Do Crossbreeding using Exotic Breeds in Goat is the Right Solution for a Low-input Production System in Ethiopia? : A Review

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ABSTRACT

Analysis and evaluation of the previous genetic improvement attempts and their fruition are paramount to make the right decision in the future. Hence, this paper reviews the status of goat genetic improvement programs through quantitative evidence and elucidates how it can be implemented in the future through an intensive literature review. Goat genetic improvement through crossbreeding was initiated early in 1975. However, most crossbreeding programs have lacked analysis of the existing resources and infrastructure and also lack long-term strategies. As a result, crossbreeding program was discontinued without significant contribution due to incompatibility of the exotic genotype with low-input production systems. On the other hand, the moderate to high genetic variation within a population open the window for within-breed selection. Accordingly, a well-designed within-breed selection program was initiated late in 2013 for specified breeds. Currently, governmental and non-governmental institutions plan to scale up community-based within-breed selection program. Besides, the efficiency of assisted reproductive technologies in goat genetic improvement was evaluated by ICARDA and reported a moderate achievement. However, the application of molecular technologies in Ethiopia is only limited to diversity studies. Nevertheless, there is an opportunity to use molecular technologies to enhance the genetic progress of a genetic improvement program. In conclusion, the expected benefits from crossbreeding program were not obtained and will not be obtained under the existing low input-production system. Therefore, a within-breed selection program would be an ideal option for the existing low-input production system if integrated with assisted reproductive and molecular technologies.

Key words: Crossbreeding, Genetic diversity, Molecular technologies, Optimization, Selection.

Goats (*Capra hircus*) are among the most important livestock species which highly contribute to the livelihoods of resource-poor farmers in Ethiopia (Mekuriaw *et al*. 2016). There are around 32.74 million goats in Ethiopia (CSA, 2018) and categorized into 8 genetically distinct groups (Alemu, 2004). Goat production is ideal for poverty alleviation due to their high multiplication rate, adapting to a wide range of agro-ecologies including harsh climatic conditions, low capital investment, ability to better utilize the limited and poor quality feed resources as compared to large ruminants (Solomon *et al*., 2014).

Regardless of the aforementioned merits, the contribution of this sector for producers and to the national economy is low (Solomon *et al*. 2014). On the other hand, the demand for meat in Ethiopia is growing at an unprecedented rate due to population growth, urbanization, increasing of incomes and changes in diets. Therefore, to meet the ever-increasing demand for animal products and thus contribute to economic growth, genetic improvement has been proposed as one of the major tools in developing countries. Accordingly, crossbreeding program was considered as one genetic improvement tool and milk-type exotic breeds such as Saanen, Anglo-Nubian, Toggenburg and meat-type Boer goats have been introduced to Ethiopia with the aid of different non-governmental and governmental institutions since 1975. Besides, an organized community-based within-breed selection program was initiated in 2013 with the support of SIDA project (Woldu *et al*. 2016) and ICARDA.

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Evaluation of the previous genetic improvement attempts and their fruition is immensely important to make the right decision in the future. However, there is no comprehensive information about the status and future prospects of goat genetic improvement programs in a low-input production system. Hence, this paper reviews the status of goat genetic improvement and discusses how it can be implemented in low-input production system for the future through an intensive and systematic literature review.

Crossbreeding attempts and their fruition

Crossbreeding program

Goat genetic improvement through crossbreeding using exotic breeds was initiated earlier and has been conducted by different governmental institutions (Ethiopian Institute of Agricultural Research, Regional Agricultural Research Institutes, Ministry of Agriculture, Hawassa University, Haramaya University and Mekelle Univesity) and non-governmental institutions (Langston University, FARM Africa/ Dairy Goat Development Project and Ethiopian Sheep and Goat Productivity Improvement program) as noted by Solomon *et al*. (2014). Accordingly, exotic goat breeds such as Saanen, Anglo-Nubian, Toggenburg and Boer goat have been introduced in Ethiopia since 1975 (Solomon *et al*. 2014; Abegaz and Gizaw, 2015) in order to improve milk production and growth performance of indigenous goats through cross--breeding. The performance of crossbred goats compared to indigenous goats is presented in the coming sections.

Milk production potential of crossbred goats

According to Awigchew *et al*. (1989), Sannen × Afar does with 25% blood level produce 29% more milk than purebred Afar does without any reduction in other productivity and reproductive traits under similar management. However, Galal *et al*. (1982) reported that milk yield increased by 50% in Saanen crossbred but the crossbred goats were less adaptive to the areas than local breeds or Adal. Likewise, Tsegahun *et al*. (2000) noted that the average milk yield of indigenous highland goats from three-month lactation was improved from 19 kg to 52 kg in 50% Saanen crossbred does, with a slight reduction in reproductive rates and a minor improvement in the growth potential of crossbred goats. These results indicated the non-suitability of high-grade crossbred goats for the existing low-input production system.

Under a smallholder management system, Anglo-Nubian × Hararghe Highland goats had higher daily milk yield (0.56 vs 0.38 litters), lactation length (4.2 vs 3.07 months), lifetime milk yield and births per year than local goats (Hararghe Highland goat). Conversely, crossbred goats had lower longevity, lower number of births per lifetime and higher mortality rate than local goats (Nigussie, 2010). Besides, According to Ayalew (2003), Anglo-Nubian crossbred goats do not offer a significant advantage over local goats under subsistence farming conditions. Generally, the resulted benefit from dairy goat crossbreeding program was found to be negligible (Ayalew *et al*. 2003; Kosgey *et al*. 2006) because of the incompatibility of the genotype with the existing low-input production system.

Growth performance of crossbred goats

Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) imported Boer goat from South Africa to improve growth and carcass traits of indigenous goat and crossing with Boer sire was conducted since 2007. The birth weight of Boer crossbred goats varied from 2.51 kg (Teklebrhan, 2018) to 3.0 kg (Teklebrhan, 2018). Six-month weight for Boer × indigenous goat ranges between 11.6 kg (Mustefa, 2017) and 18.95±0.23 kg (Belay *et al*. 2014) under on-station management. The yearling weight of crossbred Boer goat was varied from 16.4 kg to 27.8 kg (Table 1). The crossbred should perform ≥20-30% better than purebred animals to consider crossbreeding as an option (Gibson and Cundi, 2000; FAO, 2010). However, except for Boer × Abegelle goat, the difference in the growth performance of crossbred and purebred indigenous goats seems to be negligible (Table 1). Accordingly, most goat crossbreeding activities based on Boer goat in Ethiopia were discontinued. This is not meaning that the Boar goat had poor genetic potential as the expression of genes are under the influence of environment. We will see the impact of the environmental stimuli (nutrition) in the next section.

Feedlot performances of crossbred goats

In Ethiopia, both crossbreeding and modification of feeding management were conducted in order to enhance the productivity of goats. Scholars evaluated the performance of indigenous and Boer crossbred goats under extensive, semi-intensive and intensive management (Table 2). The feedlot performances of Boer crossbreeds under supplementation were higher than indigenous goat breeds. For example; the hot carcass for Central Highland and their crossbred with Boer goat under supplementation was 11.5 kg and 15.4 kg, respectively according to Tesema *et al*. (2018). Similarly, Mohammed *et al*. (2012) reported a 9.23 kg carcass weight for Boer × Arsi Bale goat which was higher than Arsi Bale goat (6.23 kg). According to Tilahun *et al*. (2014), the carcass weight of Boer × Central Highland goat was higher by 3.8 kg than Central Highland goat under supplementation. In addition, crossbred goats were grown faster and performed better than indigenous goats. These studies showed the genetic potential of Boer crossbred goats to outgrow and outgain than indigenous goats under improved management. However, under a low level of management, the performance of Boer crossbred goats was not superior to indigenous Ethiopian goat breeds (Mohammed *et al*. 2012; Tesema *et al*. 2018). These all suggest that Boer crossbred goats are suitable for moderate to high input production system while indigenous goats are performing well than crossbred goats under a low-input production system.

Management system had a pronounced influence on the feedlot performances of goats. For instance, the hot carcass (HC) yield of Central Highland goat under semi-intensive management system was 12.5 kg (Deribe and Taye, 2013) and 11.53 kg (Tesema *et al*. 2018) respectively, whereas under an intensive management system; the value of HC was 7.8 kg (Tadesse *et al*. 2015) and 9.0 kg (Tilahun *et al*. 2014) respectively. Similarly, under intensive management system, Sebsibe *et al*. (2007) reported 8.02 kg for Afar goat while Terefe *et al*. (2013) noted 13.61 kg under a semi-intensive management for the same breed. These results clearly exhibited the superior feedlot performances of goat under semi-intensive management than intensive management.

Fitness of crossbred compared to indigenous goats

Reproduction and survival are fitness traits strongly influenced by environmental origins and associated selection

Table 1: Growth performance of Boer × indigenous goats.

Breed	BWT	WWT	SMWT	YWT	Management	References
Abergele	1.91±0.04	6.84±0.19	9.13±0.31	14.1±1.20	Extensive	Deribe (2008)
Boer × Abergele	2.9±0.09	15.3±0.38	18.95±0.23	27.8±0.53	Semi-intensive	Belay *et al.* (2014)
Central Highland	2.01±0.03	9.02±0.18	13.82±0.39	20.6±0.74	Extensive	Deribe and Taye (2013)
Boer × CH	2.6±0.02	9.63±0.15	13.5±0.20	19.5±0.38	Semi-intensive	Deribe *et al.* (2015)
Boer × CH	2.68±0.04	9.11±0.19	11.6±0.26	16.4±0.38	Semi-intensive	Mustefa (2017)
Woyito Guji	2.03±0.04	9.04±0.18	11.49±0.47	-	Extensive	Zergaw *et al.* (2016a)
Boer × WG	2.89±0.38	10.4±1.86	13.9±2.19	19.0±3.51	Extensive	Girma *et al.* (2016)
Boer × SES	3.00±0.10	11.0±0.10	15.5	-	Semi-intensive	Teklebrhan (2018)
Boer × HH	2.50±0.10	10.0±0.30	14.5	-	Semi-intensive	Teklebrhan (2018)

CH: Central Highland; WG: Woyito Guji; SES: Short-eared Somali; HH: Hararghe highland goat.

Table 2: Feedlot performance of indigenous goats and their crossbred with Boer goat.

Breed	Feeding duration	Extensive (hay/grazing only)				Semi-intensive and intensive				References
	(month)	ADG	HCW	DPSW	DPEW	ADG	HCW	DPSW	DPEW	
Afar	12-15	63.7	10.6	44.4	55.3	85.6	13.6	47.3	58.2	Terefe *et al.* (2013)
Afar	8-12	-	-	-	-	36.7	8.02	44.6	55.0	Sebsibe (2007)
AB	10-13	-	-	-	-	20.8	6.23	41.1	49.0	Mohammed *et al.* (2012)
B × AB	12-15	-	-	-	-	36.6	9.23	41.1	50.0	Mohammed *et al.* (2012)
Bati/CH	12-15	-	-	-	-	42.1	7.8	41.5	51.2	Tadesse *et al.* (2015)
CH	12-15	37.6	11.2	38.9	49.5	54.0	12.5	50.2	50.2	Deribe and Taye (2013)
B × CH	6-9 to 12	-	-	-	-	52.5	12.8	44.4	-	Tilahun *et al.* (2014)
CH	6-9 to 12	-	-	-	-	32.1	9.0	42.8	-	Tilahun *et al.* (2014)
B × CH	9-12	0.74	9.63	45.9	51.3	97	15.4	50.3	54.3	Tesema *et al.* (2018)
CH	9-12	23.5	8.33	45.8	49.8	86.2	11.5	48.1	51.7	Tesema *et al.* (2018)
HH	10-12	-0.56	6.65	37.8	51.9	42.77	10.05	46.66	55.83	Tamir and Awuk (2015)
HH	12-15	-	-	-	-	51.4	8.3	43.9	54.4	Tadesse *et al.* (2015)
SES	12-15	-	-	-	-	41.3	7.2	41.9	53	Tadesse *et al.* (2015)
LES	8-12	-	-	-	-	43.9	5.98	42.9	53.1	Sebsibe (2007)

AB: Arsi-Bale; CH: Central highland; HH: Hararghe highland; LES: Long-eared Somali; SES: Short-eared Somali goat. ADG: Average Daily gain; HCW: Hot carcass weight; DPEW: Dressing percentage as proportion of empty body weight; DPSW: Dressing percentage as proportion of slaughter body weight.

pressures (van der Waaij, 2004). Survival is an important health trait that influences the overall goat productivity. A higher prevalence (42.2%) of major health problems (Hunduma *et al*. 2010) and higher mortality rate (47.6%) for pure Boer goat was reported by Molla (2016) in Ethiopia. Besides, the pre-weaning survival of Boer × Central Highland goats was 53.57% (Mustefa, 2017) under the on-station management system which is discouraging. On the other hand, Tesema *et al*. (2017) reported a relatively better survival rate (75.8%) for the same crossbred goats. Likewise, a lower survival rate (64.8%) was noted for Boer × Woyito-Guji goats. In contrast, relatively better survival of indigenous kids under extensive management system, *i.e.* 85.8% for Central Highland goat (Deribe, 2008) and 88% for Small-eared Somali goat (Zeleke, 2007) was reported. The superiority of indigenous goats in terms of survival may not be surprising as they are the results of natural selection. However, the lower survival rate, despite intensive health care in research stations is an indication of questionable Boer goat's adaptation to the smallholder management system.

Reproductive merit is an important consideration when evaluating the strengths and weaknesses of new breeds in particular production environments (Browning *et al.* 2004). The litter size at birth, litter size at weaning, litter weight at birth and litter weight at weaning for crossbred goats were not superior to the indigenous Central Highland goat (Mustefa, 2017; Tesema, 2019). In addition, the conception rate was higher for crossbred goats but the kidding rate was found to be similar for both genotypes (Mustefa, 2017). These all clearly indicate the similarity of both genotypes in terms of reproductive traits.

Skin quality of crossbred compared to indigenous goats

In developing countries like Ethiopia, skins are the most important items to generate foreign currency. Skin thickness for Boer × Arsi-Bale goat (1.18 mm) reported by Mohammed *et al.* (2012) was relatively lower than the report of Tadesse (2015) for Bati goat (1.32 mm), Hararghe Highland goat (1.56 mm) and Short-eared Somali goat (1.23 mm). The tensile strength estimated for all local goat types (Tadesse, 2015) and crossbred goats (Mohmmed *et al*. 2012) is higher than the minimum standard (19.6 N/mm^2) and also the elongation percentage is found within the acceptable range (40-80%). On the other hand, leathers from Boer × Arsi-Bale goats (Mohammed *et al*. 2012) tended to have lower tear strength which is lower than the minimum standard of good quality leather (49.1 N/mm). This indicates that indigenous goats had better skin quality compared to Boer crossbred goats.

Within-breed selection attempts

Since domestication, humans also selecting their goats based on a certain criterion (most of the time based on maternal history, production performance and some other traditional systems). However, this type of selection has not defined objective/goal and well-designed structure for the operation of the program and dissemination of the genetic gain. Lately, community-based breeding programs (CBBPs) with a well-defined breeding goal for Abergelle, Central Highland and Woyto-Guji goats were initiated in six villages (two villages for each breed) in 2013 with the help of SIDA (Swedish) funded project as reported by Woldu *et al*. (2016). A one-tier breeding structure or selection of bucks from the whole goat population is being implemented for the aforementioned breeds (Jembere, 2016).

According to Birhanie *et al*. (2018) the birth weight of progenies of selected Abergelle bucks (2.39±0.02 kg) was significantly heavier than base flock progenies (2.17±0.02 kg). However, the weight improvement is not continued in the subsequent growth stages. Moreover, the daily milk yield for the progenies of selected bucks was significantly lower than the base flock does (372±14.8 ml Vs 408±6.72 ml). On the other hand, Gobeze *et al*. (2018) noted that the mean birth weight of Abergelle kids increased from 1.6±0.05 kg to 2.3±0.06 kg and yearling weight increased by 9% (from 15.4±0.4 kg to 16.8±0.45 kg) with three round selections. Likewise, Abegaz *et al.* (2019) noted that six-month weight and yearling weight in Central Highland goats around Gondar has been improved by 2.15 kg (from 11.87 to 14.02 kg) and by 2.69 kg (from 18.71 to 21.40 kg), respectively. The genetic progress can be affected by the genetic variation, genetic correlation, the number of traits included in the selection index, heritability of traits, selection intensity and the efficiency of record keeping. In fact, the genetic change per year expected from a within-breed selection is slow which is about 0.5-3% (Kosgey *et al*. 2006). But these relatively small improvements are cumulative and permanent. Currently, livestock agency, research institutions and ICARDA plan together to scale-out participatory CBBP in different areas of the country for sustainable productivity improvement and economic returns.

Opportunities for within-breed selection

Within-breed genetic variation

Based on the physical description and management system there are 14 goat types in Ethiopia and Eritrea (FARM-Africa, 1996). Of these, eleven are found in today Ethiopia and according to Alemu (2004) these 11 Ethiopian populations were grouped into eight distinct genetic entities by using microsatellite DNA markers. Recently, the genetic diversity and structure of 14 Ethiopian indigenous goat populations were analyzed using SNP genotypes and re-grouped into seven goat types based on the admixture and phylogenetic network analyses.

According to Mekuriaw and Joram (2015), the genetic structure and diversity of indigenous goat and sheep populations in Ethiopia are highly influenced by admixture and the variation among populations is ≤1%. Likewise, Mekuriaw (2016) noted that the overall average F_{ST} value (genetic divergence) among Ethiopian goat populations was 2.6%. Consistently, a relatively low level of genetic differentiation among Ethiopian indigenous goat populations was also reported by Hassen *et al*. (2012b) and Alemu (2004) with F_{ST} values of 5.0% and 6.4%, respectively. However, there is a considerable amount of variability within indigenous goat breeds (HE = 0.58 by Alemu, 2004; 0.68 by Hassen *et al*. 2012b; 0.38 Mekuriaw, 2016) which exhibited the possibility of genetic improvement through within-breed selection. Ethiopian indigenous goats are known for heat stress, drought stresses resistance, diseases resistant and productive under scarce feed resources (Table 3). These all features are ideal biological weapons to resist climate change (the threat of the planet) and the resulted in effects.

Performance variation and unique traits of indigenous goats

There is a higher variation among indigenous goats in terms of growth performance (Table 4). Based on this review, the birth weight of indigenous goat varies from 1.50 kg for Mid rift valley goat (Alemu *et al*. 2000) to 2.81 kg for Begait goat and also six-month weight varied from 7.85 kg for Mid rift valley goat (Alemu *et al*. 2000) to 17.7 kg for Central Highland goat (Alemu, 2015). Besides, the yearling weight of indigenous breeds was ranged between 12.8 kg for Mid rift valley goat (Alemu *et al*. 2000) and 24.1 kg for Begait goat (Abirham *et al.* 2019). Under extensive management system, the growth performances of Central Highland and Begait goat seem to be greater than the other goat breeds/populations. Moreover, the performances of these two breeds were varied across different studies conducted on the same breed; this indicates the presence of within-breed variation which could open the window for genetic improvement of growth traits through selection. Indeed, this variation could be partly explained by different environmental factors.

Besides growth performance, other goat breed/ populations have their own unique merit, for example, Abergelle, Woyto-Guji and Afar goats are known for their heat and drought tolerance; Kaffa and Gumuz (Western Lowland) goats had better prolificacy; Long-eared Somali, Short-eared Somali and Begait goats are known for their milk production potential and Agew (Western Highland) goats had better growth rate and also resistance of cold stress. In the previous genetic improvement attempts, selection was conducted mainly for production traits. However, selection of goats for their unique traits and economically important traits has an important economic, social, cultural role, eco-syestem contribution and enable to respond to climate change.

Future scenarios in goat genetic improvement

Optimization of alternative breeding scenarios

The effective utilization of resources required for breeding in order to increases the genetic gain and economic return

Table 3: Goat populations and their distribution across production system and agro-ecology.

Population	Production system	Agro-ecology	Main products	Special trait
Abergelle	Mixed crop livestock	Sub-humid	Milk and milk products, skin and manure	Heat and drought tolerance
Afar	Pastoral	Arid and Semi-arid	Milk and milk products, meat, skin and social function	Heat and drought stresses resistance
Agew/Western highland	Mixed crop livestock	Humid	Meat and skin	Growth and resisted cold stress
Arsi-Bale	Mixed crop livestock	Humid	Milk, meat, skin, fiber, manure and social function	-
Barka	Mixed crop livestock	Arid and Semi-arid	Milk and skin	Milk production
Central highland/ Bati	Mixed crop livestock	Humid	Milk and milk products, good quality skin and manure	Skin quality and heat and drought stresses resistence
Gumuz/Western lowland	Mixed crop livestock	Sub-humid	Meat, milk, skin	Prolificacy and resist to heat stress
Hararghe highland	Mixed crop livestock	Humid	Meat, milk, manure and social function	-
Kaffa	Mixed crop livestock	Humid	Meat, milk, skin, social function	Prolificacy and trypanotolerant
Long eared Somali	Pastoral	Arid and Semi-arid	Milk, meat, skin and social function	Milk and survival
Nubian	Mixed crop livestock	Arid and Semi-arid	Milk and skin	Milk
Small-eared Somali	Pastoral	Arid and Semi-arid	Milk and milk products, meat, skin and social function	Milk and survival
Woyto-Guji	Pastoral	Arid and Semi-arid	Milk and milk products, meat, skin, manure and social function	-

Source: FARM Africa (1996); Hassen *et al.* (2012); Gatew (2014); Alemu (2015); Zergaw (2016b).

Table 4: Growth performances of indigenous Ethiopian goats.

Breed	BWT	WWT	SMWT	YWT	Management	References
Arsi-Bale	1.91±0.03	6.65±0.19	9.03±0.29	14.3±0.40	Semi-intensive	Bedhane *et al.* (2013)
Begait	2.81±0.04	11.1±0.43	16.4±0.49	24.1±0.48	Semi-intensive	Abirham *et al.* (2019)
Boran Somali	2.32±0.52	7.13±1.5	9.30±1.72	13.0±2.65	Semi-intensive	Alemu *et al.* (2000)
Mid rift valley	1.50±0.00	6.89±2.31	7.85±1.53	12.8±2.29	Semi-intensive	Alemu *et al.* (2000)
Abergele	1.91±0.04	6.84±0.19	9.13±0.31	14.1±1.20	Extensive	Deribe (2008)
Abergele	2.21±0.05	6.87±0.14	9.51±0.20	14.2±0.20	Extensive	Hagos *et al.* (2018)
Abergele	2.0±0.04	7.20±0.17	10.1±0.25	15.9±0.40	Extensive (CBBP)	Gobeze *et al.* (2017)
Abergele	2.28±0.02	7.40±0.09	9.48±0.15	-	Extensive (CBBP)	Birhanie *et al.* (2018)
Begait	2.85±0.04	10.5±0.27	13.8±0.24	22.9±0.36	Extensive	Hagos *et al.* (2018)
Begait	2.59±0.03	10.3±0.46	14.7±0.57	20.6±0.54	Extensive	Abirham *et al.* (2019)
Borana	2.36±0.05	10.34±0.12	13.9±0.22	-	Extensive	Gatew (2014)
SES	2.15±0.08	8.52± 0.30	13.7±0.36	-	Extensive	Gatew (2014)
Bati	2.70±0.05	10.4±0.18	15.6±0.19	-	Extensive	Gatew (2014)
CH	2.01±0.03	9.02±0.18	13.8±0.39	20.6±0.74	Extensive	Deribe and Taye (2013)
CH	2.29±0.03	10.7± 0.30	17.7±0.50	-	Extensive	Alemu (2015)
CH	2.68±0.04	9.42±0.19	15.7±0.54	-	Extensive	Zergaw *et al.* (2016a)
Woyito-Guji	2.03±0.04	9.04±0.18	11.5±0.47	-	Extensive	Zergaw *et al.* (2016a)

CBBP: Community-based breeding program; CH: Central Highland goat; SES: Short-eared Somali goat.

is called optimization. Now a day, a deterministic simulation model (ZPLAN) is appropriate for the optimization of an alternative breeding program. This program evaluates alternative breeding programs in terms of annual genetic gain for the individual trait, annual monitoring genetic gain for the aggregate genotype, discounted profit and discounted return for a given investment period (William *et al.* 2008). Based on this principle, different alternative breeding scenarios were designed and tested for specified indigenous Ethiopian goat breeds such as Abegelle, Western Lowland, Central Highland and Woyto-Guji goat (Abegaz, 2014; Jembere, 2016). Implementing these recommended alternative breeding scenarios could result in higher genetic and economic returns.

Assisted reproductive technologies

Assisted reproductive technologies have a tremendous role in goat production; it used to efficient utilization of animals with high genetic merit, worldwide exchange of genetic material, reduce generation interval, reduces sexually transmitted diseases, increases the rate of genetic progress and to preserve genetic resources for possible use in the future (Paramio and Izquierdo, 2014). Although there are various reproductive technologies, AI and MOET are the most widely utilized and applicable technologies in goat genetic improvement. For example; one buck ejaculates 1 ml in volume with a high concentration of spermatozoa (4×10^9) (Paramio and Izquierdo, 2014). In natural mating, these amounts of semen are invested for mating of one doe. However, the semen can be extended in ultrahigh-temperature bovine skim milk to achieve a dose of 200×10^6 sperm per goat diluted in 0.1 ml thereby used for about 20 does through AI. There was a complain about the efficiency of AI, nonetheless, Batista-Arteaga *et al.* (2011) noted a 70% kidding rate from fresh semen and 46% kidding rate from frozen semen. Likewise, a study conducted in Ethiopia by support of ICARDA noted that synchronization of Abergele goat with PMSG+Enzaprost®, PGF2α (single injection) and PGF2α (double injection) resulted in 87.6%, 61.4% and 53% estrus response, respectively. After hormone injection, the insemination time ranges from 36 to 48 hours was recommended and the average conception rate was 65.4% (Wondim, 2019). It is quite clear that the expected genetic gain increases with the increase of selection intensity. Thus, selecting only the elite bucks and using AI could be an ideal solution especially in community-based breeding programs. Besides, in the case of crossbreeding, the cost associated with importation and maintaining of exotic goat breeds would be decreased through semen importation.

Crossbreeding and even the existing within-breed selection programs in Ethiopia aim to exploit the potential of male germplasm over females. However, it is possible to exploit genetically superior females through combinations of superovulation, synchronization and embryo transfer technology. Productive genes carried by dams can be more rapidly spread within a population by having less valuable dams carrying offspring of elite females instead (Givens *et al*. 2007). A donor doe can produce 5 to 12 good embryos per flush (http://abga.org/wp-content/uploads/2016/01/) and sometimes up to 20 viable embryos (http://www.transova.com/services/embryo-transfer-in-small-ruminants) rather than producing one or two embryos in the natural system. Therefore, these technologies have an indispensable role in increasing the rate of goat genetic improvement as well as give an opportunity to utilize the genetic contribution of both elite males and females simultaneously.

Molecular technologies

Integrating phenotypic selection program with molecular technologies like genomic selection is imperative to fill the shortfalls of conventional selection programs and it could be used to reduce generation interval, to increases selection accuracy and increase rates of genetic improvement due to genotyping of animals at an early age in both sexes. However, the applications of such types of technologies in developing countries were challenged by the existing infrastructures, poor record-keeping, technical skill and cost for DNA collection, gene mapping, marker genotyping, QTL detection and genetic analysis. The problem of technical skill and genotyping costs is expected to reduce overtime and organized record-keeping mechanisms will be established through awareness creation although it takes a long time and thereby implemented at least for specified goat breeds. For example; the phenotype and pedigree records have been recorded for goats in CBBPs and a data recording and management system was developed jointly by EMBRAPPA-Brazil and ICARDA (Mrode *et al*. 2018). This can be used as a foundation for the implementation of genomic selection in the future.

In most of goat genetic improvement programs, mating is based on multiple-sires and thereby difficult to identify the sire of kids. However, the accuracy and completeness of pedigree is an essential feature for genetic evaluation and to increasing the rate of genetic gain. Markers of DNA, microsatellites and SNPs are used to assign true parents among candidates using a likelihood-based approach (Rupp *et al*. 2016). Molecular tools enabling for investigations on genome-wide signatures of selection for mainly adaptive and reproduction traits. Molecular information is used to know breed composition of crossbred animals in crossbreeding programs through admixture analysis, to estimate inbreeding level and to assign mating (Rupp *et al*. 2016; Mrode *et al*. 2018). These all are fruitions of molecular technologies that could be integrated with the existing goat genetic improvement programs for a better genetic gain and profitability of goat production.

Conclusion

In conclusion, there were no clear modalities for goat genetic improvement in Ethiopia. Most crossbreeding programs have lacked analysis of the existing resource and infrastructure which can support crossbreeds and also lack long-term strategies. Besides, crossbreeding activities were relying on support of non-governmental organizations/projects and thus their sustainability determined by the duration of projects. Accordingly, goat crossbreeding programs were discontinued without tangible benefit. Response of meat-type crossbred Boer goats for a moderate to high level of supplementation and better heath clearly exhibited their suitability for medium to high input production systems. Thus, the management level especially nutrition and health must be improved in order to exploit the expected benefits from crossbreeding in a low-input production system. Otherwise, the within-breed selection program integrated with assisted reproductive technologies and molecular information/technologies would be an ideal option for the existing low-input production system.

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