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Comparison of Bamboo and Wire Types of Battery Materials on the Welfare and Production Performance of Laying Hen

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Abstract. *This research aimed to determine the comparison of types of battery materials for laying hens, specifically bamboo and wire, on the welfare and production performance of laying hens. The material for this research consisted of 100 laying hens of the ISA Brown strain aged 54 weeks. The variables observed included livestock welfare, which was assessed through behavioral aspects (eating, drinking, and resting), while the production performance variables observed included HDP (Hen Day Production), egg weight, egg mass, and FCR (Feed Conversion Ratio). The research method employed an experimental approach using the T-test (independent sample). Two treatments were used, each with 50 replications. The results of the research indicated that the difference in treatment using* T_1 *(bamboo battery materials) and* T_2 *(wire battery materials) affected livestock welfare and production performance. The research results demonstrated that the behavior of bamboo batteries was considered better in terms of livestock welfare because they were able to better prevent heat stress. In terms of production performance, wire batteries exhibited higher Hen Day Production (HDP) and were better at preventing disease than bamboo batteries. However, bamboo batteries had a higher egg weight due to the frequency of feeding chickens being higher than wire batteries. Improved sanitation management is necessary for batteries made from bamboo because they tend to more easily become a medium for the growth of germs, lice, and fungi, which can cause disease and result in decreased production performance.*

Keywords: *Bamboo battery, poultry welfare, production performance, wire battery*

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IINTRODUCTION

Currently, cage housing is regarded as a global main stream production system for laying hens. However limited living space and confinement of birds in cage cause welfare and health problem. Manupulable materials can reduce behavioral disorders. In cage rearing, laying within five weeks old are constanly kept in metal cages without litter platform and ramps can effectively promote locomotion and avoid disturbances when the chick and pullets are resting (Van Den Brand et al., 2004; Xu et al., 2022)

The various cage materials utilized by farmers include wire, bamboo, and wood. Factors that influence the selection of cage materials are price, durability, and availability in the field. Bamboo and wire materials are generally chosen by farmers as materials for making layer cages due to considerations of affordable prices and durability. Currently, there is not a uniform approach to testing wire cages, which are a challenge because of the minimal surface area and the wire tend to damage collection devices that work well on other surfaces. Wire cages are most commonly used for poultry housing worldwide (Appleby, 1998) Bamboo is a naturally available, fast growing and renewable resource. Bamboo plants are found all over the world in tropical and non-tropical regions. Asia pacific region is specifically rich in bamboo biodiversity. Due to high energy demand of existing construction materials and scarcity of other naturally available materials like wood, bamboo is a good alternative for construction (Fahim et al., 2022).

Different types of cage materials affect the comfort of laying hen and have an impact on the laying hen production performance. This study aims to determine the differences in cage materials on the welfare and production performance of laying hens.

THEORETICAL STUDY

Layer strain refers to chicken varieties with very fast growth and high egg production capabilities. Some of the superior characteristics of layer strain were rapid growth, the ability to produce eggs achieve 250-280 eggs/year with an average egg weight of about 50-60 g, and efficient feed conversion achieving 2.2-2.5. Laying hens can be categorized into two types, i.e. light and medium type (Hyline International, 2016).

Laying chickens are a type of chicken that is very efficient at producing eggs. This chicken has good potential to cultivate because it is not complicated to care for, and can produce quickly. The eggs produced by laying hens are very popular with the public as an affordable source of nutrition. One of the laying hen strains that is often reared in

Indonesia is the Isa Brown strain because it can produce up to 250-300 eggs per bird per year (Yilmaz Dikmen et al., 2016) Battery laying hens are a cage system for use in raising laying hens on a large scale. Farmers can make battery system cages for laying hens using materials made of bamboo or wire (Merdana et al., 2022). Selection of the type of material used in the construction of laying hen batteries is very important to ensure livestock welfare and production performance.

Bamboo batteries have advantages including easier availability and very affordable prices, so they can help reduce capital expenditure for laying hen breeders (Fahim et al., 2022; Hasan et al., 2020). Bamboo batteries have the disadvantage of being a construction material because they have relatively low resistance to pests, so they require extra protection against pest attacks and have a lower lifespan than wire materials.

Wire batteries or what is often known as " wire mesh " is a material made from steel wire woven to form a net. The advantage of wire is that it is resistant to weather, fungus, and ectoparasitic pests, and has a fairly long serviceable, while the disadvantage of wire is its relatively higher cost compared to bamboo.

When it comes to birds, their behavior is often linked to their level of welfare. This can be interpreted that the behavior of birds can function as an indicator that reflects their welfare because behavior has the potential to reflect the feelings and mental condition of the bird (Pohle & Cheng, 2009; Yilmaz Dikmen et al., 2016).

The production performance of laying hens is also a key factor in the success of a livestock business. Production performance includes Hen Day Egg Production (HDP), egg weight, egg mass, and Feed Conversion Ratio (FCR) (Gerber, 2005). The influence of the type of battery material on the production performance of laying hens needs to be studied to ensure that the choice of battery material does not only pay attention to livestock welfare but also does not reduce production efficiency.

Currently, there is debate regarding the type of material that is better to use in laying hen batteries, whether bamboo or wire. The comparison of battery material types is intended to find out which one is better for livestock welfare and the production performance of laying hens.

RESEARCH METHODS

The research used 100 laying hens of *the ISA Brown strain* aged 54 weeks. The choice of the *ISA Brown* strain as a type of livestock was made deliberately because this laying hen is widely known as a productive variety and is generally used as a choice in the context of commercial farming. The choice of 54 weeks of age was also made deliberately considering that at this point the chickens are approaching their culling period and their productivity tends to decrease gradually (Management Guide Alternative Production Systems 2, n.d.). This follows the opinion of (Olgun et al., 2007),the peak production of laying hens occurs at the age of 28-30 weeks and then experiences a gradual decline, reaching 65% of daily production at the age of 82 weeks. These chickens are placed in battery cages made from two different types of materials, namely bamboo and wire.

The battery cages used for laying hens have length x width x height dimensions of 35cm x 30cm x 30cm per plot. Each battery plot accommodates two laying hens. Feed and water containers made from Parallon pipes split into two parts have been installed in each battery compartment. The cage uses two different types of materials, namely bamboo and wire. The roof of the cage is made of asbestos, while the base is made of wood. Equipment used in the research included digital scales, thermometers, video recording equipment, tripods, feed containers, drinkers, hoses, and egg trays. Apart from that, supporting equipment such as calculators and cleaning equipment such as brooms and shovels are also used. The feed ingredients used consist of corn, rice bran, and Cargill SLC layer phase concentrate.

The feed used is *self-mixing* with a ration composition of 50% fine corn, 35% Cargill SLC concentrate, and 15% rice bran, giving around 115 grams per head per day. (Prasetyo et al., 2022) noted that standard feed consumption for laying hens during the production period ranges from 110 to 120 grams per day. Food is provided twice a day, in the morning at 07.00 WIB and the afternoon at 13.00 WIB, while drinking is provided freely or *ad libitum*.

The research uses experimental methods with the T-test (*independent sample t-test*). The following are the stages of the research method that will be carried out. Each group will be given a different treatment, namely P 1: Use of bamboo material batteries and P 2: Use of wire material batteries. Measurement of Poultry Welfare: laying hen will be evaluated by measuring behavioural aspects (time to eat, drink, and rest) (Anderson et al., 2004; Appleby, 1998). with 2 treatments and 50 repetitions of laying hens which will be observed with a video recorder after feeding at noon at 13.00 WIB and repeated every week.

Production Performance Measurement: The production performance of laying hens will be measured using product parameters such as *Hen Day Egg Production* (HDP), egg weight, *egg mass,* and *Feed Conversion Ratio* (FCR) with data collection carried out every day.

The data that has been collected will be processed by applying the T-test method (t-*test independent sample*) to test differences in livestock welfare and production performance between the two types of battery materials.

RESULTS AND DISCUSSION

Data from research on poultry welfare through behavior from the influence of bamboo and wire battery material types on laying hens of *the ISA Brown strain* including eating, drinking and resting behavior are presented in Table 3.

Table 3. Results of analysis of the influence of bamboo and wire battery material on poultry behavior.

Battery materials	Behavior (minutes/hour)		
	Eating	Drinking	Resting
Battery Bamboo (n = 200)	19.39±5.31	5.67±1.73	35.00±5.58
Battery Wire (n = 200)	17.74±5.50	6.07±1.81	36.20±5.81
Sig.	0.003	0.026	0.037

Data from research on the performance of laying hens from the influence of the type of bamboo and wire battery material on laying hens of the *ISA Brown strain* include *Han Day Production* (HDP), egg weight, *egg mass* and feed conversion (FCR) which are presented in Table 4.

Table 4. Results of Analysis of the Effect of Bamboo and Wire Battery Material Types on HDP Production Performance, Egg Weight, *Egg Mass* and FCR Material baterai

Treatment	Performa Produksi			
	HDP (%)	Egg Weight (g)	*Egg Mass* (g)	FCR
Bamboo battery (n = 28)	83.14±4.26	62,65±0,85	51.97±3.06	2.22±0,14
Wire battery (n = 28)	86,93±4.23	59,79±0,99	52.07±2.95	2.22±0.12
Sig.	0.002	0.001	0.902	0.870

Note: HDP=*Hen Day Production*, FCR=*Feed Conversion*

Livestock welfare is based on behavior on bamboo and wire material batteries as shown in Table 3. Eating behavior shows significant differences ($P>0.05$), Drinking behavior shows significant differences ($P>0.05$) and resting practice shows significant differences in results ($P>0.05$). The reason given for the obvious difference is that bamboo material cages are believed to be better able to ward off exposure to solar heat because the larger diameter prevents chickens from exposure to solar heat radiation and has insulating properties (does not conduct heat). This follows the opinion of (Adriant et al., 2019), who stated that bamboo is a potential insulation material because it has low thermal conductivity. Bamboo has a much smaller thermal conductivity than wire material with a value of 0.72 W/mK (Adriant et al., 2019; Fahim et al., 2022). Meanwhile, wire batteries are conductors in (Agustina & Astuti, 2015) research, which states that iron wire has a high level of conductivity with a value of 80 W/mK.

The iron wire will get hot when exposed to the hot sun so that the chicken cannot release body heat into the battery medium and has a small diameter so that the chicken can be exposed to direct exposure to the sun's heat. This follows the opinion of (NUGROHO & WALUYO, 2021), who stated that during the day because of the hot sun, the wire will also become hot. The comparison of Hen Day Production (HDP) can be seen from Table 4, that the average HDP value in the treatments shows the order from largest to smallest, namely P2 (86.93 ± 4.23) and P1 (83.14 ± 4.26). Statistical analysis shows that there is a significant difference ($P<0.05$) in the influence of different battery materials on Hen Day Production (HDP).

The wire material battery treatment has a higher HDP value than the bamboo material battery treatment. This is believed to be caused by the wire material which has the advantage of a smaller wire diameter of only 2.7-3.4 mm so that the cage has good air circulation and cleanliness. maintained, and dry conditions can prevent odors, moisture, and mold growth. Good air circulation also makes the cage more sterile with minimal pests, lice, and disease germs, so it can contribute to chicken health and optimize production. Additionally, when battery cages are exposed to sunlight, the temperature of the wires increases, which can help eliminate germs, bugs, and mold, causing the death of these microorganisms. After spraying disinfectant, the wire material tends to be dry and not damp, whereas the bamboo material, which absorbs water, will become stuffy when exposed to the heat of the sun, which can cause respiratory diseases so production performance decreases.

Bamboo cages have a larger diameter, namely 3cm so that chicken droppings can get stuck in the battery cross-section which can cause disease and eggs being exposed to chicken droppings. The number of fleas in bamboo material cages is higher than fleas in wire batteries (Wiguna, 2019). The type of cage for laying hens influences the number of ectoparasites called *gallinae*. Bamboo cages showed higher levels, where all samples of 45 laying hens were positively infected with the ectoparasite *Menopon gallinae* for a total of 933 ectoparasites. On the other hand, wire battery cages showed lower levels, with 42 chickens positively infected and 3 chickens negative, for a total of 550 ectoparasites.
Small pests really like places that are damp and not exposed to the sun. Small pests can hide themselves in cracks or gaps around the chicken coop, especially in bamboo batteries. These places provide a safe place to breed and avoid direct exposure to the external environment. The presence of small fry can cause a decrease in the productivity of laying hens by more than 25% (Barrow et al., 2021). Decreased chicken health due to grasshopper bites facilitates pathogen attacks on their bodies, making chickens more susceptible to bacterial or viral infections (Barrow et al., 2021; Dewi et al., 2023).

According to the (Barrow et al., 2021), preventing gourmands can be done by keeping the coop and nest clean from chicken droppings, regulating air circulation, ensuring sunlight can enter the coop, and maintaining the cleanliness and sanitation of the coop. The disturbances caused by *Ornithonyssus bursa* need to be reduced, and one of the common methods used by breeders is the use of synthetic insecticides. Synthetic insecticides are toxic chemical compounds that are effective in dealing with destructive insects such as grasshoppers(Dively et al., 2020; Ph & Note, 2023). Even though insecticides themselves can quickly eradicate disease vectors, continued use of synthetic insecticides can have negative impacts on human health and the environment (Yennie & Elystia, 2013). Some of the adverse impacts that synthetic insecticides can cause include resurgence, resistance, and potential environmental pollution (Hinz & Linke, 1998). Comparison of egg weight based on data in Table 4, differences in battery materials show a significant influence on egg weight with statistical test results showing significant differences ($P<0.05$). The largest treatment means, respectively, were P1 (62.65 ± 0.85) and P2 (59.79 ± 0.99).

The difference between the standard weight *of ISA Brown eggs* and the treatment was caused by the high cage temperature, reaching 36°C during the day, which caused heat stress *during* the study. This finding is in line with the views of (Setiawati et al., 2016a, 2016b), which states that temperature has a significant influence on production performance and egg quality. High temperatures can harm chickens, affecting egg production and quality. (Fadhlurrohman et al., 2021) added that chickens that experience *heat stress* tend to produce eggs with a smaller weight and size. Elevated temperature can also cause a decrease in ovarian weight and the number of follicles.

Cages made of bamboo material are considered more effective in preventing exposure to solar heat because they have a larger diameter are insulating, and do not conduct heat. In contrast, wire batteries are conductive and have a small diameter, allowing chickens to be directly exposed to the sun's heat. This statement is in line with the findings of (de Reu et al., 2009; Perić et al., 2016), which states that environmental temperature can affect the weight of chicken eggs.

Laying hens have better production performance in neutral temperatures, around 18°C to 28°C. Wind speed also influences chickens, where wind speed that is appropriate to cage conditions can maintain cage temperature and reduce the risk of heat stress in chickens, which in turn can increase egg productivity (Dameanti et al., 2020). (Setiawati et al., 2016a) added that factors such as *hen day production*, feed consumption, and *egg mass* can also influence egg weight. As the age of the chicken increases, the chicken's body weight also influences the weight of the eggs produced.

Egg mass, also known as *egg mass*, is an indicator of daily production efficiency which is calculated by dividing the total weight of eggs by the number of chicken population. According to (Kleyn, 2013), when *egg mass* is high, egg production tends to be high, and conversely, if *egg mass* decreases, egg production will also decrease. The results showed that *egg mass* in battery cages made of bamboo and wire, as shown in Table 4, showed no significant difference (P>0.05). The explanation for the non-significant difference is that P1 has a higher HDP value, but a smaller egg weight, while P2 has a lower HDP, but a larger egg weight so that *the egg mass* achieves relatively the same results.

According to (Sudjarwo et al., 2022), *the egg mass value for ISA Brown* strain laying hens aged 54 weeks should reach 59.7. The research results showed that *the egg* *mass value* at P1 was 51.97 ± 3.06 and P2 was 52.07 ± 2.95, which was a lower value than the standard, the biggest factor was caused by heat stress. Keeping laying hens at a cage air temperature that is higher than optimal requirements can cause stress in the poultry due to heat stress (Tamzil, 2014). (Felver-Gant et al., 2012; Olgun et al., 2007) added that hot and humid cage conditions can hurt livestock.

(Flachowsky, 1997; Sibbald & Slinger, 1963) stated that feed conversion is a comparison between feed consumption and production, and the higher the feed conversion value indicates the less efficient use of feed. In this study, feed conversion (FCR) in battery cages with bamboo and wire materials, as seen in Table 4, shows the average treatment results in sequence from the smallest to P2 (2.22 ± 0.12) and P1 (2, 22±0.14). Statistical analysis showed that the differences were not significant (P>0.05). Similarities in chicken *strain*, chicken age, and diet were considered as reasons for nonsignificant differences. This is considered to affect the metabolic ability and absorption of nutrients by the chicken's body, so feed conversion shows a higher figure compared to the *ISA Brown standard* which should have an FCR of around 1.97 at 54-57 weeks of age (Utomo, 2018), whereas in the panel research Santosa et al. 2019, states that the average FCR of battery cage laying hens at 56 weeks of age is 2.2.

The difference in FCR values between types of cage materials is influenced by several factors including body weight growth, feeding management, feed consumption, and the environment. According to (Vilariño et al., 1996), the physical form of feed, nutritional content in the ration, maintenance, stress, and gender also has a role in influencing FCR. *Strain* and environmental factors also play a role in feed conversion rates (Sharma et al., 2022). High feed conversion can be caused by high feed consumption but results in low egg weight (Utomo, 2018). Conversely, a low feed conversion indicates efficiency and economy in feed quality. (Kleyn, 2013; Muharlien et al., 2020) also stated that the amount of feed consumed and the nutritional content in the feed are the main factors that influence egg production.

CONCLUSIONS AND RECOMMENDATIONS

The results of the research can be concluded that the welfare of livestock based on behavior (eating, drinking and resting) of bamboo batteries is considered better because it can ward off heat stress better. The production performance of wire batteries shows that

Hen Day Production (HDP) is higher and better at preventing *ectoparasites* than bamboo batteries. Bamboo batteries have a higher egg weight because the chicken's feeding frequency is higher than wire material batteries when heat stress occurs.

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REFERENCES

Adriant, Z., Yulianto, Forster, R., & Zariatin, D. L. (2019). The Effect Of Mesh Size On Mechanical And Thermal Properties Of Bamboo Composites. *Journal of Energy, Mechanical, Material, and Manufacturing Engineering*, *10*(20).

Agustina, I., & Astuti, D. (2015). Prosiding Seminar Nasional Fisika dan Pendidikan Fisika (SNFPF) Ke-6 2015 Penentuan Konduktivitas Termal Logam Tembaga, Kuningan, dan Besi dengan Metode Gandengan. *FKIP UNS Journal Systems*, *6*(1).

Anderson, K. E., Davis, G. S., Jenkins, P. K., & Carroll, A. S. (2004). Effects of bird age, density, and molt on behavioral profiles of two commercial layer strains in cages. *Poultry Science*. https://doi.org/10.1093/ps/83.1.15

Appleby, M. C. (1998). Modification of Laying Hen Cages to Improve Behavior. *Poultry Science*. https://doi.org/10.1093/ps/77.12.1828

Barrow, P., Nair, V., Baigent, S., Atterbury, R., & Clark, M. (2021). Poultry Health: A Guide for Professionals. In *Poultry Health: A Guide for Professionals*. https://doi.org/10.1079/9781789245042.0000

Dameanti, F. N. A. E. P., Firdaus, M. A., Titisari, N., Aditya, S., & Guritno, I. (2020). Pengaruh Faktor Lingkungan terhadap Produktivitas Telur Ayam Kampung Unggulan Balitbangtan (KUB) Fase Layer. *Jurnal Medik Veteriner*. https://doi.org/10.20473/jmv.vol3.iss2.2020.166-172

de Reu, K., Rodenburg, T. B., Grijspeerdt, K., Messens, W., Heyndrickx, M., Tuyttens, F. A. M., Sonck, B., Zoons, J., & Herman, L. (2009). Bacteriological contamination, dirt, and cracks of eggshells in furnished cages and noncage systems for laying hens: An international on-farm comparison. *Poultry Science*. https://doi.org/10.3382/ps.2009-00097

Dewi, K. M., Rochdiani, D., & Sudrajat, S.-. (2023). STRATEGI PENGEMBANGAN AYAM RAS PETELUR DI DESA CIBATU KECAMATAN KARANGNUNGGAL. *Jurnal Ilmiah Mahasiswa AGROINFO GALUH*, *10*(1). https://doi.org/10.25157/jimag.v10i1.9053

Dively, G. P., Patton, T., Barranco, L., & Kulhanek, K. (2020). Comparative efficacy of common active ingredients in organic insecticides against difficult to control insect pests. *Insects*, *11*(9). https://doi.org/10.3390/insects11090614

Fadhlurrohman, R., Suarman, D. F., & ... (2021). Pengaruh Faktor Lingkungan Terhadap Reproduksi Ayam Ras Petelur. *Prosiding ….*

Fahim, M., Haris, M., Khan, W., & Zaman, S. (2022). Bamboo as a Construction Material: Prospects and Challenges. *Advances in Science and Technology Research Journal*, *16*(3). https://doi.org/10.12913/22998624/149737

Felver-Gant, J. N., Mack, L. A., Dennis, R. L., Eicher, S. D., & Cheng, H. W. (2012). Genetic variations alter physiological responses following heat stress in 2 strains of laying hens. *Poultry Science*. https://doi.org/10.3382/ps.2011-01988

Flachowsky, G. (1997). Basic animal nutrition and feeding. *Animal Feed Science and Technology*. https://doi.org/10.1016/s0377-8401(97)84958-9

Gerber, N. (2005). Factors affecting egg quality in the commercial laying hen : a review. *Egg Producers Federation of New Zealand Inc.*, 1–28.

Hasan, M. M., Talukder, S., Mandal, A. K., Tasmim, S. T., Parvin, M. S., Ali, M. Y., Sikder, M. H., & Islam, M. T. (2020). Prevalence and risk factors of Campylobacter infection in broiler and cockerel flocks in Mymensingh and Gazipur districts of Bangladesh. *Preventive Veterinary Medicine*. https://doi.org/10.1016/j.prevetmed.2020.105034

Hinz, T., & Linke, S. (1998). A comprehensive experimental study of aerial pollutants in and emissions from livestock buildings. Part 2: Results. *Journal of Agricultural and Engineering Research*, *70*(1), 119–129. https://doi.org/10.1006/jaer.1998.0282

Hyline International. (2016). Hy-Line Brown commercial layers managmenet guide. *Hy-Line Brown Commercial Layers Management Guide*.

Kleyn. (2013). Chicken Nutrition. A guide for nutritionists and poultry professionals. *Book*.

ManageMent guide Alternative production systems 2. (n.d.).

Merdana, I. M., Suada, I. K., Robi, I. M., & Sadhi, I. D. M. N. (2022). Total Bakteri dan Coliform Limbah Tempat Pemotongan Ayam Tradisional Setelah Perlakuan Serbuk

Biji Kelor. *Buletin Veteriner Udayana*. https://doi.org/10.24843/bulvet.2022.v14.i05.p04

Muharlien, M., Sudjarwo, E., Lestari Yulianti, D., & Setyo Prayogi, H. (2020). Evaluation of booster additive with different DOC body weight on Broiler production performance in closed house. *Jurnal Ilmu-Ilmu Peternakan*, *30*(3), 254–260. https://doi.org/10.21776/ub.jiip.2020.030.03.11

NUGROHO, Y. A., & WALUYO, W. (2021). Investigasi Sagging Metoda Parabola pada Saluran Transmisi Terhadap Parameter Temperatur pada Saluran 150 Kv pada Gardu Induk Cigereleng. *MIND Journal*, *6*(1). https://doi.org/10.26760/mindjournal.v6i1.46-56

Olgun, M., Çelik, M. Y., & Polat, H. E. (2007). Determining of heat balance design criteria for laying hen houses under continental climate conditions. *Building and Environment*. https://doi.org/10.1016/j.buildenv.2005.09.002

Perić, L., Đukić Stojčić, M., & Bjedov, S. (2016). Effect of Production Systems on Quality and Chemical Composition of Table Eggs. *Contemporary Agriculture*. https://doi.org/10.1515/contagri-2016-0014

Ph, J. J., & Note, K. (2023). *Cleaning and Disinfecting in Organic Poultry Production*. *603*(1), 603–606.

Pohle, K., & Cheng, H. W. (2009). Comparative effects of furnished and battery cages on egg production and physiological parameters in White Leghorn hens. *Poultry Science*, *88*(10). https://doi.org/10.3382/ps.2009-00171

Prasetyo, A. K., Anggriawan, R., & Afikasari, D. (2022). PENGARUH PEMBERIAN ASAM SITRAT (CITRIC ACID) SEBAGAI FEED ADDITIVE TERHADAP FCR (FEED CONVERTION RATIO) DAN HDP (HEN DAY PRODUCTION) AYAM PETELUR DI KECAMATAN BADAS KABUPATEN KEDIRI. *Jurnal Agriovet*, *5*(1). https://doi.org/10.51158/agriovet.v5i1.792

Setiawati, T., Afnan, R., & Ulupi, N. (2016a). Performa Produksi dan Kualitas Telur Ayam Petelur pada Sistem Litter dan Cage dengan Suhu Kandang Berbeda. *Jurnal Ilmu Produksi Dan Teknologi Hasil Peternakan*. https://doi.org/10.29244/4.1.197-203

Setiawati, T., Afnan, R., & Ulupi, N. (2016b). Performa Produksi dan Kualitas Telur Ayam Petelur pada Sistem Litter dan Cage dengan Suhu Kandang Berbeda Productive Performance and Egg Quality of Layer in Litter and Cage System with Different Temperatures. *Januari*, *04*(1), 197–203.

Sharma, M. K., McDaniel, C. D., Kiess, A. S., Loar, R. E., & Adhikari, P. (2022). Effect of housing environment and hen strain on egg production and egg quality as well as cloacal and eggshell microbiology in laying hens. *Poultry Science, 101*(2). https://doi.org/10.1016/j.psj.2021.101595

Sibbald, I. R., & Slinger, S. J. (1963). Factors Affecting the Metabolizable Energy Content of Poultry Feeds. *Poultry Science*. https://doi.org/10.3382/ps.0420137

Sudjarwo, E., Muharlien, M., Sjofjan, O., & Yulianti, D. L. (2022). Production Performance of Layer Strain Hy-Line Brown in Different Cage Locations in Closed House. *E3S Web of Conferences, 335*. https://doi.org/10.1051/e3sconf/202233500018

Tamzil, M. H. (2014). Heat Stress on Poultry: Metabolism, Effects and Efforts to Overcome. *Indonesian Bulletin of Animal and Veterinary Sciences*. https://doi.org/10.14334/wartazoa.v24i2.1049

Utomo, D. M. (2018). PERFORMA AYAM RAS PETELUR COKLAT DENGAN FREKUENSI PEMBERIAN RANSUM YANG BERBEDA. *AVES: Jurnal Ilmu Peternakan*, *11*(2). https://doi.org/10.35457/aves.v11i2.276

Van Den Brand, H., Parmentier, H. K., & Kemp, B. (2004). Effects of housing system (outdoor vs cages) and age of laying hens on egg characteristics. *British Poultry Science*. https://doi.org/10.1080/00071660400014283

Vilariño, M., Picard, M. L., Melcion, J. P., & Faure, J. M. (1996). Behavioural adaptation of laying hens to dilution of diets under mash and pellet form. *British Poultry Science*, *37*(5). https://doi.org/10.1080/00071669608417921

Wiguna, A. (2019). Pengaruh Jenis Kandang Terhadap Infestasi Menopongallinae Pada Ayam Petelur (Gallus gallus) Di Desa Krawang Sari Kecamatan Natar Kabupaten Lampung Selatan. In *Skripsi. Fakultas Tarbiyah Dan Keguruan. Universitas Islam Negeri Raden Intan Lampung*.

Xu, D., Shu, G., Liu, Y., Qin, P., Zheng, Y., Tian, Y., Zhao, X., & Du, X. (2022). Farm Environmental Enrichments Improve the Welfare of Layer Chicks and Pullets: A Comprehensive Review. In *Animals* (Vol. 12, Issue 19). https://doi.org/10.3390/ani12192610

Yennie, E., & Elystia, S. (2013). PEMBUATAN PESTISIDA ORGANIK MENGGUNAKAN METODE EKSTRAKSI DARI SAMPAH DAUN PEPAYA DAN UMBI BAWANG PUTIH. *Jurnal Dampak, 10*(1). https://doi.org/10.25077/dampak.10.1.46-59.2013

Yilmaz Dikmen, B., Dpek, A., Şahan, U., Petek, M., & Sözcü, A. (2016). Egg production and welfare of laying hens kept in different housing systems (conventional, enriched cage, and free range). *Poultry Science*, *95*(7), 1564–1572. https://doi.org/10.3382/ps/pew082