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Effect of probiotics and vitamins supplements on reproductive and egg quality of Ac chicken at 40-50 weeks old

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ABSTRACT

The study investigated the impact of probiotics and vitamins (PV) on the reproductive performance and egg quality of Ac chickens' diet. The experiment was conducted using a completely random design with 250 hens, aged 40-50 weeks, housed in cages. There were 5 treatments, each with 5 repetitions, and 10 hens per repetition. The treatments corresponding to the diets were: Control (BD), C250 (BD + 250 mg PV/kg of feed), C500 (BD + 500 mg PV/kg of feed), C750 (BD + 750 mg PV/kg of feed), and C1000 (BD + 1000 mg PV/kg of feed). The results showed that the highest laying rate (39.2%), yolk index (0.45), albumen index (0.08) and yolk colour (7.6) were in C1000. Although the C750 indicated the lowest FCR (3.78), it had the greatest egg weight (36.4 g/egg) and Haugh unit (82.8). In conclusion, probiotics and vitamins at 1,000 mg/kg diet improved Ac chicken laying rate, FCR, and egg weight.

1. INTRODUCTION

The Ac chicken (*Gallus gallus domesticus* Brisson) is a native breed traditionally raised in the Mekong Delta. Kojima et al. (2014) reported that Ac chicken contains a significantly higher amount of Carnosine (798.3 mg/100 g of breast meat) compared to White chicken (417.2 mg/100 g of breast meat). Carnosine is a protein found in the meat and brain of vertebrates, and it plays a crucial role in various physiological functions, including anti-ageing, antioxidant activity, anti-fatigue effects, and neurotransmission (Caruso et al., 2019). Carnosine has been utilised in medical treatments for various conditions, including diabetes, Alzheimer's disease, ageing, cancer, and other chronic illnesses (Derave et al., 2019). Furthermore, Ac chicken eggs are highly valued by consumers for their lack of a fishy odour, rich flavour, high-fat content, fragrant aroma, elevated protein levels in the egg whites, higher

yolk-to-white ratio, and their appealing dark colour (Le et al., 2023). Ac chickens reach sexual maturity early at 119-123 days old (Le et al., 2023), eggs weigh 31.3-36.2 g/egg and the laying rate was 52.3-58.1% at 23-37 weeks old (Nguyen & Nguyen, 2022).

There are currently various feed supplements available to enhance digestion, promote faster growth, boost reproduction, and improve egg quality in chickens. These supplements typically contain beneficial microorganisms (probiotics), as well as vitamins and minerals crucial to the egg production process. Probiotics have been shown to improve intestinal health and reduce pathogen invasion (Zhang et al., 2023). Nutrient deficiencies can negatively impact the reproductive system, leading to a decrease in egg production (Li et al., 2021). Previous research has demonstrated that adding probiotics to the diet can enhance both egg productivity and quality (Hassan et al., 2019).

Additionally, supplementing with natural vitamin E has been found to increase tocopherol levels in the tissues of laying hens, thereby improving their antioxidant capacity. These positive effects may result in improved egg production in laying hens (Zhao et al., 2021). Vitamins E and D3 have been shown to enhance the Haugh unit, with improvements in egg white quality likely due to the vitamins' role in ensuring efficient protein and energy utilization by animals, thereby boosting health and reproductive performance (Chen et al., 2020; Nemati et al., 2020). Nguyen (2019) found that supplementing vitamins and minerals in the drinking water of Hisex Brown laying hens at 43 weeks old improved egg production, eggshell thickness, and yolk colour compared to the control group. In a similar study, Nguyen et al. (2024) added 0.35% BACI EXTRA probiotic to the feed of Isa Brown hens, which led to increased laying rates, egg weight, egg productivity, and reduced feed consumption for commercial egg-laying hens. However, limited research has examined the use of probiotics and vitamins in the diet of Ac chickens during the laying stage. Therefore, this study was conducted to determine the optimal levels of probiotics and vitamins (PV) in the diet of Ac chickens, aiming to achieve high economic efficiency in egg production.

2. MATERIALS AND METHODS

The experiment was conducted from August 2023 to November 2023 at a chicken farm located in Than Cuu Nghia ward, Chau Thanh district, Tien Giang.

– A total of 5 hens were randomly placed in each cage (cage dimensions: 0.5 m length, 1.2 m width, 0.45 m height), with a stocking density of 0.12 m² per bird (area = 0.5 m × 1.2 m = 0.6 m²) (Figure 1).



Figure 1. Ac hens in cages at 40 weeks old

- Feed: The hens were provided with 3910T feed (Table 1) from Asia Nutrition Technologies Company Limited (Vietnam), at a rate of 60 g per hen per day.
- Probiotics and vitamins (Table 2) were sourced from Khang Phat Loc Trading Joint Stock Company (Vietnam).
- Drinking water: The chickens had free access to water through automatic drinking nipples.

Table 1. Feed ingredients in this study

Ingredient	Content
Crude protein (Min) (%)	18.5
Crude fibre (Max) (%)	7.0
Metabolisable energy (Min) (Kcal/Kg)	2,800
Calcium (Min-Max) (%)	3.5-4.5
Phosphorus (Min-Max) (%)	0.3-2.0
Lysine (Min) (%)	0.9
Methionine and Cystein (Min) (%)	0.8
Moisture (Max) (%)	14.0

(Source: Asia Nutrition Technologies Company Limited, Vietnam)

Table 2. The probiotics and vitamins composition in this study

Ingredient	Content
Betaglucan (Min) (mg)	50.0
<i>Lactobacillus</i> spp. (Min) (CFU)	10 ⁹
<i>Bacillus</i> spp. (Min) (CFU)	10 ⁹
<i>Sacharomomyces cerevisiae</i> (Min) (CFU)	10 ⁴
<i>Bacillus megaterium</i> (Min) (CFU)	10 ⁴
<i>Aspergillus oryzae</i> (Min) (IU)	10 ⁴
Vitamin A (Min) (IU)	5,000
Vitamin D3 (Min) (IU)	150
Vitamin E (Min) (IU)	500
Lysine (mg)	2.1
Methionine (mg)	0.5
Glucose (g)	1,000
Moisture (Max) (%)	12.0

(Source: Khang Phat Loc Trading Joint Stock Company, Vietnam)

A total of 250 hens, aged 40–50 weeks, were assigned to a randomised design with five treatments. Each treatment included five replicates, with 10 hens per unit. The treatments were as follows: the control group (C0) received a basic diet (BD); C250 was fed BD supplemented with 250 mg of PV per kg of feed; C500 received BD with 500 mg of PV per kg of feed; C750 had BD with 750 mg

of PV per kg of feed; and C1000 was provided BD supplemented with 1,000 mg of PV per kg of feed.

* **Management and care:** Hens were fed twice daily at 7:30 A.M. and 2:30 P.M., with unrestricted access to water provided through automatic nipple drinkers. The lighting schedule provided 16 hours of light per day using round bulbs, with a bulb density of 18 m² per bulb and a power output of 3-4 W/m². All chickens were vaccinated and managed according to the protocols of Asia Nutrition Technologies Company Limited (Viet Nam).

During the experiment, daily egg counts were recorded to calculate egg production as the percentage of eggs produced per hen (laying rate). Egg production and quality indicators were documented, and the methods for data collection and recording are detailed in Table 3. Each day, eggs were collected at 5:00 P.M., and 50% of the total eggs were randomly selected to assess quality indicators. Egg weight and egg shape index were measured daily throughout the experiment.

Table 3. Methodology for characterization and data collection

Indicators	Items	Data collection methods	References
Egg productivity	Hen's weight at the beginning (kg)	Record the weight of each hen before starting the experiment,	Nguyen and Nguyen (2022)
	Eggs number (EN) (eggs/10 hens)	Record the total number of eggs every day from 40 to 50 weeks old. EN = Total eggs number /hens number x 10	Le et al. (2023)
	Laying rate (LR) (%)	LR = (Eggs number per week/hens number present) x 100	Le et al. (2023)
	Feed intake (FI) (g of feed/hen/day)	Weigh the feed provided per day and the feed remaining per day. FI = (Amount of feed provide per day - amount of feed remaining per day)/10 hens	Nguyen and Nguyen (2022)
	Feed conversion ratio (FCR) (g of feed/g of egg)	Record average daily feed intake, then calculate the total amount of feed per week. Weigh the total egg weight every day, then calculate the total egg weight per week. FCR = (Total feed intake per week/Total egg weight per week)	Nguyen and Nguyen (2022)
Egg quality	Egg weight (g)	Collect eggs at 5 P.M. and weigh the eggs with the electronic scale.	Le et al. (2023)
	Egg shape index (SI) (%)	Use the digital calliper to measure the small diameter and large diameter of eggs. SI = (Small diameter/large diameter) x 100	Sandi et al. (2013)
	Egg yolk and albumen index	Break eggs and separate the albumen, yolk and shell to calculate: - Yolk index = Yolk height (cm)/Yolk diameter (cm) - Albumen index = Albumen height (cm)/Albumen diameter (cm)	Englmaierová et al. (2014)
	Shell thickness (mm)	Separate the eggshell membrane and measure it with a specialised ruler using 3 points: large, equator, and small.	Güçlü et al. (2008)
	Haugh unit (HU)	HU = 100 x log (T - 1,7 x W ^{0.37} + 7,57) T (mm): albumen thickness; W (g): egg weight.	Haugh (1937)
	Yolk color score	Determine with Roche colorimeter.	Bovšková et al. (2014)

Statistical analysis

The data were recorded using Excel and analysed with the generalised linear regression model (GLM) in Minitab 16.0, a software package designed for data analysis. Variance analysis was performed, and significant differences between and within treatment means were determined using Tukey’s test at $P < 0.05$. Experimental model according to the formula: $Y_{ij} = \mu + G_i + \xi_{ij}$ (where Y_{ij} : traits observed; μ : general mean, G_i : influence of treatments; ξ_{ij} : random error). A probability value of less than 0.05 was considered to be significant.

3. RESULTS AND DISCUSSION

3.1. Effect of PV on egg production

Table 4 illustrates the egg productivity indicators across treatments showed statistical differences ($P > 0.05$). The total number of eggs was highest in C1000 (409) and lowest in C0 (385). Similarly, the laying rate peaked in C1000 (39.2%) and was lowest in C0 (36.3%). Feed intake was also highest in C1000 (54.3 g/hen) and lowest in C500 (52.8 g/hen). Overall, egg count, laying rate, and feed intake were generally higher in diets supplemented with PV than in the control. Additionally, the feed conversion ratio (FCR) was lowest in C750 (3.78) and highest in C0 (4.14). In general, treatments supplemented with PV had lower FCR values than the control.

The positive impact of probiotics on egg production was demonstrated by Neupane et al. (2019) in Sakini and Giriraja chickens, native breeds of Nepal. Their findings indicated that probiotics containing *Bacillus subtilis* and *Lactobacillus acidophilus* improved feed absorption and enhanced metabolic processes related to reproduction, indirectly boosting egg production. Similarly, the PV used in this study, which included *Bacillus spp.*, *Lactobacillus spp.*, and vitamin E, exhibited effects comparable to those reported by Neupane et al. (2019) and Zhao et al. (2021). Jiang et al. (2013) reported that supplementing 200 mg/kg of vitamin E in the feed increased the laying rate of Hyline Brown chickens to 82.7%, compared to 80.7% in the control. Likewise, Zhao et al. (2021) found that adding 100 mg/kg of vitamin E to the diet of Hyline Brown chickens improved the laying rate to 89.0%, compared to 83.5% in the control group. In the present study, the inclusion of *Bacillus spp.*, *Lactobacillus spp.*, and vitamin E in PV showed similar benefits. Hens in the treatment groups did not show any statistical differences in initial body weight, indicating homogeneity among treatments. These findings suggest that PV, supplemented with beneficial microorganisms and vitamin E, stimulates the digestive system, enhances nutrient absorption and positively affects the reproductive process, thereby improving egg production.

Table 4. Effect of PV on reproductive performance of Ac chickens at 40-50 weeks old

Items	C0	C250	C500	C750	C1000	SE	P
Hens weight at the beginning (g/hen)	901	897	898	902	903	1.86	0.169
Eggs number (eggs/10 hens)	385 ^b	397 ^{ab}	401 ^a	407 ^a	409 ^a	3.16	0.010
Laying rate (%)	36.3 ^d	37.7 ^c	38.4 ^b	39.0 ^a	39.2 ^a	0.13	0.010
Feed intake (g of feed/hen/day)	53.2 ^{ab}	53.9 ^{ab}	52.8 ^b	53.1 ^{ab}	54.3 ^a	0.30	0.012
FCR (g of feed/g of egg)	4.14 ^a	4.02 ^{ab}	3.81 ^b	3.78 ^b	3.90 ^{ab}	0.07	0.007

^{a,b}: Means with different letters in the same row differ significantly ($P < 0.005$)

The laying rate of Ac chickens in this study was lower than that of previous studies of the same native breed. For example, Nguyen et al. (2022) found a laying rate of 54.6% in Ac chickens aged 28–39 weeks, while Nguyen and Nguyen (2022) observed a rate of 52.3–58.1% in Ac hens aged 23–37 weeks. The reason for this difference may be differences in feed, survey timing, and care and rearing conditions. According to the results of Xiang et al. (2019) on Lohmann laying hens, supplementation with *Clostridium butyricum* probiotics improved egg productivity and quality.

Supplementation at 0.5 g/kg feed increased feed intake, reduced FCR, improved laying and survival rates, increased eggshell thickness and egg white content. Probiotics containing beneficial bacteria have been shown to significantly improve digestive health in laying hens (Deng et al., 2012) by stimulating the development of microvilli in the small intestine, thereby enhancing nutrient absorption from feed.

The reduced feed conversion ratio (FCR) in the treatments may be due to the presence of beneficial bacteria in the chicken feed, which improved

nutrient absorption and metabolism, resulting in higher egg production compared to the control treatment. In the C750, due to the low feed conversion ratio (FCR), the economic efficiency of egg production was more economically efficient. Nguyen and Nguyen (2022) weeks. They reported FCR values of 2.94 and 2.98 in Ac chickens fed diets containing Moringa leaf powder and turmeric powder, respectively, at 23–29 weeks of age. In contrast, the FCR of the present study for Ac hens was lower than that observed by Nguyen et al. (2020a) for Ho chickens (FCR 4.36) and Dong Tao chickens (FCR 4.06). These differences arise from variations in survey timing, care conditions, and diet.

3.2. Effect of PV on egg quality

Table 5 shows that the egg quality indicators in treatments were all statistically significant ($P > 0.05$). The highest egg weight was observed in C750 (36.4 g/egg), while the lowest was in C0 (35.2 g/egg). The egg shape index ranged from 75.0% to 76.1%, with the highest value in C0 (76.1%) and the lowest in C500 (75.0%). Eggshell thickness was greatest in C500 and C750 (0.38 cm), followed by C250 and C1000 (0.37 cm), and thinnest in C0 (0.36 cm). Similarly, the Haugh unit (HU) increased progressively with supplementation, with the highest HU recorded in C1000 (82.0) and the lowest in C0 (79.9). The yolk colour score was also highest in C1000 (7.60) and lowest in C0 (7.40). Both egg albumen and yolk height increased with supplementation. The highest albumen height was in C1000 (9.11) and the lowest in C0 (8.03). Yolk height peaked in C1000 (15.7) and was lowest in C0 (15.1). The albumen index was highest in C1000, C750, and C500 (0.08) and lowest in C0 (0.07). Lastly, the yolk index was highest in C1000 (0.45) and lowest in C0 (0.40).

In general, egg weight in treatments supplemented with PV was higher than in the control group, demonstrating that PV positively influenced egg weight in Ac hens. The effects of probiotics and vitamin E on egg weight have been well-documented in previous studies worldwide. For instance, Bodhi et al. (2023) reported supplementing probiotics containing beneficial bacteria (*L.*

acidophilus, *L. plantarum*, and *Bifidobacterium* spp. at a density of 1.2×10^9 CFU/ml) into the diets of ISA Brown laying hens resulted in the highest egg weight (53.5 g/egg) in the treatment with 3 ml of probiotics per kg of feed, compared to 50.0 g/egg in the control. Similarly, Abdelqader et al. (2013) found that supplementing *Bacillus subtilis* inoculants increased egg weight in White chickens. Consistent results were reported by Khan and Naz (2013), who observed that probiotics containing *L. plantarum*, *L. bulgaricus*, *L. acidophilus*, *L. rhamnosus*, and *S. thermophilus* (at a density of 2×10^9 CFU/g) enhanced egg weight. Furthermore, Zhao et al. (2021) demonstrated that supplementing 100 mg/kg of vitamin E in the diet of Hyline Brown laying hens increased egg weight to 60.9 g/egg compared to 58.0 g/egg in the control. These findings collectively highlight the role of probiotics in improving feed intake and increasing egg weight, emphasising their significant contribution to enhancing poultry productivity.

The egg weights in this study were smaller than those in previous studies of other indigenous chicken breeds in Vietnam. For example, Ri chickens laid eggs weighing 41.7 g, and Mia chickens had an average egg weight of 44.7 g (Moula et al., 2012). Hmong chickens had larger eggs, with an average weight of 51.4 g (Nguyen et al., 2017). Similarly, Noi hens showed egg weights ranging from 40.2 to 40.6 g depending on the VIPR1/Hhal polymorphism (Tran et al., 2018), Bang Troi chickens averaged 48.4 g (Nguyen et al., 2020b), and Noi chickens produced eggs weighing 48.3 g (black-feathered) and 49.7 g (dark-brown) (Dang et al., 2021). Additionally, the egg weights of Ac chickens in the present study were lower than those of native chickens in Southern Ethiopia. Berhanu et al. (2022) reported egg weights of 46.6 g in the lowlands, 48.6 g in the midlands, and 45.4 g in the highlands. Similarly, chickens in the Sidama region of Ethiopia produced eggs weighing 44.9 g in the lowlands, 49.5 g in the midlands, and 42.9 g on the plateau (Legesse & Kefyalew, 2023). These differences in egg weight are largely attributable to variations in care and nutritional conditions across the studies.

Table 5. Effect of PV on egg quality of Ac chickens at 40-50 weeks old

Items	C0	C250	C500	C750	C1000	SE	P
Egg weight (g/egg)	35.2 ^c	35.7 ^{bc}	36.0 ^{ab}	36.4 ^a	36.0 ^{ab}	0.15	0.010
Egg shape index (%)	76.1 ^a	75.6 ^{ab}	75.0 ^b	75.1 ^b	75.4 ^b	0.18	0.002
Egg shell thickness (cm)	0.36	0.37	0.38	0.38	0.37	0.01	0.771
Egg albumen height (mm)	8.03 ^c	8.12 ^{bc}	8.86 ^b	9.03 ^a	9.11 ^a	0.07	0.010
Egg albumen index	0.07 ^b	0.07 ^b	0.08 ^a	0.08 ^a	0.08 ^a	0.01	0.010
Egg yolk height (mm)	15.1 ^c	15.5 ^b	15.5 ^{ab}	15.7 ^a	15.7 ^a	0.15	0.010
Egg yolk index	0.40 ^b	0.40 ^b	0.40 ^b	0.44 ^a	0.45 ^a	0.01	0.010
Egg yolk color score	7.24 ^c	7.44 ^b	7.47 ^{ab}	7.50 ^{ab}	7.60 ^a	0.26	0.045
Haugh unit	79.9 ^c	80.9 ^b	81.9 ^{ab}	82.8 ^a	82.0 ^a	0.43	0.010

^{a,b}: Means with different letters in the same row differ significantly ($p < 0.005$)

The egg shape index observed in this study was lower than that of Ac chicken eggs at 16–67 weeks of age, which averaged 77.3% (Le et al., 2024). However, the current study found that Ac chicken eggs had a higher shape index compared to native chickens in Southern Ethiopia, which were reported at 72.7% in the lowlands, 75.1% in the midlands, and 73.6% in the highlands (Berhanu et al., 2022). Similarly, Legesse and Kefyalew (2023) reported that indigenous chickens in the Sidama region of Ethiopia had egg shape indices of 73.8% in the lowlands, 72.8% in the midlands, and 73.0% in mountainous areas.

Bodhi et al. (2023) studied ISA Brown laying hens and found that supplementing their diet with probiotics (*L. acidophilus*, *Bifidobacterium spp.*, and *L. plantarum*) at a dose of 5 ml/kg of feed increased eggshell thickness to 0.36 cm, compared to 0.33 cm in the control group. Improved nutrient absorption from feed enhanced eggshell formation, resulting in thicker eggshells. Similarly, Hatairat et al. (2015) demonstrated that supplementing Brown chicken diets with 6,000 IU of vitamin D3 in a diet containing 3.5% calcium improved eggshell thickness to 0.37 cm, compared to 0.34 cm in a control diet without vitamin D3. This suggests that dietary vitamin D3 supplementation can mitigate the adverse effects of low calcium levels on eggshell quality. Increased levels of vitamin D3 enhance the production of its active form (1,25(OH)₂D₃) in the kidneys, which stimulates the synthesis of calcium-binding proteins necessary for calcium transport across the intestinal membrane and for eggshell formation (Bar, 2008). The current study also used a vitamin D3-supplemented diet, resulting in increased eggshell thickness compared to the control. The observed improvement in eggshell quality aligns with the mechanisms described by Bar (2008), in which enhanced calcium utilisation contributed to better eggshell formation.

Bodhi et al. (2023) classified the yolk index into three ascending quality groups: group I (0.485–0.521), group II (0.394–0.457), and group III (0.330–0.393). Similarly, the albumen index was categorised as group I (0.134–0.175), group II (0.092–0.133), and group III (0.050–0.091). In the present study, the yolk index fell within group II, while the albumen index was categorised under group III. However, the current findings showed lower yolk and albumen indices compared to Bodhi et al. (2023), where probiotics supplementation increased the yolk index (0.484–0.502) and albumen index (0.164–0.201) in ISA Brown eggs. The albumen index is influenced by dietary protein intake: higher protein intake promotes ovomucin production, thereby increasing the albumen index. According to Patterson and Burkholder (2003), the efficacy of probiotics depends on factors such as application method, chicken breed, feed composition, and probiotic density. Therefore, the observed differences in results between studies might stem from variations in breed, nutritional conditions, and the types of probiotics used. Bodhi et al. (2023) also demonstrated that probiotics improved the Haugh unit (HU) of ISA Brown eggs. Supplementing diets with a probiotic mixture (*L. acidophilus*, *Bifidobacterium spp.*, and *L. plantarum* at a density of 1.2×10^9 CFU/ml) at 3 ml/kg of feed resulted in significantly higher HU values (106.8) compared to the control (97.3).

The yolk colour score observed in the present study was consistent with Bodhi et al. (2023), where probiotics enhanced yolk colour in ISA Brown eggs, with scores ranging from 6.75 to 8.82 in probiotic treatments, compared to 6.70 in the control. Similarly, Neijat et al. (2015) reported improvements in yolk colour score, HU, yolk index, and albumen index in laying hens supplemented with *Bacillus subtilis* DSM29784. Sjöfjan et al. (2021) suggested that an improved intestinal

environment, achieved through probiotic supplementation, enhanced the absorption of minerals and nutrients vital for egg production, leading to better internal and external egg quality.

4. CONCLUSIONS

Incorporating 1,000 mg/kg of PV into Ac chicken diet at 40–50-week-old enhanced egg production and laying rate while lowering the feed conversion

REFERENCES

- Abdelqader, A., Irshaid, R., & Al-Fataftah, A. R. (2013). Effects of dietary probiotic inclusion on performance, eggshell quality, cecal microflora composition, and tibia traits of laying hens in the late phase of production. *Tropical Animal Health and Production*, 45(4), 1017-1024. <https://doi.org/10.1007/s11250-012-0326-7>
- Bai, S. P., Wu, A. M., Ding, X. M., Lei, Y., Bai, J., Zhang, K. Y., & Chio, J. S. (2013). Effects of probiotic-supplemented diets on growth performance and intestinal immune characteristics of broiler chickens. *Poultry Science*, 92(3), 663-670. <https://doi.org/10.3382/ps.2012-02813>
- Bar, A. (2008). Calcium homeostasis and vitamin D metabolism and expression in strongly calcifying laying birds. *Comparative Biochemistry and Physiology Part A*, 151(4), 477-490. <https://doi.org/10.1016/j.cbpa.2008.07.006>
- Berhanu, B., Aberra, M., Wondmeneh, E., & Tadelle, D. (2022). Production performance and egg quality evaluation of indigenous chickens across different agro-ecologies of Southern Ethiopia. *Veterinary Integrative Sciences*, 20(1), 133-145. <https://doi.org/10.12982/VIS.2022.012>
- Bodhi, A., Sunaryo, H. W., Maya, N. Y., Widya, P. L., Sri, H., Emy, K. S., Mohammad, A. A., Mirni, L., Gandul, A. Y., Shekhar, C., & Sarasati, W. (2023). Influence of microbiota inoculum as a substitute for antibiotic growth promoter during the initial laying phase on productivity performance, egg quality, and the morphology of reproductive organs in laying hens. *Veterinary World*, 16(7), 1461-1467. <https://doi.org/10.14202/vetworld.2023.1461-1467>
- Bovšková, H., Míková, K., & Panovská, Z. (2014). Evaluation of Egg Yolk Colour. *Czech Journal of Food Sciences*, 32(3), 213-217. <https://doi.org/10.17221/47/2013-CJFS>
- Caruso, G., Fresta, C. G., Musso, N., Giambirtone, M., Grasso, M., Spampinato, S. F., Merlo, S., Drago, F., Lazzarino, G., Sortino, M. A., Lunte, S. M., & Fillippo, C. (2019). Carnosine Prevents A β -Induced Oxidative Stress and Inflammation in Microglial Cells: A Key Role of TGF- β 1. *Cells*, 8(1), 64. <https://doi.org/10.3390/cells8010064>
- Chen, C., Turner, B., Applegate, T. J., Litta, G., & Kim, W. K. (2020). Role of long-term supplementation of 25-hydroxyvitamin D3 on egg production and egg quality of laying hen. *Poultry Science*, 99(12), 6899-6906. <https://doi.org/10.1016/j.psj.2020.09.020>
- Dang, H. V., Duong, D. V., Nguyen, H. T., Do, K. N., Le, H. T., Nguyen, H. M., Tran, U. T., Nguyen, N. H., & Dang, N. T. (2021). Growing and laying performances of two varieties of Noi chickens raised in an intensive farming system. *Vietnam Journal of Science, Technology and Engineering*, 64(2), 54-58. [https://doi.org/10.31276/VJSTE.64\(2\).54-58](https://doi.org/10.31276/VJSTE.64(2).54-58)
- Deng, W., Dong, X. F., Tong, J. M., & Zhang, Q. (2012). The probiotic *Bacillus licheniformis* ameliorates heat stress-induced impairment of egg production, gut morphology, and intestinal mucosal immunity in laying hens. *Poultry Science*, 91(3), 575-582. <https://doi.org/10.3382/ps.2010-01293>
- Derave, W., Courten, B. D., & Baba, S. P. (2019). An update on carnosine and anserine research. *Amino Acids*, 51(1), 1-4. <https://doi.org/10.1007/s00726-018-02689-9>
- Englmaierová, M., Skřivanová, V., & Skřivan, M. (2014). The effect of non-phytate phosphorus and phytase levels on performance, egg and tibia quality, and pH of the digestive tract in hens fed higher-calcium-content diets. *Czech Journal of Animal Science*, 59(3), 107-115. <https://doi.org/10.17221/7290-CJAS>
- Güçlü, B. K., Uyank, F., & İşcan, K. M. (2008). Effects of dietary oil sources on egg quality, fatty acid composition of eggs and blood lipids in laying quail. *South African Journal of Animal Science*, 38(2), 91-100.
- Hassan, M. R., Sultana, S., Al Rahman, M. O., Rabbani, M. A. G., Sarker, N. R., Ju, Y. C., & Ryu, K. S. (2019). Effect of feeding various probiotics on performance, blood properties, egg quality, and yolk fatty acid composition of laying hens. *Australian Journal of Science and Technology*, 3(1), 37-41.
- Hatairat, P., Suwanna, K., & Punyaphat, I. (2015). Effects of Vitamin D-3 and Calcium on Productive Performance, Egg quality and Vitamin D-3 Content in Egg of Second Production Cycle Hens. *The Thai veterinary medicine*, 45(2), 189-195. <https://doi.org/10.56808/2985-1130.2635>

- Haugh, R. R. (1937). The Haugh unit for measuring egg quality. *United States Egg and Poultry Magazine*, 43, 522-555.
- Jiang, W., Zhang, L., & Shan, A. (2013). The effect of vitamin E on laying performance and egg quality in laying hens fed corn dried distillers grains with solubles. *Poultry Science*, 92(11), 2956-2964. <https://doi.org/10.3382/ps.2013-03228>
- Khan, R. U., & Naz, S. (2013). The applications of probiotics in poultry production. *World's Poultry Science Journal*, 69(3), 621-632. <https://doi.org/10.1017/S0043933913000627>
- Kojima, S., Saegusa, H., & Sakata, M. (2014). Histidine-Containing Dipeptide Concentration and Antioxidant Effects of Meat Extracts from Silky Fowl: Comparison with Meat-Type Chicken Breast and Thigh Meats. *Food Science and Technology Research*, 20(3), 621-628. <https://doi.org/10.3136/fstr.20.621>
- Le, P. T., Tran, T. T., & Nguyen, N. T. (2023). Genetic variants of INHA/*PstI* and VIPR1/*HhaI* and their relationship with reproductive traits in Silkie chicken (*Gallus gallus domesticus* Brisson). *Veterinary Integrative Sciences*, 21(3), 831-841. <https://doi.org/10.12982/VIS.2023.059>
- Le, P. T., Nguyen, N. T., & Nguyen, T. (2024). Association of IGF-1/*PstI* polymorphism with egg quality of Ac chicken at 16-67 weeks old. *Journal of Animal Husbandry Sciences and Techniques*, 296, 2-7.
- Legesse, Y. T., & Kefyalew, B. R. (2023). Evaluation of fertility, hatchability and egg quality of indigenous chickens in different agro-ecologies of the Sidama Region, Ethiopia. *Veterinary Integrative Sciences*, 21(1), 201-219. <https://doi.org/10.12982/VIS.2023.016>
- Li, F., Xie, Y., Yang, X., Zhang, Y., Cheng, B., & Shan, A. (2021). Effects of nutritional restriction during laying period of fat and lean line broiler breeder hens on meat quality traits of offspring. *Animals (Basel)*, 11(8), 2434. <https://doi.org/10.3390/ani11082434>
- Moula, N., Antoine-Moussiaux, N., Do, L. D., Nguyen, T. C., Pham, D. K., Vu, T. D., Dang, B. V., Pascal, L., & Frédéric, F. (2012). Egg quality comparison of two Vietnamese chicken breeds (Ri and Mia). *Proc. The 1st Poultry International Symposium* (pp. 379-383). <https://orbi.uliege.be/bitstream/2268/133429/1/58>
- Neijat, M., Shirley, R. B., Barton, J., Thierry, P., Welscher, A., & Kiarie, E. (2015). Effect of dietary supplementation of *Bacillus subtilis* DSM29784 on hen performance, egg quality indices, and apparent retention of dietary components in laying hens from 19 to 48 weeks of age. *Poultry Science*, 98(11), 5622-5635. <https://doi.org/10.3382/ps/pez324>
- Nemati, Z., Ahmadian, H., Besharati, M., Lesson, S., Alirezalu, K., Dominguez, R., Lorenzo, M. (2020). Assessment of dietary selenium and vitamin E on laying performance and quality parameters of fresh and stored eggs in Japanese quails. *Foods*, 9(9), 1324. <https://doi.org/10.3390/foods9091324>
- Neupane, D., Nepali, D. B., Devkota, N., Sharma, M. P., & Kadaria, I. P. (2019). Effect of Probiotics on production and egg quality of dual purpose chicken at Kathmundu in Nepal. *Bangladesh Animal Husbandry Association*, 48(1), 29-35. <https://doi.org/10.3329/bjas.v48i1.44556>
- Nguyen, P. T., Hoang, M. N., Nguyen, D. V., & Vu, T. D. (2017). *Reproductivity and egg quality of H'mong chicken. In Animal Production in Southeast Asia: Current Status and Future*. Vietnam National University of Agriculture.
- Nguyen, T. T. (2019). Effect of supplementation products in drinking water on egg performance and quality of Hisex Brown laying hens during 43-50 weeks of age. *Journal of Animal Husbandry Sciences and Technics*, 247, 44-48.
- Nguyen, D. V., Hoang, M. N., Nguyen, T. D., Nguyen, P. T., & Vu, T. D. (2020a). Impact of Farming Models on the Reproductive Performance and Egg Quality of Vietnamese Local Chicken Breeds: Ho and Dong Tao. *Vietnam Journal of Agricultural Sciences*, 3(1), 495-503. <https://doi.org/10.31817/vjas.2020.3.1.02>
- Nguyen, T. H., Nguyen, V. T., Nguyen, L. T., Mai, N. T. T., & Bui, D. H. (2020b). External Characteristics and Reproductive Performance of Bang Troi Chicken. *Vietnam Journal of Agricultural Sciences*, 18(10), 823-830. (in Vietnamese).
- Nguyen, L. T., Nguyen, T. V., Nguyen, D. T. K., & Nguyen, Q. H. (2022). An Investigation on reproductive performance of ac chicken from 28-39 weeks of age. *Journal of Animal Science and Technology*, 132, 53-59.
- Nguyen, T. T., & Nguyen, H. C. (2022). Effect of *Moringa oleifera* and *Curcuma longa* powders in diets on laying performances and hatchability of local hens in the south of Vietnam. *Livestock Research for Rural Development*, 34(52). <http://www.lrrd.org/lrrd34/6/3452nthi.html>
- Nguyen, H. V., Nguyen, T. T., Ngo, T. H., & Nguyen, V. S. (2024). Study on the use of probiotic products in commercial laying hens and broiler chicken. *Journal of Animal Science and Technology*, 146, 76-84.
- Patterson, J. A., & Burkholder, K. M. (2003). Application of prebiotics and probiotics in poultry production. *Poultry Science*, 82(4), 627-631. <https://doi.org/10.1093/ps/82.4.627>
- Sandi, S., Miksusanti, S. E., Sahara, E., & Lubis, F. N. Y. (2013). The influence of fermented feed to the exterior and interior quality of Pegagan duck eggs. *International Journal of Chemical Engineering and Applications*, 4(2), 38-41. <https://doi.org/10.7763/IJCEA.2013.V4.257>
- Sjofjan, O., Adli, D. N., Sholikin, M. M., Jayanegara, A., & Irawan, A. (2021). The effects of probiotics on the

- performance, egg quality and blood parameters of laying hens: A meta-analysis. *Journal of Animal and Feed Sciences*, 30(1), 11-18.
<https://doi.org/10.22358/jafs/133432/2021>
- Tran, N. T. B., Nguyen, D. H., Vu, Q. C., Hoang, Y. T., Ta, L. T., Dinh, T. T. N., Vu, T. T., & Nguyen, T. T. D. (2018). Effect of nucleotide polymorphism of candidate genes on egg production traits in native Lien Minh chicken. *Livestock Research for Rural Development*, 30(6).
<http://www.lrrd.org/lrrd30/6/ntdt30103.html>
- Xiang, Q., Wang, C., Zhang, H., Lai, W., Wei, H., & Peng, J. (2019). Effects of different probiotics on laying performance, egg quality, oxidative status, and gut health in laying hens. *Animals (Basel)*, 9(12), 1110. <https://doi.org/10.3390/ani9121110>
- Zhang, Y., Zhang, Y., Liu, F., Mao, Y., Zhang, Y., Zheng, H., Ren, S., Gao, L., Chen, Z., Hrabchenko, N., Wu, J., & Yu, J. (2023). Mechanisms and applications of probiotics in prevention and treatment of swine diseases. *Porcine Health Management*, 9(5), 1-12.
<https://doi.org/10.1186/s40813-022-00295-6>
- Zhao, H., C, Y., Wang, S., Wen, C., & Zhou, Y. (2021). Effects of dietary natural vitamin E supplementation on laying performance, egg quality, serum biochemical indices, tocopherol deposition and antioxidant capacity of laying hens. *Italian Journal of Animal Science*, 20(1), 2254-2262.
<https://doi.org/10.1080/1828051X.2021.2002733>