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RESEARCH ARTICLE
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Effect of Photoperiod on Semen Production and Thermo-Physiological Responses of the Pearl Guinea Fowl in Hot Humid Environment

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ABSTRACT

This study examines the effect of photoperiod on sperm production and quality of the pearl Guinea fowl cock. Keets used for this investigation were subjected to different photoperiod levels: 12HL:12HD, 14HL:10HD, 16HL: 8HD, and 18HL:6HD using a white bright LED Energy saving bulbs of 120 watts with light intensity of 5.60 lux and kept from day-old to eight weeks in a completely randomized block design. Semen produced by cocks subjected to 12HL: 12HD was closely gathered, while semen produced by birds subjected to 18HL: 6HD was spread apart. Considering semen motility, sperm produced by cocks subjected to 18HL: 6HD photoperiod swam efficiently followed by cocks subjected to 16HL: 8HD and 14HL: 10HD. While sperms produced by cocks subjected to 12HL: 12HD were swimming slowly. Cocks subjected to 12HL: 12HD produced the highest (28.75) percentage of abnormal spermatozoa and the lowest (20.25%) among cocks subjected to 18HL: 6HD treatment. The highest normal spermatozoa (79.75%) were produced by cocks subjected to 18HL: 6HD treatment, and the lowest (71.25%) among cocks subjected to 18HL: 6HD treatment. The volume of spermatozoa produced was highest (3.6mL) in cocks exposed to 16HL: 8HD photoperiod and lowest (2.81 ml) in cocks exposed to 14HL: 10HD photoperiod. Cocks subjected to 18HL: 6HD level of photoperiod recorded the highest (P=0.001) white blood cells (4.48 %), while birds subjected to 12HL: 12HD had the lowest percentage of white blood cell of 2.42. In conclusion, semen quality and quantity increased with increasing photoperiod.

Keywords: Photoperiod, Guinea fowl, Semen, Spermatozoa, Thermo-physiological responses

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INTRODUCTION

Guinea fowl is among the most common poultry species raised by many small-scale poultry farmers in Ghana, especially in the Northern, Northeast, Savannah, Upper East, and West regions (Avornyo et al., 2016; Kyere et al., 2018). The commonest breeds found in Ghana are the Pearl, Black, Lavender, and White Guinea fowls. The Pearl Guinea fowl breed is the most populated bird in Ghana compared to the Black, Lavender, and White Guinea fowls (Duodu et al., 2018; Kyere et al., 2018). Guinea fowl can adapt to harsh environmental conditions and grow very fast with high production and reproduction performance even under poor environmental conditions as compared to domestic chicken (Avornyo et al., 2016). Keeping Guinea fowl has proven to be very profitable with low production input since most rural farmers keep the bird under the semi-intensive and extensive system of animal management (Kyere et al., 2018).

The major constraints affecting the growth and reproduction performance of local Guinea fowl production include seasonal breeding (Gosomji et al., 2024), day length (Okyere et al., 2020), light intensity (Raccoursier, 2016), color/wavelength of light, poor nutrition (Adjetey et al., 2014), high reproductive wastage, egg size, and poor management practices. Among the constraints as

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mentioned above, photoperiod (day length) and seasonal variations have been singled out as the major hindrance notable to affect the growth and reproductive performance of local Guinea fowls hence, the focus of this study. Manipulation of light at different regimes for broilers influence semen production and quality (Okyere et al., 2020). Hajrasouliha and Kaplan (2012) also reported that light supplementation to broiler chickens modulates systematic immune responses, reduces physiological aggressive behaviors, and improves health and welfare. Lewis et al. (2007) observed a decrease in age at sexual maturity with increasing photoperiod in broiler breeders. Similar study conducted in Ghana by Okyere et al. (2020) revealed that, Guinea fowls exposed to 18L: 6D produced high quality semen.

Lighting regimes in poultry production appear to be indispensable to maximize the growth potential and affect thermo-physiological responses, semen production, and quality of poultry birds (Wu et al., 2022). Unfortunately, this innovative technology has not been studied extensively in the case of Guinea fowls in Ghana and across the world. Currently, there is little or no research work on photoperiodic effect on semen production and thermo-physiological traits across the globe. Hence, this study is novel with unique findings which will improve poultry production especially, Guinea fowls. With the increasing concern in Guinea fowl commercialization, it is important to conduct research to delve into the semen production capacity of Guinea fowl cocks subjected to photoperiod in a hot, humid environment.

MATERIALS & METHODS

Ethical Approval

This research was developed from an ongoing PhD research work in Reproductive Physiology (Animal Science) with approval from the Animal Care and Ethics Committee from the Department of Animal Science, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana. This research also strictly followed the ethics and animal handling guidelines and procedures outline in the Guide for the care and management and use of Poultry Birds in Research and Teaching by the Federation of Animal Science Societies (American Poultry Science Association, 2020).

Information about the Study Area

This study was set up on-farm at Dawu near Jamasi in the Ashanti Region of Ghana between the period of 27th June 2023 and 17th October 2023. This study lasted for 16 weeks. Dawu is located in the Sekyere South District and on the Kumasi-Ejura road in the Ashanti Region of Ghana. Dawu is 293 meters above sea level in the transitional zone characterized by abundant tropical rain forest and well known for its poultry farming activities in the Ashanti Region. The town coordinates are 6°43'60" N and 1°31'60" W in degrees minutes seconds (DMS). The latitudes and longitude of the area are 07° 04′ and 01° 24′ degrees respectively. The average minimum and maximum temperatures recorded during the study period were 20.89 and 30.4°C, respectively (Ghana Meteorological Agency, 2023). The town experiences a bimodal rainfall pattern between April-July and August-November and also experiences a dry season which occurs during December-March.

Experimental Animals, Design and Treatments

Pearl Guinea fowls totaling 80 were randomly selected and put on four lighting treatment groups. Each treatment was replicated 4 times with 5 birds per replicate in a completely randomized design. The treatment groups were 12HL:12HD, 14HL:10HD, 16HL: 8HD, and 18HL:6HD, using bright white LED Energy saving bulbs of 120 watts and a rechargeable lamp of 120 watts with a combined mean light intensity of 5.60 lux. Where HL: Hours of light and HD: Hours of darkness.

Experimental Diets

A single diet was formulated and used for feeding the experimental birds (Table 1).

Table 1: Feed Ingredients and Quantities in the Experimental Diets

Feed ingredients	Starter (Kg)	Grower (Kg)	Breeder (Kg)
Maize	55.50	58.00	60.00
Wheat bran	8.00	13.00	17.00
Soya bean meal	18.00	15.00	12.00
Tuna fish meal	16.00	11.00	8.00
Oyster shell	1.00	1.50	1.50
Dicalcium phosphate	0.50	0.50	0.50
Vitamin premix	0.50	0.50	0.50
Common salt	0.50	0.50	0.50
Estimated compositions			
Ash (%)	16.49	15.66	15.31
Crude protein (%)	22.15	19.41	17.42
Crude fibre (%)	3.48	3.77	4.00
Moisture (%)	10.07	10.05	10.09
Ether extract (%)	4.53	4.52	4.53
ME (kcal/kg)	2789	2892	2973

ME= Metabolizable Energy

Vitamins: A (8100IU); B2 (2.00mg); B12 (5.10mg); (D3 (1511IU); E (2.60mg) and K (1.50mg); Folic acid (0.52mg); Nicotimic acid (8.11mg); Calcium Panthotenate (2.11mg); Choline Cloruro (49mg); Trace elements: Cu (4.61mg); Co (0.11mg); mg (49mg); Se (0.12mg); Antioxidant Butylated Hydroxytoluene (10.10mg); Carrier; Calcium carbonate q.s.p (2.61kg)

Feed and clean water were always available without restrictions. Health management practices were strictly followed at all stages of growth. Table 1 presents the various compositions at the starter and grower phases. The nutrient levels met the NRC (1994) nutrient requirement for growing poultry.

Male Sperm Production and Quality of the Pearl Guinea Fowl

At twenty-two weeks of age, male Guinea fowls from each of the experimental treatments were trained for eight weeks for them to be responsive to release off semen. Semen was collected using the dorso-ventral massage method described by Burrows & Quinn (1937) from the birds randomly selected from each of the replicates. The testes located at the dorsum were stroked and massaged until there is protrusion of the cloacae. The semen was milked and collected using a rubber pipette and transferred to collection vials. Semen analysis was done immediately after collection. Semen volumes were measured by using a calibrated micro pipette, and sperm concentrations were examined with a Neubauer hemocytometer. The percentage live and abnormal spermatozoa were counted after preparing smears and staining them with eosin and nigrosin according to the methods described by Lake and Stewart (1978). The sperm motility was assessed by examination of a drop of semen (5µL) under the microscope at 10x magnification as described by Hutt (2003) using Olympus BX_{43}-Standard Laboratory Microscope.

Parameters measured include semen volume, semen color, semen pH, sperm concentration, sperm mass motility, sperm morphology (normal and abnormal), and round cell differential. Semen volumes were determined by using a calibrated micro pipette; the semen was aspirated, and the volume was read and reported in mL (Burrows & Quinn, 1937). Semen color was checked with visual appraisal, and color was determined as either milky or grayish (Hutt, 2003). Semen *pH* was *measured* using a pH meter (specially treated paper blot that changes color according to the pH of the specimen it was exposed to) (Hutt, 2003). Sperm concentration was determined as the number of spermatozoa in mL of semen sample by counting the spermatozoa in a counting chamber. It was as millions of cells per milliliter (M/mL or × 10^6cells/mL) (Hutt, 2003).

Sperm motility was determined as the number of cells that were *motile* in a volume of *semen* and reported as percent cells per milliliter (cells/mL) or millions of cells per milliliter (1× 10^6/mL) (Lake and Stewart, 1978). Sperm morphology was determined by measuring the shape of sperm cells and reported as a percentage of normal sperm cells and abnormal sperm cells (big head cells, double tail cells). Maximal leucocyte and erythrocyte concentrations were determined as a number of white blood cells and red blood cells in mL of the semen sample and reported as millions of cells per milliliter (1×10^6cells/mL) (Hutt, 2003).

Thermo-Physiological Traits of the Pearl Guinea Fowl

Body temperature, rectal temperature, respiratory rate, and pulse rate were the major thermo-physiological traits considered in this study. The body temperature of the Guinea fowls was determined by inserting a digital thermometer manufactured by Hong Kong Digitmex Instrument Limited, China, about an inch into the vent of the birds and waiting for 30 until the thermometers' beeping reached a constant reading, and the reading was recorded (Popoola et al., 2014). Rectal temperature was determined by using a digital thermometer manufactured by Hong Kong Digitmex Instrument Limited, China. The digital thermometer was inserted into the cloaca of the bird at a depth of 2cm for 30s and the reading was recorded. Respiratory rate was reported as the rate of flank movements per minute and was estimated as breathes/minute using respirometer manufactured by Hong Kong Digitmex Instrument Limited, China (Popoola et al., 2014; Ijadunola et al., 2020). Pulse rate was determined by placing a stethoscope (manufactured by Hong Kong Digitmex Instrument Limited, China) on the thigh of the Guinea fowl to determine rhythmic beats of the heart per minute (Popoola et al., 2014; Ijadunola et al., 2020).

Statistical Analysis

GenStat version 11.1 was used to analyze all the data collected during the conduct of this study. The average treatment means were separated using the LSD programmed in the GenStat at a 5% significant probability level (Steel and Torrie, 1980). Below is the statistical model used in this study

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

μ = The mean of the entire population

α_i = The main effect of photoperiod

e_{ij} = Is the error associated with rep k (Photoperiod)

RESULTS & DISCUSSION

Effect of Photoperiod on Semen Physical Characteristics

Semen physical characteristics such as clumps and motility were significantly (P=0.001) affected by photoperiod. However, photoperiod had no significant (P>0.05) effect on semen pH, sperm debris and sperm concentration (Fig. 1).

Fig. 1 revealed that semen produced by cocks subjected to 12HL: 12HD were closely gathered as compared with birds subjected to 14HL: 10HD and 16HL:8HD. Meanwhile, semen produced by birds subjected to 18HL: 6HD were spread apart. Considering semen motility, sperm produced by cocks subjected to 18HL: 6HD photoperiod swam efficiently followed by cocks subjected to 16HL: 8HD and 14HL: 10HD. While sperms produced by cocks subjected to 12HL: 12HD were swimming slowly.

Quality semen is an essential factor which increases high rate of fertilization in domestic animals (Wolff, 1995). Semen produce by Guinea fowl cocks contains spermatozoa released from the testicles. In this study (Fig. 1), semen produced by cocks subjected to 12HL: 12HD was very thick hence, movement was found to be poor. While, increasing photoperiod resulted in the production of lighter semen making the movement of spermatozoa very fast (Shi et al., 2021). In this study, the percentage-increasing photoperiod resulted in the production of lighter semen; motility observed ranges between 71-79.5 which were higher than the normal percentage motility of 40 and above reported by Leslie et al. (2024) for healthy cocks. The increase in percentage motility with increasing photoperiod and the decrease in clumps with increasing photoperiod is an indication that birds subjected to 14HL:10HD, 16HL:8HD, and 18HL: 6HD will be able to swim faster as compared with birds subjected to 12HL:12HD. This study corroborates with the report of Shi et al. (2021), who reported that increasing photo-stimulation reduces percentage clumps and increases percentage motility in White Leghorn roster breeders. A similar finding to this study was also reported by Mandal et al. (2022).

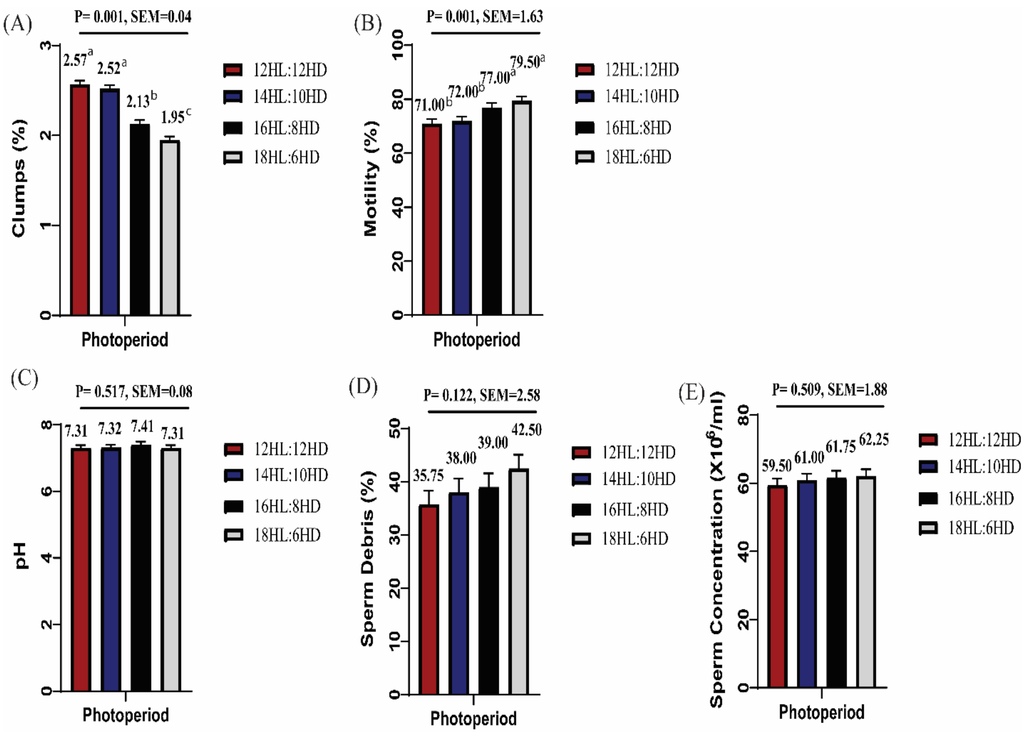

Fig. 1: Effect of Photoperiod on Semen Physical Characteristics.

Effect of Photoperiod on Semen Morphology

Results on the effect of photoperiod on semen morphological characteristics revealed a significant (P=0.001) effect on the percentage of abnormal and normal spermatozoa and the volume of spermatozoa produced by the cocks (Fig. 2 A, B, and C). Cocks subjected to 12HL:12HD produced the highest (28.75) percentage of abnormal spermatozoa and the lowest (20.25%) among cocks subjected to 18HL: 6HD treatment. The highest normal spermatozoa (79.75%) were produced by cocks subjected to 18HL: 6HD treatment and the lowest (71.25%) among cocks subjected to 18HL: 6HD treatment. The volume of spermatozoa produced was highest (3.6mL) in cocks exposed to 16HL: 8HD photoperiod and lowest (2.81mL) in cocks exposed to 14HL: 10HD photoperiod.

Successful egg fertilization in hens depends on the quantity of normal spermatozoa produce by cocks. Wolff (1995) reported that the production of high-quality semen is necessary for successful fertilization and reproduction. In this study (Fig. 2), increasing photoperiod resulted in higher production of normal spermatozoa and semen volume. This result agrees with the report of Chang et al. (2016), who indicated that light maintains higher semen quality and quantity. Physiologically, light stimulates the hypothalamus to trigger the release of sex hormones such as testosterone which is responsible for sperm production (Ozkanlar et al., 2021). Hence, this explains why birds 14HL:10HD, 16HL:8HD and 18HL: 6HD produced the highest normal spermatozoa as compared with birds subjected to 12HL: 12HD photoperiod.

Furthermore, the physiological reasons underlying the higher production of normal spermatozoa and the reduction in the production in abnormal spermatozoa with increasing photoperiod could be attributed to photoperiodic effect on metabolism. Metabolism is one of the key factors responsible for higher feed utilization, semen production and normal growth of spermatozoa (Mandal et al., 2022). Light stimulates higher production of thyroid hormones more specifically triiodothyronine which regulates metabolic activities in birds which ensures normal growth and development of spermatozoa (Chang et al., 2016; Okyere et al., 2020). Hence, this explains the reason why Guinea fowls subjected to long duration of light were able to produce the highest volume and normal spermatozoa more than birds subjected to 12HL: 12HD photoperiod.

Effect of Photoperiod on Spermatozoa Cell Differential Characteristics

Results presented in Fig. 3, A and B revealed that photoperiod had no significant (P>0.05) effect on epithelia and red blood cells but had significant (P<0.05) effect on white blood cells (Fig. 3C). The levels of white blood cells in the blood increased (P<0.05) with increasing photoperiod. Cocks subjected to 18HL: 6HD level of photoperiod recorded the highest (P=0.001) white blood cell (4.48 %) followed by 16HL: 8HD (4.07 %) and 14HL: 10HD (3.45 %). While, birds subjected to 12HL: 12HD had the lowest percentage white blood cell of 2.42.

Khodamoradi et al. (2020) reported that white blood cells in the semen can affect the normal functioning of spermatozoa, and this affects the ability of spermatozoa to swim to meet the egg in the hen's oviduct to cause fertilization. The levels of semen white blood cells increased with increasing photoperiod. The levels of semen white blood cells observed in this study ranges between 2.42–4.84% which was lower than the mean value of 5.45% reported by Okyere et. al. (2020) and 10-20% reported by Wolff (1995). This study finding is similar to the report of Wolff (1995), who reported that increasing photo-stimulation affects white blood cell production in semen. Similar findings to this study were also reported by Mandal et al. (2022).

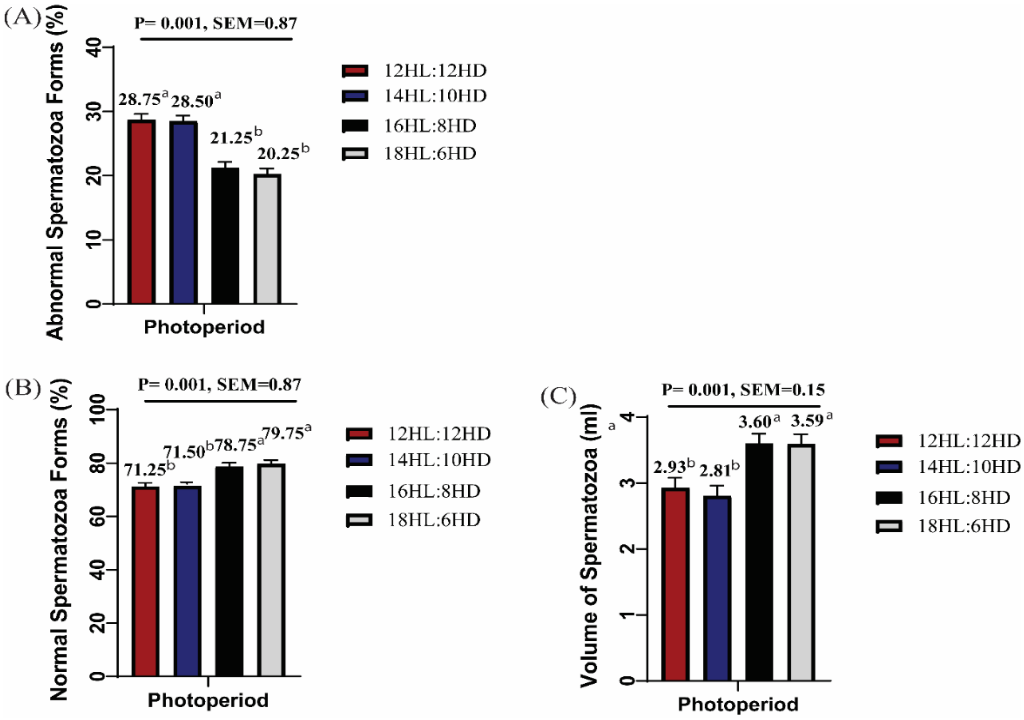

Fig. 2: Effect of Photoperiod on Semen Morphology

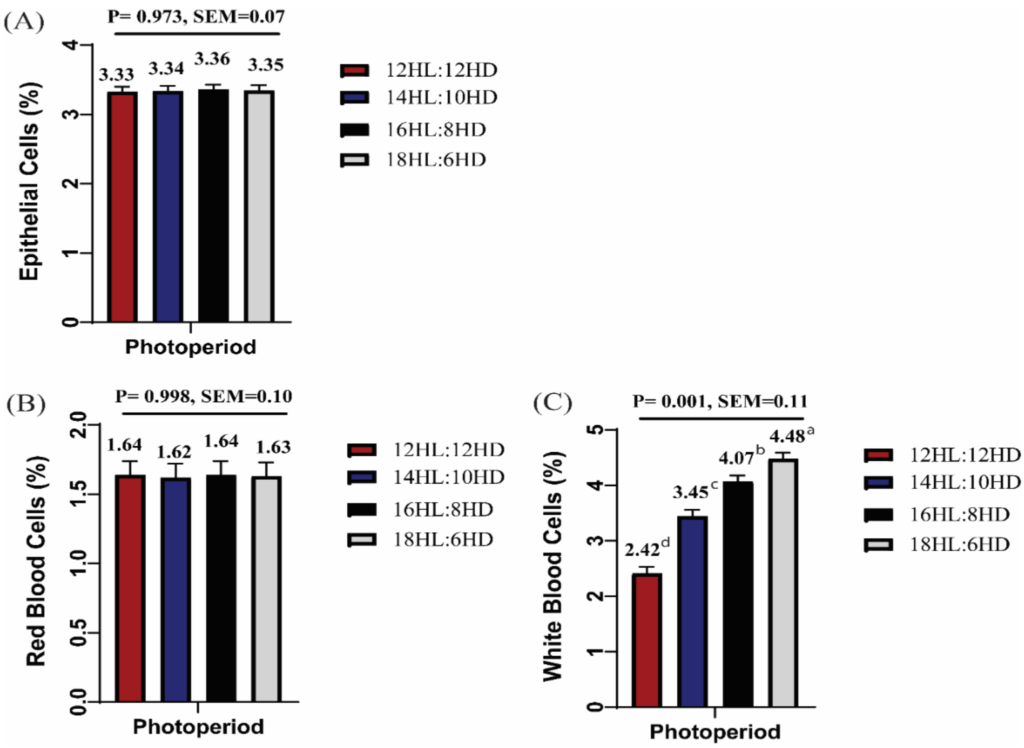

Fig. 3: Photoperiodic Effect on Spermatozoa Cell Differential Characteristics

Photoperiodic Effect on Thermo-Physiological Traits

Thermo-physiological traits of the pearl Guinea fowls as influenced by photoperiod are presented in Fig. 4 A, B, C, and D. All the thermo-physiological traits were significantly (P<0.05) affected by photoperiod (Fig. 4 A, B, C, and D). Birds subjected to 18HL:6HD photoperiod had the highest (P=0.001) body temperature (41.62°C), pulse rate (270.97 Beats/min), rectal temperature (42.99°C), and respiratory rate (42.74 Breath/min) (Fig. 4 A, B, C, and D). While, birds subjected to 12HL:12HD photoperiod recorded the lowest (P=0.001) body temperature (38.17°C), pulse rate (213.93 Beats/min), rectal temperature (39.58°C) and respiratory rate (28.15 Breath/min) (Fig. 4 A, B, C, and D).

This study revealed that body temperature, pulse rate, respiratory rate, and rectal temperature increased with increasing photoperiod (Fig. 4 A, B, C, and D). The body temperature range of 41.62-38.17°C recorded in this study (Fig. 4 A) was within the normal range (41-42°C) as reported by Attia et al. (2011). Normal body temperature in chickens is important for proper feeding, good health, and higher egg production (Maman et al., 2019). When birds are exposed to temperatures above normal (42°C), it affects feed intake, growth, and egg production and can lead to death (Ijadunola et al., 2020). Hence, this explains the reason why birds on the 18HL:6HD had the best growth and higher reproductive performance.

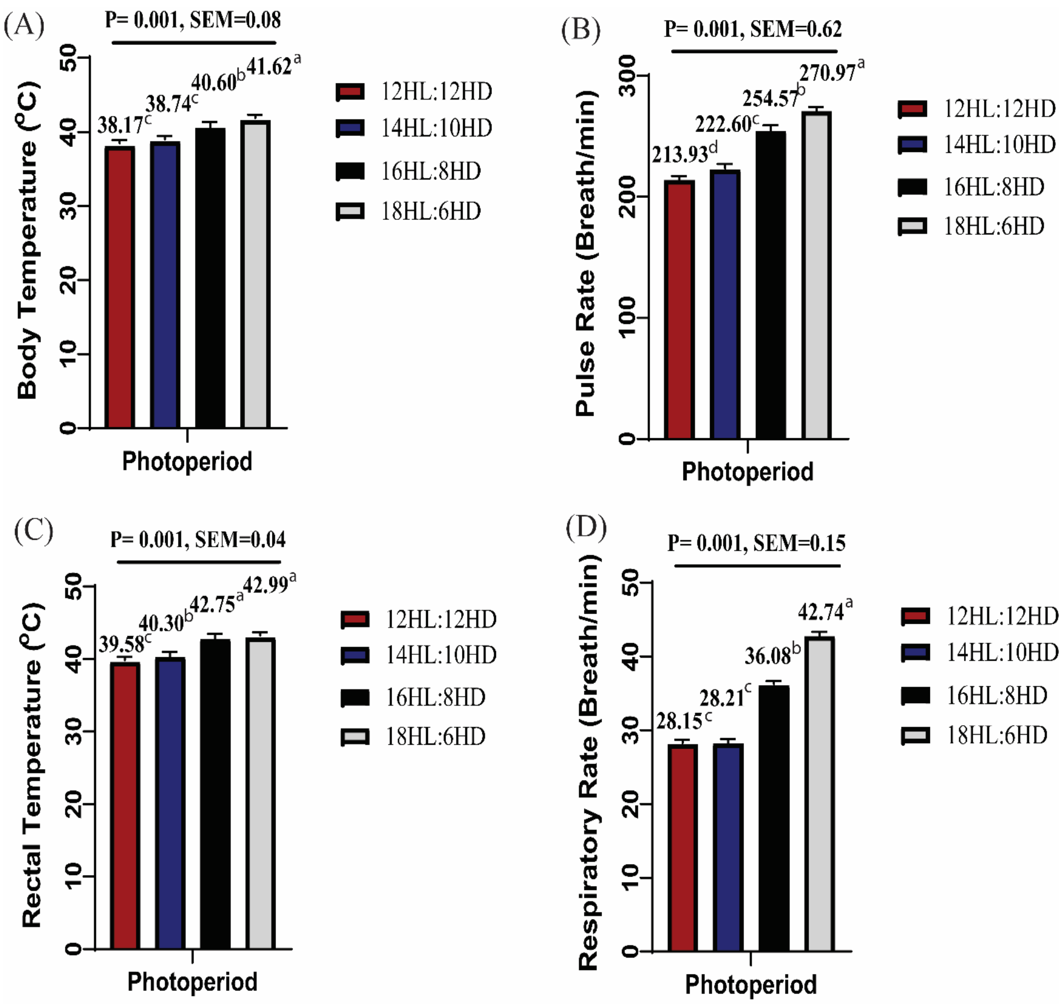

Fig. 4: Photoperiodic Effect on Thermo-Physiological Traits

The range for pulse rate in this study was observed to be 270.97-213.93 Beats/min (Fig. 4 B) and was also within the normal range of 200-400 Beats/min reported by Attia et al. (2011) and Ijadunola et al. (2020). This indicates that photoperiod had little or no adverse effect on the health status of the experimental birds. The rectal temperature in this study (Fig. 4C) ranges between 42.99-39.55°C, and the maximum rectal temperature of 42.95°C was within the normal range of 40.6-43°C reported by Robertshaw (2004). The minimum rectal temperature of 39.55 was below the normal range of 40.6-43°C reported by Robertshaw (2004). However, the range of respiratory rate (42.74-28.15 Breath/min) observed in this study (Fig. 4D) was higher than the normal range of 15-30 Breath/min reported by Attia et al. (2011) and Ijadunola et al. (2020). The variations in respiratory rate observed in this study and the normal range values could be attributed to differences in the experimental birds and the location of the various studies.

Conclusion

This study concludes that increasing semen quality and quantity increased with increasing photoperiod. A lot of abnormal spermatozoa were produced by cocks subjected to 12HL:12HD photoperiod. Cocks subjected to 16HL: 8HD photoperiod produced the highest volume of spermatozoa. This study also concludes that body temperature, pulse rate, rectal temperature and respiratory increased with increasing photoperiod.

Authors Contributions

Author CGK is the main and corresponding author respectively. Authors CGK, MB, SAO and OK conceived and design the experiment. Authors CGK, OK, PAPJ and OAK performed the study. Authors MB, SAO and OK supervised and coordinated the study. Authors CGK, MB and GTK performed and managed the statistical analysis of experimental data. Authors CGK, GTK, PAPJ and OAK prepared the draft of the manuscript. All authors critically revised the manuscript and approved the final version.

Conflict of Interest

There are no conflicts of interest in connection with this paper, and the material described is not under publication or consideration for publication elsewhere.

Ethical Standards: The manuscript does not contain clinical studies or patient data.

Data availability: All data that were evaluated during the research are available in the manuscript.

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Competing Interest: The authors have no competing interests to declare that are relevant to the content of this article.

REFERENCES

Adjetey, A.N.A., Atuahene, C.C., and Adjei, M.B. (2014). Protein requirements for laying indigenous Guinea fowls (*Numida Meleagris*) in the humid tropical zone of Ghana. *Journal of Animal Science Advance,* 4(7), 910-920.

Attia, Y.A., Hassan, R.A., Tag El-Din, A.E., and Abou-Shehema, B.M. (2011). Effect of ascorbic acid or increasing metabolizable energy level with or without supplementation of some essential amino acids on productive and physiological traits of slow-growing chicks exposed to chronic heat stress. *Journal of Animal Physiology and Animal Nutrition*, 95(6), 744–755. https://doi.org/10.1111/j.1439-0396.2010.01104.x

Avornyo, F.K., Salifu, S., Panyan, E.K., Al-Hassan, B.I., Ahiagbe, M., and Yeboah, F. (2016). Characteristics of Guinea fowl production systems in northern Ghana. A baseline study of 20 districts in northern Ghana. *Livestock Research for Rural Development, 28: 134.*

Burrows, W.H., and Quinn, J.P. (1937). The collection of spermatozoa from the domestic fowl and turkey. *Journal of Poultry Science,* 16: 19-24. https://doi.org/10.3382/ps.0160019

Chang, S.C., Zhuang, Z.X., Lin, M.J., Cheng, C.Y., Lin, T.Y., Jea, Y.S., and Huang, S.Y. (2016). Effects of monochromatic light sources on sex hormone levels in serum and on semen quality of ganders. *Animal Reproduction Science*, 167, 96-102. https://doi.org/10.1016/j.anireprosci.2016.02.012

Duodu, A., Annor, S.Y., Kagya-Agyemang, J.K., and Kyere, C.G. (2018). Influence of strain on production and some other traits of indigenous Guinea fowls (*Numida meleagris*) in Ghana. *Current Journal of Applied Science and Technology* 30 (2), 1-7. https://doi.org/10.9734/CJAST/2018/44123

Ghana Meteorological Agency (2023). https://www.meteo.gov.gh/gmet/national-meteorological-awareness-month-2023/

Gosomji, I.J., Bello, U.M., Dzenda, T., Baso, A., Arukwe, A., and Aire, A.T. (2024). Influence of photoperiod and exogenous melatonin on testis morpho-physiology of sexually mature Guinea fowl (*Numida meleagris*). *Animal Reproduction Science*, Volume?, 107410. https://doi.org/10.1016/j.anireprosci.2024.107410

Hajrasouliha, A.R., and Kaplan, H.J. (2012). Light and ocular immunity. *Current Opinion in Allergy and Clinical Immunology*, 12(15), 504-9. https://doi.org/10.1097/ACI.0b013e328357d3a4

Hutt, F. B. (2003). Genetics of the fowl: The Classic Guide to poultry Breeding and Chicken Genetics. *Northern Greek Press*, pp 445-448.

Ijadunola, T.I., Popoola M.A., Bolarinwa, M.O., Ayangbola, K.A., and Omole, C.A. (2020). Effects of supplemental Vitamins E and C on growth performance and physiological responses of broiler chicken under environmental heat stress. *Nigerian Journal of Animal Science*, 22(3), 17-25. https://www.ajol.info/index.php/tjas

Khodamoradi, K., Kuchakulla, M., Narasimman, M., Khosravizadeh, Z., Ali, A., Brackett, N., Ibrahim, E., and Ramasamy, R. (2020). Laboratory and clinical management of leukocytospermia and hematospermia: a review. *Therapeutic Advances in Reproductive Health*, 14. https://doi.org/10.1177/2633494120922511

Kyere, C.G., Annor, S.Y., Kagya-Agyemang, J.K., and Korankye, O. (2017). Effect of egg size and day length on reproductive and growth performance, egg characteristics and blood profile of the Guinea fowl. *Livestock Research for Rural Development 29(180).* http://www.lrrd.org/lrrd29/9/kyer29180.html

Lake, P.E., and Stewart J.M. (1978). Artificial Insemination in Poultry (British) Ministry of Agriculture, Fisheries and Food, Bulletin 213, London, England. http://dx.doi.org/10.5772/54918

Leslie, S.W., Soon-Sutton, T.L. and Khan, M.A.B. (2024). Male Infertility. In: StatPearls; Treasure Island (FL): https://pubmed.ncbi.nlm.nih.gov/32965929/

Lewis, P.D., Gous, R.M., and Morris, T.R. (2007). Model to predict age at sexual maturity in broiler breeders given a single increment in photoperiod. *British Poultry Science*, 48(5), 625–634. https://doi.org/10.1080/00071660701573060

Maman, H.A., Özlü, S., Uçar, A., Elibol, O. (2019). Effect of chick body temperature during post-hatch handling on broiler live performance. *Poultry Science*, 98(1), 244-250. https://doi.org/10.3382/ps/pey395

Mandal, D.K., Kumar, M., and Tyagi, S. (2022). Effect of seasons and photoperiods on seminal attributes and sperm morphology in Holstein Friesian × Sahiwal crossbred dairy bulls. *International Journal of Biometeorology*, 66(11), 2223-2235. https://doi.org/10.1007/s00484-022-02350-x

National Research Council (1994). Nutrient Requirements of Poultry. *The National Academies Press*. https://doi.org/doi.1994;10:2114

Okyere, K., Kagya-Agyemang, J.K, Annor, S.Y., Asabere-Ameyaw, A., and Kyere, C.G (2020). Influence of Season and Day Length on Production and Reproductive Traits and Egg Characteristics of the Guinea Fowl (*Numida meleagris*). *Asian Journal of Research in Zoology,* 3(1), 26-34. https://doi.org/10.9734/ajriz/2020/v3i130081

Ozkanlar, S., Kara, H., Gur, C., Gedikli, S., Kara, A., Ozudogru, Z., Ozdemir, D. and Kurt, N. (2021). Effects of photoperiod on thyroid gland development and function in growing chicks: A biochemical and morphometric study. *Animal Production Science,* 1652–1658.

Popoola, M.A., Oseni, S.O., and Ajayi, B.A. (2014). Evaluation of Heat Tolerance of Heterogeneous Rabbit Population Raised in Southwestern Nigeria. *Global Journal of Animal Scientific Research*, 2(3), 205-209. http://www.journals.wsrpublishing.com/index.php/gjasr/article/view/51/77

Raccoursier, F.M. (2016). Effect of Light Intensity on Production Parameters and Feeding Behaviour of Broilers. Graduate *Theses and Dissertations* Retrieved from https://scholarworks.uark.edu/etd/1854

Robertshaw, D. (2004). Temperature Regulation and Thermal Environment, in Dukes' Physiology of Domestic Animals, 12th ed., Reece WO, Ed. Copyright 2004, Cornell University Press.

Shi, L., Li, Y., Yuan, J., Ma, H., Wang, P., Ni, A., Ge, P., Chen, C., Li, D., Sun, Y. and Chen, J. (2021). Effects of age at photostimulation on sexual maturity and reproductive performance in rooster breeders. *Poultry Science,* 100(5), 101011. https://doi/10.1016/j.psj.2021.01.033

Steel, G.D., and Torrie, J.H. (1980). Principles and Procedures of Statistics. McGraw Hill Co. Inc. New York.

Wolff, H. (1995). The biologic significance of white blood cells in semen. *Journal of Fertility and Sterility,* 63(6), 1143-1157. https://doi.org/10.1016/s0015-0282(16)57588-8

Wu, Y., Huang, J., Quan, S., and Yang, Y. (2022). Light regimen on health and growth of broilers: an update review. *Poultry Science*, 101: 101545. https://doi.org/10.1016/j.psj.2021.101545