

## RESSALVA

Atendendo solicitação da autora,  
o texto completo desta  
dissertação será disponibilizado  
somente a partir de 21/02/2027.

**UNIVERSIDADE ESTADUAL PAULISTA - UNESP  
CAMPUS DE JABOTICABAL**

**AVALIAÇÃO DE MONOGLICERÍDEOS EM DIETAS PARA  
POEDEIRAS**

**Jaqueline Aparecida Pavanini  
Zootecnista**

**UNIVERSIDADE ESTADUAL PAULISTA - UNESP  
CAMPUS DE JABOTICABAL**

**AVALIAÇÃO DE MONOGLICERÍDEOS EM DIETAS PARA  
POEDEIRAS**

**Discente: Jaqueline Aparecida Pavanini  
Orientador: Prof. Dr. Edney Pereira da Silva  
Coorientador: Prof. Dr. Manoel Garcia Neto**

**Dissertação apresentada à Faculdade de  
Ciências Agrárias e Veterinárias – Unesp,  
Campus de Jaboticabal, como parte das  
exigências para a obtenção do título em  
Mestre em Ciência Animal.**

P337a Pavanini, Jaqueline Aparecida  
Avaliação de monoglicérides em dietas para poedeiras /  
Jaqueline Aparecida Pavanini. -- Jaboticabal, 2026  
97 p. : il., tabs.

Dissertação (mestrado) - Universidade Estadual Paulista  
(UNESP), Faculdade de Ciências Agrárias e Veterinárias,  
Jaboticabal

Orientador: Edney Pereira da Silva  
Coorientador: Manoel Garcia Neto

1. Aditivo. 2. Aves poedeiras. 3. Desempenho. 4.  
Modelagem. 5. Ovos. I. Título.

Sistema de geração automática de fichas catalográficas da Unesp. Dados fornecidos pelo autor(a).



UNIVERSIDADE ESTADUAL PAULISTA

Câmpus de Jaboticabal



**CERTIFICADO DE APROVAÇÃO**


TÍTULO DA DISSERTAÇÃO: AVALIAÇÃO DE MONOGLICERÍDEOS EM DIETAS PARA POEDEIRAS

**AUTORA: JAQUELINE APARECIDA PAVANINI**

**ORIENTADOR: EDNEY PEREIRA DA SILVA**

**COORIENTADOR: MANOEL GARCIA NETO**


Aprovada como parte das exigências para obtenção do Título de Mestra em Ciência Animal, área: Nutrição Animal pela Comissão Examinadora:

Documento assinado digitalmente  
 **MANOEL GARCIA NETO**  
Data: 14/05/2025 20:19:25-0300  
Verifique em <https://validar.iti.gov.br>

Prof. Associado MANOEL GARCIA NETO (Participação Presencial)  
Departamento de Produção e Saúde Animal / FMV UNESP Aracatuba

Documento assinado digitalmente  
 **RODRIGO KNOP GUAZZI MESSIAS**  
Data: 28/04/2025 13:31:43-0300  
Verifique em <https://validar.iti.gov.br>

Dr. RODRIGO KNOP GUAZZI MESSIAS (Participação Virtual)  
BASF S/A / São Paulo/SP

Documento assinado digitalmente  
 **SABRINA LUZIA CAETANO**  
Data: 30/04/2025 11:41:34-0300  
Verifique em <https://validar.iti.gov.br>

Profa. Dra. SABRINA LUZIA CAETANO (Participação Virtual)  
Departamento de Ciências Exatas / FCAV UNESP Jaboticabal

Jaboticabal, 21 de fevereiro de 2025

## **DADOS CURRICULARES DO AUTOR**

Jaqueline Aparecida Pavanini nasceu em 28 de abril de 1997, em Jaboticabal - SP. Filha de Simone da Costa Pires Pavanini e Carlos Alberto Pavanini. Em 2013, ingressou no curso técnico em Agropecuária no Colégio Técnico Agrícola (CTA), campus Jaboticabal - UNESP, onde também concluiu o ensino médio em 2015. Em 2019, iniciou a graduação em Zootecnia no Universidade Estadual Paulista (UNESP), campus Jaboticabal, graduando-se em junho de 2023 e no mesmo ano, ingressou no Mestrado em Ciência Animal na Universidade Estadual Paulista (UNESP), campus Jaboticabal, sob orientação do Prof. Dr. Edney Pereira da Silva.

“Não importa como você leva sua vida, sua inteligência o defenderá melhor do que uma espada. Trate de mantê-la afiada!”

- O Nome do Vento, Patrick Rothfuss

Dedico este trabalho à memória do meu pai, cuja presença continua viva em minhas lembranças e conquistas; à minha mãe, pelo amor inabalável e apoio constante; aos meus irmãos, pela cumplicidade de sempre; e a toda minha família, por nunca medirem esforços para me incentivar e apoiar.

## **AGRADECIMENTOS**

Agradeço a Deus, por me sustentar nos momentos de incerteza e iluminar meu caminho com fé e esperança.

À memória do meu pai Carlos, que, mesmo ausente fisicamente, continua sendo inspiração e força em minha vida (In memoriam);

À minha mãe Simone, por seu amor, por me ensinar a ser forte e por sempre estar ao meu lado nos dias difíceis;

Aos meus irmãos Daiane, Talisson e Jéssica, pela presença constante, pelas risadas, pelos conselhos e pelo apoio incondicional em todas as etapas da minha caminhada;

Aos amigos que a vida me deu, todos tão especiais, que seria impossível citar cada nome aqui minha gratidão sincera por cada gesto de carinho, incentivo e parceria;

Ao meu orientador Prof. Dr. Edney Pereira da Silva, e à Profa. Dra. Michele Bernadino de Lima, por sua orientação, pela confiança, pelos ensinamentos e por me guiar com paciência e sabedoria;

Ao meu coorientador Prof. Manoel, pela dedicação e pela generosidade em compartilhar conhecimento;

Aos colegas e estagiários que contribuíram com o experimento, tornando essa jornada mais leve e colaborativa;

A todos que, de alguma forma, contribuíram para a realização deste trabalho e para meu crescimento pessoal e profissional;

À UNESP/FCAV por proporcionar os recursos, a estrutura e o ambiente acadêmico que tornaram possível a realização deste trabalho;

À BASF S/A pelo suporte técnico e pelo financiamento concedido, fundamentais para a execução dos experimentos.

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

## SUMÁRIO

<b>CHAPTER I - GENERAL CONSIDERATIONS .....</b>	<b>10</b>
Organic Acids .....	10
Fatty Acids and Glycerides: Structure, Function, and Activity .....	11
Butyric Acid: Properties, Absorption, and Applications .....	12
Capric Acid and Caprylic Acid .....	13
References .....	16
<b>CHAPTER II – EVALUATION OF THE USE OF MONOGLYCERIDES IN THE SEXUAL MATURATION OF LAYING HENS .....</b>	<b>20</b>
ABSTRACT .....	20
INTRODUCTION .....	21
MATERIALS AND METHODS .....	23
Animal ethics .....	23
Feed additives .....	23
Animals and husbandry .....	23
Dietary treatments .....	24
Performance measurement .....	26
Egg Production Modeling as a Function of Age .....	26
Data analysis .....	26
Model identity and parameter equality analysis .....	27
RESULTS .....	28
Performance .....	28
Comparison of monoglycerides in egg production .....	34
DISCUSSION .....	41
CONCLUSION .....	44
REFERENCES .....	45
<b>CHAPTER III – APPLICATION OF STRUCTURAL EQUATION MODELING IN LAYER HEN NUTRITION: RELATIONSHIPS BETWEEN INTESTINAL INTEGRITY, HEMATOLOGICAL CONDITION, AND EGG QUALITY IN HENS FED MONOGLYCERIDES .....</b>	<b>47</b>
ABSTRACT .....	47
INTRODUCTION .....	48
MATERIALS AND METHODS .....	50
Animal ethics .....	50
Experimental Design and Treatments .....	50
Egg Quality .....	52
Hematological Analysis .....	52
Morphological Analysis of the Duodenum, Abdominal Fat, and Gizzard .....	52
Statistical Analysis .....	53
RESULTS .....	53
Model 1 .....	53
Model 2 .....	66
DISCUSSION .....	78
Model 1 .....	78
Model 2 .....	81

Model 1 vs Model 2.....	83
CONCLUSION .....	84
REFERENCES.....	86

## LISTA DE TABELAS

### CHAPTER I - GENERAL CONSIDERATIONS

Table 1. Common acidifiers used as additives in swine and poultry production. ....	11
Table 2. Physical and chemical properties of caprylic acid and capric acid. ....	14

### CHAPTER II – EVALUATION OF THE USE OF MONOGLYCERIDES IN THE SEXUAL MATURATION OF LAYING HENS

Table 1. Experimental diet composition and nutrients (as-fed basis, %). ....	25
Table 2. Levels of monoglycerides in diets supplemented with or without enramycin on responses of feed intake from laying pullets obtained 117 to 166 days old. ....	29
Table 3. Levels of monoglycerides in diets supplemented with or without enramycin on responses of egg production from laying pullets obtained 117 to 166 days old. ..	30
Table 4. Levels of monoglycerides in diets supplemented with or without enramycin on responses of egg weight from laying pullets obtained 124 to 166 days old. ....	31
Table 5. Levels of monoglycerides in the diets supplemented with or without enramycin on responses of egg mass from laying pullets obtained 117 to 166 days old. ....	32
Table 6. Levels of monoglycerides in the diets supplemented with or without enramycin on responses of feed conversion ratio from laying pullets obtained 124 to 166 days old. ....	33
Table 7. Results obtained for analysis of model identity and equality of parameters of egg production curve of laying pullets from 117 to 166 days of age, supplemented with 500 and 1000 mg of monoglycerides per kg of feed. ....	36
Table 8. Results obtained for analysis of model identity and equality of parameters of egg production curve of laying pullets from 117 to 166 days of age, supplemented with 0 and 500 mg of monoglycerides per kg of feed. ....	38
Table 9. Results obtained for analysis of model identity and equality of parameters of egg production curve of laying pullets from 117 to 166 days of age, supplemented with 0 and 1000 mg of monoglycerides per kg of feed. ....	40

### CHAPTER III – APPLICATION OF STRUCTURAL EQUATION MODELING IN LAYER HEN NUTRITION: RELATIONSHIPS BETWEEN INTESTINAL INTEGRITY, HEMATOLOGICAL CONDITION, AND EGG QUALITY IN HENS FED MONOGLYCERIDES

Table 1. Experimental diet composition and nutrients (as-fed basis, %). ....	25
Table 2. Principal Component Analysis of variables related to egg quality, intestinal integrity, and hematological condition in hens supplemented with monoglycerides. ..	54
Table 3. Estimated effects between the latent variables (intestinal integrity, hematological condition, and egg quality) and their respective observed variables. ..	30
Table 4. Covariance estimates between the latent variables (hematological condition,	

egg quality, and intestinal integrity) and the observed variables crypt area (CA), crypt depth (CD), yolk percentage (Y), albumen percentage (A), feed intake (FI), abdominal fat (AF), gizzard fat (GF), monoglycerides, and antibiotic.....	31
Table 5. Direct effects between the latent variables (hematological condition, egg quality, and intestinal integrity) and the variables egg production (EP), feed intake (FI), abdominal fat (AF), gizzard fat (GF), monoglycerides, and antibiotic based on the pathways of the structural equation model.....	32
Table 6. Indirect Effects Between Latent Variables (Hematological Condition, Egg Quality, and Intestinal Integrity) and Observed Variables (egg production (EP), feed intake (FI), abdominal fat (AF), gizzard fat (GF), Monoglycerides, and Antibiotic) Based on Structural Equation Modeling Paths.....	33
Table 7. Principal Component Analysis of variables related to performance in pullets supplemented with monoglycerides.....	36
Table 8. Estimates of the effects between latent variables (intestinal integrity, egg quality, hematological condition, and performance) and their respective observed variables.....	38
Table 9. Estimates of covariances between the latent variable (egg quality) and the variables abdominal fat (AF), gizzard fat (GF), monoglycerides and antibiotic.....	40
Table 10. Direct effects between latent variables (hematological condition, egg quality, intestinal integrity, and performance) and the variables abdominal fat (AF), gizzard fat (GF), monoglycerides, and antibiotic, based on the paths of the structural equation model.....	25
Table 11. Indirect effects among latent variables (hematological condition, egg quality, intestinal integrity, and performance) and the variables abdominal fat (AF), gizzard fat (GF), monoglycerides, and antibiotic, based on the paths of the structural equation model.....	76

## LISTA DE FIGURAS

### CHAPTER I - GENERAL CONSIDERATIONS

Figure 1. Structure of butyric acid. ....	12
Figure 2. Chemical structure of caprylic acid. ....	14
Figure 3. Chemical structure of capric acid.....	14

### CHAPTER III – APPLICATION OF STRUCTURAL EQUATION MODELING IN LAYER HEN NUTRITION: RELATIONSHIPS BETWEEN INTESTINAL INTEGRITY, HEMATOLOGICAL CONDITION, AND EGG QUALITY IN HENS FED MONOGLYCERIDES

Figure 1. Graphical representation of the latent variables (hematological condition, egg quality, and intestinal integrity) and their respective observed indicators.....	55
Figure 2. Graphical representation of the structural equation model evaluating the relationship between the latent variables (hematological condition, egg quality, and intestinal integrity) and the variables egg production (EP), feed intake (FI), abdominal fat (AF), gizzard fat (GF), monoglycerides, and antibiotic.....	59
Figure 3. Graphical representation of latent variables (hematological condition, egg quality, and intestinal integrity) and their respective observed indicators.....	67
Figure 4. Structural equation model showing relationships among latent variables (hematological condition, egg quality, intestinal integrity, and performance) and observed variables (abdominal fat, gizzard fat, monoglycerides, and antibiotic).. ....	71



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



## CEUA – COMISSÃO DE ÉTICA NO USO DE ANIMAIS

### CERTIFICADO

Certificamos que o projeto intitulado "Evaluation of organic acids and carbohydrases in diets for pullets and layers", protocolo nº 003761/23, sob a responsabilidade do Prof. Dr. EDNEY PEREIRA DA SILVA, 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.

Vigência do Projeto	01/07/2023 a 31/03/2024
Espécie / Linhagem	Gallus gallus domesticus / Poedeiras comerciais / Lohmann LSL-Lite
Nº de animais	480
Peso / Idade	1.110 – 1.600 kg / 15 – 42 semanas
Sexo	Fêmeas
Origem	A definir

Jaboticabal, 16 de maio de 2023.

**Profa. Dra. Paola Castro Moraes**

Vice-coordenadora em exercício – CEUA FCAV

Faculdade de Ciências Agrárias e Veterinárias  
Via de Acesso Prof. Paulo Donato Castellane, s/n CEP 14884-900 - Jaboticabal - SP - Brasil  
Tel. 16 3209-7100 - www.fcav.unesp.br

## **AVALIAÇÃO DE MONOGLICERÍDEOS EM DIETAS PARA POEDEIRAS**

### **RESUMO**

Neste estudo, foram avaliados os efeitos de diferentes doses de um blend de monoglicerídeos dos ácidos butírico, cáprico e caprílico na alimentação de poedeiras. O experimento foi conduzido no Laboratório de Ciências Avícolas (LAVINESP), da Faculdade de Ciências Agrárias e Veterinárias (UNESP/FCAV), no Campus de Jaboticabal – SP. O blend utilizado não fornece apenas os benefícios do ácido butírico, como também explora as propriedades dos ácidos cáprico e caprílico, que podem influenciar positivamente o desempenho produtivo e na saúde das aves. Avaliou-se o desempenho, qualidade dos ovos, condição hematológica e integridade intestinal das poedeiras. Foram utilizados o teste da razão de verossimilhança e o modelo de Gompertz, para determinar se as diferentes doses de monoglicerídeos tiveram um impacto significativo nos parâmetros avaliados e também foi utilizado o modelo de equações estruturais para avaliar as relações complexas das variáveis qualidade dos ovos, condição hematológica e integridade intestinal. Os resultados deste estudo contribuem para a compreensão do potencial dos monoglicerídeos como alternativa nutricional na avicultura, promovendo melhorias na produção.

**Palavras-chave:** aditivo, aves poedeiras, desempenho, modelagem, ovos.

## EVALUATION OF MONOGLYCERIDES IN DIETS FOR LAYING HENS

### ABSTRACT

In this study, the effects of different doses of a blend of monoglycerides from butyric, capric, and caprylic acids in the diet of laying hens were evaluated. The experiment was conducted at the Avian Sciences Laboratory (LAVINESP), Faculty of Agricultural and Veterinary Sciences (UNESP/FCAV), Jaboticabal Campus – SP. The blend used not only provides the benefits of butyric acid but also explores the properties of capric and caprylic acids, which may positively influence both productive performance and the health of the hens. Performance, egg quality, hematological condition, and intestinal integrity of the hens were assessed. The likelihood ratio test and the Gompertz model were used to determine whether the different doses of monoglycerides had a significant impact on the evaluated parameters. Additionally, a structural equation model was employed to assess the complex relationships between the variables of egg quality, hematological condition, and intestinal integrity. The results of this study contribute to the understanding of the potential of monoglycerides as a nutritional alternative in poultry, promoting improvements in production.

**Keywords:** additive, egg, laying hens, modeling, performance.

## INTRODUCTION

Organic acids (OAs) have been used for decades in poultry nutrition as preservatives and have gained increasing interest as an alternative to antibiotics in feed (Polycarpo *et al.*, 2017). Among OAs, the inclusion of short-chain fatty acids (SCFAs) and medium-chain fatty acids (MCFAs) in different forms, such as monoglycerides, has demonstrated potential to improve animal health, welfare, and productivity, in addition to reducing the presence of foodborne pathogens. At the same time, these compounds help minimize environmental impacts (Dittoe *et al.*, 2018; Appleton *et al.*, 2024).

Monoglycerides, composed of a fatty acid esterified to glycerol, overcome some limitations due to two main factors: they are relatively easy to handle and allow for gradual release along the intestinal tract (Bedford and Gong, 2018).

Supplementation with monoglycerides provides an immediate and additional source of energy, reducing the need for mobilization of nutrients such as proteins for this purpose (Mabayoy *et al.*, 1993). In addition, monoglycerides can be directly utilized by enterocytes for energy production, helping to maintain intestinal tissue integrity and improving nutrient utilization in poultry (Van Der Aar, Molist and Van Der Klis, 2017). Beyond benefits related to intestinal function and metabolism, these compounds exhibit anti-inflammatory properties, being able to modulate the inflammatory response, particularly through the regulation of pro-inflammatory cytokine expression (Sacakli *et al.*, 2023).

The combination of monoglycerides containing butyric, capric, and caprylic acids provides complementary benefits. Butyric acid contributes to immune enhancement and modulation of inflammatory and immune responses (Guilloteau *et al.*, 2010; Zhou *et al.*, 2014), and also stimulates angiogenesis, promoting cellular development and tissue formation (Dobson *et al.*, 1990). In turn, capric and caprylic acids help reduce contamination by *Salmonella* spp. in egg yolks and shells (Upadhyaya *et al.*, 2015), while improving nutrient bioavailability in poultry (Józefiak *et al.*, 2014).

Therefore, this study aimed to evaluate the effects of supplementing a monoglyceride blend (butyric acid, caprylic acid, and capric acid) in the diet of laying hens.

## **CONCLUSION**

The inclusion of monoglycerides in the diet of laying hens significantly improved egg quality, and the application of structural equation models proved

essential for deriving robust theoretical (latent) conclusions from operational variables (indicators).

## REFERENCES

- ABD EL-MAGED, M. *et al.* Study Productive and Physiological Performance of Sinai Laying Hens Supplemented with Fatty Acids During Late Period. **Egyptian Journal of Veterinary Sciences**, v. 55, n. 6, p. 1499–1512, 1 nov. 2024.
- ABDELQADER, A.; AL-FATAFTAH, A.-R. Effect of dietary butyric acid on performance, intestinal morphology, microflora composition and intestinal recovery of heat-stressed broilers. **Livestock Science**, v. 183, p. 78–83, jan. 2016.
- ADRIANI, L. *et al.* Effect of powder probiotic on the leukocyte, heterophil and lymphocyte level on laying hens. **Animal Science Journal**, v. 65, n. 1, 2022.
- ALEXANDRINO, S. L. DE S. A. *et al.* Microbiota intestinal e os fatores que influenciam na avicultura. **Research, Society and Development**, v. 9, n. 6, p. e87963098, 17 abr. 2020.
- APPLETON, S. R.; BALLOU, A.; WATKINS, K. L. Use of Monoglycerides and Diglycerides to Mitigate Poultry Production Losses: A Review. **Veterinary Sciences**, v. 11, n. 3, p. 101, 27 fev. 2024.
- BEDFORD, A.; GONG, J. Implications of butyrate and its derivatives for gut health and animal production. **Animal Nutrition**, v. 4, n. 2, p. 151–159, jun. 2018.
- BRISBIN, J. T.; GONG, J.; SHARIF, S. Interactions between commensal bacteria and the gut-associated immune system of the chicken. **Animal Health Research Reviews**, v. 9, n. 1, p. 101–110, 9 jun. 2008.
- CAMPBELL, T. W. Hematology of Birds. *Em: THRALL, M. A. et al. (Eds.). . Veterinary hematology, clinical chemistry, and cytology*. 3. ed. [s.l.] John Wiley & Sons, Inc, 2022. p. 254–291.
- DENG, W. *et al.* The probiotic *Bacillus licheniformis* ameliorates heat stress-induced impairment of egg production, gut morphology, and intestinal mucosal immunity in laying hens. **Poultry Science**, v. 91, n. 3, p. 575–582, mar. 2012.
- DITTOE, D. K.; RICKE, S. C.; KIESS, A. S. Organic Acids and Potential for Modifying the Avian Gastrointestinal Tract and Reducing Pathogens and Disease. **Frontiers in Veterinary Science**, v. 5, 6 set. 2018.
- DOBSON, D. E. *et al.* 1-Butyryl-Glycerol: A novel angiogenesis factor secreted by differentiating adipocytes. **Cell**, v. 61, n. 2, p. 223–230, abr. 1990.
- ECK, L. M. VAN *et al.* Lipid metabolism and body composition in long-term producing hens. **World's Poultry Science Journal**, v. 79, n. 2, p. 243–264, 3 abr. 2023.
- FENG, X. *et al.* Effects of monobutyryl supplementation on egg production,

biochemical indexes, and gut microbiota of broiler breeders. **Poultry Science**, v. 100, n. 3, p. 100907, mar. 2021.

HAMILTON, R. M. G.; BRYDEN, W. L. Relationship between egg shell breakage and laying hen housing systems – an overview. **World's Poultry Science Journal**, v. 77, n. 2, p. 249–266, 3 abr. 2021.

HISASAGA, C.; GRIFFIN, S. E.; TARRANT, K. J. Survey of egg quality in commercially available table eggs. **Poultry Science**, v. 99, n. 12, p. 7202–7206, dez. 2020.

HOFMANN, T. *et al.* Short- and long-term consequences of stocking density during rearing on the immune system and welfare of laying hens. **Poultry Science**, v. 100, n. 8, p. 101243, ago. 2021.

HU, L.; BENTLER, P. M. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. **Structural Equation Modeling: A Multidisciplinary Journal**, v. 6, n. 1, p. 1–55, jan. 1999.

JÓZEFIAK, D. *et al.* Clostridium perfringens challenge and dietary fat type affect broiler chicken performance and fermentation in the gastrointestinal tract. **Animal**, v. 8, n. 6, p. 912–922, 2014.

KAPADIA, S.; BAKER, S. J. The Effects of Alterations in Villus Shape on the Intestinal Mucosal Surface of the Albino Rat; the Relationship between Mucosal Surface Area and the Crypts. **Digestion**, v. 14, n. 3, p. 256–268, 1976.

KETTA, M.; TŮMOVÁ, E. Eggshell structure, measurements, and quality-affecting factors in laying hens: a review. **Czech Journal of Animal Science**, v. 61, n. 7, p. 299–309, 31 jul. 2016.

KLINE, R. B. Global Fit Testing. *Em*: KLINE, R. B. (Ed.). . **Principles and Practice of Structural Equation Modeling**. 4. ed. New York: Guilford Publications, 2016. p. 262–299.

KWON, O.; HAN, T.-S.; SON, M.-Y. Intestinal Morphogenesis in Development, Regeneration, and Disease: The Potential Utility of Intestinal Organoids for Studying Compartmentalization of the Crypt-Villus Structure. **Frontiers in Cell and Developmental Biology**, v. 8, 23 out. 2020.

LAMOT, D. M. *et al.* Effects of feed access after hatch and inclusion of fish oil and medium chain fatty acids in a pre-starter diet on broiler chicken growth performance and humoral immunity. **animal**, v. 10, n. 9, p. 1409–1416, 2016.

LAUDADIO, V. *et al.* Productive performance and histological features of intestinal mucosa of broiler chickens fed different dietary protein levels. **Poultry Science**, v. 91, n. 1, p. 265–270, jan. 2012.

LI, H. *et al.* Propionate inhibits fat deposition via affecting feed intake and modulating gut microbiota in broilers. **Poultry Science**, v. 100, n. 1, p. 235–245, jan. 2021.

MCDONALD, R. P. Structural Models and the Art of Approximation. **Perspectives on Psychological Science**, v. 5, n. 6, p. 675–686, 7 nov. 2010.

MINTZIORI, G. *et al.* The effect of excess body fat on female and male reproduction. **Metabolism**, v. 107, p. 154193, jun. 2020.

M'SADEQ, S. A. *et al.* Towards the control of necrotic enteritis in broiler chickens with in-feed antibiotics phasing-out worldwide. **Animal Nutrition**, v. 1, n. 1, p. 1–11, mar. 2015.

O'BOYLE, E. H.; WILLIAMS, L. J. "Decomposing model fit: Measurement vs. theory in organizational research using latent variables": Correction to O'Boyle and Williams (2011). **Journal of Applied Psychology**, v. 96, n. 4, p. 729–729, jul. 2011.

OKUMURA, R.; TAKEDA, K. Maintenance of intestinal homeostasis by mucosal barriers. **Inflammation and Regeneration**, v. 38, n. 1, p. 5, 2 dez. 2018.

PAUL, S. S. *et al.* Dietary supplementation of extracts of red sea weed (*Kappaphycus alvarezii*) improves growth, intestinal morphology, expression of intestinal genes and immune responses in broiler chickens. **Journal of the Science of Food and Agriculture**, v. 101, n. 3, p. 997–1008, 25 fev. 2021.

RYSMAN, K. *et al.* Broiler performance correlates with gut morphology and intestinal inflammation under field conditions. **Avian Pathology**, v. 52, n. 4, p. 232–241, 4 jul. 2023.

SCHUMACKER, R. E.; LOMAX, R. G. **A beginner's Guide to Structural Equation Modeling**. 3. ed. New York: Taylor and Francis Group, 2010.

SHAKERI, M. *et al.* Response to Dietary Supplementation of Glutamine in Broiler Chickens Subjected to Transportation Stress. **İstanbul Üniversitesi Veteriner Fakültesi Dergisi**, v. 42, n. 2, 4 jul. 2016.

SIROTKIN, A. V. *et al.* Body fat affects mouse reproduction, ovarian hormone release, and response to follicular stimulating hormone. **Reproductive Biology**, v. 18, n. 1, p. 5–11, mar. 2018.

ŚWIĄTKIEWICZ, S.; KORELESKI, J.; ARCZEWSKA, A. Laying performance and eggshell quality in laying hens fed diets supplemented with prebiotics and organic acids. **Czech Journal of Animal Science**, v. 55, n. 7, p. 294–306, 31 jul. 2010.

TELLEZ-ISAIAS, G. *et al.* Effects of chronic stress and intestinal inflammation on commercial poultry health and performance: A review. **German Journal of Veterinary Research**, v. 3, n. 1, p. 38–57, abr. 2023.

WISEK, W. J. The Mode of Growth Promotion by Antibiotics. **Journal of Animal Science**, v. 46, n. 5, p. 1447–1469, 1 maio 1978.

WANG, J. P.; KIM, I. H. Effect of caprylic acid and *Yucca schidigera* extract on

production performance, egg quality, blood characteristics, and excreta microflora in laying hens. **British Poultry Science**, v. 52, n. 6, p. 711–717, dez. 2011.

WANG, W. *et al.* In Vitro Antibacterial Activities and Mechanisms of Action of Fatty Acid Monoglycerides Against Four Foodborne Bacteria. **Journal of Food Protection**, v. 83, n. 2, p. 331–337, fev. 2020.

WANG, Z. *et al.* Spermidine improves the antioxidant capacity and morphology of intestinal tissues and regulates intestinal microorganisms in Sichuan white geese. **Frontiers in Microbiology**, v. 14, 16 jan. 2024.

XU, Z. *et al.* Effects of dietary fructooligosaccharide on digestive enzyme activities, intestinal microflora and morphology of male broilers. **Poultry Science**, v. 82, n. 6, p. 1030–1036, jun. 2003.

YAMAUCHI, K.; KAMISOYAMA, H.; ISSHIKI, Y. Effects of fasting and refeeding on structures of the intestinal villi and epithelial cells in White Leghorn hens. **British Poultry Science**, v. 37, n. 5, p. 909–921, dez. 1996.

YEGANI, M.; KORVER, D. R. Factors Affecting Intestinal Health in Poultry. **Poultry Science**, v. 87, n. 10, p. 2052–2063, out. 2008.

YOUSSEF, I. M. *et al.* Influence of using synbiotics by various routes on Mandarrah male chicks: intestinal bacterial counts, gut morphology and histological status. **Poultry Science**, v. 103, n. 5, p. 103601, maio 2024.

ZHANG, C. *et al.* Effect of L-theanine on the growth performance, immune function, and jejunum morphology and antioxidant status of ducks. **Animal**, v. 13, n. 6, p. 1145–1153, 2019.

ZYPHUR, M. J. When Mindsets Collide: Switching Analytical Mindsets to Advance Organization Science. **Academy of Management Review**, v. 34, n. 4, p. 677–688, out. 2009.