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REGULAR ARTICLES

Concentrate supplementations of grazing pregnant Kalahari Red goats: Effects on pregnancy variables, reproductive performance, birth types and weight of kids

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Abstract A study was conducted for 22 weeks to determine the effects of concentrate supplementations at three crude protein (CP) levels, i.e. low protein diet—LPD 12.42% CP (124.93 g day^{-1}); medium protein diet—MPD 14.18% CP (145.87 g day^{-1}) and high protein diet—HPD 16.35% CP (168.19 g day^{-1}) on some pregnancy variables, reproductive performance, birth types and weight of kids kidded by pregnant Kalahari Red goats grazed on *Chloris gayana*. Thirty-three matured Kalahari Red goats of first parity within age range of 2 to 2$^1/_2$ years with an average body weight of 38.10 ± 1.13 kg were randomly allotted to the diets with 11 goats per treatment. Data obtained were subjected to analysis of variance in a completely randomised design. It was observed that goats fed HPD had the highest ($p < 0.05$) values for products of pregnancy (10.35 kg) taken within 24hour before kidding and foetal growth rate (88.37 g day^{-1}) during pregnancy. Goats fed MPD had the lowest values ($p < 0.05$) of 9.28 kg and 80.07 g day^{-1} for each of the respective parameters. Afterbirth weight was also the highest and lowest ($p < 0.05$) for goats supplemented with HPD (3.38 kg) and MPD (3.04 kg), respectively. On the other hand, MPD-supplemented goats had the highest values ($p < 0.05$) for litter size (2.14) and litter weight (6.80 kg) at birth, the value which was the least for HPD supplementation. From the results obtained from this study, it could be concluded that concentrate diet supplementation with 14.18% CP improved litter size and weight at birth with resultant reduction in weights of pregnancy variables of pregnant Kalahari Red goats grazed on Rhodes grass.

Keywords Rhodes grass (*Chloris gayana*) · Foetal growth rate · Afterbirth weight · Sex ratio · Litter weight

Introduction

Kalahari Red is regarded as an improved goat breed that originated from South Africa. This breed is an important meat-producing goat with characteristics such as adaptation to arid and semi-arid savannah, ability to graze well with good nursing of their kids. It is regarded as a "minimum care/maximum profit" breed (Ramsay et al. 2001). Concentrate supplementation to goats at various stages of growth had been reported (Mushi et al. 2009; Kawas et al. 2010) to enhance their performance. At mid-pregnancy in particular, nutrient requirements of foetus are still low, but placenta growth is essential. If growth of placental tissue is restricted by low plane of nutrition, it will be unable to adequately nourish the foetus in the final stage of pregnancy and consequently birth weight will be compromised (Acero-Camelo et al. 2008). Rapid foetal growth rate during the last 6–8 weeks (i.e. within 3rd

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trimester) of pregnancy imposes a metabolic challenge to the doe, which is met by the mobilisation of maternal body tissue (Osuagwuh and Aire, 1990). This may result in weight loss of the doe if the dietary supply of nutrients is inadequate (Hossain et al. 2003; Rafiq et al. 2003; Joshi et al. 2004; Martin et al. 2005). Kalahari Red goats which are known to be highly prolific in their native environment have recently been introduced into Nigeria for improvement of local breeds. It is necessary to ascertain their reproductive performance in order to assess their response to various levels of crude protein in concentrate diets as supplement to grasses they graze on in South-Western Nigeria.

This study therefore seeks to investigate the effects of concentrate diets at three protein levels on some pregnancy variables, reproductive performance, birth types and weight of kids of Kalahari Red goats reared semi-intensively in South-Western part of Nigeria.

Materials and Methods

Animal Management and Experimental Procedures

A total of 33 matured Kalahari Red goats of parity one within age range of 2–2$^1/_2$ years with an average body weight of 38.10 ± 1.13 kg were used. The study was conducted at the Kalahari Red Goat Unit of Livestock Production Research Programme under the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture Abeokuta, PMB 2240, Abeokuta, Ogun State, Nigeria. Flushing was done with the experimental diets 2 weeks before commencement of the experiment. Flock treatment was carried out by the veterinarians on the farm 2 weeks before mating in order to ensure that only goats that are in good health conditions were used. Oxytetracycline 20% LA (oxytetracycline 200 mg/ml as dihydrate) was administered intramuscularly at 1 ml per 20 kg bodyweight, while Vita-Strong® Injection was administered intramuscularly at 1 ml per 10 kg bodyweight as vitamin supplement and anti-stress. Ivanor® Ivermectin Injection (Ivermectin Injection 10 mg/ml) was also administered subcutaneously at 1 ml per 50 kg bodyweight to control gastro-intestinal worms, fly larvae, lice, ticks and mites. Experimental animals were selected from the flock of 68 does. Three healthy, experienced and vigorous Kalahari Red bucks were used to detect goats on heat. The bucks used were 2$^1/_2$ years old with an average weight of 44.70 kg. Goats detected to be on heat were placed in a holding pen as experimental animals. The selected goats were ear-tagged and randomly assigned to pen houses used for the study.

Mating was done by introduction of the three Kalahari Red bucks into the pen houses (i.e. a buck/treatment). Proper observation was done to ensure that conception takes place before data collection commenced. The goats, after mating were fed experimental concentrate diets at three levels of protein. These are low protein diet—LPD (12.42% at 124.93gday^{-1}), medium protein diet—MPD (14.18% at 145.87gday^{-1}) and high protein diet—HPD (16.35% at 168.19gday^{-1}) as supplements to forage (*Chloris gayana*) on the paddock. The diets were fed to the goats at 3% of their body weight on dry matter basis. The ingredients used to compound the experimental diets included maize; unpeeled cassava root meal; wheat Offal; palm kernel cake, groundnut cake, bone meal; salt and premix. Each of the experimental diets was fed to 11 pregnant goats. Table 1 shows the gross composition of the experimental diets.

Experimental diets are fed by 08:00 and 16:30 h each day, i.e. half of the portion is fed in the morning, while the remaining portion is fed in the evening. Grazing of the goats is done by 10:00 h after feeding and goats are returned by 16:00 h daily. Fresh and clean portable water was made available to the goats daily *ad libitum*. Weights

Table 1 Gross compositions (%) of experimental diets fed to Kalahari Red does in Nigeria

Ingredients	Experimental concentrate diets		
	Low protein	Medium protein	High protein
Maize	10.0	10.0	10.0
Unpeeled cassava root meal	50.0	19.5	1.0
Wheat offal	10.0	30.0	50.0
Palm kernel cake	24.0	34.5	28.0
Groundnut cake	1.5	1.5	6.5
Bone meal	3.0	3.0	3.0
Salt	1.0	1.0	1.0
[a]Premix	0.5	0.5	0.5
Total (kg)	100	100	100

[a] Contains vitamin A (I.U.) 10,000.000; vitamin D_2 (I.U.) 2,000,000; vitamin E (I.U) 20,000; vitamin K (mg) 2250; riboflavin (mg) 5000; pyridoxine (mg) 275; biotin (mg) 50; pantothenic acid (mg) 7500; vitamin B_1 (mg) 175; vitamin B_{12} (mg) 15.0; niacin (mg) 27,500; folic acid (mg) 7500; choline chloride (mg) 400; antioxidant (mg) 125; Fe (g) 20.0; Zn (g) 50.0; Mn (g) 80.0; Cu (g) 5.0 g; I (g) 12.0; Co (mg) 200; Se (mg) 200

Table 2 Nutrient composition of experimental concentrate diets and Rhodes grass (*Chloris gayana*) fed to pregnant Kalahari Red goats

	Experimental concentrate diet			
Parameters (%)	LPD	MPD	HPD	Rhodes grass
Dry matter	88.00	90.00	90.00	39.00
Crude protein	12.42	14.18	16.35	3.24
Ether extract	7.49	4.50	8.44	0.15
Ash	7.38	6.03	8.19	3.33
Nitrogen-free extract	57.23	63.29	53.38	29.39
Organic matter	92.62	93.97	91.81	96.67
Neutral detergent fibre	54.67	55.72	57.22	58.92
Acid detergent fibre	42.46	40.32	41.73	46.72
Acid detergent lignin	23.36	25.96	25.63	24.82
Hemicellulose	12.21	15.40	15.49	12.20
Cellulose	19.10	14.36	16.10	21.90
[a]ME (MJ/kg DM)	14.95	15.64	15.60	14.56

LPD low protein diet, *MPD* medium protein diet, *HPD* high protein diet, *ME* metabolisable energy

[a] Calculated using MAFF (1984) equation

of goats are recorded within 24 h before and after kidding. Weights of kids were also recorded within 24 h of birth after drying to determine afterbirth weight which is the weights of placenta, umbilical cord and foetal membranes such as allantois, chorion and amnion (together with amniotic fluid) that are expelled from the uterus after kidding. Products of pregnancy (which are those materials produced during conception and birth) and foetal growth rate (which is the rate at which foetal materials are increasing in size daily during pregnancy) were determined as described by Akingbade et al. (2001). Data obtained were subjected to analysis of variance using completely randomised design at 5% probability. Significant means were separated using Duncan's multiple range test.

Aliquots were taken from experimental concentrate diets and Rhodes grass to determine nutrient composition of the samples. The samples were oven-dried at 65 °C for 3 days until constant weight was obtained, then milled with industrial blender into fine particles. The blended samples were kept until when needed for laboratory analysis. The nutrient composition was determined by following the procedure of AOAC. (2005) at Food Processing Laboratory in the Department of Food Science and Technology, Federal University of Agriculture Abeokuta, Nigeria. The nutrient composition of the concentrate diets fed and Rhodes grass grazed upon by the pregnant Kalahari Red goats is presented in Table 2.

Data collection

The following reproductive data were collected:

i. **Birth type:** this was obtained by recording number of kids born by the goats, where goats that kidded one kid were assigned single, two kids as twins and three kids as triplets.
ii. **Litter weight:** this was obtained by taking weight(s) of all the new-born kid(s) per doe together after their bodies were dried off either by natural air or with the use of dry towel to absorb fluid on their bodies within 24 h after kidding.
iii. **Birth weight:** this was obtained by taking weight of individual new-born kids after their bodies were dried off either by natural air or with the use of dry towel to absorb fluid on their bodies within 24 h after kidding.
iv. **Litter size/prolificacy:** this was obtained by counting number of kids born per doe.
v. **Kid's sex:** sex was recorded as either male or female kid.
vi. **Percent abortion:** this was obtained by recording the number of abortion which is natural expulsion of dead or live pre-term foetus(es) from the uterus before it was able to survive independently by each of the goats.
vii. **Incidence of dystocia:** dystocia is difficulty in parturition/kidding by pregnant goats. This was determined by the use of scale of 1–5 as described by Lusby et al. (1979) at the time of kidding by the experimental goats.

Where:

1 = no difficulty; 2 = some difficulty with no assistance rendered; 3 = light assistance; 4 = hard pull and 5 = caesarean section.

viii. **Percent stillbirth:** this was obtained by recording the number of stillbirth, which is a dead foetus by the doe (that was due for kidding) at kidding time.
ix. **Afterbirth weight:** this is the weights of placenta, umbilical cord and foetal membranes such as allantois, chorion and amnion (together with amniotic fluid) that are expelled from the uterus after kidding.
x. **Gestation length of the goats:** this was estimated by determining the length of time (in days) between successful mating and kidding for each of the goats.
xi. **Kidding interval:** this was determined by calculating intervals between two consecutive kiddings by the goats (in days) using available kidding dates (for each doe) from the breeding records.

Experimental formulae

$$\text{Fertility Rate} = \frac{\text{Number of goats that gave birth}}{\text{Number of goats mated}} \times 100$$

$$\text{Prolificacy} = \frac{\text{Number of kids kidded}}{\text{Number of goats that kidded}} \times 100$$

$$\text{Percent Abortion} = \frac{(\text{Number of goats that conceived-Number of goats that kidded})}{\text{Number of goats that conceived}} \times 100$$

$$\text{Percent Stillbirth} = \frac{(\text{Number of kids kidded-Number of live kids at birth})}{\text{Number of kids kidded}} \text{x } 100$$

$$\text{Fecundity} = \text{Fertility} \times \text{Prolificacy}$$

$$\text{Kidding Rate} = \frac{\text{Total number of kids kidded}}{\text{Number of goats mated}} \times 100$$

$$\text{Birth Type } (\%) = \frac{\text{Total number of same birth type (i.e.single, twins or triplet)}}{\text{Number of goats that kidded}} \times 100$$

$$\text{Sex } (\%) = \frac{\text{Total number of kids kidded with same sex (i.e.male or female)}}{\text{Total number of kids kidded}} \times 100$$

$$\text{Afterbirth Weight (kg)} = \text{Weight within 24hours before kidding (kg)- [weight within 24hours after kidding (kg)} + \text{Litter weight within 24hours of birth after drying (kg)]}$$

Results and discussion

Results obtained at the end of the study show that goats fed MPD recorded the lowest values for all the pregnancy variables (Table 3), whereas these values were highest for HPD-supplemented goats. This is an indication that there was a nutrient balance for maternal body development and products of pregnancy by goats fed MPD. HPD-supplemented goats mobilised most nutrient for development of products of pregnancy at the expense of maternal body development. This is in agreement with the report of Osuagwuh and Aire (1990) that during pregnancy there is preferential nutrient utilisation for foetal growth at the cost of mobilisation of maternal body tissue which resulted in weight loss of the does. Products of pregnancy and foetal growth rate ranged from 9.28 to 10.35 kg and 80.07 to 88.37 g day^{-1} respectively. This result agrees with the result of Akingbade et al. (2001) who reported that goats grazed on high protein pasture recorded higher values for products of pregnancy and foetal growth rate compared to goats on natural pastures (with low protein) that had lower values for same parameters. This suggests that high protein diets in excess of

Table 3 Pregnancy variables of gravid Kalahari Red goats grazing on Rhodes grass (*Chloris gayana*) supplemented with three concentrate diets during pregnancy and after kidding

Parameters	Experimental concentrate diet			
	LPD	MPD	HPD	SEM
Pregnancy variables				
Products of pregnancy within 24hour before kidding (kg)	10.01^{ab}	9.28^{b}	10.35^{a}	0.19
Foetal growth rate during pregnancy (g day^{-1})	85.74^{ab}	80.07^{b}	88.37^{a}	1.51
Afterbirth weight (kg)	3.23	3.04	3.38	0.35

[ab] Means on the same row having different superscript letters were significantly different ($p < 0.05$)

LPD low protein diet, *MPD* medium protein diet, *HPD* high protein diet, *SEM* standard error of means

the needs of pregnant goats are utilised by the body for improved products of pregnancy thus increased foetal growth rate. Jainudeen and Hafez (2000a) reported that the rate of foetal growth depends primarily on the feed supply and the ability of the foetus to use the feed among other factors such as genetic, environmental, growth hormone and associated factors.

Result on some reproductive performance of Kalahari Red goats grazing on Rhodes grass supplemented with LPD, MPD and HPD is presented in Table 4. The cause of cases of stillbirth and abortion recorded was not ascertained. Embryonic and foetal mortalities have been reported (Jainudeen and Hafez, 2000c) to be caused by maternal factors, embryonic factors or embryonic-maternal interactions, whereas maternal failure tends to affect an entire litter, resulting in complete loss of pregnancy. Cases of stillbirth and abortion were recorded for goats that carried twins. These foetal losses may be due to asphyxia as a result of uterine congestion and partly due to environmental stress which is in line with the report of Jainudeen and Hafez (2000c) who reported that perinatal mortality can be caused by asphyxia among other factors. The abortion rate recorded was 18.18% which is close to 17.33% reported by Akar (2013) for Saanen goats reared under rural/semi-intensive system. Mellado et al. (2004) reported that goats under extensive conditions had abortion rate of 15.2%, the value that is slightly lower than what was obtained for this study. In addition, Bushara et al. (2010) reported an abortion rate of 12.5% for grazing Taggar goats supplemented with protein diets. The variations in these abortion rates may be due to differences in the plane of nutrition, overall management and geographic locations under which the experiments were carried out. Percent stillbirth of 9.09% was obtained for goats supplemented with high protein diet, the value which is close to 10.7% obtained by Bughio et al. (2002) for Kamori goats reared semi-intensively with different protein supplementations. Akar (2013) reported stillbirth rate of 14.51%, which is higher than the value obtained for this study. This may be due to adaptation, management (Akar, 2013) and climatic differences. Dystocia was observed in a goat that gave birth to triplets under MPD supplementation. This could be as a result of primary uterine inertia that is due to excessive stretching which is common in animals that carry multiple foetuses (Jainudeen and Hafez 2000c). Percent dystocia of 9.09% was obtained for this study. This dystocia rate was lower than the reports of Konyali et al. (2007) and Akar (2013) for Saanen goats, which are 17 and 10.98–16.12% for respective author. The variations in dystocia rate might be due to foetal, maternal and/or mechanical causes (Jainudeen and Hafez, 2000c).

Table 4 Some reproductive performance of Kalahari Red goats grazing on Rhodes grass (*Chloris gayana*) supplemented with low, medium and high protein concentrate diets

Parameters	Experimental concentrate diet			
	LPD	MPD	HPD	SEM
Abortion (%)	18.18	18.18	0.00	–
Stillbirths (%)	0.00	0.00	9.09	–
Dystocia (%)	0.00	9.09	0.00	–
Fertility rate (%)	81.82	81.82	90.91	–
Prolificacy (%)	156	189	150	–
Fecundity (%)	127.64	154.64	136.37	–
Kidding rate (%)	127.27	154.55	136.36	–
Gestation length (days)	151.00	151.00	151.00	0.21
Kidding interval (days)	263 ± 38.63[a]			

LPD low protein diet, *MPD* medium protein diet, *HPD* high protein diet, *SEM* standard error of means

[a] Standard deviation

Fertility rate was highest (90.91%) for HPD-supplemented goats. Other dietary treatments recorded the same value (81.82%). The value recorded for HPD (90.91%) was similar to that of Saanen goats (88.5%) as reported by İnce (2010). Also, in an experiment conducted by Dayeh et al. (1996), it was reported that fertility rates of 94, 88 and 94% were obtained for Shami goats supplemented with low, medium and high concentrate diets respectively. Though, these percentages are higher for each of the respective dietary treatment in this study, lower fertility rates of 60 and 73.33%, and 66.67 and 100% were reported by Akingbade et al. (2001) for Nguni goats that grazed on two different pastures in years 1 and 2 respectively. The differences may be due to variations in breeding seasons, climatic factors, nutritional planes, dam's age, health status of the goats and breeds of goats used (Jainudeen et al. 2000). The prolificacy for Kalahari Red goats ranged between 150 and 189%, where goats fed MPD recorded the highest value. This range is similar to the report of Dayeh et al. (1996) for grazing Shami goats (1.53–1.88) fed with low, medium and high concentrate diets. On the contrary, Akingbade et al. (2001) reported prolificacy range of 167–192% for Nguni goats. This range is higher than what was obtained for this study. Fecundity, which is the ability to produce offspring, especially in large numbers was the highest (154.64%) and lowest (127.64%) for goats supplemented with MPD and LPD respectively. This implied that MPD had the tendency of producing more kids compared to other dietary treatments.

Kidding rate ranging from 127.27 to 154.55% was obtained. Kidding rate was the highest and lowest for MPD- and LPD-supplemented goats respectively. Akingbade et al. (2001) reported kidding rate that ranged from 106.67 to 133.30 and 125 to 191.67 for Nguni goats in a grazing experiments conducted in years 1 and 2 of his studies respectively. The highest values were reported for Nguni goats grazing on natural pasture without any supplementation. These could be so perhaps the climatic and edaphic factors were favourable for forage growth on the natural pasture, thus permitting natural selection of herbage by the goats to meet their nutrient needs (protein in particular), thereby improving their prolificacy, fecundity and kidding rate than what was obtained for this study.

Mean gestation length of 151 days with minimum of 150 days and maximum of 153 days respectively was recorded. The highest gestation length (153 days) was recorded for a doe that kidded triplets. The mean gestation length obtained was similar to 151.6 days reported by Ćinkulov et al. (2009) for German Fawn goats. Furthermore, Bawala et al. (2006), Rastogi et al. (2006) and Olomola et al. (2008) reported similar ranges for West African Dwarf goats and for some indigenous goats in India. Higher gestation lengths are reported by some authors (Hassan et al. 2010; İnce, 2010) for Jamunapuri and Saanen goats. Salim et al. (2002) reported a lower value which was 143.5 days for Black Bengal goats in a concentrate supplementation experiment conducted on sheep and goats under grazing condition. Variations in these values among the goats may be due to some physiological, environmental (Moaen-Ud-Din et al. 2008), multiple birth type (twinning, triplets), sex of offspring, parity of the dam (Jainudeen and Hafez 2000b). In addition, Jainudeen et al. (2000) also reported that gestation length is affected by dam's age, breed of goats and that the genotype of the foetus accounts for almost $^2/_3$ of the variation in gestation length of sheep; male lambs are carried longer than the female lambs and singles longer than twins.

Kidding interval obtained had a mean value of 263 days. The value implies that Kalahari Red goats can kid approximately three times in 2 years, which is similar to what is obtainable for West African Dwarf goats. The highest and least kidding intervals recorded were 306 and 190 days respectively. This mean value is similar to the reports of other authors (Bughio et al. 2002; Webb and Mamabolo, 2004; Bushara et al. 2010) for Kamori which are 260.4 days, Taggar 260 days and some South African indigenous goats that recorded 258 days. Kidding intervals reported by some authors (Ćinkulov et al. 2009; Rume et al. 2011) for German Fawn goats (337 days) and goats in selected coastal regions of Bangladesh (278 days) are higher than what was obtained for Kalahari Red goats, while Osuagwuh and Akpokodje (1984) reported a lower value of 242.33 days for West African Dwarf goats. Apparently, the variations in the values may be due to the systems of management and breeding methods (Webb and Mamabolo, 2004); geographic locations and seasons (Bughio et al. 2002); and day length, breed/genotype and nutrition (Jainudeen et al. 2000) of goats used.

Table 5 shows distribution of kids produced by Kalahari Red goats grazing on Rhodes grass (*Chloris gayana*) supplemented with three concentrate diets based on birth type and sex. Single birth recorded 22.22–50%, while twin birth had 50–66.66% for percent birth type. Goats fed HPD recorded equal percentage of single and twin birth types (i.e. 50% single, 50% twins). The single birth type percentage (50%) for high protein diet was the highest. For twin birth, MPD produced the highest number which is 66.66%. Only a doe under MPD produced triplets of 11.11%. No quadruplet was recorded for all the experimental diets. Twins birth for this study agree with the report of Bawala et al. (2006) who reported that West African Dwarf goats fed medium protein (13%) diet

Table 5 Distribution of kids produced by Kalahari Red goats grazing on Rhodes grass (*Chloris gayana*) supplemented with three concentrate diets based on birth type and sex

	Experimental concentrate diet			
Parameters	LPD	MPD	HPD	SEM
Number of goats that kidded	9.00	9.00	10.00	–
Birth type (%)				
Single birth	44.44	22.22	50.00	–
Twin birth	55.55	66.66	50.00	–
Triplets	0.00	11.11	0.00	–
Total number of kids produced	14.00	17.00	15.00	–
Litter size (kids)	1.67^{ab}	2.14^{a}	1.40^{b}	0.13
Sex (%)				
Male kids	42.86	52.94	46.66	–
Female kids	57.14	47.06	53.33	–
Sex ratio (male:female)	1:1.33	1:0.89	1:1.14	–

^{ab} Means on the same row having different superscript letters were significantly different ($p < 0.05$)

LPD low protein diet, *MPD* medium protein diet, *HPD* high protein diet, *SEM* standard error of means recorded the highest number of twining in a feeding experiment comprising of three dietary protein concentrates (10, 13 and 16% crude protein). Triplet's percentage also agrees with the results of İnce (2010) and Akingbade et al. (2001) who reported 11.5 and 11.1% for Saanen and Nguni goats respectively. In addition, single and twin births percentages for MPD agree with the result obtained by Hassan et al (2007) for Black Bengal goats, but the triplets' percentage was higher (20.39%) than Kalahari Red goats. İnce (2010) reported 77.3 and 22.7% for single and twin births respectively, for Saanen goats within age group of 2 years, he also reported 46.2, 42.3 and 11.5% for single, twin and triplet births respectively for the same breed of goat that are more than 5 years of age in the same study. Furthermore, lower single birth ranges of 18.20–33.30 and 55.60–81.80% twin birth were reported (Akingbade et al. 2001) for Nguni goats grazing on different pastures. The result obtained compared with other authors suggest that birth type is influenced by nutrition and age of does.

Goats supplemented with MPD were more superior in terms of total number of kids born per treatment and average litter size. MPD-supplemented goats recorded 17 and 2.14 kids respectively for total number of kids and litter size. This implied that goats fed MPD which consumed the highest quantities of experimental diets and grass offered recorded the best overall nitrogen utilisation, thus the highest total number of kids per treatment and litter size by producing at least a set of twins by all the goats fed the diet compared to other dietary supplementations. This was corroborated by Jainudeen et al. (2000) who reported that ovulation rate is influenced majorly by the level of nutrition, protein utilisation and season among other factors such as body size, weight and condition of the doe. In a similar experiment conducted by Bawala et al. (2006) on West African Dwarf goats, he reported that goats supplemented with diet containing 16% CP had the highest litter size (1.61 kids), followed by 13% (1.20 kids) and the lowest for 10% CP diets that recorded 1.00 kid. This report contradicted the results obtained for Kalahari Red goats. The litter sizes reported by various authors (Dayeh et al. 1996; Webb and Mamabolo, 2004; Olomola et al. 2008; Ćinkulov et al. 2009; Hassan et al. 2010; İnce, 2010) for Jamunapuri, German Fawn, Shami (Damascus), West African Dwarf and some South African indigenous goats were lower than the results of this study. But Rume et al. (2011) on contrary reported higher litter size (2.64 kids) for goats in some selected coastal regions of Bangladesh than Kalahari Red goats. The sex of kids produced under LPD and HPD was similar ($p > 0.05$), female and male kids had the highest and lowest mean values of 55.24 and 44.76% respectively. On the other hand, MPD produced more male kids (52.94%) than female kids (47.06%). İnce (2010) and Hassan et al. (2010) also reported higher percentage of male kids to female kids in their respective studies for Saanen and Jamunapuri goats. Akingbade et al. (2001) reported higher values of 60 and 56.52% for Nguni goats that grazed differently on *Leucena*/grass mixture and natural pasture respectively for female and male kids. The reason for these variations in sex percentages may be due to physiological processes and partly due to protein utilisation by the does rather than breed differences. Hafez and Hafez (2000) reported that the sex of foetus depends on inherited genes and some physiological processes such as gonadogenesis and formation and maturation of accessory reproductive organs. They reported that Wolffian and Müllerian ducts are both present in the sexually undifferentiated embryo. In the female, Müllerian ducts develop into a gonaductal system and Wolffian ducts atrophy. Reverse is the case for male foetus. The female Müllerian ducts fuse caudally to form a uterus, a cervix, and the anterior part of a vagina (Hafez and Hafez, 2000).

Results on weight of kids produced by Kalahari Red goats grazing on Rhodes grass (*Chloris gayana*) supplemented with three concentrate diets are presented in Table 6. Supplementation of Kalahari Red goats with MPD produced kids with superior birth weight (3.2 kg) and litter weight at birth (6.8 kg). This could be attributed to improved live weight changes of the goats during pregnancy due to their nitrogen utilisation, thus improved maternal body and foetal developments. This is in agreement with the report of Peart (1967) that dam's weight during pregnancy influenced kid weight at birth. Litter weight ranged from 4.72–6.80 kg with mean value of 5.53 kg for the dietary treatments. This implied that MPD supplementation improved litter weight at birth better than other dietary treatments. The range of weights at birth, weights for male and female kids obtained were 3.16–3.20, 3.15–3.23 and 2.88–3.40 kg respectively. The birth weights were similar to that of Saanen kids as reported by İnce

Table 6 Weight distributions of kids kidded by Kalahari Red goats grazing on Rhodes grass (*Chloris gayana*) supplemented with three concentrate diets based on sex and birth types

Parameters	Experimental concentrate diet			
	LPD	MPD	HPD	SEM
Litter weight at birth (kg)	5.08^b	6.80^a	4.72^b	0.38
Weight distribution on sex (kg)				
Birth weight	3.19	3.20	3.16	0.13
Male kids	3.23	3.15	3.18	0.18
Female kids	2.96	3.40	2.88	0.17
Weight distribution on birth type (kg)				
Single	3.67	3.00	3.50	0.13
Twins	2.91	3.35	2.70	0.18
Triplets	0.00	2.47	0.00	–

[ab] Means on the same row having different superscript letters were significantly different ($p < 0.05$)

LPD low protein diet, *MPD* medium protein diet, *HPD* high protein diet, *SEM* standard error of means

(2010). Contrary to the result of this study, some authors reported higher (Dayeh et al. 1996; Ćinkulov et al. 2009) and lower (Hassan et al. 2007; Olomola et al. 2008) values for German Fawn, Shami, West African Dwarf goats and Black Bengal goats. Variations in these birth weights may be due to mother's age and birth type (İnce, 2010). Weights of male kids for low and high protein diets were higher than weights of female kids. Hassan et al. (2010) obtained similar results; they reported higher birth weights for male kids of Jamunapuri goats. Reverse was the case for MPD supplementation on male and female kids' weights. MPD recorded higher (3.40 kg) weight for female kids than male kids (3.15 kg).

For weight distribution on birth type, single birth had higher weight (3.59 kg) at birth than twin birth (2.81 kg) for LPD and HPD. This result is in agreement with Bawala et al. (2006) for West African Dwarf goats. MPD had higher value for twin (3.35 kg) than single (3.00 kg) birth types, this result agreed with the report of Akingbade et al. (2001) in year 1 of a study where he grazed Nguni goats differently on *Leucena*/grass mixture and natural pastures. Triplet birth had the least weight (2.47 kg) compared to single and twin birth types, congruent to the report of Akingbade et al. (2001) for multiple births.

Conclusion

It could be concluded from the results obtained for this study that pregnant Kalahari Red goats fed medium protein diet—MPD (14.18% CP at 145.87 g day^{-1}) had improved litter size and litter weight at birth with resultant reduction in weights of pregnancy variables such as products of pregnancy and foetal growth rate which is an indication of nutrient balance for maternal body development and products of pregnancy by the does. Does fed MPD also had a triplet, the highest number of twin birth, the highest weights for female kids, twins and triplet. The supplementation of does with MPD improved generally some reproductive performance indices taken.

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Compliance with ethical standards

Conflict of interest statement: The authors declare that they have no conflict of interest.

Statement of animal rights: All applicable International, National, and Institutional guidelines for the care and use of animals were followed in the conduct of this research.

Informed consent: Informed consent was obtained from all individual participants included in this study.

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