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REGULAR ARTICLES

Effects of the breeding season, birth type and sex on growth and reproductive performances of sheep breeds

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Abstract
The study aimed at determining the effects of breed type, breeding season, sex and type of birth on the growth and reproductive traits of lambs. Two ewe breed types (Gellaper and Swakara) and four ram breed types (Damara, Dorper, GeDo and Swakara) were used. Two lambing seasons, spring (March–May) and autumn (September–November), were considered. Gellaper-based lambs born in autumn had higher ($P < 0.05$) mean birth weight (4.58 kg) compared to spring-born lambs (3.43 kg). Ram lambs were heavier ($P < 0.05$) than ewe lambs at weaning and post-weaning age. Singletons were heavier than twins ($P < 0.05$) at birth, weaning and breeding. Single and autumn-born lambs had a higher average daily gain (ADG) than spring-born lambs ($P < 0.05$). Ram lambs had a higher pre-weaning and overall ADG ($P < 0.05$) compared with ewe lambs. Swakara-based lambs gained more from weaning to mating compared to Gellaper-based lambs ($P < 0.05$). The conception, lambing and annual reproductive rate were all influenced by breed type and season ($P < 0.05$). Swakara-based lambs had higher reproductive capabilities, while Gellaper-based lambs grew faster but take longer to breed type; autumn lambing gave rise to low birth weights but heavier lambs at weaning and post-weaning, hence suitable for mutton production.

Keywords Annual reproductive rate · Daily gain · Breeding season · Lamb traits · Sheep breed types

Introduction

Sheep production is regarded as a major economic activity for sub-Saharan Africa (Chedid et al., 2014) in general and Namibia in particular. This region is characterised by hot, long dry summers with erratic rainfall, and poor soils that are deficient in organic matter. The climate has been changing over the past decades, and water availability has become a common phenomenon (Indu et al. 2015). Within the region, livestock production is generally extensive, and rangeland grazing is the only source of nutrients (Gó Mez-Brunet et al., 2008). The combined effects of climate change and low genetic variability have been a cause for concern for optimum sheep production. Nevertheless, the socio-economic role of sheep remains critical (Gómez-Brunet et al., 2008; Ben Salem and Smith, 2008), and efforts to improve productivity are germane. In Namibia, the normal breeding season of sheep is between February and March (spring) and July to September (autumn) (Gowane et al. 2014). Nonetheless, attempts to breed sheep out of season (Gavojdian et al., 2013; Kandiwa et al., 2019; Keskin et al., 2020; Norouzian, 2015; Nsoso and Madimabe, 2003) are shaky but possible.

Gellaper is a crossbreed produced from 70.3% Damara and 29.7% Dorper, which was developed to suit the harsh conditions of southern Namibia at Gellap-Ost Research Station. The breed is known for its hardiness, normal gait, straight thin motile tail, strong flock instinct, low maintenance requirements, good mothering ability and high fertility rate (Namwandi and Thawana, 2008). Karakul sheep were renamed Swakara in 2012, because of their pelts that are different from the original Karakul species. According to Itenge and Shipandeni, (2015), they have unique pelts with short hair, exceptional patterns and better hair texture. Since a large part of Namibia is arid or semi-desert, the climate is excellent for Karakul farming. Swakara/Karakul sheep have been introduced to Namibia

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since 1907, and ever since then, lamb pelts have been the main product that fetches niche prices on the world market. In addition, the breed produces good-quality meat, wool and milk (Kandiwa et al., 2019). The Swakara ewe has a prolonged breeding season and can lamb every 8 months, while the ram can successfully breed throughout the year (Mirzaei et al., 2017).

Breeding season is one of the major contributing factors to the reproductive performances of sheep breeds (Castillo et al., 2021; Gómez et al., 2012; Karatas et al., 2017; Keskin et al., 2020; Norouzian, 2015; Ortavant et al., 1988; Yilmaz et al., 2007). Most temperate breeds of sheep are seasonal breeders. A decrease in day length stimulates oestrous activity (Gómez et al., 2012; Kandiwa et al., 2019). The seasonal variation in lamb performance has been reported (Getachew et al., 2010; Keskin et al., 2020; Mirzaei et al., 2017; Norouzian, 2015; Yilmaz et al., 2007; Zaher et al., 2020). However, the year-round domestic and international demand for lamb meat is ever-increasing (Bhatti et al., 2020). Furthermore, lamb performance varies with the season (Bhatti et al., 2019; Karthik et al., 2021); thus, the production system influences this performance. In agreement, Thompson et al., (2021) reported a trade-off between reproductive (fertility, ovulation and lambing rate) and growth (lamb survival and growth rate of lambs) between spring/summer or out-of-season breeding (Bhatti et al., 2020; Zaher et al., 2020). In this context, economic viability of sheep husbandry is severely challenged; hence, accelerated lambing with a year-round breeding system is essential and hypothesised. Research work is scarce on this particular aspect, especially concerning arid environments.

Most sheep breeds are seasonal breeders exhibiting seasonal anoestrus, which is controlled by photoperiod (Gómez et al., 2012). In addition, nutrition and environmental cues restrict the arid sheep's potential in attaining global targets (Saxena et al., 2015). In the semi-arid regions of Namibia, the reproductive efficiency is relatively low, owing to high ambient temperatures along with the scarcity of feed and grazing pasture (De et al., 2015). Sheep are bred in autumn, with lambing in winter. The need to increase lamb meat production in Namibia is paramount, and efforts to do the same are welcome. Thus, the use of non-seasonal sheep breeds is a possible intervention. The influence of season on lambing in sheep production has been studied under temperate (Gavojdian et al., 2015), tropical or subtropical environments (Asadi-Fozi et al., 2020; Welday et al., 2019). We believe that similar experiments need to be done in arid conditions to improve lamb and mutton production. In this regard, the study aimed at determining the effects of breed type, lambing season, sex and birth type, on the growth and reproductive performance of sheep.

Materials and methods

Only data was collected in this study; therefore, no animal handling was done.

Study area/site

Data were obtained from the Kalahari Research Station, Namibia 22°34′46.8″ S 17°04′40.4″ E. The station is located south-eastern, 350 km from Windhoek and normally receives on average 200-ml annual rainfall, and average minimum and maximum temperatures of 05 and 40 °C respectively. The rainfall season stretches from January to April. Soils are generally red sand dunes, which are low in organic matter, relatively alkaline, and extremely dry. Around pans, soils are highly calcareous or saline, and often toxic to most vegetation. The main vegetation is dominated by browse species of *Acacia mellifera* and *Catophractus alexandrii* while grass species such as *Schmidtia kalahariensis* (annual) and *Stipagrostis uniplumis* (perennial) are dominant.

Source of data

Gellaper sheep is the most improved breed while Swakara sheep are the most common indigenous sheep breed in Namibia. The records were obtained from Kalahari Research Station for the period 2014–2017, for each ewe breed type (Gellaper and Swakara) that was bred to four ram breed types (Damara, Dorper, GeDo and Swakara) for two lambing seasons (Spring and Autumn). The data were normalised by removing outliers and incorrect or inadequate data with the intention to align distributions to a normal distribution, after which the Shapiro-Wilk test for normality, maintaining 5% as the level of significance, was applied using each response variable. Records with missing information were deleted, and a total of 1162 records were used. Two breeding seasons were regarded per year for each breed type: the wet season (autumn lambing April–June) and the dry season (spring lambing Sept–Oct). Only maiden ewe data (approximately 12 months/two teeth) was used each year. Growth (birth weight, weaning weight, average daily weight gain from birth to weaning (ADG), average daily gain from weaning to first mating (ADGWFT) and reproductive conception rate (CR), lambing rate (LR), weaning age (WA), age at first mating (AFM), lambing interval (LI), annual reproductive rate (ARR)) data were considered.

Animal management

Animals were grouped according to breed type and kept in different paddocks. All animals were managed under the extensive grazing system with no supplements throughout the study period. All animal procedures to avoid or minimize discomfort, stress and/or pain were prioritised, and medical care for animals was also considered. The personnel conducting procedures were appropriately qualified and trained; Kalahari Research Station used their qualified veterinarian and animal technicians. At the beginning of each season, 20 ewe lambs were selected (on a live-weight basis at 60% of mature body size) from each ewe breed type (Gellaper and Swakara) and were joined to one ram from each of the four ram breed types (Damara, Dorper, GeDo and Swakara); GeDo was an F1 cross between Gellaper ewes and Dorper rams. Ram breeds were selected based on body weight at puberty as well as libido test results. Rams with high libido and body mass were used. All animals were presumed to have reached puberty between 6 and 9 months, and age was the basis for consideration in the breeding programme. After the breeding period, the rams were removed from breeding paddocks until lambing, and the same was repeated for the second joining season. The joining period lasted for 40 days for each breeding season at an ewe/ram ratio of 20:1, ewe lambs were naturally bred. At lambing, offspring were identified within 24 h of birth, and birth records were captured (birth date, dam, sex, birth type, birth weight). A commercial iodine solution (disinfectant) was applied to the navel upon lambing. Ewes were allowed to suckle until weaning, which occurred approximately 106 days' post-birth. At this time, weaning weights were taken and ewe/ram lambs were separated into respective breed type groups, representing all the types. During this period, ewe and their offspring were managed together as a mob. After weaning, ewe lambs and ram lambs were separated into specific crossbred or purebred groups and observed for sexual activity to determine pubertal age or otherwise referred to as age at first mating in this study. All animals were extensively managed with no supplements.

Statistical analysis

Data on growth and reproductive performance was subjected to ANOVA, to determine the effects of non-genetic factors (breed type, sex, birth status and lambing season) on the growth and reproductive performances of lambs. The univariate least squares mean (LSM) from the general linear model (GLM) procedures of SPSS was employed. The fixed effects of ewe breed type (Gellaper Swakara), ram breed type (Damara, Dorper, GeDo, Swakara), season (Spring, Autumn), sex (Female, male) and birth status (single, twins) were fitted in the statistical model:

$$\mathrm{Y}_{ijklmno}\mu + \mathrm{E_i} + \mathrm{M_k} + \mathrm{S_1} + \mathrm{T_m} + (\mathrm{E_i x T_m}) + (\mathrm{E_i x S_1}) + (\mathrm{E_i S_j S_1 T_m}) + \mathrm{e_{ijklmno}}$$

where

$Y_{ijklmno}$ = the birth weight, weaning weight, ADG from birth to weaning, ADG from weaning to first mating of the *n*th lamb

μ = population mean

E_i = effect of *i*th ewe breed type (Gellaper, Swakara)

S_j = effect of *j*th sex of lamb (i = male or female)

M_k = effect of *k*th ram breed type (k = Damara, Dorper, GeDo and Swakara)

S_l = effect of *l*th season of birth (l = spring lambing, autumn lambing)

T_m = effect of *m*th type of birth (m = single, twin)

E_iS_j = interaction effect of the *i*th ewe breed type and *j*th sex

E_iS_l = interaction effect of *i*th ewe breed type and *l*th season of birth

$Bi \times Tm$ = interaction effect of *i*th breed type and *m*th type of birth

$E_i\ S_jS_l$ = interaction effect of *i*th ewe breed type, *j*th sex of lamb and *l*th season of lambing

$e_{ijklmno}$ = error/residual effect

The same statistical model was used for analysing reproductive performance in sheep where Y = conception rate (CR), lambing rate (LR), lambing interval (LI), weaning age (WA), age at first mating (AFM), lambing interval (LI), annual reproductive rate (ARR).

Pre-weaning ADG = (weaning weight-birth weight)/ weaning age

The annual reproductive rate was computed using the formula:

$$\mathrm{ARR} = \mathrm{ALS} * 365 \div \mathrm{LI}$$

where ARR annual reproductive rate (lambs born per breeding ewes per year); ALS average litter size; LI lambing interval.

Results

The effect of breed type (Table 1) and season (Table 2) on growth parameters was evaluated. The birth weight (BW) was different between ewe breed types ($P < 0.05$) but did not differ among ram breed types ($P > 0.05$). The overall BW from Gellaper ewes was 3.7 while that of Swakara ewes was 3.2 kg. Lambs from Swakara ewes were 1.83 kg heavier at weaning compared to Gellaper-based lambs irrespective of the ram breed type ($P < 0.05$). Swakara-based lambs gained faster from birth to weaning compared to Gellaper-based lambs, irrespective of the ram breed type ($P < 0.05$). Dorper × Swakara lambs showed the highest gain while Gellaper × Dorper lambs showed the lowest gain from birth to weaning. The ewe breed types significantly influenced the average

Table 1 Ls means (SEM) of breed type effects on growth traits at Kalahari Research Station

Ewe breed	Gellaper				Swakara			
Ram breed	Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
BW (kg)	3.6 ± 0.050	3.6 ± 0.053	3.8 ± 0.052	3.7 ± 0.046	3.2 ± 0.089	3.2 ± 0.081	3.2 ± 0.065	3.3 ± 0.053
WW (kg)	22.6 ± 0.408	22.1 ± 0.434	24.3 ± 0.424	22.2 ± 0.377	24.4 ± 0.725	25.0 ± 0.660	23.8 ± 0.533	25.8 ± 0.430
ADGBW (g/d)	168.0 ± 3.005	160.8 ± 3.189	182.5 ± 3.112	169.3 ± 2.764	233.2 ± 5.319	237.2 ± 4.842	226.1 ± 3.909	235.0 ± 3.155
ADGWTFM (g/d)	89.5 ± 2.403	89.9 ± 2.556	95.7 ± 2.497	92.8 ± 2.217	114.4 ± 4.268	116.3 ± 3.885	111.1 ± 3.137	115.2 ± 2.531

BW birth weight, *WW* weaning weight, *ADGBW* average daily gain from birth to weaning, *ADGWTFM* average daily gain from weaning to first mating

daily gain from weaning to first mating (ADGWTFM), Swakara-based lambs gained more from weaning to mating compared to Gellaper-based lambs ($P < 0.05$). The highest gains were observed with the Dorper × Swakara cross.

Spring-born lambs were 1.6 kg heavier at birth compared to autumn born lambs. At weaning, single- and spring-born lambs were 8.1 kg heavier than twins born within the same season, while single-born lambs were 6.6 kg heavier than twins born in autumn ($P < 0.05$). The average daily gains from birth to weaning (ADGBW) did not differ ($P > 0.05$) between lambing seasons; however, spring-born lambs had higher gains across all ewe and ram breed types ($P < 0.05$). Seasonal variation in gains was observed with lambs born during spring recording the least gains compared to season autumn-born lambs ($P < 0.05$). The least gains were recorded when Gellaper ewes were bred to Damara rams ($P < 0.05$). Table 3 shows the effects of birth type on the growth parameters of lambs.

Birth status significantly influenced BW ($P < 0.05$); single-born lambs were heavier than twins. Singletons were overall heavier ($P < 0.05$) at weaning than twins by 6.5 kg. Singletons gained more weight compared to twins amongst all breed types ($P < 0.05$), and the Dorper × Swakara cross showed the highest gain ($P < 0.05$). Birth status had marginal ($P = 0.045$) effects on ADGWTFM, and an interaction between ewe breed type and birth status was observed, although it was also marginal ($P = 0.046$). The sex of lambs (Table 4) at birth was significantly influenced by ewe and ram breed types ($P < 0.05$), More male kids were observed when Damara and Dorper rams were used with Gellaper ewes, while a significantly higher number of females kids ($P < 0.05$) were born when GeDo and Swakara rams were used on Gellaper ewes. On the contrary, a significantly high number of female kids were recorded when Damara and Dorper rams were used on Swakara ewes ($P < 0.05$); however, when Swakara ewes were bred to Damara rams, BW was insignificant ($P > 0.05$). The highest male BW was recorded when Swakara rams were bred to Gellaper ewes while the least female BW was recorded when Dorper rams were bred to Swakara ewes. The sex of lamb had marginal effects ($P = 0.047$), on weaning weight (WW); however, Swakara × Swakara male lambs were the heaviest at weaning while Gellaper × Dorper females were the lightest at weaning. Sex had no effect ($P > 0.05$) on ADGBW across all breed types. The sex of the lamb significantly influenced ADGWTFM ($P < 0.05$); male lambs gained more across all breed types. The CR was significantly influenced ($P < 0.05$) by ewe and ram breed types (Table 5).

Conception rates were higher with Swakara than Gellaper ewes ($P < 0.05$) and when Dorper rams were used. The highest CR was observed when Swakara and Dorper were used as ewe and ram breed types respectively. The lowest CR was recorded for Gellaper × GeDo sheep. The lambing rate was influenced by the ewe breed type ($P < 0.05$) while the ram breed type did not ($P > 0.05$). Swakara ewes (67.1%) generally were superior to Gellaper ewes (62.7%). The highest LR was observed when Swakara and Damara were used as ewe and ram breed types respectively, while the lowest LR was observed when GeDo and Gellaper were used as ram and ewe breed types respectively. Significantly higher WA was observed for Gellaper than the Swakara ewe breed ($P < 0.05$) while the ram breed had no effects ($P > 0.05$). It took more days for lambs from Gellaper to breed type compared to Swakara-based lambs ($P < 0.05$). Higher AFM was recorded for Gellaper-based lambs compared to Swakara-based lambs ($P < 0.05$). The use of Dorper and Swakara rams influenced the AFM for all ewe breeds ($P < 0.05$). Gellaper × Dorper cross showed the highest ($P < 0.05$) AFM while Swakara × Swakara purebred had the least AFM. The annual reproductive rate was significantly higher for Gellaper-based lambs than for Swakara-based offspring ($P < 0.05$). The highest ARR was observed when Gellaper and GeDo were used as ewe and ram breed types respectively. Breed type and seasonal effects on CR, LR, WA, AFM, LI and ARR (Table 6) were significant ($P < 0.05$). The ram breed type did not influence ($P > 0.05$) conception rate. Ewe * ram * season interaction was significant ($P < 0.05$). When Dorper rams were used, higher and consistent CR was observed irrespective of the season and ewe breed type ($P < 0.05$). In the second season, the highest CR were observed when Damara and Swakara sheep were used as ram and ewe breed types respectively, yet in the first season, Swakara male and female animals had the

Table 2 Ls means (SEM) of seasonal effects on growth traits at Kalahari Research Station

Ewe breed			Gellaper				Swakara			
Ram breed			Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
BW (kg)	Season	A	3.8 ± 0.074	3.7 ± 0.076	3.8 ± 0.080	3.7 ± 0.061	3.1 ± 0.089	3.1 ± 0.074	3.2 ± 0.097	3.1 ± 0077
		B	3.4 ± 0.067	3.6 ± 0.074	3.7 ± 0.065	3.4 ± 0.111	3.3 ± 0.153	3.3 ± 0.144	3.2 ± 0.087	3.7 ± 0.063
WW (kg)		A	22.3 ± 0.607	22.1 ± 0.622	25.2 ± 0.658	20.0 ± 0.564	23.6 ± 0.725	24.0 ± .603	22.8 ± 0.794	24.0 ± 0.629
		B	23.0 ± 0.546	22.2 ± .606	23.4 ± 0.535	24.3 ± 0499	25.3 ± 1.255	26.0 ± 1.174	24.7 ± 0.710	28.5 ± 0.516
ADGBW (g/d)		A	164.0 ± 4.452	164.5 ± 4.570	197.0 ± 4.832	163.3 ± 4.137	229.0 ± 5.320	237.0 ± 4.421	214.7 ± 5.829	233.4 ± 4.614
		B	172.0 ± 4.038	157.1 ± 4.449	168.0 ± 3.924	175.4 ± 3.665	238.1 ± 5.122	238.5 ± 5.211	236.2 ± 3.681	229.1 ± 3.784
ADGWTFM (g/d)		A	79.2 ± 3.571	87.5 ± 3.660	87.7 ± 3.876	96.0 ± 3.319	112.5 ± 4.268	116.2 ± 3.547	105.9 ± 4.676	114.5 ± 3.701
		B	99.9 ± 3.217	92.3 ± 3.569	103.8 ± 3.148	89.6 ± 2.940	116.3 ± 7.392	116.4 ± 6.912	116.3 ± 4.183	116.4 ± 3.036

A spring lambing, *B* autumn lambing, *BW* birth weight, *WW* weaning weight, *ADGBW* average daily gain from birth to weaning, *ADGWTFM* average daily gain from weaning to first mating

Table 3 The effect of lamb birth status on the growth of sheep at Kalahari Research Station

Ewe breed		Gellaper				Swakara			
Ram breed		Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
Trait	BS								
BW (kg)	S	4.2 ± 0.063	4.2 ± 0.051	4.2 ± 0.049	4.2 ± 0.052	3.7 ± 0.048	3.7 ± 0.047	3.7 ± 0.044	3.6 ± 0.044
	T	3.1 ± .078	3.1 ± 0.093	3.3 ± 0.091	3.3 ± 0.076	2.7 ± 0.171	2.7 ± 0.154	2.7 ± 0.123	2.5 ± 0.196
WW (kg)	S	26.9 ± 0.514	25.7 ± 0.420	25.7 ± .405	25.1 ± 0.422	27.7 ± 0.391	28.1 ± 0.388	27.7 ± 0.357	27.3 ± 0.357
	T	18.4 ± .635	18.6 ± 0.760	22.9 ± 0.745	19.3 ± 0.624	21.2 ± 1.396	21.8 ± 1.261	19.8 ± 1.004	19.7 ± 1.606
ADGBW (g/d)	S	199.2 ± 3.800	184.6 ± 3.096	192.5 ± 2.971	190.6 ± 3.095	236.1 ± 10.244	244.0 ± 9.257	240.3 ± 2.617	229.0 ± 2.621
	T	136.9 ± 4.657	137.0 ± 5.576	172.5 ± 5.470	148.0 ± 4.579	230.3 ± 2.870	230.4 ± 2.845	233.7 ± 11.788	223.1 ± 7.368
ADGWTFM (g/d)	S	89.9 ± 3.025	101.4 ± 4.474	102.1 ± 4.388	86.2 ± 2.483	113.0 ± 2.307	113.1 ± 2.282	112.5 ± 2.105	114.6 ± 2.102
	T	89.2 ± 3.736	78.4 ± 2.474	89.4 ± 2.384	99.4 ± 3.674	115.8 ± 8.219	119.5 ± 7.427	109.8 ± 5.911	117.7 ± 9.457

BW birth weight, *WW* weaning weight, *ADGBW* average daily gain from birth to weaning, *ADGWTFM* average daily gain from weaning to first mating

Table 4 The effect of lamb sex on the growth of sheep at Kalahari Research Station

Ewe breed		Gellaper				Swakara			
Trait	Ram breed	Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
	Sex								
BW (kg)	F	3.4 ± 0.070	3.5 ± 0.072	3.6 ± 0.069	3.6 ± 0.060	3.2 ± .095	3.1 ± 0.080	3.1 ± 0.089	3.2 ± 0.076
	M	3.8 ± 0.071	3.8 ± 0.078	3.9 ± 0.078	4.0 ± 0.070	3.2 ± 0.150	3.3 ± 0.140	3.3 ± 0095	3.5 ± 0.065
WW (kg)	F	22.3 ± 0.573	20.9 ± 0.585	24.3 ± 0.563	21.7 ± 0.490	24.1 ± 0.778	24.2 ± 0.655	23.3 ± 0.728	24.9 ± 0.623
	M	23.0 ± 0.582	23.3 ± 0.642	24.3 ± 0.634	22.7 ± 0.572	24.8 ± 1.223	25.7 ± 1.145	24.3 ± 0.778	27.1 ± 0.530
ADGBW (g/d)	F	165.1 ± 4.229	151.8 ± 4.294	181.7 ± 4.654	167.7 ± 3.596	232.9 ± 5.708	237.8 ± 4.810	228.8 ± 5.343	232.5 ± 3.891
	M	171.0 ± 4.271	169.7 ± 4.716	183.3 ± 4.133	170.9 ± 4.198	233.4 ± 8.978	236.6 ± 8.405	223.4 ± 5.708	236.7 ± 4.574
ADGWTFM (g/d)	F	84.5 ± 3.372	78.1 ± 3.445	84.3 ± 3.316	86.2 ± 2.885	114.3 ± 4.582	116.6 ± 3.859	109.9 ± 4.579	116.0 ± 3.669
	M	94.6 ± 3.426	101.7 ± 3.777	107.1 ± 3.734	99.4 ± 3.368	114.5 ± 7.202	116.0 ± 6.743	112.3 ± 4.290	114.1 ± 3.122

F female, *M* male, *BW* birth weight, *WW* weaning weight, *ADGBW* average daily gain from birth to weaning, *ADGWTFM* average daily gain from weaning to first mating

Table 5 Least squares means (± SEM) of breed type effects on sheep reproductive traits at Kalahari Research Station

Ewe breed	Gellaper				Swakara			
Ram breed	Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
CR (%)	76.7 ± 1.938	81.6 ± 1.938	74.1 ± 1.938	81.4 ± 1.938	82.4 ± 1.938	86.6 ± 1.938	85.0 ± 1.938	81.5 ± 1.938
LR (%)	61.3 ± 1.550	65.3 ± 1.550	59.3 ± 1.550	65.1 ± 1.550	69.2 ± 1.550	65.9 ± 1.550	68.0 ± 1.550	65.2 ± 1.550
WA (days)	112.6 ± 1.026	114.8 ± 1.093	113.1 ± 1.066	108.9 ± 0.947	91.4 ± 1.822	92.2 ± 1.659	91.3 ± 1.339	95.7 ± 1.081
AFM (days)	382.2 ± 4.820	389.1 ± 5.126	365.9 ± 5.007	386.2 ± 4.446	323.2 ± 8.559	326.2 ± 7.790	322.8 ± 6.291	338.4 ± 5.076
LI	9.2 ± 0.233	9.8 ± 0.233	8.9 ± 0.233	9.8 ± 0.233	10.4 ± 0.233	9.9 ± 0.233	10.2 ± 0.233	9.8 ± 0.233
ARR	1.9 ± 0.844	2.2 ± 0.844	2.3 ± 0.844	1.6 ± 0.844	1.7 ± 0.844	1.8 ± 0.844	1.8 ± 0.844	1.4 ± 0.844

CR conception rate, *LR* lambing rate, *WA* weaning age, *AFM* age at first mating, *AFL* age at first lambing, *LI* lambing interval, *ARR* annual reproductive rate

Table 6 Seasonal effects on sheep reproductive traits at Kalahari Research Station

Ewe breed		Gellaper				Swakara			
Ram breed		Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
Trait	Season								
CR (%)	A	77.2 ± 2.741	86.6 ± 2.741	83.2 ± 2.741	80.4 ± 2.741	89.1 ± 2.741	86.2 ± 2.741	92.1 ± 2.741	94.6 ± 2.741
	B	76.1 ± 2.741	76.7 ± 2.741	64.9 ± 2.741	82.3 ± 2.741	84.0 ± 2.741	78.5 ± 2.741	77.9 ± 2.741	68.4 ± 2.741
LR (%)	A	61.8 ± 2.193	69.2 ± 2.193	66.6 ± 2.193	64.3 ± 2.193	71.3 ± 2.193	69.0 ± 2.193	73.7 ± 2.193	75.7 ± 2.193
	B	60.9 ± 2.193	61.3 ± 2.193	52.0 ± 2.193	65.9 ± 2.193	67.2 ± 2.193	62.8 ± 2.193	62.3 ± 2.193	54.7 ± 2.193
WA (days)	A	111.8 ± 1.525	111.7 ± 1.566	108.5 ± 1.655	99.9 ± 1.417	89.7 ± 1.823	89.1 ± 1.515	91.8 ± 1.997	89.8 ± 1.581
	B	113.5 ± 1.374	117.9 ± 1.524	117.7 ± 1.344	117.9 ± 1.256	93.0 ± 3.156	95.3 ± 2.952	90.8 ± 1.785	104.5 ± 1.296
AFM (days)	A	396.7 ± 7.762	405.0 ± 7.340	382.3 ± 7.774	392.7 ± 5.896	317.4 ± 8.560	315.3 ± 7.113	324.5 ± 9.378	317.5 ± 7.423
	B	367.8 ± 6.452	373.2 ± 7.157	349.6 ± 6.313	379.7 ± 6.656	329.0 ± 14.825	337.2 ± 13.862	321.2 ± 8.389	369.9 ± 6.087
LI	A	9.3 ± 0.329	10.4 ± 0.329	10.0 ± 0.329	9.7 ± 0.329	10.7 ± 0.329	10.4 ± 0.329	11.1 ± 0.329	11.4 ± 0.329
	B	9.1 ± 0.329	9.2 ± 0.329	7.8 ± 0.329	9.9 ± 0.329	10.1 ± 0.329	9.4 ± 0.329	9.3 ± 0.329	8.2 ± 0.329
ARR	A	1.9 ± 0.118	2.2 ± 0.118	2.0 ± 0.118	1.7 ± 0.118	1.6 ± 0.118	1.7 ± 0.118	1.6 ± 0.118	1.3 ± 0.118
	B	2.0 ± 0.118	2.4 ± 0.118	2.6 ± 0.118	1.4 ± 0.118	1.8 ± 0.118	1.9 ± 0.118	2.0 ± 0.118	1.6 ± 0.118

A spring lambing, *B* autumn lambing, *CR* conception rate, *LR* lambing rate, *WA* weaning age, *AFM* age at first mating, *AFL* age at first lambing, *LI* lambing interval, *ARR* annual reproductive rate

highest CR. The animal breed type and season significantly influenced the lambing rate ($P < 0.05$). Swakara ewes showed overall higher LR than Gellaper ewes irrespective of the ram breed type used ($P < 0.05$). Lambs from Swakara ewes/rams were weaned earlier ($P < 0.05$) than lambs from Gellaper ewes, while the weaning age was extended in spring. Age at first mating was higher for lambs born by Gellaper ewes than Swakara ewes ($P < 0.05$) in both seasons. Ram breed type did not affect AFM ($P > 0.05$). The LI was significantly influenced by ewe breed type and season ($P < 0.05$). An Ewe × season interaction was observed for LI ($P < 0.05$). The LI was longer in autumn compared to spring for all breed types. Gellaper × GeDo lambs showed the least LI of 7.8 ± 0.329 in spring. The overall LI for spring lambing was 1.2 months less than for autumn lambing. The ewe and ram breed type and season significantly influenced ($P < 0.05$) ARR. Gellaper × GeDo animals showed the highest ARR in autumn, while Gellaper × Dorper animals had the highest ARR in spring ($P < 0.05$). When the Swakara breed type was used as the dam line, higher ($P < 0.05$) ARR values were obtained in spring compared to autumn among all ram breed types. Comparing the two dam lines, Gellaper sheep showed higher ($P < 0.05$) ARR values compared to Swakara between seasons. The pure Swakara animals showed the least ARR for both seasons ($P < 0.05$). The effects of birth status (Table 7) and sex (Table 8) on WA and AFM were significant ($P < 0.05$). Singletons were weaned earlier than twins, but were bred later, 382.0 and 325.2 days for singles and twins respectively.

Discussion

Birth weight is influenced by ewe breed type, season, sex of lamb and birth type in the current study. It is known that lambs heavier at birth grow faster than lightweight lambs (Dixit et al., 2001; Yilmaz et al. 2007; Rosov and Gootwine, 2013). Birth weight, an early measurable trait of great interest in all livestock species, is positively correlated with further live weights (Simasiku et al., 2019). Gellaper-based lambs were heavier at birth compared to Swakara-based lambs, showing the effects of breed type on birth weight. The effect of ewe body size could be responsible for this disparity since Gellaper are large-sized while Swakara is a medium-sized breed type. Although the effect of birth weight, sex and birth type have been discussed, ewe body size and condition seems to have a greater impact on lamb's pre- and post-natal performance (Bhatti et al., 2020, 2019; De et al., 2015). In agreement with the current results, birth weights were influenced by season (Norouzian, 2015). However, some studies have shown contrasting results where spring lambs were heavier at birth than autumn-born lambs (Norouzian, 2015). The seasonal differences in birth weight in the present study may have been partly due to ambient temperature variations and pre-natal

Table 7 Ls means (SEM) of breed type and lambs' birth status effects on reproductive traits of sheep at Kalahari Research Station

Ewe breed		Gellaper				Swakara			
Ram breed		Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
Trait	BS								
WA (days)	S	113.9 ± 1.292	116.9 ± 1.061	111.5 ± 1.018	110.2 ± 1.061	104.6 ± 0.983	105.9 ± 0.975	105.1 ± 0.897	101.7 ± 0.898
	T	111.5 ± 1.595	112.7 ± 1.910	114.6 ± 1.874	107.6 ± 1.569	78.1 ± 3.510	78.5 ± 3.171	77.5 ± 2.524	71.5 ± 4.039
AFM (days)	S	407.0 ± 6.066	397.9 ± 4.961	382.5 ± 4.780	392.4 ± 4.980	370.2 ± 4.626	374.8 ± 4.577	371.8 ± 4.222	359.8 ± 4.216
	T	357.5 ± 7.492	380.4 ± 8.971	349.4 ± 8.800	379.9 ± 7.367	276.3 ± 16.481	277.6 ± 14.893	273.9 ± 11.853	253.0 ± 4.039

Sex did not affect the weaning age of lambs ($P > 0.05$) but significantly influenced ($P < 0.05$) age at first mating at 352.7 and 357.4 days for females and males respectively

WA weaning age, *AFM* age at first mating

Table 8 Ls means (SEM) of breed type and lambs' sex effects on reproductive traits of sheep at Kalahari Research Station

Ewe Breed		Gellaper				Swakara			
Ram Breed		Damara	Dorper	GeDo	Swakara	Damara	Dorper	GeDo	Swakara
Trait	Sex								
WA (days)	F	113.5 ± 1.440	114.7 ± 1.471	113.5 ± 1.416	108.0 ± 1.232	90.3 ± 1956	89.4 ± 1.648	88.3 ± 1.831	91.9 ± 1.567
	M	111.7 ± 1.463	114.8 ± 1.616	112.7 ± 1.594	109.8 ± 1.438	92.4 ± 3.076	95.0 ± 2.880	94.2 ± 1.956	101.3 ± 1.333
AFM (days)	F	373.6 ± 6.761	396.3 ± 6.908	379.4 ± 6.650	392.2 ± 5.785	319.6 ± 9.188	316.2 ± 7.739	312.5 ± 8.602	325.2 ± 7.359
	M	390.8 ± 6.871	382.0 ± 7.575	352.5 ± 7.487	380.5 ± 6.753	326.9 ± 14.444	336.2 ± 13.523	333.2 ± 9.183	358.2 ± 6.260

WA weaning age, *AFM* age at first mating effects (Kandiwa et al., 2020). The lower spring-born lamb body weights emphasize the need for supplementary feeding and optimum management of ewes to increase foetal growth rate. Many studies (Dixit et al. 2001; Yilmaz et al. 2007; Rosov and Gootwine 2013) have shown the strong influence of season on BW of lambs which was not breed type dependent. As expected, male lambs were heavier at birth than female lambs for most of the crosses; however, Damara × Swakara cross had no difference in lamb birth weights between sexes. This was not expected but confirms the importance of targeted breeding and selection for superior dam lines with respect to birth weight since there were significant differences among all ram breed types. Previously, Loos et al. (2001) documented this result in sheep and suggested that males grow faster than respective females in utero as a result of testosterone secretion. In agreement, Wassie et al. (2019) reported that prenatal androgen treatment increases the BW of lambs. The proportional decrease in BW relative to birth type was greater in females in the current study. Differences between seasons are generally regarded as normal since they are caused by fluctuations in environmental conditions, which are difficult to control. Other factors can still affect birth weight for example nutrition, although not measured in the current study. Kumar (2022), affirmed that birth weights are affected by feeding conditions. Season, sex and birth type also influenced postnatal growth.

Weaning weight is subject to environmental variation, nutrition, breed type, birth type and sex of lamb. Season effects on weaning weights observed in the current study attest to earlier observations (Karatas et al., 2017; Keskin et al., 2020; Norouzian, 2015; Yilmaz et al., 2007; Zaher et al., 2020). Consistent with these findings, autumn-born lambs were heavier than spring-born lambs at weaning in the current study. Thus, the external environment during early growth influenced the overall pre-weaning growth rate, a common phenomenon in a variety of sheep breeds (Yilmaz et al., 2007). Swakara-based lambs gained faster from birth to weaning compared to Gellaper-based lambs, showing the breed type effects. The effect of sex and birth type on weaning weight is a result of the correlation between birth weight and weaning weight (Safari et al., 2008). It is known that mothering ability and milk yield differ among sheep breeds (Gavojdian et al., 2013; Getachew et al., 2010; Abebe et al., 2020; Namwandi and Thawana, 2008; Thompson et al., 2021; Welday et al., 2019), and indigenous Namibian breeds are known to perform better in this aspect (Namwandi and Thawana, 2008). Evidence by Kandiwa et al. (2019) and Mirzaei et al. (2017) showed that Swakara ewes produce more milk, which explains the greater weaning weights. In contrast, large-sized ewe breeds are expected to wean heavier lambs. The great genetic diversity among Namibian sheep breeds provides an opportunity for the selection of breeds that best suit various production systems and objectives.

Animal reproductive performance is influenced by breed, environment (Flinn et al., 2020; Gül et al., 2020; Kleemann et al., 2021), and management factors (Hoffman et al., 2017; Sanchez-Davila et al., 2020). The effects of breed, birth weight, and birth type on lambs have been studied (Asmare et al., 2021; Kumar, 2022; Lakew et al., 2014; Thompson et al., 2021; Welday et al., 2019; Yilmaz et al., 2007). Conception represents one of the most quantifiable traits of ewe reproductive performance. Irrespective of the ram used, conception rate was high in Swakara compared to Gellaper ewes. The high fertility rates from Dorper rams are well known (Gavojdian et al., 2015, 2013); no wonder higher CR for both ewe breed types in the current study. The effect of season on reproduction has been evaluated (Fozi et al., 2020). However, this phenomenon is not common with breeds developed under tropical and sub-tropical conditions. Such breeds would only exhibit seasonal anoestrous if moved to higher latitudes (Fozi et al., 2020). Conception rates were high with spring lambing compared to autumn lambing; similar conclusions were made by Keskin et al. (2020) in which month of birth significantly influenced both birth and weaning weight. Lambs from larger breeds are generally born heavier, while bigger litters are lighter than singletons. The amount of growth and other metabolic hormones in circulation (Loureiro et al. 2016) is a reasonable cause for these differences. According to Hoffman et al. (2017), male foetuses take generally longer in the uterus than female foetuses hence the heavier birth mass. On the other hand, twins compete for space and nutrition and thus limit their future productivity, a phenomenon known as developmental programming (Greenwood et al., 2017; Hoffman et al. 2017). Because of these underlying factors, the average age at weaning and age at first mating are significantly extended for medium to large breeds, males and singletons, and results from this study also attest to this fact. The lambing interval in our study was higher than expected (Abebe et al., 2020; Karthik et al., 2021; Welday et al., 2019) but similar to Asmare et al. (2021). The lambing interval was extended for spring lambing compared to autumn lambing. This was possible due to the effect of nutrition on ewes since animals were extensively managed with no supplements. During this season, grazing was adequate to sustain pregnant ewes; hence, they gave birth at an acceptable body condition and weight, and the negative energy balance period was significantly reduced consequently reducing the post-partum anoestrus period. It is standard practice that ewes lamb every 6 to 8 months (Fozi et al., 2020), and spring lambing is more common for both temperate and tropical breeds. Our study contradicts this generally accepted position at least with respect to the lambing interval. The annual reproductive rate of African breeds varies from 1.5 to over two lambs (Asmare et al., 2021). This is so because of continuous breeding in most extensive production systems, as well as low litter sizes. Because joining was controlled in the current study, the ARR was mostly above 2 irrespective of low twining levels particularly when Swakara ewes or rams were used. This proves that the breed has low twining potential. This was so because the lambing interval, although on the high side, fell within recommendations of between 8 and 10 for medium-sized to large sheep breeds. Breed type, season, sex and birth type significantly influenced the weaning age and age at the first mating of lambs, as was also reported by Asmare et al. (2021). Slow maturing and range breeds or extensively managed sheep may not be fertile at 7–8 months of age which is considered the standard age at puberty. However, it is encouraged to breed ewe lambs early, for increased productivity and profitability. The mechanisms that regulate seasonal breeding in sheep have been documented (Loureiro et al. 2016; Asadi-Fozi et al., 2020); they are believed to involve an interaction between changes in day length and circannual changes within the neuroendocrine system (Loureiro et al. 2016; Asadi-Fozi et al., 2020). Thus, the photoperiodic controls, the timing and duration of melatonin secretion and a variety of clock genes are responsible for this change (Fozi et al., 2020).

Conclusion

The average birth weight, weaning weight, average daily gain from birth to weaning and average daily gain from weaning to first mating ranged from 3.2 to 3.8 kg, 22.1 to 25.8 kg, 160 to 237 g/day and 89 to 116 g/day respectively. The average conception rate, lambing rate, weaning age, age at first mating, lambing interval and annual reproductive rate were 86%, 67%, 99 days, 356 days, 10.3 months and 1.8 respectively. Although breed types used in this study are out-of-season breeders, the effect of season was evident among growth and reproductive traits, and autumn lambing was preferable. Swakara ewes had higher conception rates and lambing rates and were weaned earlier with a lower annual reproductive rate compared to Gellaper ewes, hence are recommended for improving reproductive traits in sheep production. Gellaper-based lambs grew faster but take longer to breed, hence suitable for mutton production. Male and singleton lambs had higher birth weights, grew faster and gained more on daily basis. However, female singleton lambs from Damara and Dorper rams showed higher growth rates and weight gains. Autumn lambing gave rise to low birth weights but heavier lambs at weaning and post-weaning.

Author contributions All the authors contributed to the study's conception and design. Material preparation and data analysis were performed by Washaya Soul, and Mudzengi Clarice P. The first draft of the manuscript and data collection were done by Ngorio Uaipo. The data was cleaned and rearranged by Washaya Dorine D., who also reviewed and critically revised the manuscript, and all the authors commented on previous versions of the manuscript. All the authors read and approved the final manuscript.

Data availability Data will be made available on request through the corresponding author.

Declarations

Conflict of interest The authors declare no competing interests.

References

Abebe, A.S., Alemayehu, K., Johansson,A.M., Gizaw, S., 2020. Breeding practices and trait preferences of smallholder farmers for indigenous sheep in the northwest highlands of Ethiopia : Inputs to design a breeding program. PLoS ONE. 1–18. e0233040https://doi.org/10.1371/journal.pone.0233040

Asmare, S., Alemayehu, K., Abegaz, S., Haile, A., 2021. On-farm evaluation of growth and reproductive performances of Washera and Gumuz sheep in northwestern Ethiopia: Basics for setting up breeding objectives / goals. PLoS ONE 16(7): e02549241–11. https://doi.org/10.1371/journal.pone.0254924

Bhatti, M.A., Eik, L.O., Steinheim, G., Ådnøy, T., Horneland, R., Wynn, P., Hopkins, D.L., Asheim, L.J., 2020. Rangeland grazing strategies to lower the dependency on imported concentrates in Norwegian sheep meat production. Sustain. 12, 1–11. https://doi.org/10.3390/su12135340

Bhatti, M.A., Williams, T., Hopkins, D.L., Asheim, L.J., Steinheim, G., Campbell, M., Eik, L.O., Wynn, P.C., Ådnøy, T., 2019. Adapting seasonal sheep production to year-round fresh meat and halal market in Norway. Sustain. 11. 1554https://doi.org/10.3390/su11061554

Castillo, D.A., Gaitán, J.J., Villagra, E.S., 2021. Direct and indirect effects of climate and vegetation on sheep production across Patagonian rangelands (Argentina). Ecol. Indic. 124107417. https://doi.org/10.1016/j.ecolind.2021.107417

Chedid, M., Jaber, L.S., Giger-Reverdin, S., Duvaux-Ponter, C., Hamadeh, S.K., 2014. Review: Water stress in sheep raised under arid conditions. Can. J. Anim. Sci. 94, 243–257. https://doi.org/10.4141/CJAS2013-188

De, K., Kumar, D., Sethi, D., Gulyani, R., Mohammed, S., Naqvi, K., 2015. Estrus synchronization and fixed-time artificial insemination in sheep under field conditions of a semi-arid tropical region. Trop. Anim. Health Prod. 47, 469–472 https://doi.org/10.1007/s11250-014-0735-x

Dixit, S.P., Dhillon, J.S., Singh, G., 2001. Genetic and non-genetic parameter estimates for growth traits of bharat merino lambs. Small Rumin. Res. 42, 101–104. https://doi.org/10.1016/S0921-4488(01)00231-0

Flinn, T., Kleemann, D.O., Swinbourne, A.M., Kelly, J.M., Weaver, A.C., Walker, S.K., Gatford, K.L., Kind, K.L., van Wettere, W.H.E.J., 2020. Neonatal lamb mortality: major risk factors and the potential ameliorative role of melatonin. J. Anim. Sci. Biotechnol. 11, 1–11. https://doi.org/10.1186/s40104-020-00510-w

Fozi, M.A., Bradford, H.L., Notter, D.R., 2020. Direct and correlated responses to selection for autumn lambing in sheep. Genet. Sel. Evol. 52:56, 1–12. https://doi.org/10.1186/s12711-020-00577-z

Gavojdian, D., Budai, C., Cziszter, L.T., Csizmar, N., Javor, A., Kusza, S., 2015. Reproduction Efficiency and Health Traits in Dorper , White Dorper , and Tsigai Sheep Breeds under Temperate European Conditions. Asian Australas. J. Anim. Sci. 28, 599–603.

Gavojdian, D., Cziszter, L.T., Pacala, N., Sauer, M., 2013. Productive and reproductive performance of dorper and its crossbreds under a romanian semi-intensive management system. South African J. Anim. Sci. 43, 219–228. https://doi.org/10.4314/sajas.v43i2.12

Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Sölkner, J., Wurzinger, M., 2010. Herd management and breeding practices of sheepowners in a mixed crop-livestock and a pastoral system of ethiopia. African J. Agric. Res. 5, 685–691.

Gó Mez-Brunet, A., Santiago-Moreno, J., Del Campo, A., Malpaux, B., Chemineau, P., Tortonese, D.J., Gonzalez-Bulnes, A., Ló Pez-Sebastián, A., 2008. Endogenous Circannual Cycles of Ovarian

Activity and Changes in Prolactin and Melatonin Secretion in Wild and Domestic Female Sheep Maintained under a Long-Day Photoperiod 1. Biol. Reprod. 78, 552–562. https://doi.org/10.1095/biolreprod.107.064394

Gómez, A., Santiago, J., Toledano, A., López, A., 2012. Reproductive seasonality and its control in spanish sheep and goats. Trop. Subtrop. Agroecosystems 15, 25.

Greenwood, P., Clayton, E., Bell, A., 2017. Developmental programming and beef production. Anim. Front. 7, 38–47. https://doi.org/10.2527/af.2017-0127

Gül, S., Keskin, M., Biçer, O., Gündüz, Z., Behrem, S., 2020. Effects of different lambing season on some reproductive characteristics of ewes and growth performance of lambs in Awassi sheep. Livest. Studies, 60, 32–36. https://doi.org/10.46897/lahaed.779729.

Hoffman, M.L., Reed, S.A., Pillai, S.M., Jones, A.K., McFadden, K.K., Zinn, S.A., Govoni, K.E., 2017. Physiology and endocrinology symposium: The effects of poor maternal nutrition during gestation on offspring postnatal growth and metabolism. J. Anim. Sci. 95, 2222–2232. https://doi.org/10.2527/jas2016.1229

Kandiwa, E., Mushonga, B., Madzingira, O., Samkange, A., Bishi, A., Tuaandi, D., 2019. Characterization of Oestrus Cycles in Namibian Swakara and Damara Sheep through Determination of Circannual Plasma Progesterone Levels. J. Vet. Medicine pages. https://doi.org/10.1155/2019/5320718

Kandiwa, E., Nguarambuka, U., Chitate, F., Samkange, A., Madzingira, O., Mbiri, P., Bishi, A.S., Mushonga, B., 2020. Production performance of sheep and goat breeds at a farm in a semi-arid region of Namibia. Trop. Anim. Health Prod. 52, 2621–2629. https://doi.org/10.1007/s11250-020-02283-w

Karatas, A., Gokturk, S., Savas, T., 2017. An analysis on lambing season of tahirova sheep farms in Çanakkale. 2nd International Balakan Agricultural Congress 16 -18 May, Namik Kemal University, Turkey.

Karthik, D., Suresh, J., Ravindra Reddy, Y., Sharma, G.R.K., Ramana, J. V., Gangaraju, G., Pradeep Kumar Reddy, Y., Yasaswini, D., Adegbeye, M.J., Ravi Kanth Reddy, P., 2021. Farming systems in sheep rearing: Impact on growth and reproductive performance, nutrient digestibility, disease incidence and heat stress indices. PLoS One 16, 1–22. https://doi.org/10.1371/journal.pone.0244922

Kleemann, D.O., Kelly, J.M., Arney, L.J., Len, J., Tilbrook, A.J., Walker, S.K., 2021. Sexual behaviour, semen quality and fertility of young Border Leicester rams administered melatonin during spring. Anim. Reprod. Sci. 231, 106804. https://doi.org/10.1016/j.anireprosci.2021.106804

Bansal, G.K., Kumar, V., Nagda, R.K., HadaKumar, R., 2022. Factors affecting average daily gain in Sonadi sheep. Indian J. Small Rum. 28(1), 20–23 https://doi.org/10.5958/0973-9718.2022.00020.4

Lakew, M., Haile-melekot, M., Mekuriaw, G., Abreha, S., 2014. Reproductive performance and mortality rate in local and Dorper × Local crossbred sheep following controlled breeding in Ethiopia. Open J. Anim. Scie. 4, 278–284. https://doi.org/10.4236/ojas.2014.45035

Loureiro, M.F.P., Pain, S.J., Kenyon, P.R., Blair, H.T., 2016. Reproductive performance of singleton and twin female offspring born to ewe-lamb dams and mature adult dams. Proceedings of the New Zealand Society of Animal Production 2016.76, 151–154.

Loos, R.J.F., Derom, C., Eeckels, R., Derom, R., Vlietinck, R., 2001. Length of gestation and birthweight in dizygotic twins. Lancet 358, 560–561. https://doi.org/10.1016/S0140-6736(01)05716-6

Mirzaei, A., Mohebbi-Fani, M., Omidi, A., Boostani, A., Nazifi, S., Mahmoodian-Fard, H.R., Chahardahcherik, M., 2017. Progesterone concentration and lambing rate of Karakul ewes treated with prostaglandin and GnRH combined with the ram effect during breeding and non-breeding seasons. Theriogenology 100, 120–125. https://doi.org/10.1016/j.theriogenology.2017.06.005

Norouzian, M.A., 2015. Effects of lambing season , birth type and sex on early performance of lambs. New Zeal. J. Agric. Res. 58, 84–88. https://doi.org/10.1080/00288233.2014.944270

Nsoso, S.J., Madimabe, M.J., 2003. A survey of Karakul sheep farmers in Southern Kalahari , Botswana:management practices and constraints to improving production 4, 23–27.

Ortavant, R., Bocquier, F., Pelletier, J., Ravault, J.P., Thimonier, J., Volland-Nail, P., 1988. Seasonality of reproduction in sheep and its control by photoperiod. Aust. J. Biol. Sci. 41, 69–86. https://doi.org/10.1071/BI9880069

Rosov, A., Gootwine, E., 2013. Birth weight, and pre- and postweaning growth rates of lambs belonging to the Afec-Assaf strain and its crosses with the American Suffolk. Small Rumin. Res. 113, 58–61. https://doi.org/10.1016/j.smallrumres.2013.02.015

Safari, E., Fogarty, N.M., Hopkins, D.L., Greeff, J.C., Brien, F.D., Atkins, K.D., Mortimer, S.I., Taylor, P.J., Van Der Werf, J.H.J., 2008. Genetic correlations between ewe reproduction and carcass and meat quality traits in Merino sheep. J. Anim. Breed. Genet. 125, 397–402. https://doi.org/10.1111/j.1439-0388.2008.00745.x

Salem, H. Ben, Smith, T., 2008. Feeding strategies to increase small ruminant production in dry environments. Small Rumin. Res. 77, 174–194. https://doi.org/10.1016/j.smallrumres.2008.03.008

Sanchez-Davila, F., Bernal-Barragan, H., Vazquez-Armijo, J.F., López-Villalobos, N., Ledezma-Torres, R.A., Grizelj, J., Brenner, E.G., Vasquez, N.A., Palomera, C.L., 2020. Annual variation in reproductive parameters and sexual behaviour of Saint Croix rams in a semi-desert region in Mexico. J. Appl. Anim. Res. 48, 499–506. https://doi.org/10.1080/09712119.2020.1830778

Saxena, V.K., De, K., Kumar, D., Naqvi, S.M.K., Krishnaswamy, N., Tiwari, A.K., 2015. Induction of ovulation in anestrus ewes using a dopamine receptor antagonist. Theriogenology 84, 1362–1366. https://doi.org/10.1016/j.theriogenology.2015.07.020

Simasiku, L., Charamba, V., Lutaaya, E., 2019. Modeling and comparison of the maturing rates of Damara , Dorper and Swakara sheep at Neudamm Farm Welwitschia . Int. J. Agric. Scie.48, 41–48.

Namwandi, R., Thawana, S.B., 2008. The development of the gellapper sheep breed at gellap-ost research station Spotlight on Agriculture. Ministry of Agriculture, Water and Forestry, Windhoek, Namibia.

Thompson, A.N., Bowen, E., Keiller, J., Pegler, D., Kearney, G., Rosales-Nieto, C.A., 2021. The number of offspring weaned from ewe lambs is affected differently by liveweight and age at breeding. Animals 11, 1–14. https://doi.org/10.3390/ani11092733

Wassie, T., Liu, G., Jiang, X., Tesema, B., Han, Y., 2019. Immunization against Kisspeptin-54 perturb hypothalamic, pituitar, testicular signaling pathway in ram lambs. Theriogenology. 125, 193–202. https://doi.org/10.1016/j.theriogenology.2018.10.029

Welday, K., Urge, M., Abegaz, S., 2019. Sheep production systems and breeding practices for selected zones of Tigray, Northern Ethiopia. Open J. Anim. Sci. 09, 135–150. https://doi.org/10.4236/ojas.2019.91012

Yilmaz, O., Denk, H., Bayram, D., 2007. Effects of lambing season, sex and birth type on growth performance in Norduz lambs. Small Rumin. Res. 68, 336–339. https://doi.org/10.1016/j.smallrumres.2005.11.013

Zaher, H.A., Alawaash, S.A., Swelum, A.A., 2020. Effects of season and breed on the reproductive performance of sheep. J. Anim. Reprod. Biotechnol. 35, 149–154. https://doi.org/10.12750/jarb.35.2.149