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Intestinal microbiome, performance and product quality in brown and white Lohmann layer chickens at the end of the laying phase

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ABSTRACT

In this study, aging effect on gut microbiota, production performance, and product quality in two commercial laying strains Lohmann Brown and Lohmann White under intensive farming system in the Kurdistan Region were evaluated. At 90 weeks of age, a population of 504,000 hens was examined with respect to changes in composition of microbiota, egg production, carcass traits, and reproductive physiology. Inter-strain substantially disparity was demonstrated by the statistical analyses. White Lohmann chickens showed improved feed conversion efficiency and egg production due to a significantly higher abundance of beneficial lactic acid bacteria (LAB) in their cecal contents. On the other hand, the Brown Lohmann had a heavier egg, better body weight and carcass yield with better thigh, back muscle rate. Their reduced rate of mortality suggests better tolerance at late production stages. Nevertheless, their cecal microbiota showed an elevated proportion of *Enterobacteriaceae*, reflecting an unfavorable gut ecology. Reproductive organ assessment showed that White hens displayed more developed ovaries, whereas Brown chickens had larger oviducts, which likely contributed to the larger size of their eggs. Results indicated that viable plate counts and product quality in late life are more spatially associated with gut colonization than with the gut colonization levels determined by strain resistance, overall levels of host health, or the effects of age on the host morphology. These findings justify the use of customized dietary and microbiological strategies in order to ensure longevity of productive performance in aged layer flocks.

1. Introduction

Achieving the best performance and health in laying hens in current poultry farming requires an increasingly sophisticated understanding of the gut bacteria and how they interact with the physiology of the host. Especially in older layers the gut bacteria are very important in order to maintain physiological processes like reduced metabolic efficiency and general health of poultry. Two of the most commercially important breeds, Lohmann Brown and Lohmann White, have gut microbiomes that profoundly affect performance, nutrient use, immune function, egg and meat quality as birds enter the late production phase (Oakley et al., 2014, Pan and Yu, 2014).

A dynamic ecosystem, gut bacteria respond to genetic background, age, nutrition, and environmental conditions. Microbial diversity in laying hens tends to reduce with age, which might cause possible dysbiosis—an imbalance marked by a reduction in beneficial bacteria such *Lactobacillus* spp. and an increase in pathogenic strains—(Pourabedin and Zhao, 2015, Sun et al., 2021). Reduced nutrient absorption, worse feed conversion efficiency, and greater susceptibility to disease—all important determinants of the productive lifetime and economic performance of chicken flocks—are associated with this imbalance (Kogut & Arsenault, 2016).

In aged Lohmann layer hens, the loss of intestinal barrier function and impaired fermentation capacity especially reduced synthesis of short-chain fatty acids like butyrate further contribute to decreased performance and egg quality. Crucially for preserving egg integrity in late production cycles, SCFAs not only provide enterocytes with energy but also control gastrointestinal inflammation, improve calcium absorption, and assist shell development (Yuniarti et al., 2023).

Variations in performance measures between Lohmann Brown and White chickens also follow from variations in microbiota makeup, feed intake patterns, and nutrient conversion efficiency. While Lohmann Browns often demonstrate superior carcass yield and reduced mortality, Lohmann White chickens generally exceed in egg mass and FCR. Such performance is directly related to pathways regulated by the

microbiome controlling immunological resilience, digestion, and metabolism (Langkabel et al., 2022).

Apart from affecting internal physiological processes, the gut bacteria significantly determine the nutritional and sensory appeal of poultry products. Some gut bacteria improve the bioavailability of vitamins, trace minerals, and essential fatty acids, therefore raising the nutritional value of eggs (Dong et al., 2025, Muhammad et al., 2023). Dietary plans including probiotics, prebiotics, phytase, threonine, selenium, and vitamin D3 have showed potential in changing gut bacteria, improving nutritional absorption, and restoring microbial balance in aged flocks (Jha et al., 2020, Yusuf et al., 2023).

At the end of their productive cycle in the Kurdistan area, this study intends to examine the gut microbiota, production performance, and product quality between Lohmann Brown and Lohmann White chickens. By means of microbial counts, carcass traits, egg quality, and feed efficiency, the study offers important new perspectives on how microbiota targeted treatments might increase product value in elderly commercial layer hens, thus ensuring animal welfare, and so extend production.

2. Methodology

2.1 Study Location and Design

The study was conducted at the Mouh-Albaidh Company for Poultry Projects, located in Qushtapa district, Erbil, within the Kurdistan Region of Iraq. The investigation was designed to evaluate the gut microbiota, productive performance, and egg and carcass quality in two commercial strains of laying hens: Lohmann Brown and Lohmann White, at the end of their production cycle (90 weeks of age).

A total of 504,000 hens were involved in the study. They were housed in eight production houses, equally distributed between the two strains. Each house contained 63,000 hens, housed in a four-line cage system, with standard ventilation, lighting, and temperature conditions maintained as per Lohmann management guidelines.

2.2 Experimental Strains and Feeding Regimen

The hens were assigned to one of two treatments:

- **Lohmann Brown**
- **Lohmann White**

Diets were formulated according to the nutritional requirements provided in the Lohmann Brown Layer Guide (2014) and the Lohmann White Guide (2014). The chickens fed 105,118 gm/day brown Lohmann and white Lohmann, respectively and water were provided ad libitum throughout the production period. Diet compositions for both strains were designed to ensure comparable nutritional levels, with slight adjustments tailored to each strain's needs (Tables 1 and 2).

Table 1. Formulation and nutrient composition of the basal diet for Lohmann Brown

Ingredients	Amount/1000kg
Yellow corn	510
Soybean meal 46%	190
GREENMIX*	25
Wheat	100
Wheat bran	40
Vegetable oil	20
Limestone	113
Choline chloride	0.5
Enzyme	0.5
Antitoxin	1
Calculated composition	
Crude protein	14.85
ME (kcal/kg)	2714
Lysine	0.72
Methionine	0.40
Ca	3.93

*GREENMIX: vit. A= 400.000 IU, vit. D=100.000 IU, vit. E=1.200 mg/kg, K3=120,000 mg/kg, vit.B1=80,000 mg/kg, vit. B2=240,000 mg/KG, vit. B6=1,600 mg/kg, vit. B12=0.6000 mg/kg, folic acid=40,000 mg/kg, calcium propionate=8.000,000 mg/kg, biotin=0,6000 mg/kg, cholin clorid=16.000 mg.kg-1, betain=65,000 mg.kg-1, cobalt=150 mg.kg, Nacl=106.000 mg.kg, Mn=45,800 mg.kg, cupper=2.000,000 mg.kg, Si=110 mg.kg, Zn=2.400 mg.kg, Fe=27,200mg.kg, D.C.P.= 340 g/kg, toxin binder= 40.000 mg/kg, multi enzyme L= 4.000 mg/kg.

Table 2. Formulation and nutrient composition of the basal diet for Lohmann white

Ingredients	Amount/1000kg
Yellow corn	528
Soybean meal 46%	153
BIRMIX*	25
Wheat	125
Wheat bran	58
Vegetable oil	7
Limestone	102
Dicalciumphospate	1
Antitoxin	1
Calculated composition	
Crude protein	14.42
ME (kcal/kg)	2797
Lysine	0.62
Methionine	0.30
Ca	3.80

*BRIMIX 201: *vit. A=4,500,000 IU, vit. D=1,660,000 IU, vit. E=20,000 mg.kg-1, K3=1, mg.kg-1, vit.B1=1,800 mg.kg-1, vit. B2=2,500 mg. vit. B6=1,600 mg.kg-1, vit. B12=8.75 mg.kg-1, folic acid=600 mg.kg-calcium pentonite=5,500 mg.kg-1, niacinamid=18,000 mg.kg-1, biotin=60 mg cholin clorid=30,000 mg.kg-1, betain=65,000 mg.kg-1, cobalt=150 mg.kg- 1, Iodine=380 mg.kg-1, Mn=45,800 mg.kg-1, cupper=6,500 mg.kg-1, Si=110 mg.kg-1, Zn=28,300 mg.kg-1, Fe=27,200mg.kg-1, Mo=350 mg.kg-1

2.3 Performance Evaluation

Key performance metrics were assessed as follows:

- **Egg Production (%)** was recorded at the end of age per replicates (4) and calculated on a hen-day basis:
HD Egg Production (%) = (Total eggs laid/Number of hens) × 100.
- **Egg Weight (g/egg)**: A weekly average was taken from individual eggs weighed using a calibrated **Navigator™ OHAUS** electronic scale.
- **Feed Intake (g/hen/day)**: A fixed amount of 105-120 g/hen/day was provided and fully consumed. Daily feed consumption was monitored and recorded.
- **Feed Conversion Ratio (FCR)**:
FCR = Feed intake (g) / Egg mass (g)

2.4 Carcass and Organ Evaluation

At the end of the trial (90 weeks), a representative sample of hens from each house was selected (n = 20 per replicate) for slaughter and carcass traits were measured:

- **Live weight and carcass yield**
- **Breast, thigh, drumstick, wing, neck, and back weights**
- **Internal organ weights** (heart, liver, spleen, gizzard)
- **Abdominal fat content.**

2.5 Microbial Analysis

Cecal contents were collected aseptically post-mortem to analyze bacterial load. Samples were immediately transported to a microbiology lab under cold chain conditions and processed using standard serial dilution and plating methods (Kareem et al., 2016). A representative sample of hens from each house was selected (n = 20 per replicate) then every four individual samples were pooled to form a composite sample for microbial count trait were measured: Two major bacterial groups were assessed:

- Lactic Acid Bacteria (LAB)
- Enterobacteriaceae (ENT)

Bacterial counts were expressed in \log_{10} CFU/mL.

2.6 Reproductive Organ Assessment

Ovary and oviduct weights were also measured and recorded as percentages of live body weight to determine reproductive potential at the end of the production cycle.

2.7 Statistical Analysis

SAS 9.1 software was used to do statistical analysis utilizing a completely randomized design method (CRD) model. Data obtained for growth performance; product quality and bacterial count were subjected to the generalized linear model of SAS. The significant differences between the treatment means were analyzed using t-test to compare the means between the two groups. A probability level $p < 0.05$ was considered statistically significant.

3. Results and discussion

3.1 Productive Performance

Table 3 summarizes the performance characteristics of Lohmann Brown and Lohmann White chickens at 90 weeks of age. Reflecting the genetic and physiological difference between

the two strains, notable variations were found in all evaluated characteristics.

Table 3. production performances in Brown and White Lohmann 90 weeks age

Characteristics	Brown Lohmann	White Lohmann
Egg weight /gm	65.48±0.11 ^a	62.91±0.23 ^b
HD Egg production %	60.73±0.55 ^b	66.16±0.79 ^a
Feed intake/gm/hen/day	105±0.22 ^b	116.17±0.87 ^a
Body weight/ gm	2113±1.11 ^a	1841±1.21 ^b
Mortality %	7.16±0.43 ^b	10.55±0.43 ^a
Egg mass	39.80±0.63 ^b	41.63±0.56 ^a
FCR	2.62±0.16 ^b	2.81±0.23 ^a

^{ab}- Means within rows with different superscripts differ significantly at ($P \leq 0.05$).

Egg production was notably significantly higher in the White Lohmann hens (66.16%) compared to the Brown strain (60.73%). This corresponds with earlier research showing higher laying persistence in White strains resulting from more effective reproductive physiology (Bain et al., 2016, Jha et al., 2020). Suggesting an increased metabolic rate to support higher production, the White hens also had larger egg mass (41.63 g vs. 39.80 g) and feed consumption (116.17 g vs. 105 g). Conversely, the egg weight was noticeably higher in Brown Lohmann chickens (65.48 g) than in White Lohmann (62.91 g), a result consistent with previous studies showing that Brown hens generally produce bigger but less eggs (Wolc et al., 2012). The Brown chickens' larger body weight—2113 g rather than 1841 g—may help to explain their higher egg weight and supports their improved carcass production.

Fascinatingly, mortality rate was lower in Brown chickens (7.16%) than White hens (10.55%), suggesting superior survival which might be connected to enhanced intestinal stability and

immunological resilience (Pourabedin and Zhao, 2015). Reflecting superior efficiency in turning feed into egg mass, FCR favored the Brown strain (2.62) over the White Lohmann (2.81), hence benefiting high-density commercial settings.

These findings collectively reinforce the need to tailor strain selection to the desired production goals. While White Lohmann hens are more efficient in egg mass, Brown Lohmanns offer greater individual egg quality and survivability, which could be preferable under suboptimal management conditions.

3.2 Carcass Characteristics

As shown in Table 4, brown Lohmann hens significantly outperformed white Lohmann in live weight (2058.33 g vs. 1728.83 g) and carcass weight (1576 g vs. 1390.16 g), a pattern aligned with previous findings by Langkabel et al. (2022), which highlighted the superior meat yield of dual-purpose or heavier-bodied layer breeds.

Table 4. Brown and White lohmann Carcass Characteristics in 90 week age

Characteristics	Brown Lohmann 90 week	White Lohmann 90 week
Live weight (g)	2058.33±5.52 ^a	1728.83±4.41 ^b
Carcass weight	1576±3.73 ^a	1390.16±3.43 ^b
Breast w%	23.05±0.91 ^b	26.96±0.75 ^a
Whole leg %	30.81±0.82 ^a	27.73±0.61 ^b
Thigh %	17.25±0.51 ^a	14.48±0.22 ^b
Drumstick %	13.35±0.41 ^a	12.93±0.49 ^a
Wing %	14.55±2.79 ^a	12.16±0.17 ^b
Neck %	2.45±0.17 ^b	4.25±0.24 ^a
Back %	29.26±0.66 ^a	23.78±1.82 ^b
Heart %	0.78±0.07 ^a	0.81±0.07 ^a
Liver %	3.56±0.36 ^a	4.03±0.44 ^a
Spleen %	0.13±0.02 ^a	0.11±0.01 ^a
Gizzard %	5.35±0.37 ^a	4.28±0.33 ^a
Abdomen fat %	2.23±0.28 ^a	1.31±0.33 ^a

^{ab}- Means in the same superscript within rows means non-significant, means within rows with different superscripts differ significantly at ($P \leq 0.05$).

Brown hens exhibited significantly higher values in whole leg, thigh, wing, and back yields, suggesting a greater allocation of muscle mass to these areas. In contrast, White hens had significantly more breast muscle (26.96% vs.

23.05%) and neck weight, likely due to their leaner morphology.

Organ weights such as liver, spleen, and gizzard showed no major strain-related differences, although brown hens had slightly more abdominal fat (2.23%) than white hens (1.31%). This could be attributed to the higher body mass and lipid metabolism in Brown hens, which may influence consumer acceptance and processing suitability, especially in markets prioritizing leaner meat.

3.3 Gut Microbiota

Figure 1 highlights the cecal microbial load, where a strain-specific difference was observed in bacterial populations. White Lohmann hens had significantly higher levels of lactic acid bacteria (LAB) (8.91 log₁₀ CFU/mL) compared to brown (6.69 log₁₀ CFU/mL), indicating a more favorable gut microbial profile. LAB play critical roles in maintaining intestinal health, enhancing immune function, and improving nutrient assimilation (Pourabedin and Zhao, 2015, Dong et al., 2025). Higher LAB levels could be one of the reasons for the white strain's superior production and egg mass.

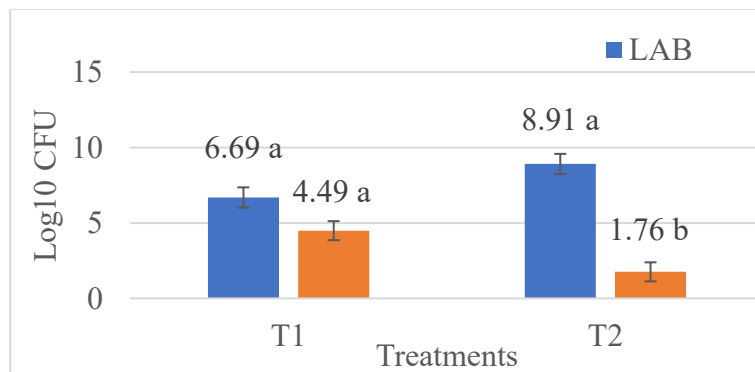


Figure 1. Differences between Brown and White Lohmann of bacterial count (Log₁₀ CFU ml⁻¹) in cecal digesta at the end of age. Different superscripts (a,b) indicate significant differences ($P \leq 0.05$). Bars represent mean \pm SEM.

Conversely, ENT counts were higher in the Brown Lohmann group (4.49 log₁₀ CFU/mL) than in the White Lohmann (1.76 log₁₀ CFU/mL). Elevated ENT levels have been associated with impaired gut health and may reflect a relative microbial imbalance or environmental stress (Cufadar et al., 2024). These observations underscore the influence of microbiota on both

performance and health outcomes in aged hens. Elevated ENT counts in the gut are associated with a shift toward a less favorable microbial balance, which can impair nutrient absorption, increase competition for available nutrients, and potentially promote the colonization of pathogenic species such as *E. coli* and *Salmonella*. These changes can lead to reduced growth performance, poorer feed conversion efficiency, and increased susceptibility to enteric disorders in chickens.

3.4 Reproductive Morphology

As shown in Table 5, reproductive tract morphology differed slightly between the strains. White Lohmanns had a higher ovary weight percentage (5.48%) than brown (4.05%), potentially reflecting greater follicular development. However, the oviduct weight was significantly higher in brown Lohmann (8.31%) compared to white Lohmann (6.76%).

Table 5. Ovary and oviduct in Brown and White Lohmann in 90-week age

Characteristics	Brown Lohmann	White Lohmann
Ovary %	4.05±0.35 ^a	5.48±1.03 ^a
Oviduct %	8.31±1.09 ^a	6.76±0.76 ^b

^{ab}- Means within rows with different superscripts differ significantly at ($P \leq 0.05$).

Ovarian development relative to body size is higher in Lohmann White chickens with a higher ovary percentage. This, in turn, indicates a bigger pool of growing follicles and a more active follicular hierarchy. This suggests that the Lohmann White chickens have a better chance of producing eggs than the other layer strain since they are probably in a later or longer reproductive period.

The hypothalamus and pituitary are influenced by the ovary's morphological status, which in turn influences the release of gonadotropins (FSH, LH). A larger and more robust ovary with functional follicles indicates a higher level of FSH stimulation and more frequent surges of LH (Bah and Johnson, 1984).

These findings suggest different strategies for reproductive resource allocation. A more developed oviduct in brown hens may contribute to larger egg sizes and shell integrity, as reported by Dong et al. (2017), while a more active ovary

in white hens likely supports their higher egg production rate.

The results obtained reveal that gut health and microbiota composition of vital importance in optimizing hen productivity and also lifetime, especially in the later life. Aging-related alteration of gut bacteria may also affect efficiency of nutrition uptake and immune function, while being modulated by the application of specific nutrients-regulome.

Optimal reproductive physiology is indicated by interrelated markers such as a high amount of egg production, an abundance of beneficial gut bacteria, and a larger proportion of ovarian layers. *Lactobacillus* and *Bifidobacterium* are two examples of beneficial bacteria that improve gut health and nutritional absorption. This is especially true for energy, amino acids, and vital minerals like calcium and phosphorus. Follicle growth and yolk generation are aided by this enhanced nutritional bioavailability, which is evident in a bigger ovary-to-body weight ratio and egg production.

The addition of probiotics, phytase, selenium and vitamin D3 has been found to produce beneficial effects in normalizing gut microbiota population and egg production in aged hens (Yuniarti et al., 2023, Muhammad et al., 2023, Yusuf et al., 2023). For instance, phytase addition enhances the bioavailability of nutrients, and selenium stabilizes muscle quality and immune response by affecting diversity of microbiota (Cufadar et al., 2024, Alshelmani et al., 2024)

Furthermore, the third-limiting amino acid threonine is involved in the synthesis of mucin of gut barrier, thus 102 contributing to the ability of old birds to maintain a microbial homeostasis and to performance parameters (Dong et al., 2017).

In conclusion, the findings of this paper suggest that genotype and some genotype-microbiota interactions are crucial for modulating the gut microbiota structure and functional characteristics of Lohmann Brown and Lohmann White hens at the end of their life and are both associated with their production efficiency and the quality of their eggs and/or meat. White Lohmann is better adapted to egg mass efficient production, while Brown Lohmann may add to

better carcass characteristics, larger egg weight and survivability.

4. Conclusion

This study draws attention to the considerable physiologic and microbial differences in brown and white hen layers, at the end of the laying cycle. White Lohmann showed higher egg mass and feed conversion, while brown Lohmann showed higher carcass yield, larger egg weight and lower mortality, indicating their potential relevance in systems with emphasis on egg size and bird survival. Significantly, disparity in the gut bacterium population, especially in LAB and ENT, defined the role of strains specific in intestinal health and productive performance.

These results testify for a strain dependent perspective of poultry management, especially in late laying stages. As poultry systems worldwide progress towards sustainability and consumer-driven nutrition, enhancing gut health and recognizing physiological aging will provide the essential routes to reveal the long-term options of performance in commercial layer hens.

References

- ALSHELMANI, M. I., EL-SAFETY, S. A., KAIRALLA, M. A. & HUMAM, A. M. 2024. Enzymes in poultry feed. *Feed Additives—Recent Trends in Animal Nutrition*.
- BAHR, J. & JOHNSON, A. 1984. Regulation of the follicular hierarchy and ovulation. *Journal of Experimental Zoology*, 232, 495-500.
- BAIN, M. M., NYS, Y. & DUNN, I. C. 2016. Increasing persistency in lay and stabilising egg quality in longer laying cycles. What are the challenges? *British poultry science*, 57, 330-338.
- CUFADAR, Y., GOLZAR ADABI, S., GÜL, E. & NOLLET, L. 2024. Effects of graded levels of dietary microbial 6-phytase on performance, intestinal histomorphology, caecal microbial population and short-chain fatty acid composition of Lohmann white-classics. *British Poultry Science*, 65, 595-604.
- DONG, A., DING, X., WANG, J., ZENG, Q., BAI, S., LIU, Y., XUAN, Y., LI, S., MU, Y. & PENG, H. 2025. Dietary *Pediococcus acidilactici* improves the intestinal functions by regulating the expression of intestinal inflammatory genes and intestinal microbiota in aged laying hens at 80–91 weeks of age. *Frontiers in Microbiology*, 16, 1530319.
- DONG, X., AZZAM, M. & ZOU, X. 2017. Effects of dietary threonine supplementation on intestinal barrier function and gut microbiota of laying hens. *Poultry Science*, 96, 3654-3663.
- JHA, R., DAS, R., OAK, S. & MISHRA, P. 2020. Probiotics (direct-fed microbials) in poultry nutrition and their effects on nutrient utilization, growth and laying performance, and gut health: a systematic review. *Animals*, 10, 1863.
- KAREEM, K. Y., LOH, T. C., FOO, H. L., AKIT, H. & SAMSUDIN, A. A. 2016. Effects of dietary postbiotic and inulin on growth performance, IGF1 and GHR mRNA expression, faecal microbiota and volatile fatty acids in broilers. *BMC veterinary research*, 12, 1-10.
- LANGKABEL, N., OSWALDI, V., MERLE, R., FLEISCHHAUER, C., HEINKE, C., ALTER, T., ELLERBOEK, L., FRIES, R. & MEEMKEN, D. 2022. The microbiological and sensory status of dual-purpose chickens (Lohmann Dual), male Lohmann Brown Plus chickens, and conventional laying hens slaughtered in a laying hen abattoir compared to conventional broilers slaughtered in a broiler abattoir. *Plos one*, 17, e0277609.
- MUHAMMAD, A., DALIA, A. & SAMSUDIN, A. 2023. Effect of Selenium-Enriched Bacteria and Other Selenium Sources on Meat Quality Parameters of Mid-Producing Lohman Brown Laying Hens. *Malaysian Journal of Animal Science*, 26.
- OAKLEY, B. B., BUHR, R. J., RITZ, C. W., KIEPPER, B. H., BERRANG, M. E., SEAL, B. S. & COX, N. A. 2014. Successional changes in the chicken cecal microbiome during 42 days of growth are independent of organic acid feed additives. *BMC veterinary research*, 10, 1-8.
- PAN, D. & YU, Z. 2014. Intestinal microbiome of poultry and its interaction with host and diet. *Gut microbes*, 5, 108-119.
- POURABEDIN, M. & ZHAO, X. 2015. Prebiotics and gut microbiota in chickens. *FEMS microbiology letters*, 362, fnv122.
- SUN, B., HOU, L. & YANG, Y. 2021. The development of the gut microbiota and short-chain fatty acids of layer chickens in different growth periods. *Frontiers in Veterinary Science*, 8, 666535.
- WOLC, A., ARANGO, J., SETTAR, P., O'SULLIVAN, N., OLORI, V., WHITE, I., HILL, W. & DEKKERS, J. 2012. Genetic parameters of egg defects and egg quality in layer chickens. *Poultry science*, 91, 1292-1298.
- YUNIARTI, M., BIDURA, I. & SITI, N. W. 2023. Effect of probiotic supplementation in the diet on the production and physical quality of eggs in laying hens. *World J Biol Pharm Health Sci*, 15, 138-44.
- YUSUF, G., MUTIA, R., WARDANI, W., AKBAR, I. & PUTRI, N. 2023. Performance, Egg Quality, Bone Health, and Immunity Assessments of Lohmann Laying Hens Supplemented with Vitamin D3 in the Diet. *Tropical Animal Science Journal*, 46, 461-470.