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REVIEW

Dorper sheep in Africa: A review of their use and performance in different environments

Julie M.K. Ojango[1]*, Moses Okpeku[2], Richard Osei-Amponsah[3], Donald R. Kugonza[4], Okeyo Mwai[1], Mizeck G.G. Changunda[5] and Victor E. Olori[6]

Affiliations: [1]International Livestock Research Institute, PO BOX 30709-00100, Nairobi, Kenya
[2]Discipline of Genetics, School of Life Sciences, University of Kwazulu-Natal, Durban South Africa
[3]Department of Animal Science, School of Agriculture, University of Ghana, Legon, Accra, Ghana
[4]Department of Agricultural Production, School of Agricultural Sciences, College of Agricultural & Environmental Sciences, Makerere University, Box 7062, Kampala, Uganda
[5]University of Hohenheim, Institute of Agricultural Science in the Tropics, Germany
[6]Research & Development Department, Aviagen Ltd, 11 Lochend Rd, Newbridge EH28 8SZ, Scotland, UK

Abstract

The Dorper breed developed in South Africa is used either as a pure breed or crossbred with existing indigenous breeds by many countries across the African continent to improve sheep production. This article presents documented information on the adoption, use, and performance of Dorper sheep across the continent of Africa and opportunities for their more sustainable production under the changing climatic conditions in Africa. Apart from the well-documented information on the Dorper sheep in South Africa, published information on the performance of the sheep is mainly from Eastern Africa. Most countries initially retained purebred Dorpers in nationally owned institutions for multiplication and crossbreeding trials with different indigenous breeds prior to distributing the crossbreds to diverse livestock keepers. The offspring produced through crossbreeding programs with the Dorper have better growth rates than indigenous breeds in the different countries; however, the performance of Dorper sheep in South Africa has not been achieved in any of the other countries. Genomic studies including Dorper sheep have identified regions of interest for resistance to brucellosis and Mycoplasma ovipneumonia that imply adaptability to challenging environments within Dorper sheep. Unfortunately, limitations in systems for guided breeding and monitoring of sheep productivity in Africa have resulted in haphazard crossbreeding of the Dorper. Targeted efforts are required across the different countries to develop breeding programs for improving locally adapted Dorper sheep populations and their crosses with indigenous breeds. New science and technologies need to be innovatively packaged and used to identify and propagate more productive and resilient Dorper and Dorper-based breed-types for the increasingly challenging tropical African range environments.

Keywords: Dorper sheep, productivity, genetic parameters, crossbreeding

Introduction

The Dorper sheep is a hardy, early maturing composite breed developed in the semi-arid Karoo region of South Africa from the 1930s (Cloete *et al*., 2000; Milne, 2000; AGTR, 2011; Zishiri *et al*., 2013). The breed was developed by the South African Department of Agriculture and cooperating farmers in the region in response to the need for a hardy productive sheep breed able to survive the arid, harsh environmental elements of the Karoo and produce good-quality meat (Ramsay *et al*., 2000). Through selective crossbreeding of the Dorset Horn sheep (known for quality meat production), with the Persian sheep (well adapted to arid environments), two variants of the breed were produced, one with a characteristic black head and white body and the other that is entirely white in color (Cloete *et al*., 2000; Milne, 2000; Schoeman, 2000; Wanjala *et al*., 2023a). The Dorper is an embodiment of adaptation to various climatic conditions, has high fertility and a good growth rate under extensive management in the semi-arid region of South Africa, and produces a high-quality carcass with well-marbled meat, making it a choice breed for meat production (Schoeman, 2000). Although developed for the arid regions, the attributes of Doper sheep in South Africa enabled the breed to be exported to many countries on the African continent, North America (United States and Canada), Australia, and in more temperate environments of Europe, New Zealand, and Tasmania (Cloete *et al*., 2000; Milne, 2000; Schoeman, 2000; Cosgrove, 2023).

*Corresponding Author: Julie M.K. Ojango. Email: j.ojango@cgiar.org

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In Africa, Dorper sheep are used for crossbreeding with various indigenous breeds raised in semi-arid environments (Getachew *et al*., 2016; Zonabend Konig *et al*., 2017; Oyieng *et al*., 2022; Besufkad *et al*., 2023).

Characteristics and performance of Dorper sheep in South Africa are well documented (Ramsay *et al*., 2000; Cloete *et al*., 2012; Zishiri *et al*., 2013; Hoffman *et al*., 2020; Kao *et al*., 2022); however, recent scientific reports on Dorper sheep in other countries of Africa are few and scattered. This review presents documented information on the adoption, use, and performance of Dorper sheep and their crosses with indigenous breeds in different countries of Africa and opportunities for their more sustainable production under changing climatic conditions.

Review methodology

When scoping information to get a general overview of what has been documented on Dorper sheep in Africa, we used "Chat GPT" to generate an initial list of topics to prioritize in the review. The general framework used in implementing the review is presented in Table 1.

A series of search strings were developed that combined components representing the scope of the proposed review including: (i) Background and distribution of Dorper sheep in Africa: Origin/Genesis of the Dorper; (ii) Breeding programs involving Dorper sheep in different countries of Africa; (iii) Genetic diversity in Dorper sheep populations across Africa: Phenotypic and Genetic parameter estimates for Dorper sheep and their crosses in different environments of Africa; (iv) Opportunities and strategies for future breeding programs involving Dorper sheep.

Search strings comprising a combination of key terms in the prioritized topics using the Boolean operators "OR" and "AND" were applied to CABI, Scopus, PubMed, ScienceDirect, Google Scholar, and a web search of Google to target grey literature, conference proceedings, and Graduate thesis that may not be in the academic databases. Only publications in English were included in the search. Considering the reviews on Dorper sheep in Africa that were published in 2000 (Cloete *et al*., 2000; Milne, 2000; Schoeman, 2000), the publication date for our search was set to publications after 1999. The search was implemented between May and August 2023.

Utilization of the Dorper in breeding programs in Africa

The exact number of Dorper sheep within the different countries of Africa is not known as such data are limited and generally not captured at country levels. The information available through the Food and Agricultural Organization (FAO) statistical database (FAOSTAT, 2023) on sheep populations is based on all sheep breeds that are found within each country and therefore reported at the country level. The Southern Africa region has the largest population of Dorper sheep, with the population in South Africa alone estimated to be more than 5 million by the Dorper Sheep Breeders' Society (Available at: https://dorpersa.co.za/breed-history/), accessed 7 October 2023. Dorper sheep were introduced in Eastern Africa around 1952 (Kariuki *et al*., 2010) and in Ethiopia in the 1980s (Getachew *et al*., 2016). The breed was subsequently established through additional importations to flocks owned by national organizations and used both as purebreds and for crossbreeding with existing indigenous breeds (Kosgey and Okeyo, 2007; Kariuki *et al*., 2010; Getachew *et al*., 2016; Ayichew, 2019).

Multiplication, breeding, and sheep improvement programs using Dorper sheep that are documented from different countries of Africa (Table 2) are managed either by government-owned or privately owned ranches. The Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) re-introduced Dorper sheep in 2007 to be multiplied through government stations and subsequently used for crossbreeding with local indigenous sheep breeds such as the Tumele, Hararghe Highland, Afar, and Menz (Lakew *et al*., 2014; Ayichew, 2019; Tesema *et al*., 2022). In Kenya, a Dorper sheep breeder's society was formed in 1970 and formerly registered in 2012 to promote the genetic improvement of a national Dorper flock (DSBSK, 2023). Though the society in Kenya has set breed standards, documentation of the performance of the registered animals is scarce. The Dorper is however widely used for crossbreeding with the indigenous Red Maasai sheep breed in Kenya (Muigai *et al*., 2009; Kariuki *et al*., 2010; Zonabend Konig *et al*., 2017).

Crossbred animals resulting from mating Dorper sheep with indigenous breeds are popular because of the fast growth rate and good market demand as meat animals (Zonabend König *et al*., 2016; Lakew *et al*., 2021; Tesema *et al*., 2022). Reports from crossbreeding Dorper sheep with the Red Maasai sheep breed in Kenya (Zonabend Konig *et al*., 2017; Oyieng *et al*., 2022; Wanjala *et al*., 2023b) and with Tumele sheep in Ethiopia (Tesema *et al*., 2020) indicate that the use of the Dorper improved the reproductive performance and growth rates of sheep under semi-arid production environments. The indigenous breeds in the different countries however display better resistance to internal parasites compared with the Dorper (Tembely *et al*., 1998; Baker *et al*., 1999; Matika *et al*., 2003; Baker *et al*., 2004). The offspring from crossbreeding programs that use Dorper sheep have been multiplied by livestock keepers rearing sheep under extensive management in semi-arid to arid environments in Ethiopia and Kenya (Kosgey *et al*., 2008; Abebe *et al*., 2015; Ayichew, 2019). Published reports on the commercialization of Dorper crossbred populations and their performance across the different farming communities are mainly from animals reared in Ethiopia and Kenya. Results from the crossbreeding of Dorper sheep with indigenous Ethiopian sheep breeds (Getachew *et al*., 2016; Ayichew, 2019) indicate that the introduction of the new breeds has had a positive effect on sheep production. However, the collection of data on the performance of the introduced breeds and their crosses in the local farming communities remains limited. The practice of ubiquitous dissemination and selling of crossbred rams for breeding to individual farmers may however dilute efforts of developing stabilized crossbred animals with improved performance (Getachew *et al*., 2016).

Table 1. The framework adopted for this review.

Steps	Outcome
Protocol	Define scope for the review: Determine key topics to be covered in the review
Search	Define the search strategy to be adopted Prioritize digital libraries to source content
Appraisal and quality assessment	Define criteria for inclusion and exclusion of publications/documents
Synthesis and review	Synthesize and iteratively categorize information collated in line with topics defined
Writing of publication	Develop narrative of organized information, iteratively review drafts to identify gaps, compare results, and derive conclusions

Adapted from Mengist *et al*. (2020).

Table 2. Documented sheep improvement programs using the Dorper breed in different countries of Africa.

Region country	Organization/institution affiliated	Indigenous breed used in crossbreeding	Reference
Southern Africa			
Botswana	Farmers in different districts	Tswana	Bolowe *et al*. (2022)
Namibia	Extensive farming systems	N/A	Kandiwa *et al*. (2020)
South Africa*	Research institutions such as Nortier experimental farm and University of Limpopo	South African Merino, N	Cloete *et al*. (2000); Milne (2000); Ramsay *et al*. (2000); Schoeman (2000); Zishiri *et al*. (2013)
Swaziland	Research institutes such as University of Free State and Malotwana Silvopastoral farm	N/A	Patricia Walker (2013); Nxumalo *et al*. (2022)
Zambia	Mazabuka Regional Research Station; Mansa Research station	Indigenous breeds	Mwenya (1994); Goma *et al*. (2007)
Zimbabwe	Research Institutes, e.g., Grassland Research Station, Matopos Research Station	Sabi	Matika *et al*. (2003); Assan and Makuza (2005)
Eastern Africa			
Ethiopia	Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP)	Hararghe Highland, Blackhead Ogaden, Menz	Abebe *et al*. (2015); Getachew *et al*. (2016); Weldeyesus (2017); Ayichew (2019); Tesema *et al*. (2020); Lakew *et al*. (2021); Tesema *et al*. (2022); Besufkad *et al*. (2023)
Kenya	Ol'Magogo Research station; International Livestock Research Institute, Kapiti; pastoral production systems and private ranches	Red Maasai Sheep	Baker *et al*. (2004); Mugambi *et al*. (2005); Kariuki *et al*. (2010); Liljestrand (2012); Zonabend König *et al*. (2017); Oyieng *et al*. (2022); Wanjala *et al*. (2023c)

*Original developers of breed.

Performance of Dorper sheep and their crosses in Africa

The economic returns from rearing non-wool sheep including the Dorper depend on the offspring produced and marketed, which in turn is influenced by the reproduction and growth performance of the animals (Cloete *et al*., 2000; Cloete *et al*., 2012; Zishiri *et al*., 2013; Deribe *et al*., 2021). A review of the performance of Dorper sheep and its crosses with other breeds under different production systems in Africa (Schoeman, 2000) noted that the Dorper was superior to the other breeds in reproductive and growth traits; however, it was noted that mortality rates of up to 49% were reported in Kenya under semi-arid conditions (Inyangala *et al*., 1992). Though the high mortality rate could make the breed unsuitable for commercial use in the more humid African Tropics, observation of flocks owned by pastoralist livestock keepers in the southern rangelands of Kenya and anecdotal information points to the contrary as Dorper sheep and their crosses are herded in large numbers and their population is increasing in Kenya (Muigai *et al*., 2009; Zonabend Konig *et al*., 2017). Corroborating this observation, subsequent publications from different countries in Africa illustrate the widespread adoption of Dorper sheep (Table 2) accompanied by changes in productivity within the specified environments as outlined below.

REPRODUCTION

Cloete *et al*. (2000) reviewed published literature on the reproduction of Dorper sheep which indicated a broad range of performance across environments. The review reported age at first oestrus to range from 213 to 328 days, with reproductive rates of 0.99–1.40 lambs per ewe mated. Subsequent studies on the fertility of Dorper sheep within Africa present a broader range in the age at first lambing (AFL) (Table 3). Zishiri *et al*. (2013) evaluated the overall reproduction, longevity, and survival of Dorper sheep in South Africa by deriving several fertility parameters. These included the number of lambing chances afforded per ewe lifetime (LC/EL = 2.45), the average litter size (1.23), the number of lambs born per ewe per lifetime (NLB/EL = 2.14), and the number of lambs weaned per ewe per lifetime (NLE/EL = 1.83). From this study, the reproductive performance of ewes defined as the total weight of lamb weaned per ewe lambing (TWW/L) was proposed as a good measure for both reproduction and fitness of ewes that can be improved through either direct or indirect selection.

Studies on Dorper sheep raised in national stations of Kenya and Ethiopia have reported the number of ewes lambing per ewe mated (EL/EM) as presented in Table 3, and the number of lambs weaned per ewe lambing. The number of ewes lambing per ewe mated reported for Dorper sheep within a mixed flock in Kenya (Wanjala *et al*., 2023c) was higher than that reported for purebred Dorper sheep at the Debre Berhan station in Ethiopia (Goshme *et al*., 2021), reflecting differences in the production environment on the fertility.

Individual fertility traits including the AFL and lambing intervals (LI) reported for pure and crossbred Dorper sheep raised in the arid rangelands of Kenya have been shown to fluctuate with variations in precipitation over the seasons and years (Ojango *et al*., 2023). From previously reviewed studies on fertility (Cloete *et al*., 2000; Deribe *et al*., 2021), it is evident that the inter-lambing period is greatly influenced by the management practices adopted by each breeder rather than the genetic potential of the animals, while post-partum anoestrus of ewes strongly depends on the lambing season and feeding level of the animals.

SURVIVAL

Lamb survival to weaning for Dorper sheep in South Africa derived as the proportion of the total number of lambs weaned over the total number of lambs born is reported to be 78% by Kao *et al*.

Table 3. Average reproductive performance (mean ± standard deviation) of pure and crossbred Dorper sheep in different countries of Africa.

Age at first lambing (days)	Lambing interval (days)	Lambs weaned per ewe mated (LW/EM)	Number of ewes lambing per ewe mated (EL/EM)	Breed	Country	References
555±6.25	287±2.38			50% Dorper × indigenous	Ethiopia	Lakew *et al*. (2014)
786±57.8	380±19		0.85±0.01	Dorper × Menz 50%	Ethiopia	Goshme *et al*. (2021)
570± 54	398±14		0.68±0.03	Dorper	Ethiopia	
346–588	198–231	0.99–1.40		Dorper	South Africa	Cloete *et al*. (2000)
	298±44.4	0.80±0.26		Dorper	South Africa	Zishiri *et al*. (2013)
756±162	418±92			Dorper	Kenya	Ojango *et al*. (2023)
720±183	411±88			75% Dorper × Red Maasai	Kenya	
690±170	422±91			50% Dorper × 50% Red Maasai	Kenya	
		0.882	1.008	Dorper	Kenya	Wanjala *et al*. (2023b)

(2022) and 88% by Zishiri *et al*. (2013) with a direct heritability estimate of 0.07±0.01. In Ethiopia, Tesema *et al*. (2020, 2021) reported mortality rates for crossbred Dorper lambs of 14% from birth to weaning, and 32.1% from birth to yearling. The main causes of mortality in the flocks were noted to be gastrointestinal parasites and pneumonia (Tesema *et al*., 2020). The results on mortality indicate the importance of managing the environment for better survival of young animals. Evaluations of the length of productive life of Dorper ewes are limited, yet the ability of ewes to remain productive over several years enhances the efficiency of production and reduces replacement costs. Cloete *et al*. (2000) reported that Dorpers remained in breeding flocks for an average of 4.7 seasons in Zimbabwe, while Zishiri *et al*. (2013) reported the heritability for stayability to 5 years of age in Dorper sheep to be less than 0.05.

GROWTH

Reports on the growth performance of Dorper sheep and their crosses with indigenous breeds in Africa include information on lamb performance from birth to weaning, and from weaning to maturity which is either reported at 9 months of age or 1 year of age. Results from published documents on the growth performance of Dorper's and their crosses from various studies on populations in Africa are presented in Table 4.

The growth of Dorper sheep and their crosses varies greatly across countries and production environments (Table 4). In South Africa, Dorper sheep are crossed with the South African Mutton Merino for meat production (Kao *et al*., 2022), and the Namaqua Africana an adapted indigenous breed for their adaptability (Cloete *et al*., 2021). Several studies present results on the growth performance of Dorper sheep and their crosses in Ethiopia (Table 4). Among these results, the study by Besufkad *et al*. (2023) presented a general decline in growth performance of the pure-bred Dorper (2012–2021) reared at a higher altitude in Debre Birhan Agricultural Research Center of Ethiopia, mainly attributed to management and nutrition of the animals post-weaning. In Kenya, Oyieng *et al*. (2022) reported improved growth rates in Dorper's and their crosses with Red Maasai sheep over 17 years under a semi-arid environment (Table 4). The crosses comprising 75% Dorper and 25% Red Maasai breed exhibited the best productivity in the semi-arid environment (Oyieng *et al*., 2022). It is however notable that Dorper sheep in South Africa exhibit the highest weights at different ages (Table 4), reflecting the potential of the breed under optimal conditions, and the gaps in performance levels attained in the different countries.

In addition to documenting weights at different ages of the Dorper sheep and their crosses in Ethiopia, the authors have calculated Kleiber ratios (KR: weight gain per unit metabolic weight) as an indicator of feed efficiency by the animals in different phases of growth (Deribe *et al*., 2021; Tesema *et al*., 2022; Besufkad *et al*., 2023). The KR for sheep in Ethiopia differ significantly depending on the proportion of Dorper genes in the animals, and depending on the phase of growth. Sheep comprising 50% Dorper and 50% indigenous breeds had a KR from birth to weaning of 6.49 relative to 5.79 for those with 75% Dorper and 25% indigenous breeds. Additionally, a higher KR is reported between weaning and 6 months of age (5.01–5.76) relative to that between 6 and 9 months of age (3.04–3.6) (Deribe *et al*., 2021; Tesema *et al*., 2022; Besufkad *et al*., 2023). Though the management and feeding of the animals are noted to influence their growth, the impacts of the different temperatures and humidity on the performance of the different breeds are not yet documented.

Phenotypic and genetic parameters of Dorper sheep and their crosses in Africa

The genetic relationships across Dorper sheep populations in Africa are poorly documented. Genetic parameter estimates for some traits are published for populations of Dorper sheep in South Africa, Ethiopia, and Kenya. Those published prior to the year 2000 are well documented in Cloete *et al*. (2000).

Heritability estimates reported for AFL and survival to weaning for Dorper sheep and their crosses with indigenous breeds in Africa are presented in Table 5. Parameter estimates for the composite fertility traits defined by Zishiri *et al*. (2013) ranged from 0.09±0.01 for NLW/EL to 0.23±0.01 for LC/EL, indicating that genetic gains in the defined fertility traits are realizable. Their study also reviewed previously reported heritability estimates for the number of lambs born per ewe joined across different parities in various sheep breeds, noting that the reported estimates tended to be low (below 0.10).

Heritability estimates for weaning weight and post-weaning weight for Dorper's across different countries of Africa are moderate (Table 5), illustrating the propensity of the sheep to transmit reasonable

Table 4. Growth performance of Dorper and their crosses (50 and 70% Dorper) with other breeds reported for different countries of Africa.

Breed	Birth	Weaning (3 months)	9 months	12 months	Country	Source
Pure-bred Dorper	4.19±0.09	32.7±0.6			South Africa	Cloete *et al.* (2021)
		30.9±0.013	45.1±0.034		South Africa	Zishiri *et al.* (2013)
	4.16±0.10	31.6±0.04			South Africa	Kao *et al.* (2022)
	3.33±0.10				Ethiopia	Goshme *et al.* (2021)
	3.39±0.08	16.18±0.35		34.43±0.79	Ethiopia	Abebe *et al.* (2015)
	3.8±0.02	19.38±0.10	29.86±0.16	36.6±0.19	Kenya	Kariuki *et al.* (2010)
	4.11±0.14			38.16±1.13	Kenya	Zonabend Konig *et al.* (2017)
	3.8±0.02	17.5±0.14	27.3±0.21		Kenya	Oyieng *et al.* (2022)
50% Dorper crossed to breed listed						
Namaqua Afrikaner	4.40±0.11	33.1±0.7			South Africa	Cloete *et al.* (2021)
Menz	2.51 ±0.11				Ethiopia	Goshme *et al.* (2021)
	2.77±0.04	12.3±0.25		31.33±0.56	Ethiopia	Abebe *et al.* (2015)
Blackhead Ogaden	3.0±0.1	15.1±0.3			Ethiopia	Teklebrhan *et al.* (2014)
Afar	2.57±0.06	9.45±0.87		24.96±3.77	Ethiopia	Abebe *et al.* (2015)
Hararghe Highland	2.9±0.1	14.9±0.1			Ethiopia	Teklebrhan *et al.* (2014)
Indigenous	3.24±0.04	14.59±0.21		31.37±0.38	Ethiopia	Lakew *et al.* (2014)
	3.03±0.03	14.4±0.18	20.3±0.28	24.6±0.32	Ethiopia	Tesema *et al.* (2022)
Red Maasai	3.79±0.12			39.37±0.97	Kenya	Zonabend Konig *et al.* (2017)
	3.4±0.02	16.6±0.11	26.6±0.15		Kenya	Oyieng *et al.* (2022)
75% Dorper crossed to breed listed						
Blackhead Ogaden	3.1±0.1	20.7±1.1			Ethiopia	Teklebrhan *et al.* (2014)
Hararghe Highland	3.1±0.2	19.2±1.1			Ethiopia	Teklebrhan *et al.* (2014)
Dorper × indigenous	3.00±0.07	15.2±0.59	21.4±0.68	26.5±0.53	Ethiopia	Tesema *et al.* (2022)
Red Maasai	4.05±0.09			38.59±0.77	Kenya	Zonabend Konig *et al.* (2017)
Red Maasai	3.72±0.02	17.64±0.11	28.82±0.16		Kenya	Oyieng *et al.* (2022)

genetic variation that will result in genetic gains in growth traits. From the estimates published, except in the study by Kariuki *et al*. (2010), the maternal effects that are important to weaning diminish with lamb age post-weaning (Table 5). Maternal effects and influence reflect the milk-producing ability and mothering behavior of ewes which support early lamb growth and survival. The total weight of lambs weaned per year as a function of the number of lambs born, their survival, and individual lamb weights at weaning as proposed in Zishiri *et al*. (2013) provides a good measure of flock productivity. The differences in genetic parameter estimates within the sub-populations of Dorper sheep in the different countries reflect significant levels of genetic diversity of the sub-populations which is yet to be exploited through structured national and regional breeding programs.

Positive and moderate genetic correlations are reported between growth traits and composite fertility traits for Dorper sheep in South Africa (Zishiri *et al*., 2013). The same study also reported positive genetic correlations between growth traits and lamb survival to weaning (0.36±0.05) and post-weaning (0.24±0.03), implying that selection for liveweight will not compromise the fitness of sheep in the South African production environments. The genetic correlation between lamb survival to weaning and litter size was however unfavorable (−0.41±0.15). Additional studies in the different production environments across the continent are however required to enhance the understanding of the relationship between survival and production traits.

Genomic studies with Dorper sheep

Genomic studies on sheep across the world have included Dorper's in a variety of ways. Analyses of the population structure of African sheep breeds using principal component analysis (PCA) and ADMIXTURE analyses show Dorper sheep to be clustered between Dorset and Blackhead Persian (Molotsi *et al*., 2017; Dzomba *et al*., 2021). The black head coloration of the Dorper and similarly colored sheep breeds have been associated with a haplotype that covers the melanocortin receptor 1 (MC1R) gene (Wang *et al*., 2021).

A study on the genomic structure of the Dorper sheep variants in South Africa and Hungary using the ovine 50K single nucleotide polymorphism (SNP) chip reported a strong genetic relationship between the white Dorper in Hungary and South Africa (Wanjala *et al*., 2023a). The Dorper variants from South Africa had a higher level of genetic diversity within the population. The genetic

Table 5. Genetic parameter estimates for growth and fertility traits in Dorper sheep and their crosses with indigenous breeds from different countries of Africa.

	Growth traits (kg)				Functional traits				
	Birth weight	Weaning weight	9-month weight	Yearling weight	Age at first lambing	Survival to weaning	Breed	Country	Source
Heritability estimates									
		0.21±0.01	0.27±0.02			0.07±0.01	Dorper	South Africa	Zishiri *et al*. (2013)
	0.24±0.09	0.10±0.07	0.08±0.06				Dorper	Kenya	Oyieng *et al*. (2022)
	0.18±0.01	0.25±0.05	0.14±0.05	0.29±0.09			Dorper	Kenya	Kariuki *et al*. (2010)
	0.33±0.07	0.38±0.07	0.40±0.07				50% Dorper × Red Maasai	Kenya	Oyieng *et al*. (2022)
	0.37±0.12	0.21±0.12					50% Dorper × indigenous	Ethiopia	Tesema *et al*. (2022)
Direct maternal heritability		0.05±0.01	0.04±0.02				Dorper	South Africa	Zishiri *et al*. (2013)
	0.16±0.01	0.19±0.04		0.18±0.06			Dorper	Kenya	Kariuki *et al*. (2010)
	0.08±0.06	0.05±0.03	0.00				Dorper	Kenya	Oyieng *et al*. (2022)
	0.12±0.05	0.00	0.00				50% Dorper × Red Maasai	Kenya	Oyieng *et al*. (2022)
	0.20±0.06	0.13±0.07					50% Dorper × indigenous	Ethiopia	Tesema *et al*. (2022)
Dam permanent environment		0.08±0.01	0.04±0.02				Dorper	South Africa	Zishiri *et al*. (2013)

differentiation between the Dorper populations was noted to be related to environmental adaptations. The first report and analysis of the full sequence of the Dorper sheep reference genome by Qiao *et al*. (2022) revealed allele-specific expression (ASE) genes related to the immune system as well as lipid metabolism and adaptation of the breed to the environment. Runs of homozygosity (RoH) of South African breeds of sheep including the White Dorper sheep using the Ovine SNP50 Illumina® bead chip array showed a majority of short, i.e., 1–6Mb RoH in the Dorper and other tested breeds (Dzomba *et al*., 2021). They found that chromosome 10, which harbours a genomic region associated with horns in sheep (Kijas *et al*., 2012), had the highest incidence of common RoH per SNP, indicating a significant change in genetic architecture due to selection for pollness in sheep. The White Dorper sheep had the smallest mean number of RoH compared to the other breeds in the study.

In a study using Oxford Nanopore Technology (ONT) sequencing and Hi-C (chromatin conformation capture) approaches, ASE genes involved in the immune system, lipid metabolism, and environment adaptation were identified in Dorper sheep (Qiao *et al*., 2022). A study by Lv *et al*. (2023) identified candidate genes associated with immunity, reproductive efficiency, and meat quality in Dorper sheep. Zhao *et al*. (2022) using a label-free proteomics approach investigated the genetic basis of body weight in the Dorper and Hu breeds of sheep. They reported several differentially abundant proteins (DAPs) associated with muscle development and fat synthesis that were significantly enriched in Kinase activity, metabolism of arachidonic acid, and biosynthesis of steroid hormones. They concluded that body weight is regulated via a variety of pathways in the Dorper and Hu sheep breeds.

Dorper sheep and their crosses have also been studied for their resistance to different diseases. Marshall *et al*. (2013) undertook a genome-wide scan to detect quantitative trait loci (QTL) for resistance to gastrointestinal nematodes in the Dorper sheep. Interesting regions were found in chromosome 26 and chromosome 2 with putative QTLs for traits of interest. They concluded that favourable QTLs for resistance to disease originated in the Dorper and the Red Maasai sheep, but these were not fixed. A study of genetic mechanisms of Brucellosis disease by Li *et al*. (2021) using whole genome sequences of samples from a population of Dorper × Hu sheep revealed suitable molecular markers for resistance to brucellosis in sheep that can be used in sheep breeding. Another study of polymorphisms associated with Mycoplasma ovipneumonia (MO) by Wang *et al*. (2020) identified that MvaI *bb* and HaeIII *ee* genotypes were predominant in breeds that were susceptive to MO, while resistant breeds like the Dorper sheep carried the MvaI cc and HaeIII dd genotypes. This indicates that MvaI *cc* and HaeIII *dd* genotypes are associated with MO resistance in sheep.

Results from the diverse studies imply that the Dorper is a resilient sheep breed with the potential to adapt to a variety of environments. In reference to the use of the Dorper in Kenya as an example, most of the local Dorper populations have been established through the initial crossing of imported Dorper rams with local fat-tailed ewes, notably the Red Maasai sheep, and subsequently back-crossing to pure Dorper rams. The Kenya Dorper sheep populations thus carry a degree of DNA inheritance from the local but more resilient Red Maasai sheep (Baker *et al*., 2003; Muigai *et al*., 2009). The diversity in the breed reflected in the relatively high degree of resilience in Dorper sheep raised in the harsh Northern and Southern rangelands of Kenya needs to be characterized and exploited through appropriately designed breeding programs.

Challenges and opportunities for breeding programs involving Dorper sheep in Africa

Results from studies on use of Dorper sheep across Africa reflect sub-optimal exploitation of the attributes of the Dorper mainly resulting from: (i) *Lack of structured breeding programs*: The absence of organized breeding programs that facilitate sustainable utilization of indigenous breeds in combination with Dorper sheep is a compelling limitation (Zonabend König *et al*., 2016). Without a structured breeding program, the establishment of clear breeding objectives and selection becomes very challenging. (ii) *The absence of well-defined breeding objectives and selection indices* prevents breeders from making informed decisions regarding crossbreeding with the Dorper breed and hinders progress in archiving desired traits and genetic improvement (Kosgey and Okeyo, 2007; Getachew *et al*., 2016; Abebe and Alemayehu, 2019). (*iii) Variation in environmental factors:* The impact of diverse environmental conditions, notably effects of high altitudes and large variations in diurnal temperatures on Dorper sheep and their crosses, has not been rigorously evaluated in Africa. Apart from studies in South Africa on the performance of the Dorper under variable environments and feeding systems, in-depth comparative studies on the adaptability and productive potential of Dorper crosses under changing climatic conditions are rarely adopted to drive strategic sheep breeding programs for improved productivity. (*iv) Genetic erosion:* There are concerns about the possible genetic erosion of indigenous breeds due to crossbreeding with the Dorper breed and other introduced breeds (Molotsi *et al*., 2020). Genetic profiles of sheep populations in pastoral communities of Kenya show massive introgression of Dorper genes in the indigenous populations resulting from haphazard crossbreeding (Muigai *et al*., 2009), which may also have diluted the adaptive capacity of the indigenous breeds in different communities.

The role of the emerging sciences (Rege *et al*., 2011) notably, innovative application of genomic technologies, emerging phenotyping methods, and reproductive technologies such as the use of surrogate sires (Gottardo *et al*., 2019) provide new opportunities for attaining faster genetic improvements in Dorper crosses in pastoral systems. Smart application of the new science would help overcome the technical, organizational, and institutional bottlenecks to genetic improvement of sheep and goat productivity in low input systems.

Establishing structured Dorper breeding programs in different countries of Africa with guidelines on options for exploiting cross-country genetic resources can help facilitate effective and sustainable crossbreeding and improvement of the animals. Through engaging the relevant livestock producers in determining breeding objectives, the risk of undervaluing and potentially deteriorating traits that may contribute in the long term to the overall efficiency and resilience of future production systems is reduced. Community-based approaches to developing and implementing sheep improvement programs (Kosgey and Okeyo, 2007; Mueller *et al*., 2015; Haile *et al*., 2019; Mueller *et al*., 2019; Haile *et al*., 2020) combined with collaborative use of reference sires could be a more viable means of introducing and propagating more productive and resilient sheep. However, this would require targeted efforts to develop capacity within communities to adopt guided animal monitoring and selection practices for flock productivity gains.

Conclusions

The performance of Dorper sheep and their crosses with indigenous breeds in Eastern Africa and South Africa is extensively documented. Outside of South Africa however, well-defined breeding objectives for using Dorper sheep guided by structured selection indices are limited. High genetic correlations reported between growth traits and net reproductive rates indicate that environments that promote improvements in live weight for young animals are beneficial for their survival. Composite traits such as the total weight of lambs weaned per year as a function of the number of lambs born, their survival, and individual lamb weights at weaning provide a good measure of flock productivity and should be considered when selecting to improve reproduction and fitness in sheep.

Results from genomic studies including Dorper sheep present evidence of markers for resistance to diseases that could be further exploited in developing breeding programs for low-input extensive production environments. Community-based breeding programs supported by smart application of emerging genomic, reproductive, and phenotyping technologies offer new opportunities for realizing faster genetic improvements. There is opportunity for new science and technologies to be innovatively packaged and used to continuously identify and propagate more productive and resilient Dorper and Dorper-based breed-types for the increasingly challenging tropical African range environments.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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AUTHOR CONTRIBUTIONS

The general structure and outline for this review was developed by J.M.K. Ojango who also undertook the lead role in presenting the content for all the sections. M. Okpeku and O. Mwai contributed to the background and the challenges and opportunities for utilizing Dorper Sheep in Africa. R. Osei Amponsah and D.R. Kugonza provided inputs on phenotypic and genetic parameter estimates, while V.E. Olori, D.R Kugonza, and M.G.G. Chagunda provided the content on genomic studies on Dorper sheep. All Authors reviewed the paper for clarity of content.

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