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Comparative study of testicular function in two races of *Gallus gallus domesticus*: the local and commercial race.

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Abstract

Poultry production in Algeria is experiencing real development in order to ensure self-satisfaction with table eggs and white meat. As a result, poultry farming has moved from a traditional production system to an intensive production system. The present study aims primarily to compare the testicular activity in two races of Gallus gallus domesticus, namely the local race (with a traditional diet) and the commercial race (with an improved intensive diet). In order to carry out this work, twenty-four adult male chickens (cocks or roosters) were divided into three batches, with eight chickens in each batch. The first batch contains chicken intended for broiler production, the second batch includes male chicken for reproduction, and the third one comprises local farm male chickens. Once the animals are bled, the blood is collected in heparinized tubes in order to measure testosterone levels. The reproductive organs, which are composed of the testicles, epididymides, and vas deferens, are then removed, weighed, and fixed in 10% formalin, for a topographic histological study. The results obtained showed that the weight of the testicle, epididymis, and vas deferens of farm and reproductive male chickens is higher than that of the meat rooster. In addition, it turned out that the structural aspect of the testicle was different from one batch to the other. Indeed, in farm and reproductive male chickens, the seminiferous tubules of the testicles are quite voluminous, and the spermatozoa are released into the lumen of the seminiferous tubules, with the presence of all the cell types of the germline in the seminiferous epithelium. It should also be added that, in male chickens grown for meat production, the seminiferous tubules are of reduced size, with a central lumen devoid of spermatozoa. In addition, the testosterone in farm and reproductive male chickens is higher than that of male chickens grown for meat production. It should be noted that rapid growth, induced by intensive feeding, should lead to obesity in selected individuals. Moreover, the reduction of the photoperiod is often accompanied by an alteration in reproductive capacities.
Keywords: Farm Rooster; production cock; breeding rooster; Testicles; Germline; Testosterone.

الملخص

يشهد إنتاج الدواجن في الجزائر تطوراً حقيقياً من أجل ضمان الاكتفاء الذاتي في بيض المائدة واللحوم البيضاء. نتيجة لذلك، انتقلت تربية الدواجن من نظام الإنتاج التقليدي إلى نظام الإنتاج المكثف. تهدف هذه الدراسة في المقام الأول إلى مقارنة نشاط الخصيتين في سلالتين من الديوك، العرق المحلي (مع نظام غذائي تقليدي) والعرق التجاري (مع نظام غذائي مكثف محسن). من أجل القيام بهذا العمل تم تقسيم أربعة وعشرين ديك إلى ثلاث دفعات، مع ثمانية ديوك في كل دفعة. تحتوي الدفعة الأولى على ديوك مخصص لإنتاج الفروج، أما الدفعة الثانية فتشمل ديوك للتكاثر، والثالثة تحتوي على ديوك مزرعة محلية. بمجرد نزف الحيوانات، يتم جمع الدم في أنابيب الهيبارين لقياس مستويات هرمون التستوستيرون. يتم بعد ذلك إزالة الأعضاء التناسلية، التي تتكون من الخصيتين، البربخ والأسهر، ووزنها وتثبيتها في 10٪ فورمالين، لإجراء دراسة نسيجية طبوغرافية. أظهرت النتائج التي تم الحصول عليها أن وزن الخصية والبربخ والأسهر في الديوك المزروعة للتكاثر أعلى من وزنه في ديوك اللحم. بالإضافة إلى ذلك، اتضح أن الجانب الهيكلي للخصية كان مختلفًا من دفعة إلى أخرى. في الواقع، في ديك المزرعة المحلية والديك التناسلي، تكون الأنابيب المنوية للخصيتين ضخمة جدًا، ويتم إطلاق الحيوانات المنوية في تجويف الأنابيب المنوية، مع وجود جميع أنواع الخلايا التناسلية في الظهارة المنوية. بالمقابل في الديوك المزروع لإنتاج اللحوم، تكون الأنابيب المنوية ذات حجم صغير، مع تجويف مركزي خالٍ من الحيوانات المنوية. بالإضافة إلى ذلك، فإن هرمون التستوستيرون بالنسبة لديوك المزروعة لتكاثر أعلى من ديوك المزروع لإنتاج اللحوم. تجدر الإشارة

إلى أن النمو السريع الناجم عن التغذية المكثفة من شأنه أن يؤدي إلى السمنة، علاوة على ذلك، غالبًا ما يكون تقليل الفترة الضوئية مصحوبًا بتغيير في القدرات الإنجابية.
الكلمات الرئيسية: ديك المزرعة، ديك الإنتاج، ديك التكاثر، الخصيتين، التستوستيرون.

Introduction

The world's poultry resources, mainly chickens, are the most ideal and economically dominant avian species, especially in rural areas of developing countries, as they are much easier to manage (Malvika *et al.,* 2019; Ouennes 2021). It is widely acknowledged that the domestic chicken (*Gallus gallus domesticus*) emigrated from the Far East and quickly adapted to diverse ecosystems around the world (Sonaiya *et al.*, 2004; Ouennes 2021). During antiquity, the rooster was revered and considered a cultural and symbolic animal. It was only around the Middle Ages that poultry became commercially important as a source of eggs and meat production (Leroy *et al.,* 2003). It is a well-known fact that poultry constitutes an appreciable and economical source of animal protein, particularly for developing countries, which has amply justified its rapid development throughout the world over the past thirty years (Sahraoui *et al.,* 2015). In addition, the genetic diversity of the *Gallus gallus domesticus* species is composed of a set of populations, including experimental lineages, commercial races, and traditional races (Boudali *et al.*, 2020). It must be kept in mind that intensive selection began during the 20th century and led to the specialization of commercial strains intended either for the production of meat or for that of eggs (Larivière *et al.*, 2008; Mahammi *et al.*, 2016). It has been reported that household consumption in Algeria is characterized by a deficit in animal proteins; it is estimated at around 33 g/person/d (Kaci, 2015). This value is almost similar to that of the majority of developing countries. The population's high demand for animal proteins has led the public authorities to move towards a different meat production policy by exploiting the breeding of short-cycle species such as poultry (Ferrah, 2010). Indeed, for several years now, poultry production in Algeria has known a remarkable development that is encouraged by the enthusiasm of consumers for products of poultry origin. It is worth indicating that the production of broilers has considerably increased as a result of the significant investments made by the private and public sectors (Larabi *et al.,* 2016; Berghiche *et al.,* 2020). Consequently, poultry farming has moved from conventional farm production to a better organized and more specialized industrial production (Kaci, 2014). For economic reasons, the selection of poultry intended for the meat market was mainly based on the criterion of exacerbated growth rate of offspring. Therefore, competition between breeders has left little room for enhancing and improving other characteristics such as fertility in female and male chickens (Hocking, 2010). Based on the above, one can therefore ask the following questions:

1- *What is the effect of intensification of breeding on the reproduction of broiler chicken*?
2- *Is there a relationship between the rearing conditions and diet, on the one hand, and the age of sexual maturity, on the other?*

Answering these two questions would certainly help us to identify the effects of breeding conditions and diet on the age of sexual maturity.

The present comparative study of the testicular function of three batches of male chickens that are raised for meat production, for reproduction, and for the farm, was carried out in order to answer these two fundamental questions.

Material and methods

Animals and experimental procedure

This study focuses on the industrial breeding of male chickens (roosters) for the production of meat at the slaughter age of 7 weeks and for reproduction at the age of 37 weeks on average, with breeders from the Wilayas (Provinces) of Blida and Djelfa. This same study also concentrated on the breeding of local roosters (or free-range farm roosters bred in private homes), at an average age of 34 weeks, raised in the wild in private homes in the Wilaya of Blida. It is useful to mention that the choice of the animals considered in this work was made on the basis of their body development. For this, a total of 24 male chickens (roosters), 8 in each group, were used, as shown in Figure 1. The roosters intended for meat (RP), were reared in a chicken coop according to an intensive poultry production *system*, and were fed with a commercial fattening feed based on barley flour, wheat, maize, and meal, in order to achieve maximum meat production in a limited period of time. However, for male chickens intended for reproduction (RR), breeding is done under more specific conditions with regard to nutrition and light. Farm roosters (RF) are traditionally raised in the gardens of individual country houses, according to an extensive system; they are left free and feed on food debris (kitchen waste, crop residues, cereals, insects and greenery).

After bleeding the animals, the blood is collected in cold heparinized tubes and then centrifuged at *3000g* for *10 minutes* to collect blood plasma and to measure testosterone as well. In addition, the reproductive organs, namely the testicles, epididymis and vas deferens, on the right and left sides of the animals, were quickly removed, weighed, and then fixed in 10% formalin for a histological and topographical study.

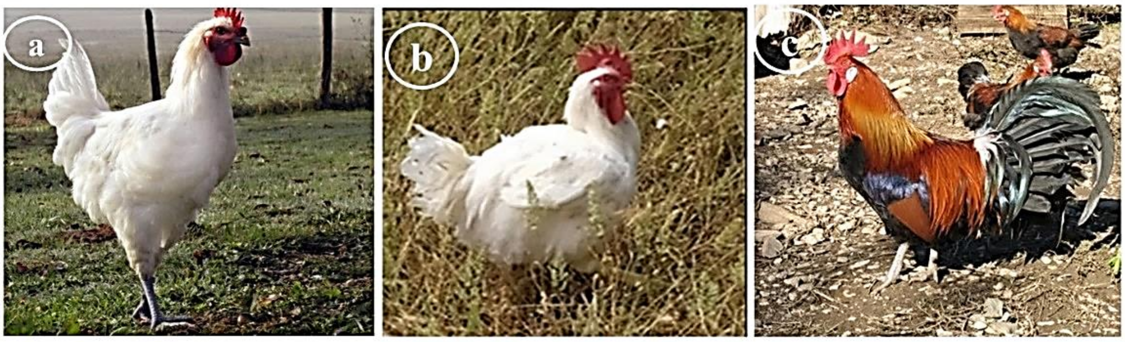

Fig. 1: Morphological aspect in *Gallus gallus domesticus*; *a: Production Roosters (RP); b: Reproduction Roosters (RR); c: Farm Roosters (RF).*

Histological technique

Once the testis, epididymis, and vas deferens were fixed, they were subjected to standard histological techniques such as dehydration in ethanol baths, at increasing temperatures, 70, 96, and 100 °C, impregnation and paraffin embedding. Afterward, 5 µm sections were made with a microtome; they were then rehydrated and stained with hematoxylin, eosin, and Masson's trichrome. The morphometric study was carried out using the Axion Vision image processing software, which makes it possible to measure, at the microscopic scale and for all three batches under study, various parameters on the surface of the seminiferous tubules and on that of the lumens, and also along their respective diameters. Note that the diameters and heights are measured in micrometers and the areas in μm^2.

Dosage of testosterone

The plasma testosterone concentrations were determined by electrochemiluminescence (ECLIA, Roche Diagnostics, Meylan, France) using an automatic analyzer of the Elecsys1010® type (Roche Diagnostics). The detection limit was set at 0.06 ng/mL. The intra- and inter-assay coefficients of variation were 1 and 3%. In addition, very weak cross reactions were observed, noting that the main steroids are likely to interfere with the dosage (percentages lower than 1%). These criteria testify to the validity of the assay used.

Statistical analysis

The results obtained are presented in the form of means ± SEM (Standard Error of the Mean). After data collection, Shapiro Wilk tests were applied to verify normality and equality of variances. The GraphPad PRISM Trial version software was used to plot the graphical representations. The statistical significance of the differences was calculated by the statistical meaning of the comparisons was calculated by the one-way analysis of variance (ANOVA) technique using the SPSS version 23. The Tukey test was used for the post hoc comparison between the experimental groups. The significance of the differences was kept at the rate of 5%.

Results

Weight parameters

It was found that the live body weight of the reproduction rooster was higher than that of the rooster for meat production (31.094%, $p = 0.0027$) and that of the farm rooster (113.3%, $p = 8.406\ 10^{-8}$). In addition, the live weight of the farm rooster was lower than that of the rooster for meat production (-38.544%; $p = 0.00031$), as can be seen in table 1. Further, it was found that the testicular weight of the male chicken for reproduction was higher compared to that of the rooster raised for meat production (2108%, $p = 0.002$) but lower than that of the farm rooster (88.12%, $p = 0.0043$). Moreover, this testicular weight in the farm rooster was higher than that of the rooster intended for meat production (4062%, $p = 6.195\ 10^{-7}$). Similarly, the weight of the epididymis in the reproduction rooster was higher than that of the male chicken for meat production (241%, $p = 0.008$) but it was lower than that of the farm rooster (-41%, p

= 0.00018). In addition, this weight was higher in the farm rooster than in the rooster (482%, p = 5.59 10^{-7}). Likewise, the weight of the vas deferens in the reproduction rooster was higher than in the meat rooster (188.05%, p = 0.00018) but lower in the farm rooster (-48%, p = 0.165 10^{-6}). In addition, table 1 indicates that this weight was higher in the farm rooster than in roosters raised for meat production (450%, p = 6.68 10^{-9}).

Table 1: Body and Reproductive tract weight in *Gallus gallus domesticus.*

Breed			**Production roosters**	**Reproduction roosters**	**Farm roosters**
Body weight		(Kg)	2.9±0.2	3.8±0.2 ^{aaa}	1.8±0.1$^{aaa ;bb}$
Testicular weight	RT+LT	(g)	1.2±0.7	29.1±2.8^{aa}	28.1±5.0$^{aaa ; bbb}$
		(g /100gp.c)	36.8±6.0	811.6±107.9^{aa}	1529.7±217.2$^{aaa ; bbb}$
Epididymal weight	RE+LE	(g)	0.15±0.007	0.64±0.13^{aa}	0.58±0.02$^{aaa ;bbb}$
		(g /100gp.c)	5.6±0.6	16.7±3.2 ^{aa}	32.9±1.4 $^{aaa ; bbb}$
Vas deferent weight	RVd+LVd	(g)	0.28±0.02	1.10±0.19^{aaa}	1.00±0.06$^{aaa ; bbb}$
		g /100gp.c)	10.3±1,6	29.7±2.7^{aaa}	56.7±3.0 $^{aaa ; bbb}$

LT: Left Testicular; RT: Right Testicular; LE= Left Epididymal; RE= Right Epididymal; LV= Left Vas deferent; RV= Right Vas deferenta vs RP; b vs RR, p = $^{aa, bb}$ = p<0.01; p = $^{aaa, bbb}$ = p<0.001

Anatomical organization of the male reproductive system

Figure 2 shows the macroscopic appearance of the reproductive system in the three groups of roosters.

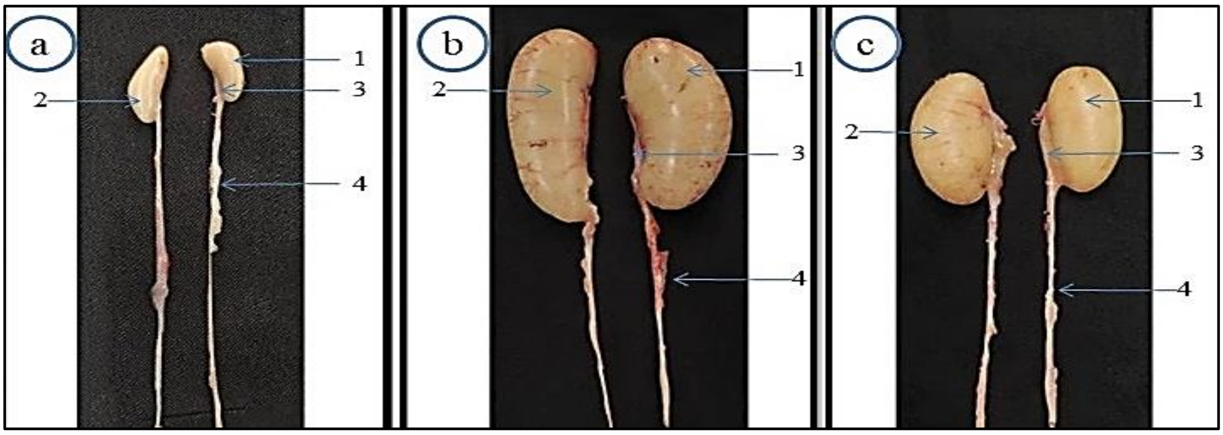

Fig 2. Anatomy of the reproductive tract of the male *Gallus gallus domesticus (a: Production Roosters; b: Reproduction Roosters; c: Farm Roosters; 1: right testis; 2: left testis; 3: epididymis; 4: vas deferens).*

Study of microscopic parameters
Structure of the testicle

Microscopic observation at low magnification (Gx10) shows the presence of two compartments in the testicular parenchyma, a tubular compartment grouping together the seminiferous tubules, which are quite voluminous in the farm rooster (Figure 3c), and the reproduction rooster (Figure 3b), which shows a well-developed lumen and an interstitial space that separates the seminiferous tubules. On the other hand, the rooster grown for meat production (Figure 3a), shows that these seminiferous tubules are quite small and very close to each other, with a reduced central lumen that is sometimes absent.

At medium magnification (Gx40), the wall of the seminiferous tubules in the farm rooster and the reproduction rooster exhibits Sertoli cells that are organized into a single layer of giant cells. They support all the germ cells. The central lumen is small in size and is occupied by spermatozoids. The basal lamina surrounding the seminiferous tubule has spindle cells, commonly called *peritubular myoid cells*. Furthermore, figure 4 (b, c) clearly depicts that the seminiferous tubules are separated by an interstitial tissue that contains the connective tissue where the Leydig cells are. However, in the rooster for meat production, the seminiferous tubules are surrounded by a basal lamina with lumen primordia that is well visible and boarded by seminiferous epithelium. These seminiferous tubules are separated from each other by an interstitial tissue that contains the connective tissue in which the Leydig cells are disseminated, as illustrated in Figure 4 (a).

Fig. 3: Histological micrographs showing seminiferous tubules in *Gallus gallus domesticus* (a– c) 10 magnifications, regressing seminiferous tubules (a), normally forming seminiferous tubules (b and c), Tunica Albuginea (TA), Interstitial Space (IS), a: Production Roosters (RP), b: Reproduction Roosters (RR) and c: Farm Roosters (RF); scale bar: 100 μm).

Further, it is worth indicating that microscopic observation, at the highest magnification (Gx100), shows that the seminiferous epithelium, in the farm rooster and the reproduction rooster, is well differentiated, with all the *germline* stem cells (spermatogonia, spermatocytes, spermatids, and spermatozoa), thus testifying to active spermatogenesis, as shown in figure 4 (e, f). The seminiferous epithelium of broiler-producing roosters consists of spermatogonia which occupies the entire surface that contains the germ cells. Figure 4 (d) shows the presence of a large lumen and empty space.

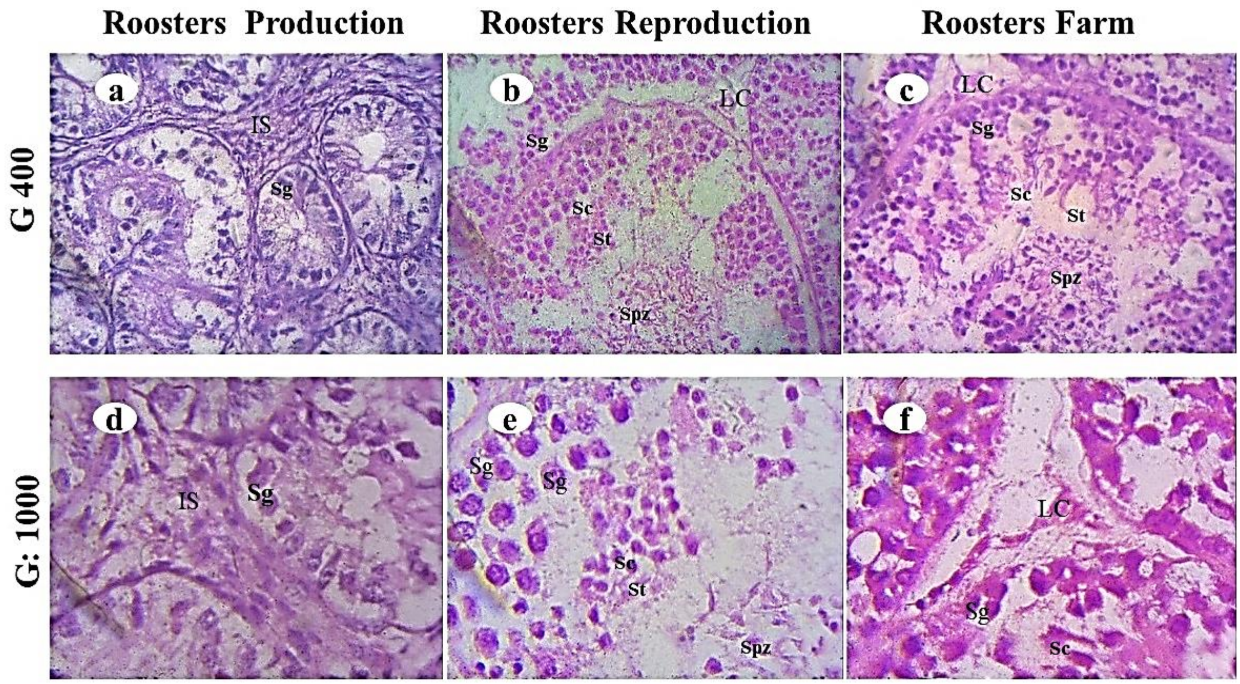

Fig. 4: Histological micrographs showing seminiferous tubules in *Gallus gallus domesticus* ((a–c) 400 magnifications, (d–f) 1000 magnification. Regressing seminiferous tubules (a), normally forming seminiferous tubules (b and c), a: Production Roosters (RP), Reproduction Roosters (RR) and c: Farm Roosters (RF); Seminiferous Tubules (ST), Intertubular Space (IS), forming seminiferous tubules with unclear delimitations of their features (*), Lumen (Lm), Blood Vessels (BV), Sertoli cells (S), Spermatogonia (Sg), Leydig Cells (LC), Spermatocytes (St), Basement membrane (Bm). scale bar: 10 μm).

The morphometric study whose results are presented in Figure 5 (a-c) shows that, in reproduction cocks, the surface of the seminiferous tubules and that of their lumens are higher than those found in meat production roosters. The respective values obtained are 679.1%, p = 510^{-9}, and 1019.2%, p = 5 10^{-9}. However, there is practically no difference compared to the farm rooster (-5.0003%, p = 0.789 and 2.6%, p = 0.964 for the seminiferous tubules and their lumens, respectively). The surface of these tubules in the farm rooster is higher than in the meat production rooster (640.2%, p = 5 10^{-9}). The same findings were observed for the lumen (1047.9%, p = 5 10^{-9}).

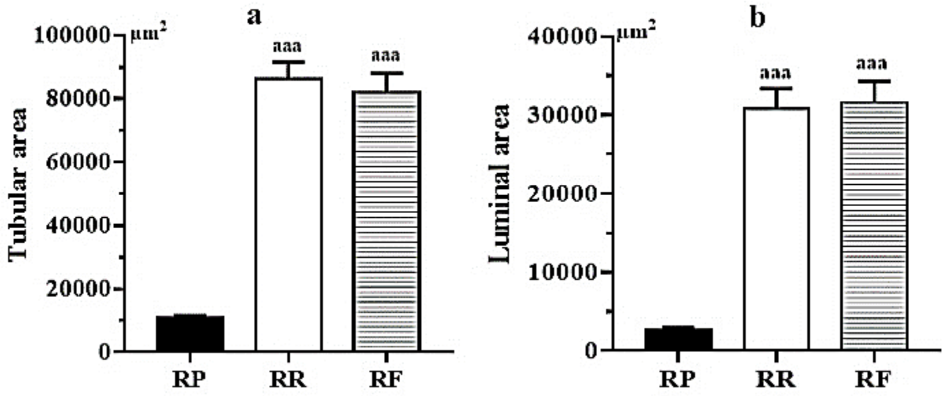

Fig. 5: Variation of seminiferous tubules surface, light surface (a: Tubular area; b: Luminal area; RP: Production Roosters; RR: Reproduction Roosters; RF: Farm Roosters (RF); p = [aa] p<0.01; p = [aaa] p<0.001).

Evaluation of plasma testosterone level

It was found that the average plasma testosterone level in the reproduction rooster was higher than that of meat production rooster (0.23 ± 0.03 ng/mL vs. 0.03 ± 0.004 ng/mL, which corresponds to 621.7%, p = 0.0016), but it is lower than that of the farm rooster (0.23 ± 0.03 ng/mL vs. 0.34±0.05 ng/mL, which corresponds to -30.2%, p = 0.1184). In addition, the average plasma testosterone level in farm roosters was higher than that of meat roosters (0.34 ± 0.05 ng/mL vs. 0.03±0.004 ng/mL, which corresponds to 934.8 %, p = 0.000018), as can be seen in figure 6.

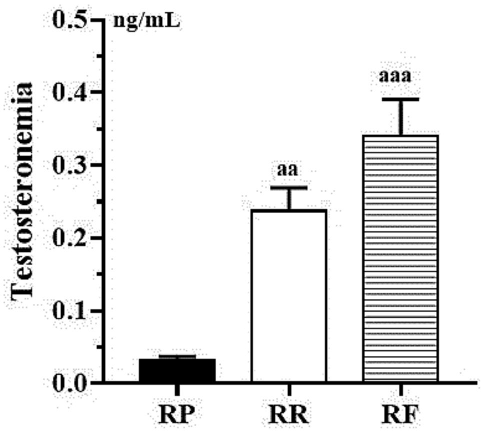

Fig. 6: Testosterone plasma level in male *Gallus gallus domesticus* (Production Roosters (RP), Reproduction Roosters (RR) and Farm Roosters (RF); p = [aa,] p<0.01; p = [aaa,] p<0.001).

Discussion

Reproduction in avian species represents a very specific process (Blesbois, 2018). They are oviparous species with internal gonads, and gametogenesis takes place at a high body temperature (40-42°C) (Santiago-Moreno and Blesbois, 2020). The male reproductive system of the poultry species shows some anatomical and physiological particularities compared to that of mammals. The male reproductive system of the cock (*Gallus gallus domesticus*) is relatively simpler than that of mammals (Nicaise, 2015; Masyitha *et al.*, 2021). The male gonads are represented by the two testes. Each testicle is covered by a white connective capsule, the albuginea, with blood vessels running along its surface (Mfoundou *et al.*, 2022). The testis is an organ of major endocrine and male reproductive importance and the seminiferous tubules within the testis are the principal site of spermatogenesis (Haseeb *et al.*, 2019).

The results obtained from this study show that the results of this study show that, the body weight of farm roosters from the Wilaya (Province) of Blida is similar to that of farm roosters in the Kabylie (Moula *et al.,* 2009) and eastern regions of Algeria (Ouennes *et al.,* 2019), but is different from that of farm roosters from Cameroon whose body weight can reach up to 2.5 kg (Ngou Ngoupayou, 1990; Fotsa *et al.,* 2007). Particularly high weights have been observed in meat-producing roosters for an age not exceeding 7 weeks because it must be remembered that these roosters are fast-growing animals (Mahammi *et al.,* 2016; Tamilselvan *et al.,* 2018). For economic reasons, the selection of poultry for the meat market was mainly based on the criterion of growth rate (Briere *et al.,* 2011; Liu *et al.,* 2019). The case of lines of meat roosters is typical. It is important to point out that the selection of fast-growing lines, which has been adopted for more than 60 years, made it possible to have roosters initially reaching 2 kg in 100 days (1950), then in 49 days (1985) and finally in 35 days (2007). However, this is not true for farm roosters whose growth rate is quite slow (Moula *et al.*, 2009).

Furthermore, the high testicular weight recorded in farm roosters and reproduction roosters means that their seminiferous tubules are quite developed. According to De Reviers *et al.*, (1972) and Masyitha *et al.,* (2021), the main factor in testicular weight growth in these roosters is in fact their well-developed seminiferous tubules. The obesity induced by force-feeding of the meat-producing rooster prevents the testicular weight from increasing (approximately -30% in 4 weeks), which is not the case for the farm rooster and reproduction rooster (Nir *et al.,* 1975). It should also be noted that a genetic improvement in the growth rate or body weight at a young age has a negative impact on the reproductive traits of male chickens. Negative correlations between body weight and sperm motility have been reported by Fotsa (2008). The particular testicular weights, varying from 1 to 5g, correspond, respectively, to the formation of the first spermatozoa and to the testicular development phase after which the meiosis seems to start operating with the same efficiency as in adults (De Reviers *et al.,* 1971). Note that this is a different situation even if the testicular weight of meat-producing roosters can reach approximately 2g. In addition, spermatogonia constitute the majority germ cell population; as spermatogenesis is blocked, roosters for meat production thus present a delay in sexual maturity. Moreover, the testicular growth in meat production roosters experiences a remarkable slowdown, and consequently, a late sexual maturity which sometimes cannot be reached. Therefore, an efficient selection process may lead to rapid growth and minimal energy consumption (Hocking *et al.,* 1989). According to Geraert (1991) and Mfoundou *et al.,* (2022) the development of gonads in most bird species is a sign of maturity and normal sexual activity under favorable conditions such as an adequate photoperiod. Although in poultry there is no real obesity, the overweight observed is rather associated with fast-growing lineages (meat production), which can have hyperphagic behavior, which is not the case for mammals. In addition, broiler rearing requires different lighting schedules, from initiation (one day old) to slaughter (Van Eekeren *et al.,* 2006). Be aware that light allows chicks to locate watering places and feeders or feed chains. It should also be noted that these types of chickens must remain in semi-darkness in order to reduce their activity as much as possible and thus improve their growth. In general, for broiler breeding, it is advisable to ensure high light intensity during the first days and then reduce it gradually (Sonaiya *et al.,* 2004). It should also be mentioned that in the cockerel, a reduction in the photoperiod delays the development of the testicles (Ingkasuwan *et al.,* 1966) and can even cause regression (Harrison *et al.,* 1970), which explains the low gonadal weight registered in the cockerel.

Furthermore, the observations made in the present study allowed confirming that the testicles of roosters have a bean-shaped whitish color. Each testicle is covered with a very thin white conjunctiva capsule, commonly called the *tunica albuginea*. These same observations were also reported by Walter (2007). Moreover, the histological sections revealed that the rooster testicle contains two types of parenchymal tissues, namely the interstitial tissue and the seminiferous epithelium. The seminiferous tubule is surrounded by a basal lamina containing peritubular or myoid cells. Moreover, the interior of the seminiferous tubule is lined by a seminiferous epithelium that is formed by Sertoli somatic cells and encloses germ cells. These same findings have been reported in several bird species (Zhang *et al.,* 2012; Al-Tememy 2010; Bakst *et al.,* 2007; Educagri 2005; Deviche *et al.,* 2011). In addition, the presence of all types of germline stem cells was noted in the farm rooster; they are distributed centripetally in the gonadal tubules with respect to spermatogenesis. The high number of spermatogonia, spermatocytes and spermatids testify to active spermatogenesis. It is worth indicating that a few spermatids begin to appear still attached to the Sertoli cell and spermatozoa accumulate in the central lumen of the seminiferous tubules, a sign of significant sexual activity. This observation is in agreement with those reported in the literature (De Reviers *et al.,* 1971; Lin *et al.,* 1993; Czubaszek *et al.,* 2019). However, the seminiferous epithelium of broiler roosters revealed the presence of spermatogonia which occupy almost the entire surface of the seminiferous tubule, indicating that sexual activity has not yet started. It should be noted that the lumens of the seminiferous tubules of farm roosters are very prominent and full of spermatozoa, indicating complete spermatogenesis, unlike those of broiler roosters which show empty lumen rudiments and show no spermatozoa, which confirms the absence of spermatogenesis. On the other hand, according to Nir *et al.* (1975), the onset of obesity decreases sperm production by 50% in males. This decline in fertility is accompanied by a 0.3°C increase in internal temperature. In addition, unlike mammals, birds do not have a pampiniform plexus (venous and arterial complex allowing the intra-testicular temperature to be maintained constant). It has been revealed that the increase in temperature, consecutive to the increase in energy resulting from force-feeding, would lead to an alteration in the functional state of the stem spermatogonia, thereby leading to a decrease in spermatozoa production (Briere *et al.,* 2011).

It is worth mentioning that the effect of the nutritional level on reproduction depends on the quality and quantity of food given to animals. It should be remembered that the effect of food on reproduction has been studied in several species. In this respect, it was found that a deficiency in vitamins A, D or E in ducks can cause disturbances in reproductive functions (Benoît, 1936). Similarly, a lack of protein and lipid intake can lead to more or less significant delays in the onset of sexual maturity in starlings (Bissonnette, 1933) and turkeys (Cecil, 1981). It was also revealed that *restricting turkey's* access to *foods* may lead to a more or less significant delay in testicular development (Moran *et al.,* 1983) and in sperm production without any real reduction in the live weight *of the adult animal* (Hocking, 1988). This food restriction can also be responsible for an onset of molt associated with a cessation of reproduction (Hocking, 1991).

Furthermore, chicken reproduction can be, to a large extent, controlled by the daily duration of light. By varying this duration, it becomes possible to better control the precocity of sperm production (De Revier *et al.,* 1977). In this respect, De Reviers and Brillard (1974) indicated that the daily duration of light has a non-negligible effect on the testis weight variation and spermatogenesis functioning of the male chicken. Traditionally, poultry has always lived in farms under sunlight whose spectrum differs significantly from that of light from an incandescent lamp, which generally promotes the smooth running of spermatogenesis, depending on the season. In addition, it is widely accepted that light plays an essential role in sexual maturation. An increase in daytime natural light, as is the case from mid-winter to mid-summer in temperate countries, should accelerate sexual maturity. The opposite effect also occurs if natural daytime light decreases, as takes place from mid-summer to mid-winter, which delays sexual maturity (Sonaiya *et al.,* 2004).

On the other hand, the testosterone level recorded in meat production roosters was found to be around (0.03 ± 0.004) ng/mL, whereas it was equal to (0.23 ± 0.03) ng/mL in reproduction roosters and (0.34 ± 0.05) ng/mL in farm roosters. It is important to have reference values to be able to determine the reproductive status of a bird based on the testosterone level measured because the basal testosterone level and sexual activity peak vary greatly according to bird species. The testosterone level (ng/mL) found in several species with sexual activity and inactivity, respectively, was found equal to 7.83 and 0.84 in the rooster, 3.63 and 1.35 in the ostrich, 5.60 and 0.60 in the wild turkey, 3.21 and 0.19 in the bar-headed goose, 1.24 and 0.59 in the rock pigeon, and 2.55 and 0.5 in the kestrel (Pichereau, 2012). It turned out that from 11 weeks of age, the testosterone level increases gradually from 0.25 ng/mL reaching approximately the value of 2.5 ng/mL when approaching the end of the pubescent period. The values found in the present work, for the meat production rooster, are much lower than those reported by Carrie-Lemoine *et al.* (1983) in meat roosters of the Hubbard strain. Indeed, the testosterone level detected at the 3^{rd} week was 0.10 ng/mL; then, it continued to evolve to reach 0.30 ng/ml at the 10^{th} week. The low testosterone level recorded in the meat production rooster explains the absence of gonadal development in this species. According to Briere *et al.* (2011), obesity induced by force-feeding in fast-growing lineages (meat production strain) leads to a decrease in fertility as a result of a decrease in the testicular weight, which is accompanied by a drop in the testosterone level, and probably also due to the exposure to low light intensity for a long time. It was also found that bird testes can secrete sex steroids, and in particular testosterone, under the control of *gonadotropin*-releasing *hormones* (Carrie-Lemoine *et al.,* 1983). Moreover, the secretion of luteizing hormone is responsible for the secretion of testosterone in the testicle (Sedqyar *et al.,* 2008). According to Pichereau (2012), exposure of immature birds to low intensity light reduces gonadotropin-releasing hormone (GnRH-I) secretion, resulting in low gonadotropin (LH, FSH) secretion and artificial light at night directly affected the expression of genes responsible for the secretion of endocrine reproductive hormones in the hypothalamus of tree sparrows the expression of genes responsible for the secretion of endocrine reproductive hormones in the hypothalamus of tree sparrows is directly affected (Zhang *et al.*, 2019). In addition, the orexigenic hormones (ghrelin and orexin) in meat production roosters stimulate food intake and inhibit the secretion of gonadotropins, which favors the stimulation of food intake and put the reproductive functions to rest (Furuta *et al.,* 2001).

Conclusion

For economic reasons, the poultry selection for the meat market is mainly based on the growth rate criterion. Thus, competition between breeders leaves little room for the improvement of other factors such as cock fertility. It has been found that selection based on growth rate decreases the fertility of bird lineages, which, unfortunately, will not be able to reproduce and may even present testicular disturbances. Moreover, an increase in the growth rate was accompanied by a significant delay in sexual maturity in the males of these lineages. The present study showed that the rapid growth of meat production roosters is accompanied by impaired reproductive capacities. In addition, gavage-induced obesity decreases testicular weight by approximately 30% in 4 weeks. Finally, the reduction of the photoperiod delays the development of testicles and can even cause gonadal regression both structurally and biochemically.

Author's Contributions

Author 1: Data analysis, drafting the article. Author 2: Data analysis, literature search. Author 3: Data analysis.

References

Al-Tememy, H. S. A. (2010). Histological study of testis in quail (*Coturnix coturnix japonica*). *Al-Anbar Journal Veterinary Science*. 3: 36-44.

Bakst, M. R.; Akuffo V.; Trefil P. and Brillard J. P. (2007). Morphological and histochemical characterization of the seminiferous epithelial and Leydig cells of the turkey. *Animal. Reproduction Science*. 97 : 303-313.

Benoît, J. (1936). Facteurs internes et externes de l'activité sexuelle 1 Stimulation par la lumière de l'activité sexuelle chez le canard et la cane domestique. *Bull. Biology.* 70: 487-534.

Berghiche, A.; Khenenou T.; Belgharbi H. and Labied I. (2020). The Production Systems, Phenotypic and Morphometric Diversity of the Local Hens "*Gallus gallus domesticus"* & quot; in Eastern Algeria. *Revista Electronica De Veterinaria*. 21(2), 1-37.

Bissonnette, T. H. (1933). Inhibition of the stimulating effect of red light on testis activity in Sturnus vulgaris (Starling) by a restricted diet. *Bull. Biology*. 65: 452-468.

Boudali, S. F.; Al-Jumaili, A. S.; Bouandas, A.; Mahammi, F. Z.; Tabet Aoul, N.; Hanotte, O. and Gaouar, S. B. S. (2020). Maternal origin and genetic diversity of Algerian domestic chicken (*Gallus gallus domesticus*) from North-Western Africa based on mitochondrial DNA analysis. *Animal. Biotechnology*. 13: 1-11.

Briere, S.; Brillard, J. P.; Panheleux, M. and Froment, P. (2011). Alimentation, fertilité et bien-être des oiseaux reproducteurs domestiques : des liens complexes. I.N.R.A. *Production. Animal.* 24 (2) : 171-180.

Carrie-Lemoine, J. ; Garnier, D. H. and Richard Yris, A. M. (1983). Evolution des taux plasmatiques de testostérone et de delta 4-androstènedione chez le coq Hubbard en croissance [Variations of plasma levels of testosterone and delta 4-androstenedione in growing Hubbard cockerels]. *C R Seances Acad Sci III*. 296 (15): 701-718.

Cecil, H. C. (1981). Effects of dietary protein on body weight and reproductive performance of male turkeys fed low protein diets during the breeder period. *Poultry. Science*. 61: 1866-1872.

Czubaszek, M.; Andraszek, K. and Banaszewska, D. (2019). Influence of the age of the individual on the stability of boar sperm genetic material. *Theriogenology* 15; 147: 176-182.

De Revier, M. and Brillard, J. P. (1974). Le développement testiculaire chez le coq : Influence de la durée quotidienne d'éclairement sous photopériodes constantes. *Annales de biologie animale, biochimie, biophysique.* 14 : 591- 600.

De Revier, M. and Brillard J. P. (1977). Le développement testiculaire chez le coq : action de variations progressives de la durée quotidienne d'éclairement. *Annales de biologie animale, biochimie, biophysique*. 17 : 179-186.

De Reviers, M. ; Richetin, C. and Brillard, J. P. (1971). Le développement testiculaire chez le coq - II- Morphologie de l'épithélium séminifère et établissement de la spermatogénèse. *Annales de biologie animale, biochimie, biophysique.* 11(4) : 531-546.

Deviche, P.; Hurley, L. L. and Bobby Fokidis, H. (2011). Avian testicular structure, function, and regulation. *Hormone. Reproduction. Vertebre., Birds, Elsevier*. 4 : 27-70.

Educagri, (2005). Reproduction des animaux d'élevage. Anatomie. *Physiology. Reproduction., Dijon*, 407p.

Ferrah, A. (2010). La filière avicole Algérienne : Diagnostic et stratégies. *Cahier de l'I.N.A., Alger*, 11p.

Fotsa, J. C. ; Pone, K. D., Manjeli, Y. and Ngou Ngoupayou, J. D. (2007). The state of Cameroon rural chickens: production and development perspectives for poverty alleviation. *Ghanaian Jornal. Animal. Science*. vol. 2 & 3 : 175-180.

Fotsa, J. C. (2008). Caractérisation des populations de poules locales (*Gallus gallus*) au Cameroun. *Thèse de doctorat, Agroparistech*, Paris, p. 301.

Furuta, G. T.; Turner, J. R.; Taylor, C. T.; Hershberg, R. M.; Comerford, K.; Narravula, S.; Podolsky, D. K. and Colgan, S. P. (2001). Hypoxia-inducible factor 1- dependent trefoil factor protects barrier function during hypoxia. *Journal. Experience. Medecine*. USA, 193(9) : 1027-1034.

Geraert, P.A. (1991). Métabolisme énergétique du poulet de chair en climat chaud. *I.N.R.A. Prouction. Animal*. Paris, 4(3): 257-267.

Harrison, P. C.; Latshaw, J. D.; Casey, J. M. and Mcginnis, J. (1970). Influence of decreased length of different spectral photoperiods on testis development of the fowl. *Journal. Reproduction. Fertilité*. 22: 269-275.

Haseeb, A.; Bai, X.; Vistro, W. A.; Tarique, I.; Chen, H. and Yang, P. (2019). Characterization of in vivo autophagy during avian spermatogenesis1. *Poultry Science*. 98, 5089-5099.

Hocking, P.; Waddington, D.; Walker, D. and Gilbert, A. (1989). Control of the development of the ovarian follicular hierarchy in broiler breeder pullets by food restriction during rearing. *British. Poultry. Science.* 30: 161-173.

Hocking, P. M. (1988). Effect of restriction body weight gain or limiting the photoperiod during rearing on sexual maturity, viability and semen production in large white turkey males. *British. Poultry. Science*. 29: 531-544.

Hocking, P. M. (2010). Developments in poultry genetic research 1960-2009. *British. Poultry. Science*. 51 (1): 44-51.

Hocking, P. M. (1991). Effects of controlling body weight on the semen production of large white turkey males. *British. Poultry. Science.* 33: 211-218.

Ingkasuwan, P. and Ogasawara, F. X. (1966). The effect of light and temperature and their interaction on the semen production of White Leghorn males. *British. Poultry. Science*. 45 : 1199-1206.

Kaci, A. (2014). Les déterminants de la compétitivité des entreprises avicoles algériennes. *Thèse de doctorat, E.N.S.A.*, El Harrach, Alger, 243p.

Kaci, A. (2015). La filière avicole algérienne à l'ère de la libéralisation économique. *Cah Agric.* 24 : 151-60.

Larivière, J. M. and Leroy, P. (2008). Conservation et valorisation de la diversité des ressources génétiques du poulet en Europe : initiatives et perspectives. *Annale de Médecine Vétérinaire.* 152 : 203-220.

Leroy, P.; Thewis, A. and Huart, A. (2003). Troupeaux et cultures des tropiques ; dossier spécial volaille, Kinshasa. *Centre agronomique et vétérinaire tropicale de Kinshasa*. 96 p.

Lin, M. and Jones, R. C. (1993). Spermiogenesis and spermiation in the Japanese quail (*Coturnix coturnix japonica*). *Journal of Anatomy*. 183 (3): 525-535.

Mahammi, F. Z.; Gaouar, S. B.; Laloë, D.; Faugeras, R.; Tabet-Aoul, N.; Rognon, X.; Tixier-Boichard, M. and Saidi-Mehtar, N. (2016). A molecular analysis of the patterns of genetic diversity in local chickens from western Algeria in comparison with commercial lines and wild jungle fowls. *Animal Breeding and Genetic*. 133(1): 59-70.

Malvika, S.; Ghosh, P. R.; Dhar, B.; Devi, N. N.; Paul, R.; Halder, A. and Ghosh, S. K. (2019). Genetic status of indigenous poultry (red jungle fowl) from India. *Gene*. 705, 77-81.

Masyitha, D.; Akmal, M.; Gholib, G. and Wahyuni, S. (2021). Morphoanatomy and Gonadosomatic Index (GSI) of Testis of Turkey (Meleagrisgallopavo) at Different Ages. In Proceedings of the 2nd International Conference on Veterinary, Animal, and Environmental Sciences, ICVAES, Banda Aceh, Indonesia, 22–23 October 2020; Atlantis Press: Amsterdam, The Netherlands; 140-142.

Mfoundou, J. D.; Guo, Y.; Yan, Z. and Wang, X. (2022). Morpho-Histology and Morphometry of Chicken Testes and Seminiferous Tubules among Yellow-Feathered Broilers of Different Ages. *Veterinary Science*. 9, 485.

Moran, E. T.; Ferket, P. R.; Etehes, R. J. and Blaekman, J. R. (1983). Influence of a low plane of nutrition during sexual development on subsequent reproductive performance of small white breeder toms. *Poultry Science*. 62 : 1093-1100.

Moula, N. ; Antoine-Moussiaux, N. ; Farnir, F. ; Detilleux, J. and Leroy, P. (2009). Réhabilitation socioéconomique d'une poule locale en voie d'extinction : la poule Kabyle (Thayazit lekvayel). *Annales de Médecine Vétérinaire*. 153: 178-186.

Ngou Ngoupayou, J. D. (1990). Country report on smallholder rural poultry production in Cameroon. In: CTA seminar proceedings, small holder rural poultry production. Thessalonica, Greece. 2: 39-47.

Nicaise, C. (2015). Système génital male. *SVETB303,* p9.

Nir, I.; Waites, G. M. and Cunningham, F. J. (1975). Obesity induced by force-feeding and accompanying changes in body temperature and fertility in the male domestic fowl. *British Poultry Science*. 16: 505-515.

Ouennes, H.; Afri Bouzebda, F.; Bouzebda, Z. ; Majdoub, S. ; Djaout, A. and Smadi, A. M. (2019). The characterization of Post-Mortem Sperm of Local Chicken Cocks in Eastern Algeria. *Journal of World 's Poultry Research*. 9(2) : 59-67.

Ouennes, H. (2021). Utilisation du sperme epididymaire en vue de la mise en place d'une banque génétique. PhD thesis in veterinary science. University of Souk Ahars. Algeria.

Pichereau, A. (2012). Les techniques de prélèvement et d'insémination artificielle chez les oiseaux. Thèse de doctorat, E.N.V. Alfort, 83p.

Sahraoui, N. ; Brahim Errahmani, M. ; Ammi-Baaziz, D. ; Hezil, N. ; Bennadji, M. A. ; Boulariah, H. ; Chaouadi, D. ; Hornick, J. L. and Guetarni, D. (2015). Effet de l'extrait végétal de Yucca Schidigera sur l'excrétion oocystale chez le poulet de chair. *Revue Marocaine des Sciences Agronomiques et Vétérinaires.* 3 (2) : 53-57.

Santiago-Moreno, J. and Blesbois, E. (2020). Functional Aspects of Seminal Plasma in Bird Reproduction. *International Journal of Molecular Sciences*. 21(16), 5664.

Sedqyar, M.; Weng, Q.; Watanabe, G.; Kandiel, M. M. M.; Takahashi, S.; Suzuki, A. K.; Taneda, S. and Taya, K. (2008). Secretion of inhibin in male Japanese quail (*Corturnix japonica*) from one week of age to sexual maturity. *Journal* of Reproduction and *Développement.* 54(2): 100-106.

Sonaiya, E. B. and Swan, S. E. J. (2004). Production en aviculture familiale : un manuel technique. Organisation des Nations Unies pour l'Alimentation et l'agriculture, *FAO/Productions et Santé Animales.* Rome, 134 p.

Tamilselvan, S.; Dhote, B. S.; Singh, I.; Mrigesh, M.; Sathapathy, S.; Mahanta, D. and Gross. (2018). Morphology of testes and gonadosomatic index (GSI) of guinea fowl (Numida meleagris). *Journal. Entomology. Zoology. Study*. 6, 156-159.

Blesbois, E. (2018). Bird Reproduction Overview. In Encyclopedia of Reproduction; Skinner, M.K., Ed.; Academic Press: Cambridge, MA, USA, 6, 579-585.

Van Eekeren, N.; Maas, A.; Staatkamp, H. W. and Verschuur, M. (2006). L'élevage des poulets à petite échelle. *Digigraphi, Wageninagen-Pays Bas*, 97p.

Walter, J. B. (2007). Reproductive Biology and Phylogeny of Birds: Phylogeny, Morphology, Hormones and Fertilization. *Jam. Ed., Enfield, N.H., Sci. Pub.*, 609p.

Zhang, X.; Yang, W.; Liang, W. ; Wang, Y. ; Zhang, S. (2019). Intensity dependent disruptive effects of light at night on activation of the HPG axis of tree sparrows (Passer montanus). *Environmental. Pollution.* 249: 904-909.

Zhang, X. Y.; Wen, X. X.; Zhao, L. and He, J. P. (2012). Immunolocalization of Smad 4 protein in the testis of domestic fowl (*Gallus domesticus*) during postnatal development. *Acta. Histochem*. 114: 429-433.