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REVIEW

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A review of the potential and constraints for crossbreeding as a basis for goat production by smallholder farmers in Ethiopia

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Abstract

Background: The purpose of this review was to provide and synthesize validated and up-to-date scientific knowledge on the benefits and drawbacks of crossbreeding as a basis for goat production by Ethiopian smallholder farmers. The majority of Ethiopian smallholder farmers and pastoralists rely on goat production for their livelihoods. Ethiopia's goat population is extensive, with eight genetically recognized indigenous goat breeds. These breeds, on the other hand, do not produce exceptionally well, and their contributions to smallholder farmers and the national economy fall far short of their complete output potential.

Main body of the abstract: In this regard, during the past many years, numerous goat productivity development programs in Ethiopia have collaborated to design and implement crossbreeding as a basis for goat production by smallholder farmers. Crossing indigenous goats (i.e., Afar and Somali goats) with exotic goat breeds, including Saanen, Anglo-Nubian, Toggenburg, and Boer goats, was done primarily to increase the output of indigenous goats. This crossbreeding plan, however, unsuccessful due to a number of factors, including a lack of baseline production data, poorly managed institutional synergies, and little or no consideration of smallholder farmers' needs, opinions, active participation, decisions, and local practices. In addition, insufficient and poor-quality feeds and forages, the termination and weakness of goat genetic improvement projects, disease and parasite incidence, poor veterinary services, and a lack of infrastructure are all major reasons for crossbreeding failure as a basis for goat production by Ethiopian smallholder farmers.

Short conclusion: Crossbreeding as a basis for goat production by Ethiopian smallholder farmers was made possible by the presence of vast indigenous goat breeds with diverse performance parameters throughout the country, as well as the engagement of both governmental and non-governmental groups. In contrast, a lack of baseline production data, a lack of well-organized institutional synergies, and little or no consideration of smallholder farmers' needs, decisions, participation, and local practices were the main roadblocks to planned crossbreeding as a basis for goat production by smallholder farmers in Ethiopia.

Keywords: Constraints, Crossbreeding, Ethiopia, Smallholder farmers' goat production, Potential

Background

Sheep and goat production are important sources of income, poverty alleviation, and food security for the majority of Ethiopian smallholder farmers and pastoralists (Monau et al. 2020). Overall, the number of goats in the country is projected to be 50.50 million, with indigenous breeds accounting for 99.97% of the total (CSA 2020). It accounts for 16.8% of total meat supply (Ameha, 2008) and 16.7% of milk consumed in many parts of the country (Tsedeke 2007). Goats are a very important animal, especially for poor pastoral communities, because they have a unique ability to adapt and

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maintain themselves in severe climates or habitats (Solomon et al. 2014). Other than religious and cultural values, they are used as a source of risk mitigation during agricultural failures, property security, and financial savings (Feki 2013).

Most smallholder farmers and pastoralists in Ethiopia keep few to large number of goats for food (meat, milk), income, dung, wool, and skin production, as well as to fulfill numerous cultural and religious roles (Aynalem et al. 2018). However, indigenous goat breeds do not have high productivity, and their contribution to smallholder communities and the national economy is much below their total production potential (Hulunim et al. 2019; Dereje et al. 2019). For instance, the Afar goat is a low-yielding breed with a protracted maturation period. When they are 3–4 years old, females reach their mature body weight of 33 kg. The breed has a maximum twinning rate of 40% until their third kidding, and a 12-week lactation cycle provides a maximum milk production of around 25 L. Their reproductive rates were reduced when they were mated at less than 12-month intervals (Tsegahun et al. 2000). A crossbreeding program with the Saanen breed revealed that the half-breed was unsuited to the environment and could not thrive even under on-station supervision. Both purebred Afar and quarter-bred Saanen kid's post-weaning growth rates were around 50 g/day, and they did not respond well to extra feeding. Their growth rate was unaffected by castration, but their market worth increased. On the other hand, a comparison of Somali and Anglo-Nubian goats handled uniformly at Haramaya University revealed that Anglo-Nubian goats produced more milk during the first 6 weeks of lactation (41 kg, or 0.97 kg/day versus 125.3 kg, or 2.98 kg/day) and had larger liters. Due to a higher twinning rate of roughly 50%, Highland goats appear to produce more babies per kidding than Afar goats. The indigenous highland goats' average milk production following 12-week lactation was barely 19 kg. With a minor drop in reproductive rates and a marginal rise in the growth potential of crossbreds, this was enhanced to 52 kg in half-bred Saanen does. This meant that larger levels of Saanen crossbred had lower reproductive rates and that milk production did not increase (Tsegahun et al. 2000).

Accordingly, planned crossbreeding as a basis for goat production by smallholder farmers has been established and practiced in Ethiopia for several years in order to improve the productivity of indigenous goat breeds. This was primarily done to boost the genetic potential of local goat breeds by combining them with exotic goat breeds like Saanen, Anglo-Nubian, Toggenburg, and Boer goats. However, it has unsuccessful in all agro-ecological zones of the country under smallholder farmer production systems (Chiemela et al. 2015; Ahmed 2017). Furthermore, through the support of several goat productivity enhancement programs, crossbreeding as a basis for goat production by smallholder farmers has been designed and implemented throughout the country for nearly twenty-seven years (i.e., by governmental and non-governmental organizations). However, the results showed that crossbreds (for example, Boer cross with Konso goats) were less productive than indigenous goat breeds, especially under smallholder farmer management systems or village production systems (Tadelle et al. 2014). Consequently, since 2007, Boer goats have been introduced and crossed with Ethiopian indigenous goat breeds such as Abergele, Central Highland, and Woyto-Guji goats in order to increase meat yield through crossbreeding (Abegaz and Gizaw 2015; Tesema et al. 2020).

Moreover, Ethiopia's economic development plan has included and continues to use crossbreeding with exotic breeds in order to increase goat productivity (Shapiro et al. 2015). Ethiopia has been importing different exotic dairy goat breeds (Sannen, Togunburg, and Anglo-Nubian goats) as well as the meat-type Boer goat since late 1975 (Abegaz and Gizaw 2015). The huge frame, quick development rate, and carcass attributes of the Boer goat are well-known (Malan 2000). Ethiopian indigenous goat breeds such as Central Highland, Abergele, and Woyto-Guji goats were crossed with improved Boer goat varieties to improve growth performance and meat output. The crossbreeding strategy included the importation of pure Boer bucks, on-station multiplications of 50% F1 crossbred bucks, and the distribution of Boer crossbreds to farmers' flocks for crossing with indigenous goats. Several institutes distributed F1 Boer crossbred bucks to smallholder farmers with the primary purpose of enhancing meat production through crossbreeding and on-farm genotype performance assessment. Farmers cross indigenous females with 50% Boer crossbred males. In a low-input production system, however, crossing indigenous goats with Boer goats does not significantly increase goat production (Tesema et al. 2020).

In this sense, multiple studies have been conducted in various parts of the country in order to identify the possible grounds for the unsuccessfulness of crossbreeding as a basis for goat production by smallholder farmers. However, the most restrictive reasons and potential for crossbreeding as a basis for goat production by smallholder farmers in Ethiopia have not been well investigated and collated. Therefore, the goal of this review was to give and synthesize validated and up-to-date scientific information on the restrictions and potential for crossbreeding as a basis for goat production by Ethiopian smallholder farmers with the following specific objectives:-

- Describe the possibility of crossbreeding being used as a basis for smallholder goat production.
- Identify the drawbacks of crossbreeding as a basis for smallholder goat production.

Review methods

As part of its procedural methodology, this review conducted a larger literature search and synthesis of relevant peer-reviewed journal articles, workshop papers, books, thesis works, and symposia. The potential and restrictions of crossbreeding as a basis for goat production by smallholder farmers in Ethiopia were comprehensively explored in the research publications. Web of Science and Scopus reports were used to search international databases and platforms for English publications published without regard to publication year. The review process was aided by a search of relevant papers using the following keywords.

The TITLE-ABS KEY ("Constraints" OR "potential" OR "crossbreeding" OR "as a basis for smallholders" AND "goat production" OR "Ethiopia") was used to supplement the review process. Initially, studies that were not appropriate for the outcome of interest were omitted from this review. As a result, based on the inclusion criteria, suitable papers were assessed to synthesize knowledge and experience, and 47 publications were included (Fig. 1). The review focused on providing a complete assessment of the potential and restrictions of crossbreeding as a basis for smallholder goat production. As a result, the potential and constraints for crossbreeding as a basis for goat production by smallholder farmers in Ethiopia were critically assessed, with a focus on the constraints for crossbreeding as a basis for goat production by smallholder farmers, based on empirical data sources and opinions. Finally, concluding observations and future views were drawn. In order to realize the goal of the crossbreeding program as a basis for goat production by smallholder farmers in Ethiopia, adequate consideration should be given to the aforementioned hurdles when adding exotic genotypes.

Main text

Potentials for crossbreeding as a basis for goat production by smallholder farmers

The support of non-governmental organizations such as FARM Africa and Agri-service Ethiopia, as well as governmental organizations such as the Ministry of Agriculture, higher learning institutions (universities and colleges), Ethiopian agricultural research institutions, and agricultural development offices as part of the Ethiopian Sheep and Goat Produce Project, were the major opportunities for implementing strategic crossbreeding as a basis for goat production by smallholder farmers in Ethiopia (Ahmed 2017). In addition to the foregoing, the presence of eight genetically recognized indigenous goat breeds with large populations and diverse performance parameters (i.e., dairy, meat, and dual types) in all agro-ecological zones of the country provides another major opportunity for smallholder farmers to use crossbreeding as a basis for goat production (Kebede et al. 2012). As a result, Ethiopia has a large goat population with a variety of breed kinds that are scattered throughout the country (Table 1). It offers a lot of potential for improving indigenous goat productivity and implementing planned crossbreeding as a basis for goat production by smallholder farmers in Ethiopia.

According to the latest estimates, Ethiopia has a goat population of around 50.50 million. Pastoralists (i.e., Somali, Afar and others) raise enormous flocks of goats in the country's lowlands, which account for a substantial share of its total (Table 2). Kassahun and Solomon (2008) noted that the indigenous Ethiopian goats breeds are distributed in different parts of the country [i.e., Abergelle goats (distributed in Tigray and Amhara region), Afar goats (mostly found in Afar region), Arsi-Bale goats (Oromia region), Begayit (Barka) goats (they are mainly found in western Tigray), Central Highland goats (mainly found in the Central highlands, west of the Rift Valley, Wollo, Gondar and Shoa), Hararghe Highland goats, Keffa goats (found in the highlands and lowlands of Keffa and South Shoa zones of the southern region), Somali goats (northern and eastern Ogaden, Dire Dawa), Western Highland goats (South Gondar, Gojam, Wollega and West Shoa), Western Lowland goats(Gumuz region) and Woyto-Guji goats (South Omo to southern Sidama and Wolayita Zone)].

Constraints to crossbreeding as a basis for goat production by smallholder farmers

According to many smallholders in many parts of the country, the most pressing challenges for goat crossbreeding are a lack of feed, a high incidence of disease and parasites, and the crossbreds' poor adaptability. According to Leroy et al. (2015), the ability to express genetic potential (i.e., feed supplies and veterinary services) and the availability of credit are the most important elements in crossbreeding programs in poor countries. According to Hulunim et al. (2019), the most significant obstacles to goat production, are a lack of fodder and illnesses. In general, inadequate and poor quality feeds and forages, a lack of appropriate documentation, unclear breeding and dissemination programs, diseases and poor veterinary service, a lack of infrastructure, and the termination and weakness of goat improvement projects were among the most limiting factors that hampered the

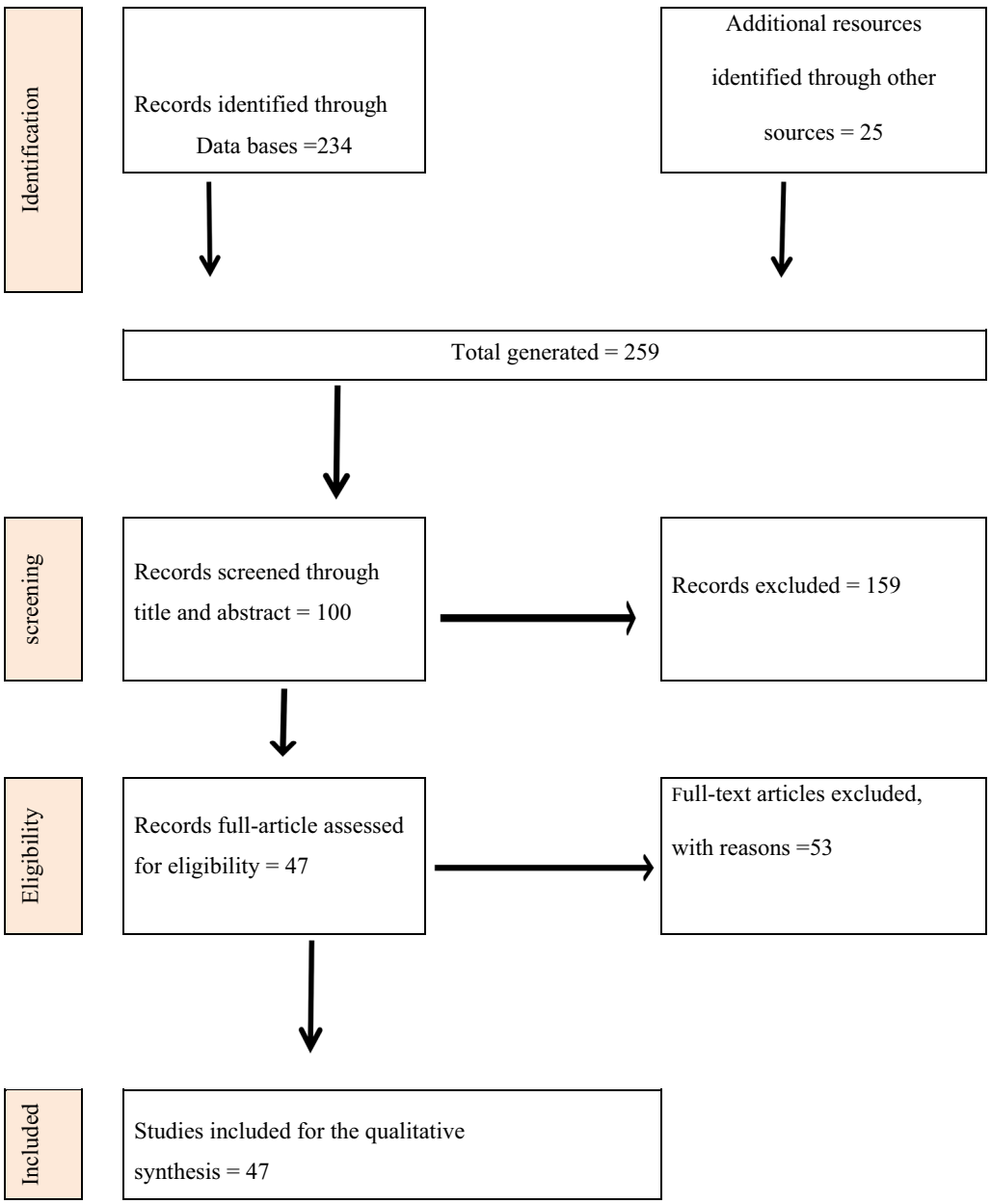

Fig.1 The flowchart for determining which studies are qualified focuses on the limitations and potential of crossbreeding as a basis for goat production by Ethiopian smallholder farmers

Table 1 Distribution of Ethiopian goats by agro-ecological zone (%). *Source*: Jankhe (1983)

Zone	Land area	Goat population	Human population
Arid	44.5	38.0	5.6
Semi-arid	10.1	22.0	43.4
Sub-humid	7.7	5.0	4.9
Humid		3.0	2.5
Highland	37.7	32.0	43.6

success of crossbreeding as a basis for goat production by smallholder farmers in Ethiopia (Aschalew et al. 2000).

Inadequate and poor quality feeds/forages/

The lack of sufficient and good quality feeds and forages is one of the primary impediments to the success of planned crossbreeding as a basis for goat production by smallholder farmers in Ethiopia, because crossbreds require better feed (forages) and nutritional management

Table 2 The numbers and regional distribution of indigenous Ethiopian goat breeds. *Source*: CSA (2020)

Region	Total number of goat population
Tigray	4,838,969
Afar	8,531,082
Amhara	6,883,316
Oromia	7,526,644
Somale	17,001,672
Benshangul-Gumuz	404,015
Gambela	134,206
SNNP	4,819,573
Harari	103,567

than indigenous goats. According to the same authors, a lack of good quantity and quality feed might stifle the productivity of both indigenous and crossbred goats, particularly in smallholder farmers' production systems across the country's agro-ecological zones (Diriba and Kebede 2020). Likewise, IGAD (2011), Legese and Fadiga (2014) and Beyene et al. (2018) identified feed shortages, both in quality and quantity, as one of the main constraints to goat production in the country, which may arise as a result of prolonged drought, which results in below-average rainfall, causing feed and water shortages.

In addition, Tesfaye (2008) stated that the most nutritious foliage is swiftly consumed and that later animals will have consumed the rejected residue. This circumstance leads to a decrease in feed quality, which reduces the nutrient intake of the animals or causes them to fall below their maintenance requirements. Natural grazing and crop residues, on the other hand, are the major feed resources for goat production in Ethiopia, according Adane and Girma (2008), Gebreegziabher et al. (2016), Tesfahun et al. (2017) and Fikiru (2020), but the quality and supply of these resources is seasonally variable; as a result, grazing resources in the highlands are diminishing due to increases in cropping land and bush. This can be one of the most significant impediments to effective crossbreeding as a basis for goat production by smallholder farmers in Ethiopia, as crossbreds require more attention than local goat breeds.

Furthermore, Tegegn and Askale (2017) stated that grazing grounds are becoming increasingly densely populated and, as a result, pastures are overstocked and overgrazed. As a result, lesser grass species frequently invade them. During the dry season, grazing resources are quickly depleted, and goats are unable to maintain their body weight. Also, Alemayehu and Reynolds (2006) stated that in both the highlands and lowlands of Ethiopia feed or forage shortages, both in quantity and quality, worsen during the dry season. This situation is far worse for crossbreds, as they require better feeding, foraging, and maintenance than native goat breeds. The major feed resources for goat production in Ethiopia represent various agro-ecologies (Table 3). According to the statistics, natural pasture grazing, agricultural leftovers, and non-conventional feeds are the principal feed sources for goat production in many sections of the country. However, the quality and availability of these resources vary according to the season.

Lack of appropriate documentation, breeding and dissemination programs

The lack of clear and documented goat crossbreeding programs and dissemination strategies, as well as little or no consideration of smallholder farmer knowledge, skills, perceptions, decisions, and indigenous practices, are the major limiting factors for smallholder farmers in the country to achieve crossbreeding as a basis for goat production (Solomon et al. 2010). According to the same authors, smallholder farmers in Ethiopia had limited or no active participation in the design and implementation of goat crossbreeding initiatives. In addition, Aynalem et al. (2018) stated that the country's goat

Table 3 Major feed resources for goat production in different parts of Ethiopia. *Source*: Yenesew (2009)

Sites					
Feed resources	**Gomma, Dale**	**Bure, Fogera**	**Halaba, Ada'a Liben**	**Metama, Alamata**	**Mieso**
Natural pasture grazing	****	****	***	*****	*****
Crop stubble	**	***	****	**	**
Fallow grazing				***	
Crop residues	**	**	**	**	*
Non-conventional	****	**	***		
Browse Spp	**		***		****
Improved forages			*		

The number of asterisks (*'s) denotes the important feed resource based on the percentage of farmers who selected feed resources as crucial in boosting goat production

crossbreeding programs lacked breeding schemes to sustain cross breeding at the nucleus centers (controlled) and at the village or smallholder farmer level, and that the dissemination of improved genotypes from this program was arbitrary and unintentional. This could be one of the reasons for smallholder farmers' failure to employ crossbreeding as a basis for goat production, resulting in a decrease in goat genetic diversity in the country. Moreover, Kosgey and Okeyo (2007) identified a number of interconnected factors as the main constraints, including the lack of viable and sustainable crossbreeding as a basis for goat production by smallholder farmers, because the success of crossbreeding technology ultimately depends on the net benefits of the smallholder farmers themselves (their developments).

In the same way, Banerjee et al. (2000) stated that there is a dearth of baseline production data as well as an organized and structured goat breeding program in the country, preventing the effective exploitation of Ethiopia's great genetic variation in breeding methods. On the other hand, Institute of Biodiversity Conservation [IBC] (2004) and Aynalem et al. (2018) found that the country's goat cross breeding program did not take smallholder farmers' requirements, views, decisions, and active participation into account during the design and implementation process. Getachew et al. (2018) also stated that in the country, breeding programs or schemes were not considered participatory ways of breeding objective identification and understanding the context of local breeding practices for the overall goal of designing and implementing smallholder farmer-based breeding programs in pastoral areas. The same authors also looked at whether pastoralists of various goat breeds followed the breeding procedures, breeding aims, and selection criteria.

Furthermore, earlier crossbreeding as a basis for goat production by smallholder farmers in the country did not involve smallholder farmers actively from the planning stages to the execution of breeding programs. However, it lacked a characterization of genetic resources, a description of production systems, and a participatory definition of smallholder farmers' selection criteria for smallholder farmers or community-based breeding initiatives. As a result, smallholder farmers and pastoralists in Ethiopia have a significant practical obstacle in implementing a goat cross breeding program (Kosgey et al. 2006).

Diseases and poor veterinary service

Diseases and parasites are one of the major limiting factors for improving smallholder farmer goat productivity in Ethiopia's majority production systems/agro-ecological zones, and they can also cause high mortality and poor reproductive and growth performance in goats, resulting in lower output per animal and flock off-take rates (Belete et al. 2015; Fikru and Gebeyew 2015; Yemane et al. 2020). Similarly, lumpy skin disease, external parasites (tick paralysis), internal parasites (fasciolosis), trypanosomiasis, and heartwater are the most important diseases that affect both improved as well as local goat productivity in different parts of the country (Aklilu 2008; Tesfaye 2009; Grum 2010; Tegegne 2012). They're also to blame for a lot of kid deaths and poor skin quality. In accordance with this review, Table 4 lists the principal goat diseases that impede goat productivity growth in Ethiopia, representing various agro-ecologies, in order of importance as reported by farmers. As a result, one of the most efficient ways to boost goat output in Ethiopia is to provide cheap veterinary services.

The lack of veterinarians (people), as well as a lack of inputs such as medications, vaccines, and equipment, were the key impediments to providing successful veterinary services to smallholder goat farmers, particularly in pastoral areas (Arse et al. 2013; Fikiru 2020). This could be one of the most significant obstacles to smallholder farmers in Ethiopia using crossbreeding as a base for goat

Table 4 Major goat diseases that hamper goat productivity improvement in different parts of Ethiopia in order of importance as expressed by farmers. *Sources*: Tesfaye (2009)

Diseases		Districts							
Scientific name	Local name	Halaba	Dale	Fogera	Bure	Metema	Mieso	Atsbi-Womberta	Alamata
Trypanosomiasis	Shillo		1						
Pasteurellosis	Inqit/gororsa/ankelikil	3			1	3	4		2
Heart water	Harisho		2						
Ectoparasitosis/tick/lice	Meziger/kuridid/tigegna/engira		5		4	4	5	4	6
Fasciolosis	Losha/lugo	1							
Endoparasitosis	Tilatil/deisha		4					5	
Mange/skindiseases	Kukini/ekeke		3			4	6	2	1

production. Animal health care constraints in the Dale pilot weredas in Southern Ethiopia (Table 5). According to the research, the primary restrictions on animal health services are the lack of veterinary clinics, excessive drug prices, a paucity of veterinary personnel, and inaccessibility. Major goat diseases that hamper goat productivity improvement represent different agro-ecologies in Ethiopia in order of importance as expressed by farmers.

Lack of infrastructure

Because there is no nearby market, there is a lack of infrastructure (roads, cars, etc.) to move live goats and their goods from remote rural smallholder farmers or goat producers to urban markets. With little water and fodder, goats are typically transported long distances for selling as shown in Fig. 2. Goats have also walked large distances in search of food and water. These factors also have a significant impact on the county's crossbred goat output (Banerjee et al. 2000; Adane 2008).

Termination and weakness of goat improvement projects

According to Ahmed (2017), the bulk of goat crossbreeding operations in the country lacked well-organized institutional synergies and termination strategies. This is because the majority of goat projects lack a clear goal that is linked to smallholder farmers' breeding goals and production conditions. Another key flaw in goat initiatives was the failure to generate a sustainable source of high-quality goat breeding stock. Furthermore, smallholder farmers adopted crossbred genotypes at a relatively low rate (Teressa 2004).

Table 6 lists goat production constraints by production system and agro-ecologies in ranking order based on smallholder farmers' responses in pilot weredas in Ethiopia. According to the statistics, the primary limiting factors preventing smallholder farmers from improving goat production in the country are a lack of feed (both in terms of quality and quantity) and the incidence of various diseases and parasites. As a result of the sum of these impacts, unproductive (inferior) crossbreds are produced

Table 5 Constraints in animal health delivery in Dale Pilot Learning Woredas, Southern Ethiopia. *Source*: Endeshaw (2007)

Constraints	Percentage of respondents			
	Moist Dega	Moist Woina Dega	Moist Kola	Overall
Absence of veterinary clinics	33.3	31.1	66.7	35.8
Shortage of veterinary personnel	13.3	25.6	0.0	20.5
Inaccessibility	6.7	20.0	33.3	20.0
High drug price	33.3	6.7	0.0	14.2
Shortage of drugs	13.3	1.1	0.0	2.5
No problem	0	8.9	0.0	6.7

Fig.2 Trekking and transporting goats to market in some parts of the country (Solomon et al. 2010)

Table 6 Ethiopian goat production restrictions, ranked by smallholder farmers' replies to represent pilot weredas. *Source*: Solomon et al. (2010)

Parameters	Pilot weredas/zones			
	Halaba	Metema	Dale	Bure
Shortage of feed	2	6	1	3
Diseases/parasites	1	1	2	1
Water shortage	5	–	–	5
Incidence of drought	7	–	–	–
Lack of inputs	6			
Inadequate veterinary service				2
Market access		4	5	4

compared to indigenous goat breed types, especially under smallholder farmer management systems.

Conclusions

The purpose of this review was to provide and synthesize validated and up-to-date scientific knowledge on the benefits and drawbacks of crossbreeding as a basis for goat production by Ethiopian smallholder farmers. Crossbreeding as a basis for goat production by smallholder farmers was made possible by the presence of indigenous goat breeds with varying performance qualities throughout Ethiopia, as well as the collaboration of both governmental and non-governmental entities. In contrast, the main roadblocks to planned crossbreeding as a basis for goat production by smallholder farmers in Ethiopia were a lack of baseline production data, a lack of well-organized institutional synergies, and little or no consideration of smallholder farmers' needs, decisions, participation, and local practices. Furthermore, insufficient and poor-quality feeds and forages, the cancellation and weakness of goat genetic improvement projects, disease and parasite prevalence, poor veterinary services, and a lack of infrastructure were among the most limiting factors for goat crossbreeding strategies to be implemented in smallholder farmers' production systems across the country. Therefore, in order to achieve the goal of the crossbreeding program as a basis for goat production by smallholder farmers in Ethiopia, due consideration should be given to the above obstacles while adding exotic genotypes.

Abbreviations

ATA: Ethiopian agricultural transformation agency; CSA: Central statistical agency; EIAR: Ethiopian institute of agricultural research; ESAP: Ethiopian society of animal production; IBC: Institute of biodiversity conservation; ICARDA: International center for agricultural research in the dry areas; IGAD: Intergovernmental Authority on Development; ILRI: International livestock research institute; SNNP: Southern nations, nationalities, and people's region.

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Authors' contributions

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Consent for publication

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Competing interests

The author declares that there is no competing interest.

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