Testicular Sperm Reserve, Semen Characteristics and Morphology of rabbit Bucks fed Groundnut and Moringa Forage Meal Based Diets

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Abstract

Nutrition plays a role in the development and functions of the testes. Nutritional effect on reproduction in animals occurs through direct effect on reproductive organs by providing nutrients and energy required for reproduction, and also through indirect effect of hormonal influences on reproduction. *This study was designed to determine the effects of groundnut and moringa forage meal-based diets on sperm reserve, semen characteristics and morphology of adult rabbit bucks. Twenty-five 7-month old rabbit bucks, weighing 2.0-3.5 kg, were randomly allocated in a 2x2 plus 1 factorial arrangement in a completely randomized design. The factors were forage type (groundnut and moringa forage meals), forage levels (0, 10 and 20% forage). The forage meals were used to substitute the concentrate diet at the various levels to form complete diets. Results obtained indicated that forage level had significant (P<0.05) effect only on right testis sperm concentration; being significantly (P<0.05) higher in rabbit bucks fed 20% forage meal diet than those on 0 and 10% forage meal diets. There were non-significant (P>0.05) effects of forage level on all the other sperm reserve parameters measured. Forage type and interaction between forage type and level had non-significant (P>0.05) effects on all sperm reserve parameters. Forage level had non-significant (P>0.05) effect on semen characteristics, except sperm motility and its concentration that were enhanced (P<0.05) by 20% forage meal diet than 10% forage meal diet. Forage level had significant (P<0.05) impact on live and dead sperm cells as well as bent tail and normal cells being higher for 20% forage meal diet for live and normal sperm cells and lower for dead and bent tail than 10% forage meal diet. Forage type and level had non-significant (P>0.05) effect on cytoplasmic droplet, free tail and detached head. Only bent tail was significantly (P<0.05) affected by the interaction between forage type and level. The results indicate that the inclusion levels of groundnut and moringa forage meals up to 20% had positive influence on sperm concentration of the right testis, sperm motility and its concentration as well as improved live and normal sperm cells but decreased dead and deformed sperm cells of rabbit bucks.*

Keywords: Forage, semen characteristics, morphology motility, domestic rabbits

Running title: Sperm reserve, semen characteristics and morphology of rabbits fed groundnut and moringa forage meal based diets

Reserve de Spermatozoïdes Testiculaires, Caractéristiques du Sperme et Morphologie des Lapins Males Nourris avec des Régimes à Base De Farine de Cacahuète et de Moringa

Résumé

La nutrition joue un rôle dans le développement et les fonctions des testicules. L'effet nutritionnel sur la reproduction chez les animaux se produit par un effet direct sur les organes reproducteurs en fournissant les nutriments et l'énergie nécessaires à la reproduction, ainsi que par un effet indirect des influences hormonales sur la reproduction. Cette étude a été conçue pour déterminer les effets des régimes à base de

farine de cacahuète et de moringa sur la réserve de spermatozoïdes, les caractéristiques du sperme et la morphologie des lapins mâles adultes. Vingt-cinq lapins mâles de 7 mois, pesant entre 2,0 et 3,5 kg, ont été répartis de manière aléatoire dans un arrangement factoriel 2x2 plus 1 dans un design complètement aléatoire. Les facteurs étaient le type de fourrage (farines de cacahuète et de moringa), et les niveaux de fourrage (0, 10 et 20 % de fourrage). Les farines de fourrage ont été utilisées pour remplacer le régime concentré aux divers niveaux pour former des régimes complets. Les résultats obtenus indiquent que le niveau de fourrage avait un effet significatif (P<0,05) uniquement sur la concentration de spermatozoïdes dans le testicule droit ; étant significativement (P<0,05) plus élevée chez les lapins mâles nourris avec un régime de farine de fourrage à 20 % que chez ceux à 0 et 10 % de farine de fourrage. Il n'y avait pas d'effets significatifs (P>0,05) des niveaux de fourrage sur tous les autres paramètres de réserve de spermatozoïdes mesurés. Le type de fourrage et l'interaction entre le type de fourrage et le niveau n'avaient pas d'effets significatifs (P>0,05) sur tous les paramètres de réserve de spermatozoïdes. Le niveau de fourrage n'avait pas d'effet significatif (P>0,05) sur les caractéristiques du sperme, sauf que la motilité des spermatozoïdes et sa concentration étaient améliorées (P<0,05) par le régime à 20 % de farine de fourrage par rapport à celui à 10 %. Le niveau de fourrage avait un impact significatif (P<0,05) sur les spermatozoïdes vivants et morts, ainsi que sur les cellules à queue courbée et normales, étant plus élevés pour le régime à 20 % de farine de fourrage pour les spermatozoïdes vivants et normaux et plus faibles pour les spermatozoïdes morts et à queue courbée que pour le régime à 10 % de farine de fourrage. Le type de fourrage et le niveau n'avaient pas d'effet significatif (P>0,05) sur les gouttelettes cytoplasmiques, la queue libre et la tête détachée. Seule la queue courbée a été significativement (P<0,05) affectée par l'interaction entre le type de fourrage et le niveau. Les résultats indiquent que les niveaux d'inclusion de farines de cacahuète et de moringa jusqu'à 20 % ont eu une influence positive sur la concentration de spermatozoïdes dans le testicule droit, la motilité des spermatozoïdes et sa concentration, ainsi qu'une amélioration des spermatozoïdes vivants et normaux, mais une diminution des spermatozoïdes morts et déformés des lapins mâles.

Mots-clés : Fourrage, caractéristiques du sperme, morphologie, motilité, lapins domestiques

Introduction

Reproductive efficiency and fertility in animals are affected by a number of factors. These factors include age, nutrition, environment, health status or disease, frequency of use, management and congenital abnormalities (Oyeyemi and Okediran, 2007). Nutritional effect on reproduction in animals occurs through direct effect on reproductive organs by providing nutrients and energy required for reproduction in male and female animals, and also through indirect effect of hormonal influences on reproduction. Medicinal plants are extensively used to relieve sexual dysfunction or as fertility enhancing agents, through their nutritional content known to improve sexual performance and fertility (Yakubu *et al.,* 2007; Sumalatha *et al.*, 2010). Oyeyemi and Okediran (2007) suggested that adequate nutrition with high percentage protein will improve the motility and concentration of spermatozoa.

Semen evaluation is used as a criterion of fertility in male animals (Moghaddam *et al.,* 2012). The estimation of extragonadal testicular sperm reserve is proved to be more reliable than gonadal reserve in assessment of semen quality (Ritar *et al.,* 1999). Abba and Igbokwe (2015) determined sperm reserves from slaughtered domestic animals. Sperm reserves were positively correlated with testicular weight and scrotal circumference of bucks (Ajani *et al.,* 2015). Sperm traits – characteristics, livability and morphology- determine the fertilizing capacity of the semen (Ewuola, 2013; Okoro et al., 2016). Semen characteristics are not the only criteria to evaluate the reproductive capacity of the male:

the study of testicular and epididymal sperm reserves are also essential for a careful assessment of fertility (El-Kon *et al.,* 2011).

Many leguminous forages provide high-quality low-cost feed materials for ruminants and pseudo-ruminants such as rabbits. However, the utilization of forage species by rabbits is higher for leafy succulent woody species (Aduku *et al*., 1986). Studies have shown that rabbits can utilize 50 g of concentrate with forage grasses or legumes without adverse effect on their growth and general performance (Bamikole and Ezenwa, 1999; Iyeghe-Erakpotobor *et al*., 2002; Iyeghe-Erakpotobor, 2006), or raised on diets consisting entirely of forages and cereal by-products (Cheeke, 1986). Groundnut (*Arachis hypogea*) foliage has potential as valuable feed supplement for rabbits, as it is rich in crude protein, minerals, and has high organic matter and protein digestibility (Blümmel *et al.,* 2005, Ozyigit and Bilgen, 2012). Recently, there has been interest in the utilization of *Moringa oleifera* commonly called (moringa, drumstick tree or red horse tree), a potential inexpensive protein source for livestock feeding (Terzungwe *et al.*, 2013). Moringa leaves are rich in amino acids, fatty acids, vitamins, minerals (Moyo *et al*, 2011; Teixeira *et al*., 2014; Rezis *et al*., 2014), antioxidants such as ascorbic acid, flavonoids, phenolics and carotenoids (Alhakmani *et al*., 2013). Moringa boosts sperm count thus improving fertilization of the egg (Cabacungan, 2008), increase epidermal wall thickness and lumen formation (Lilibeth and Glorina, 2010). An increase in the antioxidant enzyme system levels by Moringa treatment can favour reproductive process and enhance spermatogenesis (George *et al.,* 2017). This study was therefore designed to determine the effect of feeding rabbits with groundnut and *moringa* forage meal diets at graded levels on sperm reserve, semen characteristics and morphology of adult rabbit bucks

Materials and Methods

Experimental Location

The experiment was conducted at the Rabbitry Unit, Swine and Rabbit Research Programme, National Animal Production Research Institute (NAPRI), Shika, Zaria. Shika is located in the Northern Guinea Savannah on latitude 11° 12'N and longitude 7°33" with altitude of about 610 mm above sea level (Ovimaps, 2016). The temperature varies from 14°C during the early dry season (November–January) and 39.3°C during the late dry season (February to April).

Sourcing and Processing of Test Ingredients

Moringa leaves was purchased from the market at Giwa, Giwa Local Government Area, Kaduna State. Groundnut haulm was obtained after harvesting the seed from the Feed and Nutrition Research Programme (FNRP), National Animal Production Research Institute (NAPRI) demonstration plots. The forages were air dried in a well-ventilated room to maintain its greenish colour and quality. The forages were toll milled and bagged before use.

Experimental Animals and Management

Twenty-five 7-month old crossbred rabbits (New Zealand White X Chinchilla) weighing between 2.0-3.5 kg, were used for this experiment. They were sourced from the Rabbit Research Unit NAPRI, Shika-Zaria. The animals were weighed and randomly allocated to dietary treatments in a 2x2 plus 1 factorial arrangement in a completely randomized design. The factors were forage type (groundnut and moringa forages), forage levels (0, 10 and 20% forage meal). The forage meals were used to substitute the concentrate diet at the various levels to form complete diets.

The treatments were as follows:

1. 100% concentrate diet (0% forage meal diet),
2. 90% concentrate plus 10% forage meal (10% groundnut or moringa forage meal) and

3. 80% concentrate plus 20% forage meal (20% groundnut or moringa forage meal)

The concentrate diet consisted of: 39.24% maize, 15% maize offal, 42.26% groundnut cake, 3% bone meal, 0.25% salt, 0.25% vitamin/mineral premix. The experimental diets were offered to the rabbits at 150g per rabbit daily at 08:00 am and clean water was offered to the rabbits *ad libitum* in flat bottom earthen pots with curved rims to prevent feed wastage. The rabbits were allowed to acclimatize to the experimental diets for one week.

Measurement of sperm reserve, semen characteristics and morphology

Semen ejaculate was collected from four bucks per treatment at monthly interval by 9:00 am in the morning. Semen collection was commenced after four weeks of feeding and was continued for six months. A teaser doe was used and semen was collected by means of artificial vagina (internal temperature maintained at 37°C). Volume of ejaculated semen was measured using a-2 mL calibrated collecting tube (Iraqi *et al.*, 2012), any gel in the ejaculate was discarded. Percentage motility of spermatozoa was estimated by adding one drop of fresh semen to a test tube containing 1 mL warm physiological saline solution (0.9 % NaCl) and suspended in a water bath at 37°C for 20 min. The mixture was shaken slowly and then a drop was taken from the test tube with a warm Pasteur pipette and placed on a clean warm slide. The drop was covered by a warmed cover slip and immediately examined under high power magnification (x400). Percentages of live spermatozoa and differentiation between live and dead spermatozoa was assessed by eosin-nigrosine stain technique. Duplicate smears were made and a total of 200 spermatozoa were counted. Live spermatozoa were unstained while dead spermatozoa were stained according to Dott and Foster (1972).

Semen pH was measured using chemo craft indicator paper (Model 8685, AZ Instrument, Taiwan) which was commensurate from 1 to 14 with various colour showing the pH. A part of the paper was immersed in the semen, removed and placed on the colour chart: the corresponding colour was recorded as the pH value. Semen colour was visually observed immediately after semen collection and was coded as: milky=1, creamy=2 before statistical analysis.

The morphological evaluation of normal and abnormal spermatozoa was determined in the same smears prepared for live/dead ratio observed under x400 objective lens using an Olympus CX21 microscope (model: CX21FS1, Olympus Corporation, Tokyo, Japan). The total per hundred spermatozoa was also calculated. Semen was extended 200-fold with physiological saline solution (0.9% NaCl) and a drop of eosin stain. Sperm cell concentration was estimated using haemocytometer and Thoma-Zeiss cell counter. Examination was made under the high power magnification (x400). Semen characteristics and morphology were determined according to the methods described by Hafez (1986) which was later modified by Olfati *et al.* (2012). Two male rabbits were randomly selected from each treatment and euthanized at the end of the study. The testes were weighed individually. The sperm reserves were determined using methods described by Ewuola (2013).

Statistical Analysis

Data collected were subjected to two-way analysis of variance (ANOVA) using SAS 9.0 (SAS, 2001). Significant differences in means between treatments were separated using Pairwise difference (SAS, 2001). Shapiro-Wilks test was used to test the assumptions of

normality for the levels of the independent variables.

Results and Discussion

The effects of forage type and level on testicular sperm reserves of rabbit bucks is presented in Table 1. Forage type had non-significant (P>0.05) effect on all the parameters measured. Evans (2023) also did not observe significant (P>0.05) effect of level of cassava peel meal on testis weight, volume, and length of rabbit bucks. However, forage level had significant (P<0.05) effect only on right testis sperm concentration; being significantly (P<0.05) higher in rabbit bucks fed 20% than those fed 0 and 10% forage meal diets. Ewuola *et al.* (2019) reported that testicular sperm reserves decreased as level of moringa increased from 2.5% to 5.0 and 7.0% in the diet of rabbit bucks and suggested toxic effect of some anti-nutritional components in moringa such as tannin to be the reason for this decrease. Ibiwoye *et al.* (2023) reported similar significant (P<0.05) effect of graded levels of ascorbic acid on right testis sperm reserves and not on left testis sperm reserve of rabbit bucks. Contrary to this result, Ewuola *et al*. (2019) reported significant effect of level of moringa leaf meal on right and left testicular sperm reserves in rabbit bucks. The results of this study might suggest that bioactive compounds such as phenols, saponins, and tannins found in the forages fed might have improved the reproductive functions and sperm reserves in the testis of the rabbit bucks. Moringa leaf meal contains phytochemicals such as β-carotene and tocopherol, which enhances sperm formation (Adeyemi *et al*., 2014, Ewuola *et al.*, 2019). Contrary to the results of this study, Hammed and Amao (2022) reported significant effect of graded levels of *Nigella sativa* seeds on testicular parameters of rabbit bucks. However, the high testicular sperm reserve on 2.5% moringa diet reported by Ewuola *et al.* (2019) was adduced to result from beneficial effect of moringa leaf in stimulating spermatogenesis and sperm cell formation in the testes. There is a dearth of information on groundnut forage meal on sperm reserves.

Effect of forage type and level on semen characteristics of rabbit bucks is presented in Table 2. Forage type had non-significant (P>0.05) effect on semen volume, sperm motility, semen pH, sperm concentration and semen colour while sperm motility and sperm concentration were significantly (P<0.05) affected by forage meal level. Rabbit bucks fed 0 and 20% forage meal diets had significantly (P<0.05) higher sperm motility than those fed 10% forage meal diet. Sperm concentration of rabbit bucks fed 20% forage meal diet was similar with those fed 0% forage meal diet but significantly (P<0.05) higher than 10% forage meal diet. Forage level had non-significant (P>0.05) effect on all the other parameters measured. Ukpabi *et al.* (2012) in Iwuji *et al*., 2020) reported that some plants improved libido, sexual behaviour, mating performance and spermatogenesis. It appears that, the forages used in this study had similar effect on spermatogenesis even the concentrate control. Contrary to the results of this study, *Dialium guineensis* leaf meal fed at 30% had significantly (P<0.05) higher total sperm count, sperm concentration and lower abnormal sperm cells compared with the concentrate (0%) (Iwuji *et al*., 2020).

Table 1: Effect of forage types and levels on testicular sperm reserve of rabbit bucks

Parameters	Concentrate	Forage types in diet		P value	Level of forage in diet (%)			P value
		Groundnut	Moringa		0	10	20	
Right testis weight (g)	1.30±0.27	1.97±0.19	1.74±0.19	0.195	1.30±0.27	1.97±0.19	1.75±0.19	0.199
Left testis weight (g)	1.44±0.20	1.64±0.14	1.81±0.14	0.360	1.44±0.20	1.66±0.14	1.78±0.14	0.423
Right testis length (cm)	2.55±0.47	2.55±0.33	2.75±0.33	0.900	2.55±0.48	2.68±0.34	2.63±0.34	0.976
Left testis length (cm)	2.50±0.52	3.23±0.37	2.70±0.37	0.473	2.50±0.55	2.93±0.39	3.00±0.39	0.758
Right testis volume (mL)	0.75±0.50	0.00±0.36	1.30±0.34	0.096	0.75±0.69	0.85±0.49	0.45±0.49	0.841
Left testis volume (mL)	0.75±0.49	0.00±0.35	1.25±0.35	0.101	0.75±0.68	0.75±0.48	0.50±0.48	0.922
Right testis sperm concentration ($x10^6$/mL)	6.50±2.86	7.75±2.02	9.50±2.02	0.679	$6.50±1.97^b$	$5.75±1.39^b$	$11.50±1.39^a$	0.050
Left testis sperm concentration ($x10^6$/mL)	9.50±2.39	6.25±1.69	8.75±1.69	0.476	9.50±2.31	6.00±1.63	9.00±1.63	0.371

^{ab}Means with different superscripts in the same row are significantly (P<0.05) different

Table 2: Effect of forage types and levels on semen characteristics of rabbit bucks

Parameters	Concentrate diet	Forage types		P value	Forage levels (%)			P value
		Groundnut	Moringa		0	10	20	
Characteristics:								
Semen volume (mL)	1.34±0.18	1.24±0.13	1.29±0.13	0.901	1.34±0.18	1.140±0.13	1.40±0.13	0.340
Sperm motility (%)	81.20±3.96	77.10±2.80	76.56±2.87	0.612	$81.20±3.87^a$	$72.20±2.73^b$	$81.67±2.79^a$	0.035
Semen Ph	7.16±0.17	7.18±0.12	7.27±0.12	0.817	7.16±0.17	7.18±0.12	7.27±0.12	0.817
Sperm concentration ($x10^9$/mL)	124.32±11.50	131.14±8.13	132.87±8.30	0.829	$124.32±11.07^{ab}$	$115.00±7.82^b$	$149.69±7.99^a$	0.008
Semen colour	1.56±0.10	1.48±0.07	1.50±0.07	0.810	1.56±0.10	1.50±0.07	1.48±0.07	0.808

^{ab}Means with different superscripts in the same row are significantly (P<0.05) different

Sperm motility of 72.20-81.67% obtained with groundnut and moringa forage meal diets are however, higher than 62.50-65% observed for *Dialium guineensis* leaf meal by Iwuji *et al.* (2020). Sperm concentration of 124.32 -132.87 $x10^9$ obtained for the forages in this study is higher than 46.32-94.33 $x10^7$ (Adeyemi *et al*., 2014) and 126 to 154 $x10^6$ (Abu *et al*., 2013). Several plant phytochemicals are associated with better sperm quality (De Cosmi *et al*., 2021; Talebi *et al*., 2022 in Zhao *et al.*, 2023).

The effect of forage type and level on sperm morphological parameters of rabbit bucks is shown in Table 3. Forage type had non-significant (P>0.05) effect on all morphological parameters measured. However, forage level had significant (P<0.05) effect on live and dead sperm cells as well as spermatozoa with bent tail and normal cells. Rabbit bucks fed 20% forage meal diet had similar (P>0.05) live and normal sperm cells as those fed 0% forage meal level, but significantly (P<0.05) higher sperm cells than those fed 10% forage meal diet. Dead and bent tail sperm cells of rabbit bucks fed 10% forage meal diet was similar as those fed 0% forage meal diet but was significantly (P<0.05) higher than on 20% forage meal diet. Forage level had non-significant (P>0.05) effect on spermatozoa with cytoplasmic droplet, free tail and detached heads. Significantly lower sperm motility (72.20 vs 81.67) and lower live sperm count (73.30 vs 81.35) but higher dead sperm count (27.30 vs 18.65) was observed in rabbit bucks fed 10% forage meal diet compared to those fed 20% forage meal diet in this study. George *et al.* (2017) reported that sperm motility and live sperm count were significantly increased while percent of dead spermatozoa significantly decreased due to dietary treatment of Moringa in rabbit bucks. Overproduction of seminal reactive oxygen species may be directly related to the occurrence of abnormal spermatozoa (Agarwal *et al*., 2014 in Zhao *et al*., 2023).

The result of the interaction between forage type and level on sperm morphology of rabbit bucks is presented in Table 4. The results indicated that only spermatozoa with bent tails was significantly (P<0.05) affected by the interaction. Rabbits bucks fed 10% groundnut forage meal diet had significantly (P<0.05) higher spermatozoa with bent tails than bucks fed 20% groundnut, 10 and 20% moringa forage meal diets and the concentrate control. The reason for the higher spermatozoa with bent tail on 10% and not 20% groundnut forage meal diet is not clear. However, groundnuts contain the bioactive phytochemical isoflavones in addition to phytoestrogens and stilbenes. According to Zhao *et al.* (2023), high isoflavone intake was positively associated with risk of teratozoospermia (a condition characterized by majority of sperm having abnormal structure). Based on the forgoing, the 20% groundnut forage meal diet ought to have had higher abnormal sperm cells than the 10% level, which was not the case in this study. Moringa leaf and seeds contains saponins, phenolic compounds, flavonoids, and alkaloids (Unuigbe *et al.,* 2015). According to Unuigbe *et al.* (2015), the leaf and seed extracts of moringa exhibited remarkable, concentration-dependant increase in radical scavenging activities with IC_{50} values ranging from 5.72-42.56 µm/mL, with the ethyl acetate fraction of the leaf being the most active. This might explain the lower sperm abnormality in both 10 and 20% moringa forage meal diets in this study.

Table 3: Effect of forage types and levels on sperm morphology of rabbit bucks

Parameters	Concentrate diet	Forage type		P value	Forage level (%)			P value
		Groundnut	Moringa		0	10	20	
Morphology (%):								
Live sperm	76.40±2.74	77.60±1.93	76.87±1.97	0.930	76.40±2.64^{ab}	73.30±1.87^{b}	81.35±1.90^{a}	0.012
Dead sperm	23.60±2.72	22.40±1.93	23.75±1.97	0.873	23.60±2.61^{ab}	27.30±1.85^{a}	18.65±1.88^{b}	0.006
Cytoplasmic droplet	4.72±0.84	4.78±0.59	4.44±0.61	0.916	4.72±0.84	4.84±0.59	4.37±0.61	0.855
Free tail	3.12±0.83	3.96±0.59	4.29±0.60	0.523	3.12±0.83	4.62±0.59	3.60±0.60	0.273
Detached head	6.68±1.182	5.06±0.84	5.75±0.85	0.531	6.68±1.17	6.36±0.83	4.40±0.84	0.160
Bent tail	6.160±0.96	7.22±0.68	5.21±0.69	0.119	6.160±0.93^{ab}	7.76±0.66^{a}	4.65±0.67^{b}	0.005
Normal cells	77.16±2.80	79.46±1.98	80.81±2.02	0.573	77.16±2.76^{ab}	77.04±1.94^{b}	83.33±1.98^{a}	0.052

^{ab}Means with different superscripts in the same row are significantly (P<0.05) different

Table 4: Interaction between forage types and levels on sperm morphology of rabbit bucks

Forage	Concentrate diet	Groundnut forage diet		Moringa forage diet		P value
Level	0	10	20	10	20	
Morphology (%):						
Live sperm	76.40±2.64	72.31±2.59	83.33±2.70	74.37±2.70	79.37±2.70	0.262
Dead sperm	23.60±2.62	27.69±2.57	16.67±2.67	26.87±2.67	20.62±2.67	0.369
Cytoplasmic droplet	4.72±0.84	5.423±0.83	4.083±0.86	4.21±0.86	4.67±0.86	0.293
Free tail	3.12±0.83	4.88±0.82	2.96±0.85	4.33±0.85	4.25±0.85	0.276
Detached head	6.68±1.18	5.92±1.15	4.12±1.20	6.83±1.20	4.67±1.20	0.877
Bent tail	6.16±0.91^{b}	9.54±0.89^{a}	4.71±0.93^{b}	5.83±0.93^{b}	4.58±0.93^{b}	0.054
Normal cells	77.16±2.75	75.00±2.60	84.29±2.81	79.25±2.81	82.37±2.81	0.270

^{ab}Means with different superscripts in the same row are significantly (P<0.05) different

Conclusion

It can be concluded that the inclusion levels of forages *vis á vis Arachis hypogea and Moringa oleifera* up to 20% is shown to positively influence sperm concentration of the right testis, sperm motility and its concentration as well as improved live and normal sperm cells but decreased dead and deformed sperm cells of the rabbit bucks. Also, the highest inclusion level **(**20%) of these forages did not cause any reproductive deformity in the rabbit bucks evidenced in better testicular sperm reserve and semen characteristics but decreased deformities of the sperm cells of the animals.

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