



Review of the reproductive performances of sheep breeds in Ethiopia

Documenting existing knowledge and identifying priority research needs

Acknowledgements

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Acronyms

AI:	Artificial insemination
AP:	Age at puberty
BMP15:	Bone morphogenetic protein 15 gene
BW:	Body weight
SC:	Scrotal circumference
ED:	Epididymal diameter
ELISA:	Enzyme-linked immunosorbent assay
Fec genes:	Fecundity genes
GDF9:	Growth and differentiation factor 9 gene
GnRH:	Gonadotrophin releasing hormone
ICARDA:	International center for agricultural research in the dry areas
ILCA:	International livestock center for Africa
ILRI:	International livestock research institute
ng:	Nanogram
SME:	Syndrome: Starvation/mismothering and exposure syndrome
SNP:	Single-nucleotide polymorphism
TD:	Testicular diameter
TL:	Testicular length
VC:	Value chain

Purpose of the review

There are numerous benefits of reviewing the current state of knowledge related to the reproductive performances and characteristics of Ethiopian sheep. First, compilation of this information serves as a resource material for scientists actively performing research within Ethiopia. It also contributes to the understanding of data being collected and interpreted by researchers.

Second, it allows researchers to identify gaps in the current knowledge and determine future research priorities. Being aware of past research allows scientists to avoid duplication and increases collaboration. Increasing collaboration is vital due to limited funding for agricultural research. Collaboration also increases productivity and enhances partnerships between institutions.

Third, compiling existing research can help influence policymakers. Sheep play an important role in the rural economy of Ethiopia, but their productivity is among the lowest in sub-Saharan Africa. There have been attempts to improve the productivity of native Ethiopian breeds through crossbreeding with imported genotypes, but there have been little efforts to select indigenous breeds for improved productivity including reproduction. Identifying gaps in the current state of knowledge might encourage new investments in research. Understanding existing knowledge – or the lack of it – is critical to those formulating agricultural policies.

1. Introduction

In Ethiopia, small ruminants are mainly kept by smallholder farmers and the rural poor. With 25.5 million sheep and 24.1 million goats, Ethiopia's small ruminant population is among the largest in sub-Saharan Africa and the largest in East Africa (FAOSTAT, 2012; <http://faostat3.fao.org/home/E>).

The annual meat production from small ruminants (154,000 tons) is relatively small as compared to the large number of animals (50 million). The annual per capita supply of sheep and goat meat is only 1.6 kg (FAOSTAT, 2012). Recent estimates of average off-take rate, defined as the proportion of animals sold or consumed in a year, from sheep and goat herds between 2008 and 2010 were 30-38 percent (ILRI, 2014, unpublished report). Off-take rates of only seven percent were reported in the Ethiopian highlands (Negassa and Jabbar, 2008). Such a low percentage reflects diminished herd productivity.

Due to growing urbanization, the demand for and price of sheep and goat meat is increasing. From 2000 to 2008, the price of live sheep and sheep meat increased by 157 percent, and live goat and goat meat increased by 107 percent (Fadiga and Amare, 2010). The rising demand for small ruminant meat necessitates an improvement in current inefficient production and marketing systems.

As a result, the CGIAR Research Program on Livestock and Fish initiated the Ethiopian small ruminant value chain development project. The Livestock and Fish small ruminant value chain development program began in mid-2012. The approach during the first year of the program was to closely engage with partners, build a strong team, and conduct rapid value chain assessments. The value chain assessments contributed to the formulation of "best bet" intervention plans for each of the sites.

Genetic improvement of small ruminants was identified as one of the "best bets" in Ethiopia's highland areas. As part of this project, community-based breeding programs established in an earlier project (located in Horro, Menz, Bonga and Abergelle) were strengthened and new ones established in Atsbi and Doyogena. Currently, improved rams in these sites are selected and shared to serve the ewes and does in the communities. However, in order to scale out this technique and expand the use of improved rams and bucks, it is important to explore the options for the delivery of improved genetics. In this respect, development of efficient and affordable synchronization protocols may be an important step towards improving the delivery system of improved rams.

Before embarking on studies to identify approaches and methodologies for the dissemination of improved genetics, it is essential to review and document the current knowledge about the sheep genetic resources available in Ethiopia. Reproductive fitness, ability, and performance are at the core of the production process.

Therefore, this working paper will (1) provide a review of the current knowledge related to the reproductive performances and characteristics of sheep breeds in Ethiopia and (2) identify priority research development needs.

Sheep contribute substantially to the livelihoods of rural households as a source of income, food (meat and milk), and industrial raw materials (skins and wool). In addition to adding to socioeconomic and cultural functions, sheep contribute to risk mitigation during crop failures, increase property security, and serve as a form of investment (Tibbo, 2006). At the farm level, sheep contribute up to 63 percent of the net cash income derived from livestock production in the mixed farming system.

2. Sheep breeds in Ethiopia and their geographic distribution

A summary of the classification of Ethiopian sheep based on their morphological characteristics and geographic distribution (Gizaw, 2008) is presented in Table 1.

Table 1: Classification of Ethiopian Sheep

Sheep types	Other names	Ecology	Geographic distribution	Important physical features	Population (000)
SUB-ALPINE SHORT-FAT-TAILED GROUP					
Menz	Legegora, shoa, Abyssinian, Ethiopian highland sheep	Sub-moist/dry, sub-alpine highlands (2500 and 3200 m)	North Shoa zone of Amhara State	Short fat tail turned-up at end; small body size; short-legged; long fleece with coarse wool; commonly black with white patches, white, brown, white with brown patches; straight-faced; horned males; short semi-pendulous ears with 12% rudimentary ears in the population. Kept by Amhara community	971.4
Sekota	Tigray highland, Abergelle	Cool, dry/sub-moist highlands (2000 m); semi-arid river valley	Wag Himra zone of Amhara State and Tigray State	Short fat tail turned-up at end and fused with main part; medium-sized; predominantly brown or white coat, few black with brown belly; white animals have finer hair or woolly udder-coat; semi-pendulous or rudimentary ears in Wag Himra and Tigray, predominantly rudimentary in Tekeze valley. Reared by Agew, Tigray and Amhara communities	732.3
Semien		Alpine mountains (3000-4000 m) including Semien Wildlife park	North Gondar zone of Amhara State (Debark, Dabat, Janamora, Wegera)	Short fat tail; well-developed woolly undercoat; plain brown, plain white, brown/white with white/brown patches, plain black and black with brown belly; unique long laterally spiral horn in males and short horns in most females; largest of the highland woolled sheep. Reared by Amhara community	347.6
Tikur		Sub-alpine highlands (3000 m)	North Wollo zone of Amhara state	Short fat tail; woolly undercoat; predominantly black (60%) coat; small body size; majority short semipendulous ears, 24% rudimentary ears. Reared by Amhara community	525.3
Wollo		Cood highland (2000-3200 m)	South Wollo zone of Amhara state	Short fat tail with short twisted/coiled end, occasionally turned up at end; small size; well-developed woolly undercoat; predominantly black, white or brown, either plain or with patches of white, black or brown; long hair with woolly undercoat; horned males. Reared by Amhara community	1395.9
Farta		Sub-moist highland (2000-2500 m)	South Gondar zone; Gondar Zuria, Belesa, Dembia districts	Short fat tail; medium size; woolly under coat; commonly white (37.5%), brown (27.5%) and black with brown belly (15%), white/brown with brown/white patches; males are horned. Reared by Amhara community	555.6
Washera	Agew, Dangilla	Wet, warmer mid-highlands (1600-2000 m)	West and East Gojam and Agew Awi zones of Amhara state; Dangur, Madura districts	Short fat tail; large body size; short-haired; predominantly brown; both males and females are polled. Reared by Amhara and Agew communities	1227.7
HIGHLAND LONG-FAT-TAILED GROUP					
Adilo		Wet, warmer mid-highland (1800-2000 m)	North Omo, Derashie, Gedio and Amaro zones of Southern State; some northern Borena districts (1300 – 2400 m)	Long fat tail; large size; short-haired; males are short-horned and 18.4% of ewes are horned; predominantly brown (94.3%), brown with white patches (32%), black (19%) and black with brown patches (9%). Reared by southern communities	407.7
Arsi-Bale		Mainly wet, cool and warmer highlands (2000-3300); sub-moist lowlands	Arsi, Bale, E. Shoa, W. Harerghie zones; some districts in Borena zones of Oromia; Hadya, Gurage, Kembata & Sidama zones	Long fat tail with twisted end in some animals; medium size; hairy fiber, especially in adult ewes, males have minor wool growth in some parts of the body; males and most females (52%) are horned; large size; coat colors are brown (35.1%), brown with white patches (24.3%), black, white, and combinations of above colors. Reared by Oromo community	6345.1

Horro		Cool, wet highlands (2991 m) to humid mid-highlands (1600 m).	East Welega, West Welega, Illubabor, Jimma and West Shoa zones of Oromia; some bordering Gambella and Benishangul districts	Long fat tail extending below hock, either straight (51.4%) or coiled/twisted (48.6%) at the tapering end; prominent fat tail in males; large, leggy and prolific; dominant colors are brown and fawn, belly is lighter especially in adult ewes, less frequent are black, white, brown with white patches; both sexes are polled. Reared by Oromo, Benishangul and Gambella communities	3409.3
Bonga	Gesha, Menit	Humid mid-highland zone (1200 – 2500)	Keffa, Sheka and Bench zones of Southern State	Long fat tail with straight tapering end (98.4%); hair sheep; large size; predominantly plain brown (57.9%) or with black (0.9%) or white (5.3%) shade, plain white (10.5%) or with brown patches (10.5%), and black (2.6%); both sexes are polled. Reared by Keffa, Sheka and Bench communities	517.5
Harerghe Highland			Metta, Gorogutu and Dedere districts in east Harerghe zone; Oromia	Long fat tail with tapering end; strait or twisted/coiled at the tip.	
LOWLAND FAT-RUMPED/TAILED GROUP					
Afar	Adal, Danakil	Mainly arid lowland(<1000 m); mid-highland (1200–1900 m)	Afar state; bordering Tigray, Amhara; E./W. Harerghe; E. Shoa of Oromia	Wide fat tail, in some large fat tail reaching below the hock; hair fiber; medium size; characteristically uniform creamy white/ beige coat; rudimentary ear; polled; dewlap. Reared by Afar, Amhara, tigray communities	681.9
BHS	Wanke, Ogaden, Berbera black head	Mainly arid lowlands (215-900 m); highlands (up to 2000 m)	Somali state; lowlands of Bale, Borena and south Omo zones; part of east Harerghe	Short fat rump with a stumpy appendage; uniform white body and black head and neck; polled; convex face, especially in males; short, outward forward drooping ear; well-developed dewlap. Reared by Somali and Oromo, Konso and south omo communities	906.2
LOWLAND THIN-TAILED GROUP					
Gumz		Moist lowlands (< 1000 m)	Benishangul-Gumz state; lowlands of North Gondar	Long thin tail; somewhat dwarf; convex face profile; long pendulous ear; commonly plain brown or with patch (39.4%), white with brown or black patch (21%), black (15.8%), white, black with white patch, brown with black patch; polled. Reared by Gumz and Amhara communities	50.9

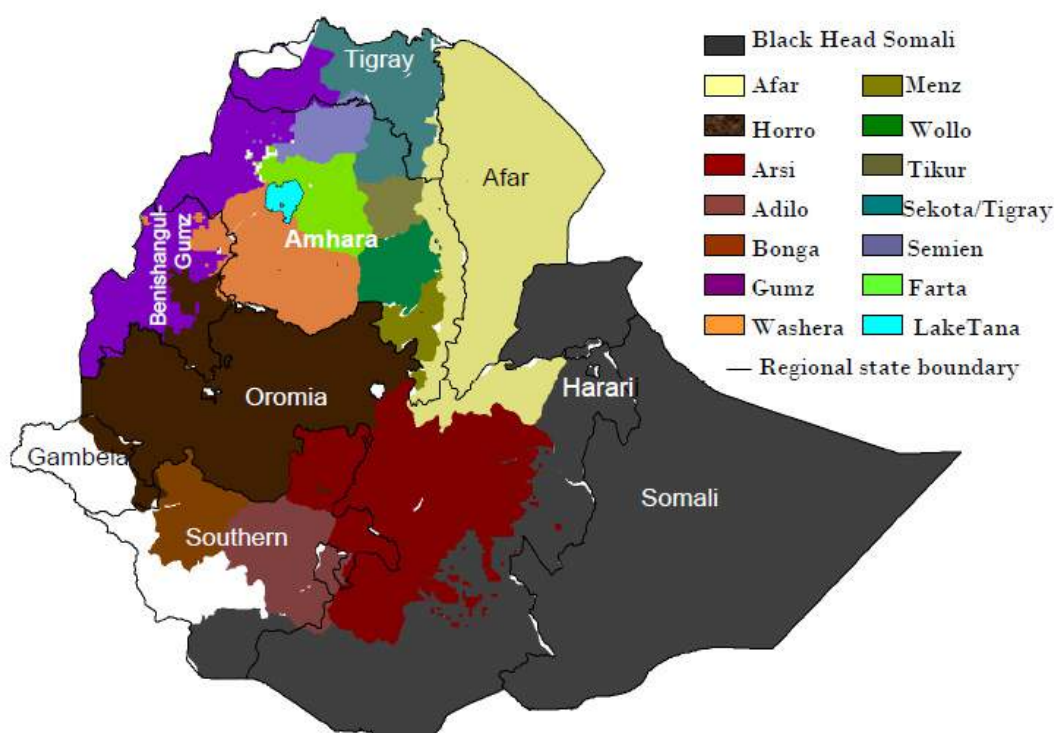


Figure 1: Geographic distribution of sheep in Ethiopia

3. Female reproductive characteristics

3.1 Puberty

The preferred definition of puberty in female sheep is the age the growing female displays first estrus. A study conducted by Mukasa-Mugarwa and Lahlou-Kassi (1995) investigated the reproductive performance of Menz sheep in the Ethiopian highlands. Researchers reported that lambs attain puberty at 10 months of age and 16.9 kg mean weight, corresponding to 56 percent of mature body weight. This is lower than the 11.5 months previously reported by Mukasa-Mugarwa et al. (1991). Research has found that 70 percent of Menz ewe lambs are capable of reaching puberty before 14 months (Demeke et al., 1995). Progesterone concentrations, determined by the ELISA technique, were basal (≤ 1.0 ng/ml) before puberty. Subsequently, 63 percent of lambs exhibited a “silent ovulation” prior to first behavioural estrus. Transient rises of progesterone were not observed in 45 percent of lambs conceiving at first mating. Further, 21.1 percent of the animals did not ovulate during the first estrus, which may bias estimates of puberty onset based only on first estrus behaviour (Mukasa-Mugarwa and Mutiga, 1993).

The onset of puberty is earlier with higher weaning weights; it is probable that poor nutrition can delay puberty by one season. Improved growth rate and body weight, resulting from better post-weaning nutrition, advanced the attainment of puberty in Menz ewe lambs (Mukasa-Mugarwa et al., 1991). The same study demonstrated the following results due to improved nutrition:

- Post-weaning average daily weight gain up to puberty increased by six to 26 g/day.
- Conception rate at first estrus increased by nine to 16 percent.
- Mortality rate reduced by 24 to 31 percent.
- The age at first lambing reduced by two to five months.

Crossbreeding Menz (a polyestrous breed) with Corriedale and Awassi breeds (that have long breeding seasons) did not significantly influence age or weight at puberty. The proportion of sheep lambing was also not influenced (Demeke et al., 1995).

For lambs born in the dry period, there is no evidence that drenching impacts the post-weaning daily gain or onset of puberty. However, specific drenching improved the growth of lambs born during the period of short rains (43.8 vs. 33.8 g/day) and caused a decrease in growth of lambs born during the period of heavy rains (26.0 vs. 33.8 g/day).

Characteristics of puberty can differ for the various sheep breeds. Age at puberty is impacted by genotype, the season of birth (for seasonal breeds), and plan of nutrition. For example, Horro ewe lambs can have their first oestrus 28 days earlier than the Menz counterparts (Toe et al., 2000).

3.2 Ovarian cycle and related endocrine events

Measuring the concentration of hormones associated with reproductive functions in female animals provides insight about their reproductive status. In particular, measuring the level of progesterone secreted by the corpus luteum can be very informative. Progesterone profiles in Menz sheep during pubertal development, estrus cycle, pregnancy, and post-partum anoestrus were similar to those of temperate breeds (see the review by Mukasa-Mugarwa et al., 1992). The mean length of estrus cycles was 17.2 ± 1.0 days (Mukasa-Mugarwa et al., 1990). Animals experiencing silent estrus were detected by hormone analyses.

Plasma progesterone concentrations (assessed with ELISA) in 20 Menz ewes during their estrus cycles greatly varied between ewes (range 2.43-4.80 ng/ml) and between days of their estrus cycles (0.32-5.84 ng/ml). Progesterone values were under 1.0 ng/ml from two days before to four days after es-

trus. Hormone concentration rose steadily to peak at 5.0-5.6 ng/ml on days 10 to 14 (peak luteal phase). This was followed by a rapid decline to 3.0 ng/ml on day 15, 0.8 ng/ml on day 16, and 0.2 ng/ml on the day before estrus (regression of the corpus luteum). It is concluded that the ELISA method can be used to assess progesterone levels in Ethiopian sheep with accuracy. Also, progesterone levels in plasma of under 1.0 ng/ml are indicative of either anoestrus or the follicular and early luteal phases of the estrus cycle (Mukasa-Mugarwa et al., 1990).



Ram of the Doyogena breed

3.3 Estrus activity and seasonality

Seasonality of reproduction is a characteristic of sheep breeds from temperate latitudes where variations in the photoperiod trigger changes in ovarian cyclic activity between seasons. In tropical and equatorial latitudes, seasonality of reproduction is less important. While sheep in these latitudes might not be susceptible to changes in the photoperiod, alterations can result from other environmental and social cues, such as feed availability, ambient temperature, and social interactions (such as the presence of rams or estrus ewes in the flock).

The distribution of lambings of Menz ewes among months of the year suggests year-round lambing with a peak in October and November. Most conceptions took place in June and July, which is the beginning of the major rainy season in the area (Agyemang et al., 1985). Although Menz ewes are year-round breeders, they appear to experience a reduction in sexual activity from June to September, which corresponds to the wet season. Only 79 percent of ewes displayed cyclic estrus activity in August and the number of heats per ewe per month dropped to 1.3 during the wet season.

Progesterone profiles of the Menz ewes in the Ethiopian highlands revealed the failure of certain ewes to show estrus in the wet period. This is due to increased frequency of ovulations that are not accompanied by estrus, known as silent heat (Mukasa-Mugarwa and Lahlou-Kassi, 1995).

A study conducted by Mukasa-Mugarwa et al. (1993) found that ewes came into estrus 21 times (range 18-23) a year with no significant impact from level of nutrition. In the same study, other findings were as follows:

- Mean cycle duration was 17.9 days
- 22 percent of cycles were short (< or = 13 days)
- 56 percent of cycles were normal (14-19 days)
- 11 percent of cycles were long (20-26 days)
- Eight percent of cycles were silent or missed (27-40 days)
- Three percent experienced anoestrus (> or = 40 days)

3.4 Parturition interval and post-partum anoestrus

A lambing interval of eight months is achievable in Ethiopian sheep (Table 2). This indicates that Menz sheep are capable of three lambings in two years, except where specific management systems are set otherwise. This interval is influenced by several factors, such as previous litter size, parity, and lambing season.

The lambing interval does not appear to be influenced by birth or weaning weight (Mukasa-Mugarwa and Lahlou-Kassi, 1995). A study by Mukasa-Mugarwa and Ezaz (1991) found that 65 percent of the ewes conceived within 90 days of lambing (before lamb weaning) and went on to achieve an eight-month lambing interval, suggesting that postpartum anoestrus was also not impacted by suckling.

Table 2: Age at first lambing and lambing interval of some Ethiopian sheep breeds (compiled by Zeleke Mekuriaw <http://www.slideshare.net/ILRI/sheep-training-mekuriaw1oct2014>)

Breed	Management type	Age at first parturition (months)	Lambing interval (months)
Adilo	Traditional	14.6	N/A
Arsi-bale	Traditional	12.7	7.8
Bonga	Traditional	13	8
Menz	Traditional	14-16	7-10
Menz	Station	15	8.4
Washara	Traditional	15	9

Under research station conditions, Menz ewes lambing in both short and long rainy seasons experienced decreased lambing intervals compared to ewes giving birth in the dry season (Mukasa-Mugarwa and Lahlou-Kassi, 1995). Postpartum anoestrus was about 76 days and 65 percent of ewes lambed three times in two years with a gestation period of 149 days. Twice weekly progesterone determinations showed that 67 percent of the ewes experience silent ovulation at approximately 66.4 + 10.5 days postpartum. It also indicated that 30 percent of the ewes experience silent ovulation before their first observed estrus (Mukasa-Mugarwa and Ezaz, 1991).

4. Reproductive performances of the female

4.1 Age at first lambing

The majority of studies report the age of first lambing for Ethiopian sheep within the range of 411-475 days (Table 2). Ewes under village management conditions in southwestern Ethiopia, demonstrated a mean age of 404 days at first lambing (Belay and Haile, 2009). The same pattern was found for Afar sheep under pastoral management (Gizaw et al., 2013).

Estrus was observed in ewe lambs at the age of five to six months, indicating that even though puberty might be attained at an earlier age, fertility will only improve with age and weight (Mukasa-Mugerwa et al., 1993). Menz ewes can first lamb at 15 months of age (Mukasa-Mugarwa and Lahlou-Kassi, 1995). One study in the highlands of central Ethiopia determined that the age at first parturition was not influenced by genotype or supplementary feeding (Demeke et al., 1995). Another study found that the age at first lambing is significantly impacted by the season and type of birth of the ewe lamb (Dibissa, 2000).

4.2 Conception rates and fertility

In Menz ewes, Mukasa-Mugerwa and Lahlou-Kassi (1995) reported high conception rates ($\geq 90\%$) but lambing rate was 72 percent. This suggests moderate embryonic mortality. Conception rate by rank of mating is affected by the age of the ewe (Table 3).

Table 3: Conception rate of pubertal ewes vs. mature ewes (Mukasa-Mugerwa and Lahlou-Kassi, 1995)

	First Mating	Second Mating	Third Mating
Pubertal ewes	69%	29%	2%
Mature ewes	78%	18%	4%

Research shows that lambing rates (lambs born/ewes mated) are impacted by breed. For example, Menz ewes had an 81 percent lambing rate compared to 76 percent experienced by Horro ewes (Berhan and Van Arendonk, 2006).

There is a lack of information on reproductive losses (fertilization failure, embryo mortality) in the literature on Ethiopian sheep. One study reported that abortion rates are high and variable (3.7 to 40 percent) among breeding females (Abassa, 1995). Better knowledge of embryo-uterine / environment-ovarian interactions in Menz sheep is needed to help improve the management of early pregnancy, fetal, and new-born losses. Such knowledge will also increase the impact of technologies, such as artificial insemination and embryo transfer.

Slaughtering of pregnant ewes in the Ethiopian highlands also contributes to depressed conception rates. Most farmers in the Ethiopian highlands sell their sheep to generate income. A study found that 70.1 percent of the females slaughtered for market consumption were pregnant and 24 percent were carrying twins (Mukasa-Mugerwa and Tekelye 1988). A high proportion of these females were pregnant in their third to fifth month of gestation. The authors extrapolated reproductive efficiency from this data and concluded that if pregnant ewes were not slaughtered and were allowed to lamb, the fertility rate would have been 73.2 percent, fecundity 125.1 percent, and twinning rate 25.1 percent.

4.3 Gestation rate and related physiological events

Researchers determined the mean gestation length to be 150 ± 3 days and not impacted by breed (Mukasa-Mugerwa and Viviani, 1992; ILCA, 1994; Mukasa-Mugerwa and Lahlou-Kassi, 1995).

Progesterone concentrations in peripheral plasma of Menz ewes were monitored weekly during gestation using ELISA assays. Mean hormone concentrations were basal, ≤ 1.0 ng/ml at service, but increased to 4.7 ng/ml on day 14 and remained elevated throughout pregnancy. The concentrations differed significantly between ewes and stage of gestation, but not due to number or sex of fetuses. Progesterone production was also not related to weight of lambs at birth ($r = 0.24$).



Bonga sheep suckling its quadruplets

Progesterone levels increased to 8.4 ± 0.3 ng/ml by day 35 (first trimester), 13.2 ± 0.4 ng/ml by day 75 (second trimester) and 13.8 ± 1.0 ng/ml by day 126 (third trimester). This was followed by a gradual decline during the last three weeks, with levels reaching 1.0 ng/ml two to four days after lambing. It was concluded that elevated progesterone levels 18 to 22 days after mating indicate continued luteal function and/or pregnancy in Menz sheep (Mukasa-Mugerwa and Viviani, 1992).

4.4 Litter size

Various studies (Mukasa-Mugarwa et al., 2002; Abegaz et al., 2000; Dibissa, 2000) reported litter size between 1.04 and 1.34. A twinning rate of 4.2 percent was reported by Agyemang et al. (1985).

Table 4: Average litter size for some Ethiopian sheep breeds (compiled by Zeleke Mekuriaw, <http://www.slideshare.net/ILRI/sheep-training-mekuriaw1oct2014>)

Breed	Management type	Litter size
Adilo	Traditional	1.42
Arsi-bale	Traditional (Kofele)	1.24
Arsi-bale	Traditional (Alaba)	1.70
Bonga	Traditional	1.4
Horro	Station	1.34
Menz	Traditional	1.11
Menz	Station	1.12
Washara	Traditional	1.11

Litter size is influenced by genotype, parity, season, and ewe body weight at mating (Mukasa-Mugarwa and Lahlou-Kassi, 1995). For Horro sheep, litter size increased with parity from 1.26 in primiparous ewes to 1.44 for ewes of parities five and above. With respect to weight of ewes at mating, litter size increased by 2.5 percent for each kilogram increase in weight (Abegaz et al., 2002).

Abegaz et al. (2000) and Berhan and van Arendonk (2006) reported that there were no significant differences in litter size between Horro and Menz ewe, which may equate to no differences in ovulation

rate. However, the annual program report of ILCA (1994) reported that litter size was slightly higher in Menz (1.16) than in Horro ewes (1.13).

The management system is also a major source of variation in litter size as reported by Mekuriaw et al. (2013); this is indeed the case of Washera sheep for which performances were significantly higher under farm management in comparison to on-station.

There is a disparity between the *in utero* and the field litter size, which would be related to prenatal losses of at least 12 percent (Mukasa-Mugerwa and Lahlou-Kassi, 1995).

4.5 Lamb survival

Studies in Ethiopia indicate perinatal lamb mortality, often defined as losses within the first four days of life, is 18 percent (Njau et al, 1988) to 19.3 percent (Mukasa-Mugerwa et al., 1994a) for Menz lambs. The overall least-squares mean survival rate of Washera sheep from birth to one month was 93 percent, at three months it was 86 percent, at six months it was 78 percent, at nine months it was 72 percent, and at 12 months it was 67 percent (Mekuriaw et al., 2013).

Table 5: Pre-weaning mortality rates for some Ethiopian sheep breeds (compiled by Zeleke Mekuriaw <http://www.slideshare.net/ILRI/sheep-training-mekuriaw1oct2014>)

Breed	Management type	Pre-weaning mortality rates (%)
Adilo	Traditional	19.5
Arsi-bale	Traditional	20
Arsi-bale	Traditional	28.4
Bonga	Traditional	20.8
Horro	Station	25.3
Horro	Station	24.3
Menz	Station	8.8
Menz	Station	15
Menz	Traditional	27
Menz	Station	10.6
Washera	Traditional	6.4

Perinatal mortality is severely affected by birth weight. Mortality rates decline from 63 percent below one kg birth weight to 31.2 percent between one and two kg and 1.4 percent between two and three kg birth weight (Mukasa-Mugerwa and Lahlou-Kassi 1995). Mukasa-Mugarwa et al. (1991) found that up to 13.4 percent of new-born lambs averaging 1.3 ± 0.6 kg birth weight died on the day of parturition. Most of the lambs with less than two kg weight at birth die within 24 hours of delivery due to starvation/mismothering and exposure (the SME syndrome) (Mukasa-Mugerwa et al., 1994a).

Single lambs were born heavier than twins (2.0 ± 0.6 and 1.7 ± 0.5 kg), but litter size had no impact on survival. Birth weight was related to lamb rectal temperature and viability at birth ($r=0.42$ and 0.68 , respectively) and increased with dam gestational live weight gain, placental weight, and number of cotyledons ($r=0.39-0.55$, respectively) (Mukasa-Mugerwa et al., 1994a).

Pre-weaning mortality is high for Ethiopian sheep breeds (Table 5) and was reported to reach 15 percent (Mukasa-Mugerwa and Lahlou-Kassi 1995). At first lambing, lamb mortality is higher (33 percent) in ewe lambs that only grazed compared to supplemented animals (seven percent). This highlights the dual advantage of adequate early nutrition to enhance pubertal onset and to minimise perinatal losses in the primiparous ewes (Mukasa-Mugerwa and Lahlou-Kassi, 1995). Mortality is also impacted by season, type of birth, and sex of the lamb (Tibbo, 2006).

Under the same environmental conditions, studies have shown that Menz lambs have a higher survival rate than Horro lambs (Table 6; Mukasa et al., 1999; Berhan and Van Arendonk, 2006). Causes of mortality were similar in Horro and Menz. Pneumonia was responsible for over half of all deaths, followed by digestive/gastrointestinal problems, endoparasitism, SME complex, and septicaemia.

Table 6: Comparing survival rates of Menz and Horro lambs

	Menz lambs	Horro lambs
Lamb mortality rates	13 percent	27 percent
Pre-weaning mortality	19.2 percent	33.1 percent
Post-weaning mortality	25.9 percent	54.5 percent
Cumulative mortality up to yearling age	30.2	69.6 percent

Within breed, sires were a significant source of variation for lamb growth and survival (Mukasa et al., 1999; Tibbo, 2006). Sires also are a major source of variation for progeny survival at six, nine, and 12 months of age, but not at younger ages. The best and worst mortality rates for Horro ram sired progeny groups up to one year of age were 22 and 80 percent, respectively. The same estimates in Menz rams were 11 and 48 percent (Mukasa et al., 1999).

5. Reproductive performances of the male

5.1 Puberty

For Menz ram lambs, Mukasa-Mugarwa and Ezaz (1992) found that at puberty the mean age was 288 ± 6 days, body weight was 19.3 ± 0.4 kg, and condition score was 2.6 ± 0.06 . These figures varied according to season of birth, level of nutrition, and weaning weight. Another study (Toe et al., 2000) reported a mean age at puberty of 322.7 days for Horro and Menz ram lambs.

Age at sexual maturity for Afar ram lambs is 7.10 months under pastoral management (Gizaw et al., 2013). Semen and spermatozoa traits improve with age (Rege et al., 2000). For Horro and Menz breeds, researchers found no significant breed differences in any of the reproductive traits studied, with the exception of semen volume at nine months being 0.67 ml for Horro compared to 0.39 ml for Menz. A difference was also observed with the proportion of dead spermatozoa at 12 months (0.18 versus 0.23 for Horro and Menz respectively). Season has a significant impact on most of the traits studied, which was mainly attributed to nutrition (Rege et al., 2000).

Daily gains in live weight and scrotal circumference (SC) for the period from weaning to puberty varied with level of nutrition, but not with drenching (Mukasa-Mugarwa and Ezaz, 1992). At puberty, SC averaged 21.5 ± 0.3 cm. It increased linearly and was strongly correlated with age, body weight, wither height, and heart girth. The authors concluded that post-weaning nutrition management strongly influenced lamb weight gain, which is related to testicular growth and puberty onset in Menz ram lambs. The authors proposed a scrotal size measurement as a criterion for early selection of tropical ram lambs (Mukasa-Mugarwa and Ezaz, 1992). SC was also suggested by Toe et al (2000) as the most appropriate selection candidate for the genetic improvement of male reproductive performance in these breeds.

Additionally, Menz rams presented a better soundness (libido and fertility) than Horro males and this was reflected in a higher conception rate at first and second estrus (80 and 18 percent, respectively) (ILCA, 1994).



NARS researcher assessing a ram's external reproductive organs

5.2 Sexual activity

Rams of Ethiopian sheep breeds experience a depression in their fertility during the rainy season (Mukasa-Mugarwa and Lahlou-Kassi, 1995).

Gizaw and Thwaites (1997) found that mating had adverse effects on live weight, body condition, and SC of Horro rams. There is a tendency for mean daily live weight loss to rise with increasing number of services during the period of peak sexual activity and over the whole joining period. Changes in SC were not significantly correlated with sexual activity. Pre-joining live weight and SC had no significant impact on the proportion of ewes served, rate of return to first service, and fertility. High losses of live weight and SC were observed during the stage of peak sexual activity. Increasing the supplementary feed provided to working rams at this stage, especially if the ewe/ram ratio is to be increased, is suggested.

In Horro rams, there is no significant benefit to be gained by increasing mating weight and SC from 30 kg and 27 cm to 40 kg and 31 cm respectively (Gizaw and Thwaites, 1997).

6. Ewe productivity

For Menz sheep kept on station, the annual reproductive rate is 1.4 lambs per ewe (Mukasa-Mugerwa, and Lahlou-Kassi, 1995). A lower rate of 1.03 was reported by Agyemang et al. (1985).

Prewaning mortality (15 percent) and slow growth (resulting in 8.6 kg weaning weight) limit the overall productivity index of Menz sheep to 11.0 kg/ewe/year (Mukasa-Mugerwa and Lahlou-Kassi, 1995).

In the traditional management system – where most animals are raised – further studies are required on better nutrition and control of diseases (endoparasitism) in young animals to increase reproductive efficiency, flock productivity, and number of animals for finishing and slaughter (Mukasa-Mugerwa and Lahlou-Kassi, 1995).



Selected Bonga ewes in the community based breeding program

Productivity is impacted by the lambing season. Productivity was 0.76 for ewes that lambed in the wet season and 0.53 for those that lambed in the dry season. A study on the reproductive productivity of Horro and Menz sheep in both the wet and dry seasons discovered that Menz ewes had a significantly higher overall weaning rate (lambs weaned per ewe mated) at 0.73 than Horro ewes at 0.57 (Mukasa-Mugerwa et al.; 2002). However, Menz ewes showed their superiority in weaning rate over the Horro ewes more clearly when lambing in the wet season (0.85 versus 0.67, respectively) than when lambing during the dry season (0.59 versus 0.47, respectively) (Mukasa-Mugerwa et al., 2002).

Expressed in terms of potential offtake of yearling sheep from flocks of Menz or Horro ewes lambing in either the wet or dry seasons, overall flock productivity of Menz sheep was approximately three-fold greater than a flock of Horro sheep when they lambed in the wet season. When lambing occurred in the dry season, the productivity was approximately two-fold greater (Mukasa-Mugerwa et al., 2002).

Lifetime productivity of Horro sheep maintained at Bako Agricultural Research Center was investigated (Duguma et al., 2006). Information recorded from a database of 212 ewes with 848 lambing records was used to study the following reproductive traits:

- total number of lambs born per ewe lambing over two to four lambing opportunities,
- total number of lambs weaned per ewe lambing over two to four lambing opportunities, and
- total weight of lambs weaned per ewe lambing over one to four lambing opportunities.

The results showed that ewe yearling weight significantly impacted all of the considered reproduction traits, with the exception of total number of lambs weaned per ewe lambing over two parities. Twin born ewes tended to produce more number of lambs of greater weight, than ewes born single, though the difference was not significant. All simple correlations between total weight of lambs weaned per ewe lambing over the first parity and total weight of lambs weaned per ewe lambing over the latter parities were high, positive, and significant. Researchers concluded that selection for total weight weaned per ewe lambing over the first lambing season could be used to indirectly improve ewe lifetime productivity.

7. Modification of reproductive function

7.1 Feeding strategies

7.1.1 Effect on reproductive performances of the ewe

In one study, a concentrate mixture was used to create four levels of nutrition – poor, low, medium, and high – for Menz ewe lambs at weaning (90 days). The objective was to achieve different pre-mating growth rates. Improved nutrition increased the average daily post-weaning weight gain by six to 26 g/day up to puberty. Improvements in nutrition also increased conception rate at first estrus by nine to 16 percent and reduced the mortality rate by 24 to 31 percent. Additionally, the age at first lambing was reduced by two to four months with adequate improved nutrition (Mukasa-Mugerwa et al., 1991).

Mukasa-Mugerwa et al. (1993) investigated the impact of nutrition on estrus and ovarian activities in Menz ewes. In this study, the control group was fed only hay. Ewes in the high nutrition group each received an additional 400 g/day of concentrate feed. A marked reduction in sexual activity from June to September was noted, which was not significantly influenced by feeding levels. Researchers found that levels of nutrition did not account for the significant difference in percentage of short (<13 days) or long (20-26 days) estrus cycle duration in Menz ewes (Mukasa-Mugerwa et al., 1993).

Interaction between genotype and nutritional supplementation had significant impacts on post-partum ewe body weight (Demeke et al., 1995). Cross-breeding significantly increased lamb body weight. Supplementation significantly increased post-partum ewe body weight. This indicates that natural pastures do not supply enough nutrition to allow ewes to reach their optimal body weight.

Another study of pregnant Menz ewes contained a control group that only grazed and a group consisting of ewes that grazed and received 400 g/day of concentrate feed during the first, second, and third trimester. The twinning rate increased from zero in ewes weighing 15 kg or less at mating to 31 percent for ewes weighing 30 kg or more. Six percent of ewes lost weight during pregnancy. Thirty-one percent of ewes gained less than 3.5 kg (the mean birth and placenta weight) and 63 percent gained over 3.5 kg (Mukasa-Mugerwa et al., 1994c). Researchers suggested that there was no advantage in supplementing ewes in the first trimester, but extra feed in the second and third trimester increased dam weight gain. In particular, dams supplemented during the third trimester produced heavier lambs with better survival and were themselves heavier during postpartum. The authors concluded that grazing Menz sheep need to be managed to mate at 25 kg or greater for increased twinning. These lambs require extra feed in the third trimester to produce lambs of at least two kg birth weight with a perinatal death risk of less than 10 percent. The reduced reproductive wastage will help to improve current flock production efficiency (Mukasa-Mugerwa et al., 1994c).

7.1.2 Effects on reproductive performances of the ram

Negussie et al. (2000) studied the impact of increasing the levels of *leucaena leucocephala* leaf hay fed to highland male sheep that were maintained on a roughage diet. This study found that increasing leucaena leaf based supplementation at 300 g/head/day increased the percentage of motile cells (10 vs. 76 percent) and mass activity/motility score (1.5 vs. 3.2) of spermatozoa. This diet reduced the incidence of total morphologically defective sperm cells (34 vs. 5 percent). Significant increase was also seen in the volume of ejaculate (0.36 vs. 1.1 ml), sperm concentration (2.8 vs. 7.1×10^9 ml⁻¹), and total number of spermatozoa per ejaculate (1.96 vs. 5.92×10^9 per ejaculate). Testicular size showed significant differences among treatment groups and generally increased with supplementation. It was concluded that supplementation of up to 300 g/head/day of leucaena leaf resulted in improved feed intake, testicular growth, sperm production, and semen quality of Ethiopian highland sheep offered a chickpea haulm basal diet (Negussie et al., 2000).

7.2 Hormonal treatment for estrus synchronisation

When estrus synchronization with intravaginal progesterone sponges was implemented, most of the ewes from Menz and Horro breeds (83 percent) came in estrus after hormonal treatment. Out of these, 81 percent were synchronised and mated within five days after sponge removal (Mukasa-Mugerwa et al., 2002). Evaluating progesterone concentrations showed that 98 percent of the ewes synchronised by intravaginal sponges were cycling at mating. The mean interval from sponge removal to estrus was 4.5 ± 0.4 days and the fertility rate was 65 percent.

Menz ewes have more acceptable reproductive performance than Horro ewes following controlled breeding using fluorogestone acetate (FGA) intravaginal sponges (Table 7). Mukasa-Mugerwa et al. (2002) found that the percentage of ewes experiencing estrus synchronisation was 10 percent higher after hormonal treatment in the wet season compared to the dry season. Additionally, synchronisation was seven percent higher for Menz sheep compared to Horro sheep. Of the ewes that eventually lambled, 73 percent conceived in the first estrus, 17 percent during the second, and 10 percent during the third or subsequent estrus with an average of 1.5 services per pregnancy.

Table 7: Differences between Menz ewes and Horro ewes following controlled breeding using fluorogestone acetate (FGA) intravaginal sponges (Berhan and Van Arendonk, 2006)

Reproductive performance	Menz ewes	Horro ewes
Fertility rate	79 percent	70 percent
Weaning rate	92 percent	78 percent
Lamb mortality rate	13 percent	27 percent

Premating ewe nutrition management or treatment with gonadotropins can increase litter size (prolificacy) by 10 to 40 percent. However, increasing ewe's nutrition plan did not have an impact on litter size (Mukasa-Mugerwa et al., 1991).

One study found that twinning rate increased from 11 percent in the control group to 23 - 50 percent in ewes treated with 200 and 300 I.U. pregnant mare serum gonadotropin. Such an increase was not impacted by whether estrus synchronisation occurred by using prostaglandin F₂ α or progestagen-impregnated sponges (Mutiga and Mukasa-Mugerwa, 1992).

7.3 Ram effect

For seasonal breeds, the "ram effect" is a potent natural tool used to advance the breeding season, shorten postpartum anoestrus, and advance age at puberty. Rams are normally kept with the flock round the year. Instead, if rams are kept separate and introduced into the flock only during the mating season, fertility and kidding rates increase significantly, and flocks can grow much faster.

In the past, it was believed that the ram effect was not possible for use on cycling females because luteal progesterone would block the GnRH response to the socio-sexual signals. Studies have proven this belief incorrect (Hawken et al., 2007; 2009). In sheep, there is an evidence of cycle synchronisation among females in the flock exposed to rams (Hawken et al., 2008). One study introduced rams into two different groups of mature Menz ewes. Group one was completely isolated from rams for one year. Group two was exposed to a vasectomized ram for one year. The introduction of rams to both groups resulted in a low overall level of estrus synchrony (27 percent). However, synchronisation was higher for the group isolated from rams for one year (38 percent) as compared to those exposed to the ram (17 percent). The mean interval from ram introduction to estrus was 12.2 days, but this was significantly shorter for isolated ewes (9.4 versus 14.8). The study also found that the response to ram stimulation was not influenced by the level of feeding (high or low) prior to the ram introduction. This study demonstrated that, although a natural tool, the ram effect could be useful to synchronise the reproductive cycle of tropical sheep with feed and other management resources (Mukasa-Mugerwa et al., 1994b).

7.4 Genetic improvement of reproductive traits

Genetic characterization is a prerequisite for any selection programme. Improvement by selection of reproductive traits is usually a slow process yielding substantial progress after several generations. Currently, there have been no attempts to improve reproductive efficiency of Ethiopian sheep breeds by selection. Mekuriaw and Haile (2014) previously reviewed studies that attempted genetic characterization, which is summarized below.

Ewe reproduction traits include fertility, litter size, and lamb survival. Estimates of heritability for these traits are low in Ethiopian sheep, reflecting the generally small genetic variance for most reproductive traits. Heritability estimates for fertility ranged from 0.02 to 0.06 depending on whether the service sire was considered as fixed effect or not (Abegaze, 2000). Heritability estimates of litter size for Horro sheep ranged from 0.06 under the repeatability model to 0.17 under the sire model; the direct heritability was 0.11 (Abegaze and Duguma, 2000). Heritability of twinning for Horro sheep was estimated to be 0.15 and 0.07 for the direct additive and repeatability models (Abegaze et al., 2002), which is slightly higher than 0.06 to 0.11 estimated by Abegaze (2000). The estimates of heritability for lamb survival varied depending on the model used. The values obtained from survival analysis (0.003 to 0.18) were higher than those obtained with the mixed Linear Model (0.005 to 0.05) (Tibbo, 2006).

Estimates of heritability of body weight (BW) and testicular traits – including SC, testicular diameter (TD), testicular length (TL), and epididymal diameter (ED) – for Menz and Horro ram lambs have also been studied. Researchers found that SC had the highest heritability estimates at six (0.45) and at 12 months (0.41) (Toe et al., 2000). Repeatability and heritability estimates for the other traits were generally low to moderate. Heritability estimates were 0.29 for BW, 0.09 for TD, 0.11 for TL, and 0.12 for ED. Only repeatability estimates for BW (0.34) and SC (0.25) were significant. Same researchers found that heritability of age at puberty (AP) was low and varies from 0.16 to 0.14. Genetic correlations of AP with testicular measurements, especially with SC (0.57 and 0.78 at nine and 12 months, respectively) and TD (0.72 and 0.83), were desirable and generally high (Toe et al., 2000).

Rege et al. (2000) found that heritability estimates of mass motility at nine months, individual motility at nine months and at 12 months, and proportion of abnormal spermatozoa at nine months were respectively 0.32, 0.32, 0.16 and 0.35. The genetic correlations of SC with semen volume (0.55, S.E. 0.11), mass motility (0.62, S.E. 0.20), individual motility (0.54, S.E. 0.12), concentration (0.25, S.E. 0.04), and proportion of abnormal spermatozoa (0.75, S.E. 0.24) in 12-months old rams indicated that selection based on SC has a positive correlation with semen quality and spermatozoa production.

Gizaw and Joshi (2004) estimated the repeatability of twinning to be 0.16 for Horro sheep. The genetic correlation of twinning with birth weight and weaning weight was 0.77 and 0.26. Additionally, the genetic correlation between litter size at weaning with birth weight and weaning weight were 0.45 and 0.84, respectively (Abegaze, 2002).

8. Identifying gaps and future research needs

Despite the substantive research that has occurred related to the reproduction of sheep breeds in Ethiopia, a number of topics have been insufficiently addressed or ignored, highlighting the need for international research centres to continue to fund national level research. Additionally, capacity development of Ethiopian researchers must continue due to the country's lack of reproductive physiologists and reproductive practitioners in the area of small ruminant reproduction.

Priority areas for future research include the following:

- Expand research to study a diverse selection of sheep breeds. Most of the existing research pertains to Horro and Menz sheep. Increasing the study of different breeds will help unlock more information on the reproductive potential and performance of Ethiopian sheep, which are widely distributed in the different agro-ecological areas throughout the country.
- Increase the assessment of reproductive traits based on real-scale field measurements instead of data obtained on-station.
- Investigate non-progestogen protocols for synchronization of estrus. Interest is increasing in synchronization protocols that avoid the use of synthetic progestogens, which have the reputation to lead to “non clean estrus” and generate high levels of residues in the end products. Ethiopian sheep breeds, because of their non-seasonal character, may be highly responsive to protocols associating prostaglandins and GnRH coupled to timed nutritional inputs. The resulting estrus is more natural, which may promote higher conception rates and litter size.
- Study the response of Ethiopian breeds to artificial insemination (AI). None of the laboratories in Ethiopia are equipped to undertake all the steps of AI, resulting in a research void. AI research is an important component for supporting genetics and enhancing the efficiency of community-based breeding programs.
- Expand research related to genomics of reproductive traits. Numerous studies in sheep have indicated that ovulation rate and litter size are genetically regulated by fecundity (Fec) genes. Among these Fec genes, bone morphogenetic protein 15 (BMP15) and growth and differentiation factor 9 (GDF9) are paralogous genes encoding the most important oocyte-derived factors regulating ovarian folliculogenesis. Numerous mutations have been found in both genes that are associated with alterations in ovarian function. In sheep, all these mutations show the same phenotype – homozygous carrier ewes are sterile and heterozygous carriers demonstrate increased ovulation rate. Future research should focus on identifying these mutations. The incorporation of these mutations into well-designed selection programs can result in rapid genetic process in reproductive efficiency.

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