Effects of Artificial Photoperiod on Reproductive organ in Japanese Quail

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Introduction

Light is the most crucial exogenous management factor which controls various physiological and behavioral activities in birds (Mushtaq et al., 2014). Light helps birds do various metabolic and rhythmic activities (Abdou et al., 2021). Rhythmic activities include circadian rhythm (Benstaali et al., 2001), controlled by artificial lightning. Artificial lighting is widely used in the modern poultry housing system (Patel et al., 2016), which have shown great result in early sexual maturity, growth performance, temperature control, production, reproduction (Abdou et al., 2021), and immune response (Sharideh et al., 2021). In modern poultry housing systems, artificial light with various light intensities (Lewis & Morris, 2019), photoperiod (Lei et al., 2018), uniformity (Akyuz et al., 2019), and wavelength (Lewis & Morris, 2019) are used. Light possesses two different types of response in the presence of lights with different intensities and wavelengths. Photo sexual response is stimulated from hypothalamus reception of light while Growth & behavior response is influenced through retinal photoreception in birds (Lewis & Morris, 2019). The light with a longer wavelength can easily penetrate the skull and skin present in the head to activate the hypothalamus pituitary-gonadal (HPG) axis, which causes secretion of gonadotropin-releasing hormone (GnRH)and gonadotropin-inhibitory hormone (GnIH) from the hypothalamus (Lewis & Morris, 2000). HPG axis helps in the development of reproductive parts as well as ovarian follicle in a bird (Hernandez and Bahr, 2003; Jing et al., 2019). GnRH is produced during long photoperiod (Light period), while GnIH is secreted during short photoperiod (Dark period) because of the higher production of melatonin from the pineal gland. Melatonin production always stimulates the hypothalamus to produce GnIH, which is controlled by deiodinase type 2 and 3 (Perfito et al., 2015) to inhibit the process of reproduction in birds. On the other hand, GnRH stimulates the anterior pituitary gland to produce a large amount of follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which later acts on the sex organ to produce reproductive hormones (estrogen, progesterone, and androgen). Thus, produced reproductive hormones result in increased follicular development, ovarian weight (Mitchell, 1970), and oviduct formation (Scanes et al., 2020). In addition to this, androgen helps in increasing the size of the testicle and semen concentration (Scanes et al., 2020). Japanese Quail is known as a small bird having true photoperiod. The photoperiod is the most important part of the light, which shows the length of the light period within 24 hours of the light/dark cycle (Lewis, 2009). Photoperiod in summer increases as day length increases and in winter decreases as daylight decreases. The long day is indicated as a stimulatory photoperiod, while the short day is a non- stimulatory photoperiod. Stimulatory photoperiod always has a positive impact on reproduction and early maturation (Lewis, 2009). As photoperiod increases, the growth of ovarian follicles and reproductive organs also increases because of the increase in the production of sex hormone and its receptors (Jing et al., 2019). Prolonged non-stimulated photoperiod causes photo-refractoriness and may impair reproductive functions (Soni et al., 2021). In the previous study on Coturnix quail, when immature Quail having both sexes were exposed to 12 hours or more hours of light within 24 hours, it resulted in the increased growth and maturity in male testicles, ovaries, and oviduct. However, a non-stimulatory light period of fewer than 12 hours (per day) resulted in delayed sexual maturity and impaired reproduction (Wilson et al., 1966; Tanaka et al., 1966; Soni et al., 2021) causes the decreased size of testicles, ovary, and oviduct.

The main purpose of this experiment was to find the effects of artificial photoperiod on the growth and development of the reproductive organs in Japanese Quail. In addition to this, our goal is also to find the best artificial photoperiod in a reproductive and fertility standpoint of view.

Materials and methods

Experimental Birds

150 Japanese quails were used in this study by Dr. Andrew Benson at UGA Poultry Science Research Center. Japanese Quail were grown in a battery cages housing system from Day 1 to seven weeks of age (WOA). They were raised under proper brooding conditions and provided with unlimited access to food

and water supply. There were three treatments in which males and female Quail were kept. Sex was determined by observing the breast color and speckle. The bird with speckled breast was female, while the orange breast was male Quail. Each treatment comprises 50 birds (25 male and 25 female). To distinguish them from each other, Three different color bands [Red (R), Orange(O), and Yellow (Y)] were used in their legs. Each color was assumed as a treatment. In the treatment A, birds having Red band were maintained under non-stimulatory light condition for 7 weeks while in the treatment C, birds with Orange band were provided with stimulatory light condition for 7 weeks. In a similar way, in the treatment B, birds with Yellow band were kept in a non- stimulatory light condition for the first 5 weeks and then, they were moved to a stimulatory light condition for additional 2 weeks. This research was carried under the observation of the Institutional Animal Care and Use Committee (IACUC) and University Research Animal Resources (URAR).

Figure 1. Male and female Japanese Quail with bands on their legs. Treatment A, B, and C were provided with red, yellow, and orange bands, respectively, in their legs.

Lightening Paradigm

A single room at UGA Poultry Science Research Center was divided into three different optically isolated partitions. Each partition was treated as a treatment in which treatment A was provided with 6 hours of light or 18 hours of dark, which is also called non-stimulatory light condition (Darkroom), while treatment C was provided with 18 hours light and 6 hours dark (Lightroom) is also called stimulatory condition. In addition to this, treatment B was provided first with five weeks non-stimulatory light condition and then two weeks stimulatory light condition. Similarly, in treatment A, the light always turns on at 9 am and goes off at 3 pm, while in treatment C, lights get turned on at 6 am and go off at midnight. In a similar way, treatment B had the same lightning period as treatment A for the first five weeks and later set up the lightning period as treatment C for the remaining two weeks. LED lights were used in this experiment with the same intensity (5 lux) (Molino et al., 2015) in all treatments.

Measurement of body weight, male testis, female ovaries, and oviduct

After the Quail was reached 7 WOA, they were euthanized by using CO_2 gas at the Poultry Science building laboratory. A 0.001g precision balance lab scale and a digital scale were used. First, each male and female of different treatment were weighed and recorded. After measuring weight, all birds' abdominal cavity was opened with the help of scissors. In male Quail, testis was taken out, and testicular weight was measured. In females, the ovaries and oviduct were taken out gently and measured using a 0.001g precision balance lab scale. All the weight obtained from male and female reproductive organs is recorded according to different treatments.

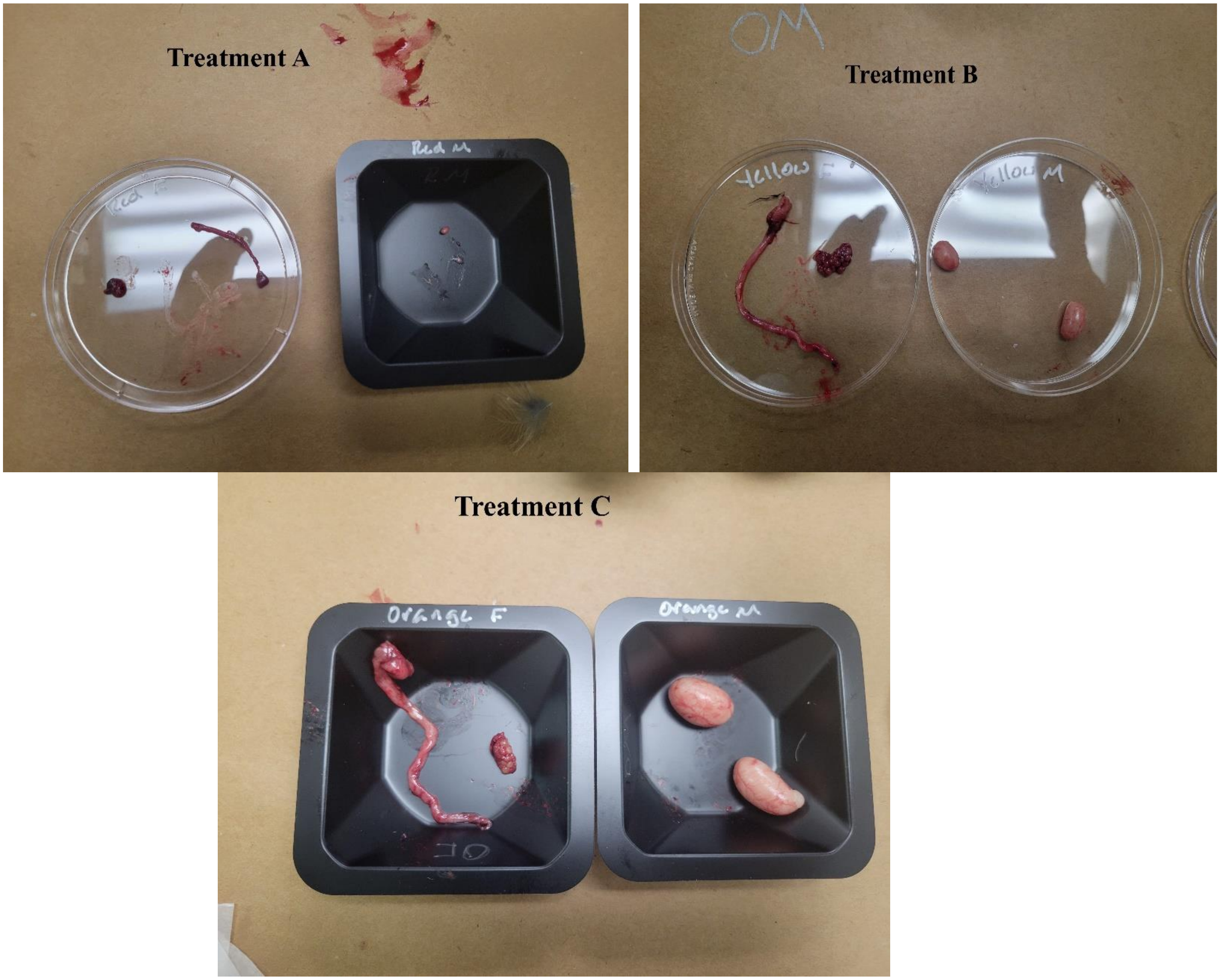

Figure 2. Different treatments have different shape, size, and weight reproductive organs. Treatment C was having the largest size ovary, testes, and oviduct, while Treatment A consisted of smallest size ovary, oviduct, and testes

Data analysis

The data entry was done in excel. Data analysis plots were visualized using Python 3.7 (Python for Data Science). Descriptive statistics were performed for calculation of average in body weight, testes, ovary, and oviduct.

Result

Overall, stimulatory photoperiod in Treatment C during 7 WOA had resulted in increased weight of testes, ovary, and oviduct, among other treatments. However, bodyweight is found to be least in Treatment C. The mixture of stimulatory and non-stimulatory photoperiod (Treatment B) showed increased body weight in both sexes. Among both sexes, the bodyweight of females was found to be higher than the bodyweight of males. In addition to this, Treatment C was found to have the least body weight, as shown in figure 2, which is because of continuous stimulatory photoperiod. Detailed results for the average weight of testes, ovaries, and oviducts compared to body weight among each treatment were presented in the following graphs.

Body weight

Japanese quail body weight was found significantly higher in Treatment B, while least in Treatment C. In each treatment, Females had more bodyweight in comparison to bodyweight of males. The average body weight of males in Treatment A, B, and C was found to be 219.4 grams, 233.48 grams, and 220.45 grams, respectively. However, the average body weight of females in Treatment A, B, and C were found to be 237.46 grams, 251.2 grams, and 244.48 grams, respectively.

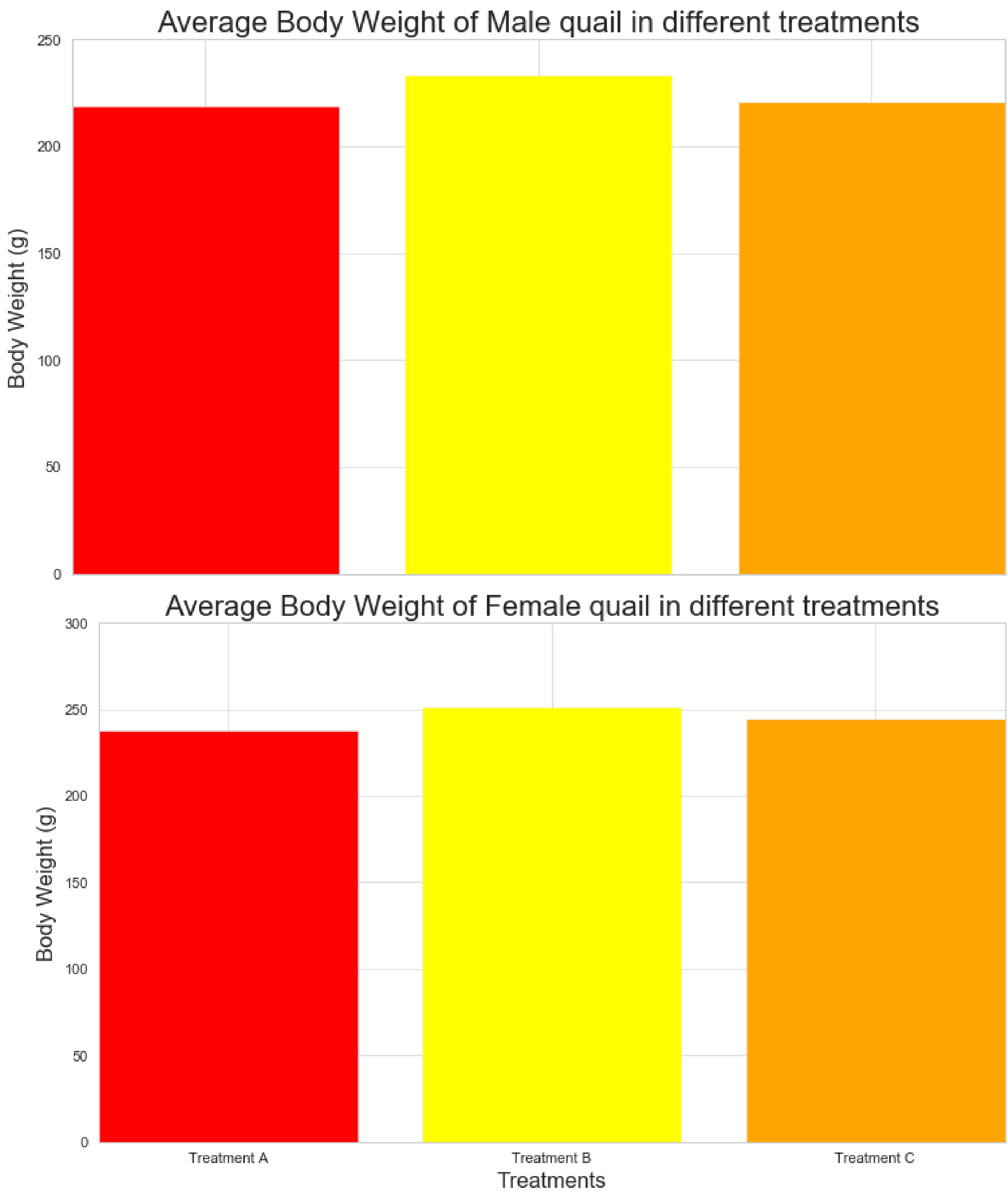

Figure 3. Average weight of male and female Quail in the Treatment A, B, and C. It shows that the females were having the highest weight in comparison to males. Treatment B reflects the highest body weight of males and females while Treatment C had the least.

Testicular weight

Paired testes average weight from each treatment was found to be highest in Treatment C (3.35 grams) but lowest in Treatment A (0.141 grams). Average testes weight of 2.04 grams was found in Treatment B because of the later stimulatory photoperiod of 2 weeks. It was also found that Quail having the highest body weight does not show that it have larger testes. In male Quail, average body weight in treatment A, B, and C was 219.4 grams, 233.48 grams, and 220.45 grams, respectively. From the data collected, we can observe that testes weight in males was indirectly proportional to body weight during the photoperiod.

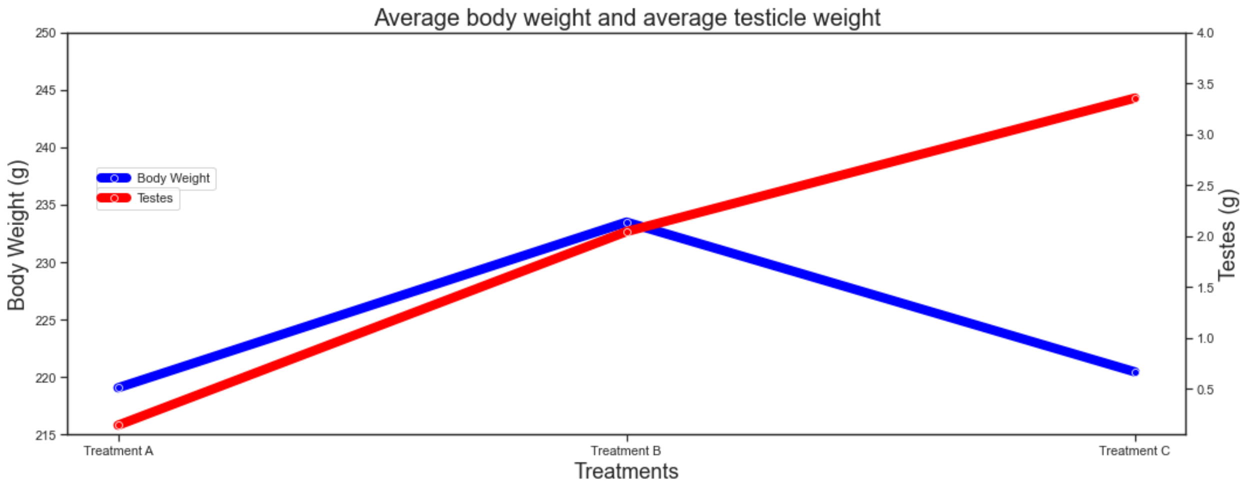

Figure 4. Treatment C showed big size and weight testicles compared to Treatment A and B because Treatment C was exposed to a stimulatory photoperiod. Treatment A was results in small sized testicles because of non-stimulatory photoperiod.

Figure 5. Comparing average body weight of male Quail with average testes weight

Ovary weight

The ovary size and weight of Japanese Quail were observed differences in the different treatments. As stimulated photoperiod results in higher production of the reproductive hormone, which causes an increased in ovary size. The ovary size in Treatment C was found to be larger than Treatment A and B. Treatment C had the highest average ovary weight of 1.17 grams. However, the least average ovary weight was observed in Treatment A (0.11 grams). Treatment B had the highest average ovary weight (0.58 grams) than Treatment A but lower than Treatment C. In addition to this, the average body weight in Treatment B (251.2 grams) was found to be higher than the Treatment A (237.46 grams) and C (244.48 grams).

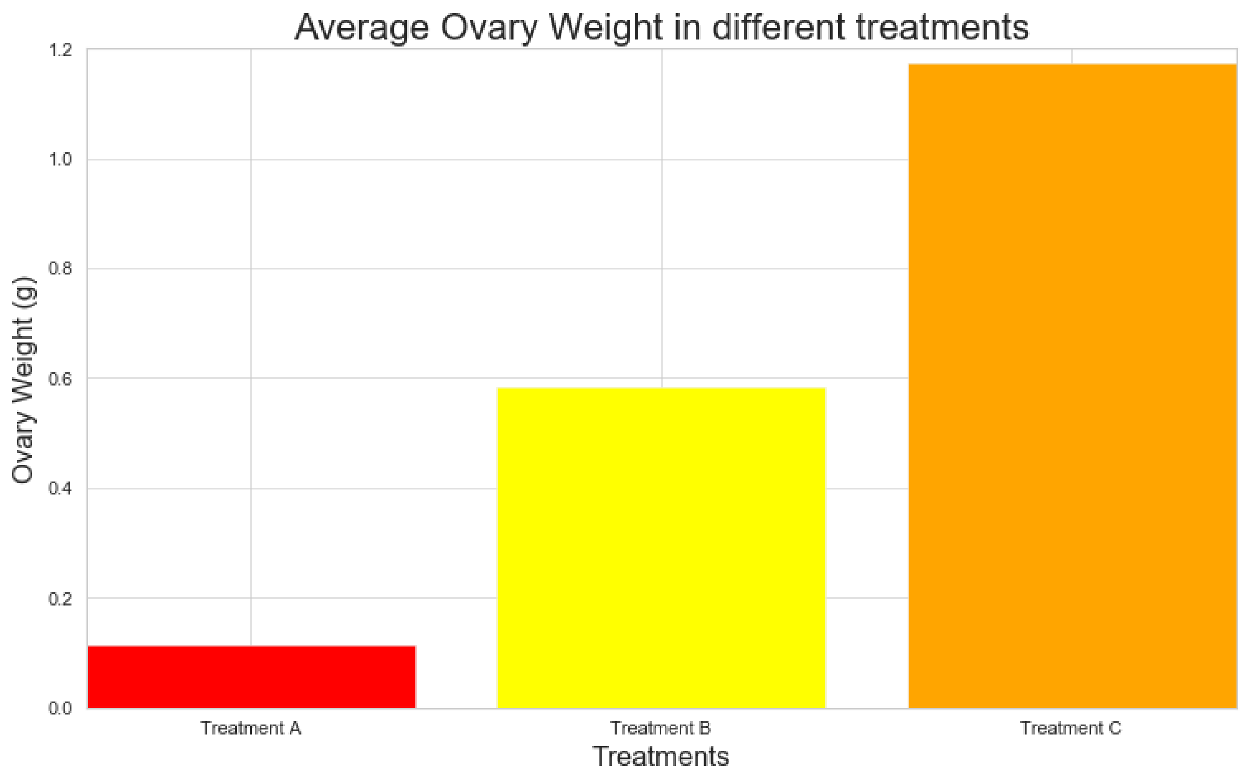

Figure 6. Various ovary sizes and weights in Japanese Quail according to different treatments provided. Treatment C shows the greatest size and weight of ovaries, while Treatment A shows the smallest size and weight ovaries.

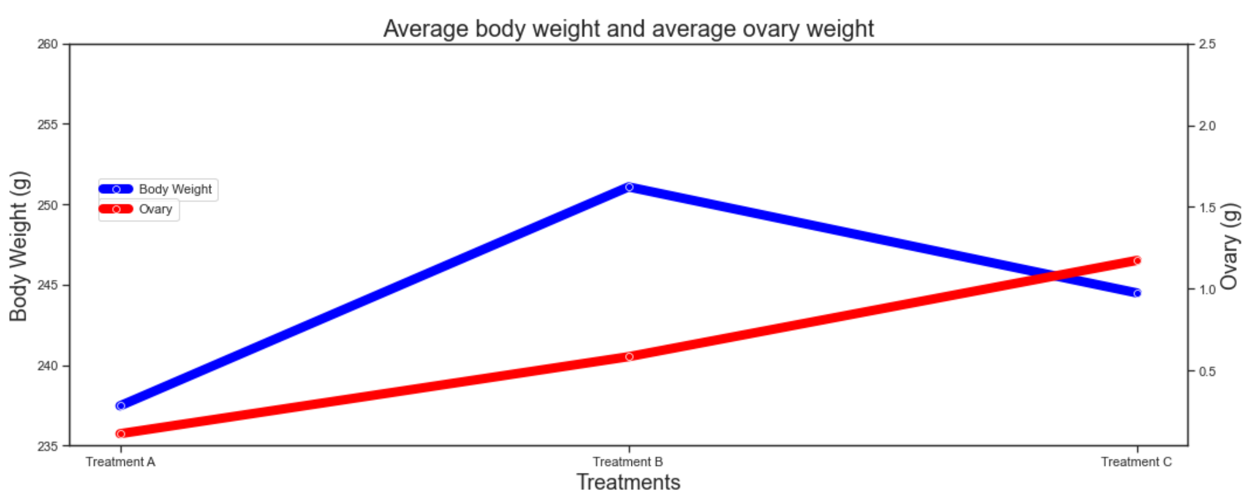

Figure 7. Comparing average body weight of female Quail with average ovary weight

Oviduct Weight

Oviduct size increases when there is higher production of sex hormone and thus, a stimulated photoperiod of 16 hours per day stimulates sex hormone production by activating the HPG axis. Treatment C had stimulated photoperiod, so it resulted in increased size and weight oviduct (2.03 grams) than other treatments. Treatment A had the least oviduct weight (0.05 grams) because of the non-stimulated photoperiod.

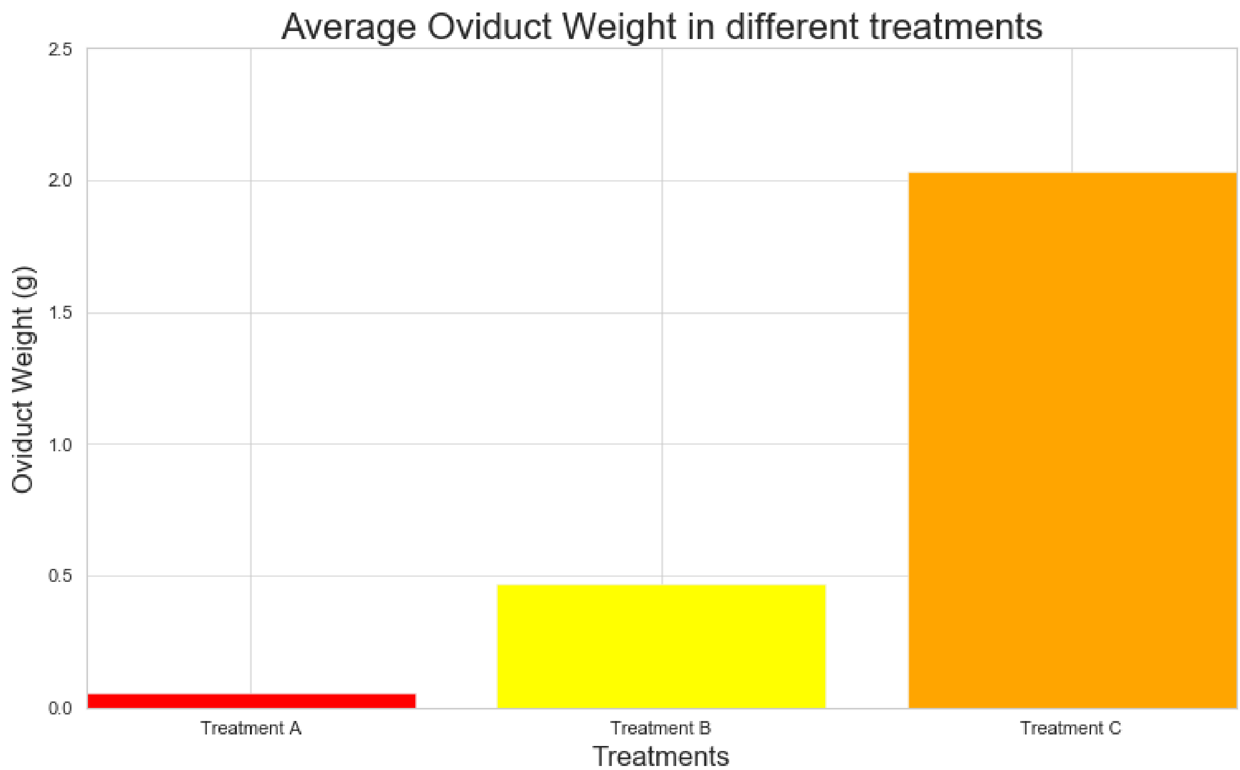

Figure 6. Different size and weight oviducts in different treatments. Treatment C had oviduct with largest size and weight, while Treatment A had small oviduct size and weight.

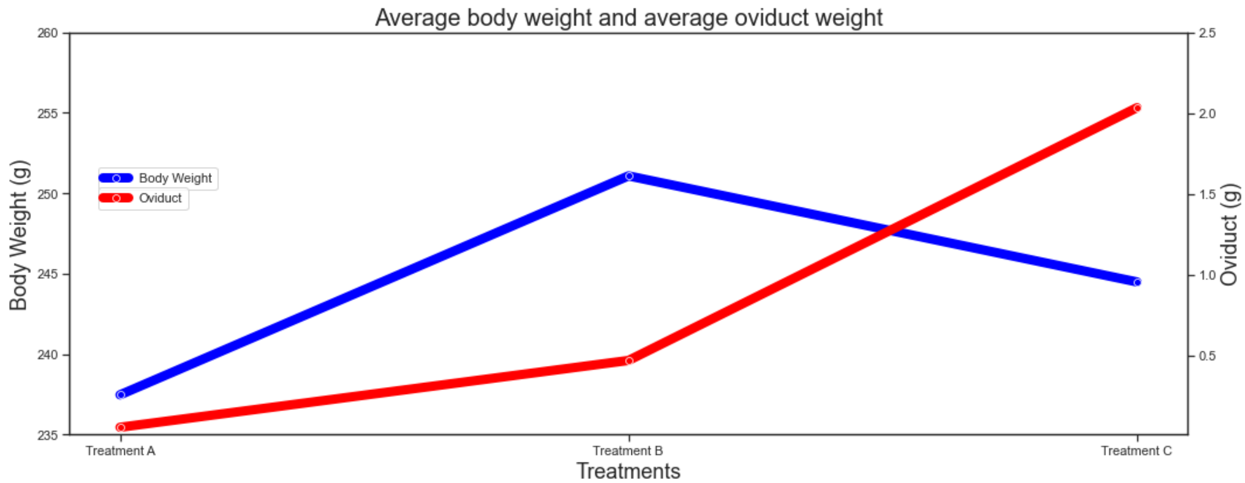

Figure 8. Comparing average body weight of female Quail with average oviduct weight

Discussion

Photoperiod plays an important role in increasing productivity by increasing growth performance and development of reproductive parts (Chen et al., 2007; Wang et al., 2019). Increase in photoperiod stimulates HPG axis to regulate the production of reproductive hormones which include FSH, LH, progesterone, androgen, and estrogen (Wang et al., 2019). Thus, produced reproductive hormones not only help in development of testes, ovary and oviducts but also play a vital role in the production and development of follicles. Wang et al. (2019) found that the photoperiod of over 16 hours resulted in higher production of FSH and LH. FSH and LH helps in development of follicles as well as reproductive organs. Development of ovarian follicles increases egg mass which causes higher egg production. In addition to this, reproductive hormones increase the size and weight of ovary, oviduct, and testes. Similarly, in our experiment, we found that the treatment with a stimulated light period of 16 hours shows great increase in size & weight of testis, ovary as well as oviducts. However, non-stimulatory light conditions of 6 hours light resulted in the smallest size and weight testes, ovary & oviduct. Decreased in photoperiod causes the secretion of an increased amount of melatonin from pineal gland. Melatonin stimulates hypothalamus to promote the production of GnIH and inhibit the synthesis of GnRH. GnIH not only inhibits follicular development but also affects the growth and development of reproductive organs. Thus, they have decreased the size and weight of reproductive hormones. The change occurs in the growth and development of follicles and reproductive organs when Quail moved from non-stimulated light condition to simulated light condition. The growth and development which was inhibited gets turned on as the photoperiod increases. Thus, photo refractoriness change into juvenile photo refractoriness as soon as photoperiod increases in long day like Japanese Quail.

Conclusion

This experiment on photoperiods proved that different photoperiods have different effects on reproductive organs and follicles. As photoperiod increases, reproductive growth and performance also increases. Quail under stimulated light photoperiod of 16 hours light or 8 hours dark period shows a significant increase in weight and size of reproductive organs. However, Quail was exposed to a non-stimulated light condition of 8 hours light or 16 hours dark period resulting in least weight and size of reproductive organs. Thus, stimulated light condition was found to be the best photoperiod for the early maturation, ovarian morphological development, testicular growth, and reproductive hormone secretion in Japanese Quail. In addition to this, further research must be conducted to find the effects of different kinds of artificial lightning on reproduction, genetics, growth performance, and nutrition in Japanese Quail.

References

- Abdou, F. H., Fiky, A. E., Elewa, E. A., & Mahmoud, A. T. A. (2021). Effect Of Using Color Light Emitting Diodeon Some Physiological Parameters In Two Strains Of Broilers. Menoufia Journal Of Animal Poultry And Fish Production, 5(3), 37-54.
- Benstaali, C., Mailloux, A., Bogdan, A., Auzeby, A., & Touitou, Y. (2001). Circadian Rhythms Of Body Temperature And Motor Activity In Rodents: Their Relationships With The Light-Dark Cycle. Life Sciences, 68(24), 2645-2656.

- Chen, H., Huang, R. L., Zhang, H. X., Di, K. Q., Pan, D., & Hou, Y. G. (2007). Effects Of Photoperiod On Ovarian Morphology And Carcass Traits At Sexual Maturity In Pullets. Poultry Science, 86(5), 917-920.
- Cui, Y. M., Wang, J., Hai-Jun, Z., Feng, J., Wu, S. G., & Qi, G. H. (2019). Effect Of Photoperiod On Ovarian Morphology, Reproductive Hormone Secretion, And Hormone Receptor Mrna Expression In Layer Ducks During The Pullet Phase. Poultry Science, 98(6), 2439-2447.
- Cui, Y. M., Wang, J., Hai-Jun, Z., Feng, J., Wu, S. G., & Qi, G. H. (2019). Effect Of Photoperiod On Ovarian Morphology, Reproductive Hormone Secretion, And Hormone Receptor Mrna Expression In Layer Ducks During The Pullet Phase. Poultry Science, 98(6), 2439-2447.
- Hernandez, A. G., & Bahr, J. M. (2003). Role Of Fsh And Epidermal Growth Factor (Egf) In The Initiation Of Steroidogenesis In Granulosa Cells Associated With Follicular Selection In Chicken Ovaries. Reproduction-Cambridge-, 125(5), 683-691.
- Juss, T. S., Meddle, S. L., Servant, R. S., & King, V. M. (1993). Melatonin And Photoperiodic Time Measurement In Japanese Quail (Coturnix Coturnix Japonica). Proceedings Of The Royal Society Of London. Series B: Biological Sciences, 254(1339), 21-28.
- Lewis, P. D. (2009). Photoperiod And Control Of Breeding. Biology Of Breeding Poultry, 29, 243-260.
- Lewis, P. D., & Morris, T. R. (2000). Poultry And Coloured Light. World's Poultry Science Journal, 56(3), 189-207.
- Lewis, P. D., & Morris, T. R. (2000). Poultry And Coloured Light. World's Poultry Science Journal, 56(3), 189-207.
- Mitchell, M. E. (1970). Treatment Of Hypophysectomized Hens With Partially Purified Avian Fsh. Reproduction, 22(2), 233-241.
- Molino, A. B., Garcia, E. A., Santos, G. C., Vieira Filho, J. A., Baldo, G. A. A., & Paz, I. A. (2015). Photostimulation Of Japanese Quail. Poultry Science, 94(2), 156-161.
- Molino, A. B., Garcia, E. A., Santos, G. C., Vieira Filho, J. A., Baldo, G. A. A., & Paz, I. A. (2015). Photostimulation Of Japanese Quail. Poultry Science, 94(2), 156-161.
- Parvin, R., Mushtaq, M. M. H., Kim, M. J., & Choi, H. C. (2014). Light Emitting Diode (Led) As A Source Of Monochromatic Light: A Novel Lighting Approach For Behaviour, Physiology And Welfare Of Poultry. World's Poultry Science Journal, 70(3), 543-556.

- Patel, S. J., Patel, A. S., Patel, M. D., & Patel, J. H. (2016). Significance Of Light In Poultry Production: A Review. Advances In Life Sciences, 5(4), 1154-1160.
- Perfito, N., Guardado, D., Williams, T. D., & Bentley, G. E. (2015). Social Cues Regulate Reciprocal Switching Of Hypothalamic Dio2/Dio3 And The Transition Into Final Follicle Maturation In European Starlings (Sturnus Vulgaris). Endocrinology, 156(2), 694-706.
- Scanes, C. G., Butler, L. D., & Kidd, M. T. (2020). Reproductive Management Of Poultry. In Animal Agriculture (Pp. 349-366).
- Sharideh, H., & Zaghari, M. (2021, March). Effect Of Dietary L-Tryptophan Supplementation And Light-Emitting Diodes On Growth And Immune Response Of Broilers. In Veterinary Research Forum (Vol. 12, No. 1, Pp. 63-67). Faculty Of Veterinary Medicine, Urmia University.
- Shi, L., Li, Y., Sun, Y., & Chen, J. (2018). Research Progress On The Regulatory Mechanism Of Lighting Schedule Affecting The Reproduction Performance Of Chickens. Scientia Agricultura Sinica, 51(16), 3191-3200.
- Soni, R., Haldar, C., & Chaturvedi, C. M. (2021). Retinal And Extra-Retinal Photoreceptor Responses And Reproductive Performance Of Japanese Quail (Coturnix Coturnix Japonica) Following Exposure To Different Photoperiodic Regime. General And Comparative Endocrinology, 302, 113667.
- Tanaka, K., Wilson, W. O., Mather, F. B., & Mcfarland, L. Z. (1966). Diurnal Variation In Gonadotropic Potency Of The Adenohypophysis Of Japanese Quail (Coturnix Coturnix Japonica). General And Comparative Endocrinology, 6(1), 1-4.
- Wilson, W. O., Abplanalp, H., & Arrington, L. (1962). Sexual Development Of Coturnix As Affected By Changes In Photoperiods. Poultry Science, 41(1), 17-22.