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Review Article

Male Rabbit Reproductive Physiology

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Abstract

Domestic rabbits are mammals in the family Leporidae of the order Lagomorpha and are found in several parts of the world. This animal is fertile, very prolific, and has a short reproductive cycle. The meat quality is good and the leather can be sold, it is also used for antibody production in laboratories and by the pharmaceutical industry. But lack of information and technological backwardness are responsible for low reproductive index in Brazilian warrens. Rabbit bucks are ready for reproduction at 32 weeks of age, when the spermatical production stabilizes. This study was carried out to gather relevant information about the anatomic and physiologic aspects of rabbit reproduction, such as reproductive tract peculiarities, occurrence of puberty, sexual maturity, spermatogenesis and seminal characteristics of rabbits.

Keywords: males, anatomy, semen, rabbit.

INTRODUCTION

The first warren with controlled food was in France where they were kept within the monastery walls, between the VI and X centuries (Lebas *et al.,* 1997; Lowe, 2010). Subsequently, they became famous because of their meekness, size and variety (Lowe, 2010). It is noteworthy that these animals are herbivores that feed by grazing, and forage is efficiently transformed into food. An important aspect of meat production is the ability to convert plant proteins of low nutritional value for humans into animal protein of high food value (Lebas *et al.,* 1997). In some countries, such as the United States, rabbits are raised primarily for non-food purposes, such as toxicology studies (Santos-Filho *et al.,* 2007). The leather of this species is high quality and is used to make clothes and hats, to cover bicycle seats, make crafts, etc. Rabbits are also used in the cosmetics industry and medical and pharmaceutical research laboratories (Dontas *et al.,* 2011). These animals are also raised for exhibition and as pets; it is considered the third most popular pet in the world, behind only dogs and cats (Brown, 2001; Huerkamp, 2003; Richardson, 2003; Moreki, 2007).

It is emphasized that in the creation bound trade, this species has many advantages in its breeding, such as not requiring large areas, acceptance of fibrous foods (Carabaño and Piquer, 2003) and use of family labor, low level of investment and others. The objective of the present review was to show the anatomy and physiology of the male rabbit with emphasis on aspects related on their seminal characteristics.

Reproductive anatomy

The reproductive system consists of the testes (2), epididymis (2), ampoules (2), vas deferens (2), urethra, penis, preputial glands (2) and the accessory glands. It presents a peculiarity in the external genitalia, which is common in marsupials and rabbits, a well-developed scrotum located cranial to the penis and the urogenital opening (Capello and Lennox, 2006).

The scrotum has few hairs (Donnelly, 2004), and it is formed by the tunica vaginalis, tunica dartos and cremaster

muscle. Its main function is to keep the testicles away from the abdominal cavity, so that the right testicular temperature is maintained between 0.5 and 4°C below body temperature, as required for normal spermatogenesis (Alvariño, 1993). The scrotum and abdomen have communication through the inguinal ring, which conveys the excretory duct (vas deferens) that comes from the epididymis. During periods of sexual inactivity or stress the testicles return to the abdominal cavity through the inguinal ring, and may go down again by the action of the cremaster muscle (Alvariño, 1993; Capello and Lennox, 2006). They are positioned cranially to the penis (Brewer, 2006; Capello and Lennox, 2006), located in the scrotum, each one on one side of the inguinal line, positioned almost horizontally (Holtz and Foote, 1978a). Rabbit testicles are similar to those of cats, but can move freely from the scrotum to the abdomen through an opening in the inguinal canal (Brewer, 2006). Soft tissue herniation and strangulation of the bowel is prevented by a large fat mass associated with the epididymis, which lies in the inguinal canal when the testis is in the scrotum (Donnelly, 2004). The position of the testicles depends on many factors, including body position, body temperature, reproductive activity, repletion of the gastrointestinal tract, amount of abdominal fat (Capello and Lennox, 2006) and stress (Richardson, 2003). According to Fraser (1988), the appearance and testis weight depend on the location. For example, testes located in the scrotum are heavier, firm in texture and red in coloring. Abdominal testes are light, reddish-brown and limp.

Cryptorchid rabbits keep the sex drive, but fertility is impaired. The scrotum does not develop, but if there is the scrotum and the testicles are not palpable, it is likely that they are retracted into the inguinal canal or abdominal cavity (Paré and Paul-Murphy, 2004). The authors noted that, based on other species, it would seem prudent to assume a pattern of inheritance for cryptorchidism, at least in some rabbits. Rabbits with cryptorchidism should be castrated using a standard approach in the abdominal midline. Dorsomedial to the end portion of the testis, a set of efferent tubules pierces the tunica albuginea and enters the initial segment of the head of the epididymis. The functional part of the epididymis consists of a single duct. It originates in the efferent ducts; it is highly curled over the head, body and tail of the epididymis, and connects straight to the vas deferens (Holtz and Foote, 1978a). The authors note that the tail of the epididymis is in the shape of a U. The rabbit is one of the species in which sperm stored in the cauda epididymis exhibit vigorous motility even in their own fluid (Turner and Reich, 1985).

The vas deferens extends dorsocranial the body of the epididymis through the inguinal canal and enters in the abdominal cavity (Holtz and Foote, 1978a). The final portion of the vas deferens forms a loop around the ureter and at this point becomes fusiform. Although the thickness of the diameter does not differ from the rest of the vas deferens, this segment is generally called ampulla (ampulla vas deferens).

The glands of the rabbit reproductive tract differ in number, location, size and proportion, among other aspects, like those in other mammals (Vasquez and Del Sol, 2009). This set of glands consists of a vesicular gland, bulbourethral gland and a complex formed by the prostate, pro prostate and paraprostate (Holtz and Foote, 1978a; Vásquez and Del Sol, 2009). According to Hafez (1995), they contribute to the greater part of the volume of ejaculate. The vesicular gland is located between the prostate gland complex (a very muscular bag with a glandular lining) and the two ampoules which are side by side. Thus, the vesicular gland is variable in length and sometimes becomes temporarily enlarged, depending on the amount of fluid therein. This fluid fluctuates from slightly viscous to gel consistency (Holtz and Foote, 1978a). This gland contributes 45.6% of the ejaculate volume of rabbits (Del Niño Jesus *et al.,* 1997). Some authors have reported that the rabbit prostatic complex, which is located on the dorsal side near the urethra and the bladder, consists of the seminal vesicle, vesicular gland and prostate gland (Seki and Suzuki, 1989). Others say that the prostatic complex is formed by the vesicle gland, coagulation gland, dorsal ventral lobe of the prostate and bulbourethral glands (Cockle *et al.,* 1989). However, to standardize the terms and facilitate understanding, this article will adopt the terminology proposed by Holtz and Foote (1978a) and adopted by Dimitrov and Stamatova (2011) and Vasquez and Del Sol (2002). The names used were adopted according to embryological origin and morphology of the glands. The coagulation gland is called the pro prostate, the dorsal lobe and ventral prostate paraprostate. These authors affirm that the prostate complex consists of three lobes: pro prostate, prostate and paraprostate (two units). It is noteworthy that the different elements of the rabbit prostate gland have anatomical, histological and immunohistochemical varieties, suggesting that each part of the gland plays a specific role in reproduction (Dimitrov, 2010).

The prostate is located caudally to the vesicular gland and cranially to the prostate and the latter is located cranially to the bulbourethral glands (Vásquez and Del Sol, 2002). This gland is not derived from the wollfian duct, nor is the source gel mass (erroneously called the coagulation gland). Nor is it a lobe of the prostate, but an independent glandular unit that has a separated duct system. The accumulation of white granular secretion in the pro prostate gland gives a whitish appearance and makes the compartmentalization visible observed from the outside (Holtz and Foote, 1978a).

The prostate gland is yellowish-white in color and is located between the pro prostate and bulbourethral glands (Vásquez and Del Sol, 2002). It shares the same connective tissue capsule as the pro prostate, and only a small layer of tissue separates these two glands (Holtz and Foote, 1978a). The paraprostate glands are small and were named this way because they are located on both sides of the prostate. In other words, the right and left sides are located ventrally and sideways to the pro prostate (Dimitrov and Stamatova, 2011). They have an irregular embossed surface and are

hammer-shaped (Vásquez and Del Sol, 2002).

The rabbit bulbourethral gland is a small mass of glandular tissue that is surrounded by a capsule and widely covered by skeletal bulb glandular muscle that separates it into lobules. This gland originates in the urethral wall, as distinct from other species. It is fairly small in the rabbit, but relatively larger than that of man (Vásquez and Del Sol, 2001).

The penis is the copulatory organ. An unusual feature of the rabbit is the absence of the glans in the penis (Brewer, 2006), but the body of the penis is cylindrical, 40-50 mm long and the diameters decrease at its end. During rest from sex, it lies in the foreskin, which is located ventrally to the anus (Alvariño, 1993; Brewer, 2006) and caudally to the testicles (Capello and Lennox, 2006). The rabbit preputial glands are imperceptible and are embedded in the dermis around the preputial orifice and it is believed that they are increased sebaceous glands (Holtz and Foote, 1978a).

Puberty and Sexual Maturity

Rabbits are well known for their ability to reproduce quickly. Puberty occurs between 4-6 months, and in smaller breeds it occurs earlier than in larger breeds (Harcourt-Brown, 2002). In rabbits, sexual maturity varies with age (125-150 days), breed, lineage, food and environmental factors such as photoperiod, temperature and seasonality.

According Macari and Machado (1978), puberty in rabbits precedes the appearance of sperm in the ejaculate, so that puberty and sexual maturity are different phases. Skinner (1967) affirmed that at 63 days of age, rabbit testes descend into the scrotum. Other studies revealed that although the rabbit is pubertal in 4 months, the testes are not in the scrotum yet, the descent is observed into the scrotum only at six months of age (Fraser, 1988). However, sexual maturity is defined as the moment at which the daily spermatozoa production ceases to increase, which is reached at 32 weeks in New Zealand White rabbits (Amann and Lambíase Jr., 1967; Lebas *et al.* 1997). Studies revealed that this species reaches sexual maturity at 18 weeks of age (Chubb *et al.,* 1978; Frame *et al.,* 1994). For Skinner (1967), rabbits are pubertal when their testicles become androgenically active and accessory glands begin to produce fructose and citric acid and the animal assumes a characteristically male behavior. In this context, in rabbits, sperm appear closer to the end than the onset of puberty.

Spermatogenesis

Spermatogenesis starts between 42 and 63 days of age, but sperm do not appear in ejaculated sperm before 119 days (Skinner, 1967). It is known that spermatogenesis is a process that depends on the low temperature of the scrotum. Thus, temperatures higher than that of the scrotum (e.g., abdominal temperature) may block spermatogenesis (Hua *et al.,* 2000).

The total estimated duration of spermatogenesis in rabbits depends on the point chosen as the beginning of spermatogenesis. If it is judged that spermatogenesis begins with the first part of a series of division of spermatogonia leading to the production of primary spermatocytes, then about four cycles of the seminiferous epithelium (4 x 10.9 = 43.6 days) are required. However, it is assumed that spermatogenesis begins with the formation of spermatogonia stem and that the lifetime of such stem cells is a cycle of seminiferous epithelium, then spermatogenesis extends approximately 4.75 cycles and 51.8 days (Swierstra and Foote, 1965). Morton (1988), considering that one cycle lasts 10.8 days and not 10.9 as suggested by Swierstra and Foote (1963), who stated that spermatogenesis in this species lasts about 48 days.

Swierstra and Foote (1963) demonstrated that the cycle of seminiferous epithelium of rabbits is divided into eight stages, using as criterion the shape of the spermatids core, the location of spermatids and spermatozoa in relation to the basement membrane, the presence of meiotic figures and release of spermatozoa in the lumen (Swierstra and Foote, 1963). The authors also reported that during spermatogenesis there is considerable loss of spermatogenic cells in the rabbit. There are about 20% fewer spermatids than expected from the theoretical considerations. A smaller number of spermatids were also observed by Morton (1988) and Zhang *et al.* (2002). Swierstra and Foote (1963) reported that most of this loss occurs during and immediately after the two maturation divisions. However, recent studies have demonstrated the presence of round spermatids in the epididymis (sloughing of spermatids), in other words, they leave the testes before maturation (Zhang *et al.,* 2002). The authors also suggest that the age of the animal and season contribute to the sloughing of spermatids, which may occur more frequently after puberty or when spermatogenesis begins to occur in an active form (Zhang *et al.,* 2002).

In this species, multinucleated spermatids are often found (giant spermatids), but this incidence may be increased by stress or environmental management (Morton *et al.,* 1986; Morton, 1988; Tsunenari and Kast, 1992; Barakat, 2007). Multinucleated spermatids are easily recognizable because they are spherical in shape and have from two to four small, rounds, pyknotic cores with dense chromatin (Morton *et al.,* 1986; Tsunenari and Kast, 1992).

The testis is the main source of testosterone in rabbits (Castro *et al.,* 2002). It is also the main androgen produced during sexual maturation (Chubb *et al.,* 1978). Although their essential function is the maintenance of normal

spermatogenesis, serum testosterone levels above the baseline level do not appear to influence the efficiency of spermatogenesis (Castro *et al.,* 2002). However, around the 6th week there is a quick increase in FSH and LH concentrations in blood, which precede the onset of testosterone secretion and consequently the manifestation of puberty (Chubb *et al.,* 1978). This relationship between FSH and androgen suggests that FSH may play a regulatory role of steroidogenesis during rabbit puberty.

Sperm production

The testicles continue to grow and increase sperm production until six months of age (Morton, 1988). Spermatozoa can already be present in the cauda epididymis at around 15 weeks of age (Chubb *et al.,* 1978). The authors also noted that daily spermatozoa production increases from 15 to 52 weeks of age. Other studies reported that there is positive correlation between the gonadal reserve and testicular weight (Orgebin-Crist, 1968) and body of the rabbit (Ewuola and Egbunike, 2010). However, daily exposure to a continuous 14 hour light period negatively affects gonadal reserves (Orgebin-Crist, 1968). According to the author, under normal conditions, the average yield is 147.4 10^6/ day and 1g of testis produces 26.5 x 10^6 spermatozoa/ day. However, if the animal is subjected to a rate of two weekly collections, the daily release of spermatozoa in the ejaculate is consistently lower than the testicular production, indicating that approximately 50% of the spermatozoa produced are reabsorbed (Holtz and Foote, 1972).

Different daily production of spermatozoa has been observed: 148 ± 11x10^6 spermatozoa per day (Amann and Lambíase Jr, 1967), 187×10^6 / day (Holtz and Foote, 1972) and 210x10^6/day (Amann and Lambíase Jr, 1969). It is noteworthy that the rhythm of semen collection does not affect daily spermatozoa production (Amann, 1966). A recent study showed that in this species, the spermatozoa reserve is smaller in the left testis and left epididymis than in the right ones (Ewuola and Egbunike, 2010).

Semen characteristics

The semen is a mix of spermatozoa produced by the testes and seminal plasma secreted by the epididymis and different accessory glands, which are combined at the time of ejaculation (El-Azim and El-kamash, 2011). However, rabbit semen consists of two main parts, a fluid and a gelatinous portion (Mukherjee *et al.,* 1951).

Gel plug

The gel plug or gelatinous mass from rabbit semen originates in the vesicular gland (Holtz and Foote, 1978a; Del Niño *et al.,* 1997) and it is androgen-dependent (Parson, 1950; Bell and Mitchell, 1984). It consists of a significant amount of estrogenic substances and citric acid, and small amount of fructose (Parson, 1950; Mukherjee *et al.,* 1951; Holtz and Foote, 1978b). When animals subjected to two daily semen collections the gelatinous mass can be found in 75.4% of first ejaculates, but only 4.8% in the second ejaculate (Amann, 1966; Amann and Lambíase Jr, 1967; Holtz and Foote, 1978b). A large number of spermatozoa can be entrapped and the gelatinous mass seminal inactive, but after dilution in saline solution and incubated at 37°C, the gelatinous mass dissolves releasing the spermatozoa, which in turn become highly active (Mukherjee *et al.,* 1951). It is believed that this occurs because during ejaculation the two semen fractions are in a fluid state (Mukherjee *et al.,* 1951). Later studies showed that the consistency of the fluid contained in the vesicular gland varies from slightly viscous to gelled (Holtz and Foote, 1978a). Although it is common in rabbit semen, no function was found for the gel apart from preventing the loss of retrograde spermatozoa in rodents (Quesenberry *et al.,* 2004). This function has also been suggested by Mukherjee *et al.* (1951), who speculated that after ejaculation, the gel fills the vaginal lumen as buffer coagulation. Thus, IRRG Guidelines (2005) recommends removing the gel immediately after collection and before evaluating rabbit semen.

Seminal plasma

It represents the fluid portion of the semen and its presence positively affects the survival and parameters of spermatozoa motility in rabbits (Castellini *et al.,* 2000, Hagen *et al.,* 2002). Seminal plasma contains constituents such as carbohydrates, lipids, proteins and minerals (Holtz and Foote, 1978b; Müller and Kirchner, 1978, Castellini *et al.,* 2006b; Zaniboni *et al.,* 2004), which are important for sperm metabolism. Fructose and glucose is one of the main energetic constituent in semen, as well as substrates for the sperm cell metabolism (Mann, 1946; Arruda-Alencar, 2011). Previous studies have found that the initial fructose concentration in the seminal plasma is usually higher in the summer (245.9mg/dl), while the testosterone level is high in the spring (137.0mg/dl), while the testosterone is low level (Okab, 2007). Thus, the concentration of fructose in seminal plasma reflects the testosterone activity and semen quality (Mann and Parsons, 1947; Okab, 2007). However, the sugar concentration in rabbit semen is well below that found in

ruminants (Anand, 1973; Mendoza *et al.,* 1989; Roca *et al.,* 1993). Another sugar identified in rabbit seminal plasma was glucose (Arruda-Alencar, 2011), that despite being present in low concentrations (13.8 to 22mg/dL) was considered an effective constituent of seminal plasma in this species.

Rabbit seminal plasma contains Na, K, Ca, Mg, Se and Zn (Holtz and Foote, 1978b; Castellini *et al.,* 2007), and some trace elements such as Cu, Fe, Mn, Cd, Pb and Ni (Lukáč *et al.,* 2009). The Na and K were found in similar concentrations (1:1), but the mineral concentrations cited are much smaller than those found in other species (Blackshaw and Salisbury, 1957; Holtz and Foote, 1978b). Thus, it contributes little to maintaining the semen osmotic pressure, so it seems that the organic components are the main constituents responsible for this maintenance (Holtz and Foote, 1978b). Seminal Na reduces significantly in the case of removal of the seminal vesicle gland (Del Niño Jesus *et al.,* 1997). A previous study on the effect of different Ca, K and Cl concentrations in diluting of washed and unwashed semen demonstrated that washing does not significantly affect spermatozoa motility in rabbits (Blackshaw, 1953). Oliveira *et al.* (2004) affirmed that the inclusion of Zn in the breeding diet can affect the amount of spermatozoa.

Rabbit seminal plasma also contains several drops and vesicles (prostatic secretory granules) of different sizes and origins, which play different roles that are partially unknown (Castellini *et al.,* 2006a). Mourvaki *et al.* (2010) suggested that the prostatic secretory granules may represent a source of protection for spermatozoa against oxidative stress *in vitro* by supplying the spermatozoa with endogenous alpha-tocopherol.

Sperm Motility

Motility is a common feature of spermatozoa in the entire animal kingdom, and show is the percentage of spermatozoa moving steadily in a straight line (Chrenek *et al.,* 2007). Moreover, for species with internal fertilization, motility is important for the transport of spermatozoa in the reproductive tract and oocyte penetration (Holt and Van Look, 2004). For the determination of motility, drops of a suspension of semen should will be placed on slide and covered with cover slide and observed on microscope slides cover glasses (Emmes, 1947; IRRG Guidelines, 2005). The subjective estimation of the evaluation of motility and sperm morphology are the two most widely used laboratory tests to evaluate semen in rabbit season insemination (Lavara *et al.,* 2008a). These characteristics result in potential spermatozoa fertility, because there are some correlations between seminal parameters with motility, indicating the relationship between morphometric parameters and semen quality of rabbits (Hagen *et al.* 2002; Lavara *et al.,* 2008b).

Until recently, the sperm quality was evaluated based on the subjective evaluation of parameters such as mass and individual motility, as well as subjective parameters such as the concentration and morphology (Verstegen *et al.,* 2002). The authors affirm that subjective estimates of semen parameters are affected by many factors, including changes in the training and experience of the evaluators. Computerized spermatozoa analysis (CASA) was developed for an objective assessment of spermatozoa motility. This system includes a phase contrast microscope equipped with a heating plate, connected to a high resolution video camera and a computer (IRRG Guidelines, 2005). However, this system requires large investment. In goats, the motility evaluation method was superior to the conventional computer (Cavalcante *et al.,* 2005).

Roca *et al.* (2000) rated the progressive motility of spermatozoa in rabbits using an arbitrary scale 0-5 (0, 1, 2, 3, 4 or 5, D 0-10, 10-25, 25-50, 50-70, 70 -90 or 90-100%, respectively, showing progressive spermatozoa motility). The age at which 50% of sperm cells in the ejaculate have motility is 117 days (Bell and Mitchell,1984).

Spermatozoa morphology

In rabbit, the characteristics of semen, in particular morphological, feature from medium to high heritability (Lavara *et al.,* 2008c), and can be evaluated optical microscopy procedures using different staining techniques (IRRG Guidelines, 2005).

In resume, the rabbit sperm morphometric measurements were: total length from 46 to 55µm (Cummins and Woodall, 1985; Eddy, 2006); head length from 7.8 to 8.6µm (Bedford, 1963; Gravance and Davis, 1995); middle piece is 8.5µm with mitochondria arranged and about 41 turns (Eddy, 2006); the main piece measures about 38µm long (Cummins and Woodall, 1985). The head is shaped like a spatula and the acrosome does not extend beyond the core, and it also has a small equatorial region (Phillips, 1977; Eddy, 2006).

Kuzminsky *et al.* (1996) developed an illustrated guide to various abnormalities of rabbit semen. The average values observed by quantitative optical microscopy (x400) were: 18.2% total abnormalities, head abnormalities 2.9%, tail abnormalities 13.6% and 1.7% broken spermatozoa. The authors suggested counting only the curly tails to speed up the process of semen analysis, because these are the most representative of abnormalities in the tail and are easily observed under an optical microscope, even when viewed under low magnification. They also affirm that for an acceptable ejaculate the concentration of spermatozoa with curly tails should not exceed 17-18% of 200 cells observed. It is worth noting that rabbit spermatozoa are very sensitive to high ambient temperatures, and abnormal spermatozoa

can indicate a heat stress condition suffered by the animal (Finzi *et al.,* 1995). The authors also asserted that this condition can be easily observed by the increase in the number of curly tailed spermatozoa, since this abnormality has 80% correlation with total morphological abnormalities.

Among other abnormalities Branham (1969) found that the presence of the intermediate piece of the protoplasmic drop is associated with low rabbit spermatozoa displacement speed. The rabbit spermatozoa acrosome is evident as a swelling in the anterior margin of the head (Gould *et al.,* 1971). The lines demarcating the equatorial segment are much closer together than in the hamster.

Semen volume and sperm concentration

The ejaculate volume and sperm concentration in rabbits may range from 0.3 to 0.6ml and 150-500x10^6 sperm/ml, respectively (Adams and Singh, 1981; Lebas *et al.,* 1997). However, seminal characteristics can vary among different breeds: Rex (0.54 ± 0.03ml, 415.10 ± 10.11x10^6 sptz/ml), New Zealand White (0.54 ± 0.04ml; 416.72 ± 9.16 x 10^6 sptz/ml), California (0.62 ± 0.03ml, 454.11 ±11.40 x10^6 sptz/ml) and Baladi Red (0.56 ± 0.04ml, 423.23 ± 12.11x10^6 sptz/ml) (Amann, 1966; Hassanien and Baiomy, 2011). Other factors that may vary these parameters include diet (Kamel and Attia, 2011), collection frequency (Amann, 1966, Castellini *et al.,* 2006c), age (Theau-Clement *et al.,* 2009), ejaculate sequences and ambient temperature (Finzi *et al.,* 1994). It is noteworthy that the semen volume seems to be more affected by temperature than the sperm concentration (Garcia-Tomás *et al.,* 2008, Roca *et al.,* 2005).

Lebas *et al.* (1997) affirmed that when sexual stimulation was performed without copulation, 1-2 min before copulation, the sperm concentration increases. Previous studies have shown that this type of stimulation increases the number of spermatozoa in the vas deferens and consequently in the ejaculate (Prins and Zaneveld, 1979). According to the authors, this is because, in rabbits, during sexual stimulation sperm are moved from the epididymis into the vas deferens where they are quickly removed during ejaculation. The vas deferens is then restored to the gradient sperm maintained during rest sexual. Thus, the vas deferens is an active organ during sexual inactivity (Prins and Zaneveld, 1979).

Color and aspect of semen

Some studies have reported that rabbit semen is white and the intensity depends on sperm concentration (Alvarez *et al.,* 2006; Bilbao, 1996). There are some ratings for the color of rabbit semen. For Bilbao (1996), the semen is often pearly white and ivory, but gray semen is considered of poor quality. Alvarez *et al.* (2006) reported that milky-white semen is the best and predominant in the rabbit and represents normal semen with good quality. Yellowish semen is often contaminated with urine that is normally obtained when the temperature is too high in artificial vagina (Chang, 1959).

Several studies have associated color and appearance as a single parameter (Scapinello *et al.,* 1997; Matavelli, 2008, and El-Azim El-kamash, 2011). Normal semen is white, homogeneous and opalescent (IRRG Guidelines, 2005). According to Matavelli (2008), the ejaculate is mostly milky-white, but the best quality is found in creamy-white semen. Arrebola and Fernandez (2011) reported that pearly-white semen is good quality and other colors are classified as poor. Likewise, a uniform appearance is the most desirable.

CONCLUSIONS/ CONCLUDING REMARKS

Knowing the anatomy of the rabbit genital tract is closely related to certain characteristics present in the semen of animals of this species, such as the presence of the gel fraction derived from the vesicular gland of hexoses as fructose, glucose and citric acid, added by the prostatic complex. The semen composition and volume are also influenced by the size of the accessory glands, which in turn is influenced by testicular testosterone production, among other factors.

Sperm production begins in puberty, a cyclical process that results in sperm production. However, sexual maturity is only defined when the sperm concentration stabilizes and the males become able to fertilize females. The knowledge of these physiological parameters allows experts and producers to rationally exploit the full reproductive capacity of the players, without harming their body development.

Another aspect of utmost importance is the knowledge of the semen characteristics of rabbits, such as sperm concentration, motility, vigor and the occurrence of changes in the sperm cell, and these characteristics are taken into account in both andrological examinations performed during selection for breeding, and for the assessment prior to the semen processing performed soon after collection and before practicing insemination. Variations of these parameters may occur due to the action of certain genes regulated by environmental factors such as nutrition and thermal comfort in the accomoation.

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