os cálculos da produção de calor a partir do volume de consumo de O_2 e produção de CO_2, permitindo verificar a taxa de recuperação dos gases e, consequentemente, a viabilidade do sistema de CI. Após a validação do sistema de CI, realizou-se um ensaio com frangos de corte de 15 a 21 dias de idade, objetivando desenvolver equações de predição de EL dos ingredientes, utilizando 48 dietas formuladas com ingredientes tradicionais e não tradicionais, visando uma ampla variação na composição nutricional. As medições a mensuração da produção de calor e coleta de excretas, para determinação da EMA, EMAn e EL. O desenvolvimento das equações de predição de EL baseando-se na composição nutricional através de análises de regressão múltipla. A avaliação do valor energético de fontes de óleo e gordura seguiu o protocolo do experimento anterior, determinando o valor energético (AME e EL) do óleo de soja e gordura de aves. Por fim, propôs-se um modelo teórico mecanicista para estimar o valor de EL dos alimentos, considerando a utilização dos nutrientes e o metabolismo animal. Os resultados obtidos sublinham a relevância do estudo do metabolismo energético, considerando os procedimentos metodológicos e a determinação do valor de EL dos ingredientes para frangos de corte, demonstrando sua aplicabilidade na produção comercial de aves.

Palavras-chave: Calorimetria indireta, frangos de corte, metabolismo energético, utilização de energia

ABSTRACT – This work aims to establish the net energy (NE) system for broiler chickens, elucidating the energy metabolism of the birds and the methodological approaches used in the investigation of this metabolism. To achieve this goal, a literature review was conducted, along with validation assays of the indirect calorimetry (IC) system and biological assays to determine the NE value of feed for broiler chickens. The NE system for these animals has been sparsely explored, given that its application in the formulation of commercial feeds remains limited. In this context, a comprehensive literature review was conducted, focusing on conceptual principles, the evolution of studies on avian energy metabolism, and the various methodologies used for its evaluation. The experimental assays were conducted using six respirometry chambers, based on the open-circuit IC system with negative pressure, equipped with metabolic cages, waterers, and trough feeders, configured to accommodate groups of broiler chickens. The flow system was monitored by a negative pressure pump with an integrated flowmeter for flow control. Gases were measured by a paramagnetic O_2 analyzer and an infrared CO_2 analyzer, integrating a set of components characteristic of the Sable System Classic Line. Additionally, an assay was conducted to implement and evaluate the IC system through statistical procedures and simulations, considering the dynamics of atmospheric gases. From this assay, a spreadsheet in MS Excel was developed to automate the calculations of heat production from the volume of O_2 consumption and CO_2 production, allowing the verification of gas recovery rate and, consequently, the viability of the IC system. Following the validation of the IC system, an assay was conducted with broiler chickens aged 15 to 21 days, aiming to develop prediction equations for the NE of ingredients, using 48 diets formulated with traditional and non-traditional ingredients, aiming for a wide variation in nutritional composition. Measurements included the measurement of heat production and collection of excreta, for the determination of apparent metabolizable energy (AME), nitrogen-corrected AME (AMEn), and NE. The development of NE prediction equations was based on nutritional composition through multiple regression analyses. The evaluation of the energy value of oil and fat sources followed the protocol of the previous experiment, determining the energy value (AME and NE) of soy oil and poultry fat. Finally, a mechanistic theoretical model was proposed to estimate the NE value of feed, considering nutrient utilization and animal metabolism. The obtained results underline the relevance of studying energy metabolism, considering the methodological procedures and the determination of the NE value of ingredients for broiler chickens, demonstrating its applicability in the commercial production of poultry.

Keywords: Broiler chickens, energy metabolism, energy utilization, indirect calorimetry.

CHAPTER 1 – General considerations

GENERAL CONSIDERATIONS

Introduction

Energy is one of the most important components in poultry diets, essential to broiler chickens' growth and development. Additionally, dietary energy content is known as the chief driver of feed intake regulation, as broiler chickens intake enough feed to meet their energy requirements for maintenance and growth (Emmans, 1994; Hughes, 2008; Lopez and Leeson, 2008). Consequently, other essential nutrients, chiefly amino acids, must be proportionally adjusted in relation to energy. Modern broiler chickens consume approximately 10% of their body weight in dry matter bases (Nascimento et al., 2020). In this sense, these birds demonstrate high growth rates even when exposed to significant variations in dietary energy concentrations (Zuidhof et al., 2014). However, it is undeniable that dietary energy influences on the body composition (Lopez and Leeson, 2008).

The complex relationship between energy and nutrients, their mechanism involved in feed intake regulation, and how they influence body composition make it an important topic to understand how animals use energy. The intricate understanding of energy metabolism in poultry chickens has been a continuous and enduring subject of interest since the early days of modern poultry science (NRC, 1994). In the early 20th century, researchers and nutritionists recognized the importance of achieving optimal energy balance in poultry diets to enhance growth, production, and overall performance (Hurwitz et al., 1978). Meanwhile, the energy utilization of birds and understanding how the animal allocates energy under different conditions are currently being studied, along with a more accurate determination of the energy values of feeds. This interest from researchers was favored by technological advancements, efficient dissemination, and ease of sharing results, as well as more fluid communication among researchers, promoting the standardization of procedures and methodological protocols that reduce the variability of results and their discrepancies. Methodological tools and their proper application are crucial in studies of energetic metabolism and any biological assay.

Regarding studies about energetic metabolism through biological assays, two components must be considered: the animal ("machine") and the feed ("fuel"). The observation of both factors that induce (the feed) and express (the animal) a response (variations on the metabolism) should be considered simultaneously to elucidate the questions proposed in each study. This introspection about the energy metabolism evaluation in poultry and their corresponding interpretations resulted from discussions inspired by Dr. Jaap van Milgen lectures, so both this review and the manuscripts presented here attempt, in part, to propose results based on these interpretations.

In practical terms, feed evaluations are the main objective of nutritionists due to the feed cost involved in the animal protein production industry. The primary energy sources in poultry diets are cereal grains, generally complemented by vegetable oils derived from seeds. Depending on geographical regions, corn may dominate practical diets in Brazil and the United States, while wheat may prevail in Europe and Australia (Ravindran and Brair, 1991). Other ingredients like triticale, barley, and sorghum are sporadic and contingent upon availability (Hughes, 2003). It is worth noting that the available energy content of these ingredients varies significantly based on their physicochemical composition (Hughes and Choct, 1999). In this way, it is important to explore novel systems to evaluate energy accurately.

In this sense, this work was developed to explore the principal conceptual bases involved in the energy metabolism of broiler chickens and the methodological tools used for energy metabolism studies and reach a domine of the topic to develop the net energy system to be applied in broiler chickens.

Conclusion

The transition to an NE system necessitates initial investments in research, training, and potentially new feed analysis and formulation technologies. However, the long-term benefits, such as cost reductions and improved product quality, will likely offset these initial expenses.

Overall, transitioning to an NE system in broiler chicken nutrition promises substantial improvements in feed formulation precision, production efficiency, environmental sustainability, and economic returns for the poultry industry. Achieving these benefits will require collective research, education, and infrastructure development efforts to embrace this advanced approach to energy evaluation in poultry diets.

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