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SMALL RUMINANT PRODUCTION SYSTEMS AND BREEDING PROGRAMS IN ETHIOPIA: ACHIEVEMENTS, CHALLENGES AND LESSONS LEARNED: A REVIEW

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REVIEW

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ABSTRACT: Indigenous small ruminants (sheep and goats) in Ethiopia are very important sources of both tangible and intangible benefits to resource-poor farmers. To date, the country has more than 60 million heads of shoats raised in different production systems, yet their productivity and contribution to the agricultural and national economy is far below the potential. Limited genetic potential has been identified as a major constraint to increased productivity. Various small ruminant genetic improvement programs, aimed at improving the productive and reproductive performance of indigenous breeds, were therefore implemented in the country. Crossing local breeds with their exotic contemporaries was one of such programs commenced since 1944 on sheep and the mid-1970s on goats. Due to different reasons, however, the small ruminant crossbreeding programs in Ethiopia did not deliver the anticipated benefit to smallholder farmers and hence many of the crossbreeding programs were failed. Following the tragic and fruitless ending of small ruminant crossbreeding programs, centralized nucleus-based selection programs were then implemented widely in different parts of the country with the objective to achieve highly productive and prolific genotypes. Despite several efforts made towards this end, the selection programs in various nucleus centers did not provide the desired genetic improvements and generally yielded unsatisfactory results. As a result, a viable option that fits well with the prevailing low input production systems was therefore required. One such option that has recently stimulated a global interest was community-based breeding program. The program was implemented and tested in Ethiopia as early as 2003 on the adapted local breeds in four regions across the country. It had a promising start and by now it realized several achievements. Hence, the program should be part of the national livestock breeding policy.

Keywords: Breeding Programs, Ethiopia, Production systems, Small ruminants

INTRODUCTION

Small ruminants (shoats) in Ethiopia are important sources of both tangible (income, meat, milk, skins and manure) and intangible (saving, insurance against emergency, cultural and ceremonial) benefits that vary among different cultures, socio-economies, agro-ecologies and locations (Workneh et al., 2003; Kosgey, 2004). To date, the country has more than 30.7 million heads of sheep and 30.2 million heads of goats (CSA, 2016); nine sheep (Gizaw et al., 2007) and seven goat (Mekuriaw, 2016) breeds kept in diverse production systems and different agro-climates ranging from the hot arid and semiarid areas to the cold humid highlands. Estimates indicate that 99.72% of the sheep and 99.97% of the goats are indigenous breeds (CSA, 2016) that are evolved to survive in harsh environments at the expense of all other factors (production included).

In Ethiopia, almost all sheep and goats are produced in mixed crop-livestock and pastoral and agro-pastoral production systems characterized by low levels of input and technologies, feed scarcity and disease challenge (Alemayehu, 2006). The mixed crop-livestock production system is often found in the highland agro-ecological zones where livestock production is secondary to crop production. The system comprises of very small flock sizes due to shrinkage of grazing areas per household, limited feed availability and land degradation (Tesfaye, 2004; Solomon et al., 2014). On the other hand, the pastoral and agro-pastoral production systems are found in the arid and semi-arid agro-ecological zones where the majority of small ruminants are concentrated. These areas are the

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major sources of livestock products for the Ethiopian export market (Solomon et al., 2010; Legese and Fadiga, 2014). The pastoral system is based on wide-ranging communal grazing lands primarily using natural vegetation where thorny enclosures are common while the agro-pastoral system is characterized by a combination of pastoral and mixed crop-livestock production systems with periodic use of crop residues (Grum, 2010).

Given large number of indigenous sheep and goats, their contribution to the agricultural and the overall national economy is however far below the potential (Legese and Fadiga, 2014). Similarly, compared to all other countries and the global average, the productivity of Ethiopian small ruminants is reported to be one of the lowest. This could be attributed to their various interactive factors such as poor genetic performance exacerbated by low input traditional production system (Gizaw et al., 2008). Cognizant of this fact, a number of sheep and goat improvement programs, aimed at improving the performance of indigenous breeds without losing their capacity to survive in harsh environments, were conducted in the past (Workneh et al., 2003).

One of such programs was crossbreeding the indigenous breeds with temperate breeds to combine high yielding capacity of exotic genotypes with better adaptation attributes of their indigenous counterparts (Tesfaye, 2004). However, the belief that crossbred genotypes have better performance than indigenous breeds led to indiscriminate crossbreeding (Gizaw et al., 2013). In fact, few crossbred sheep and goats equally combined both production and adaptation features and performed better than the indigenous breeds under on-station conditions; yet such superiorities were not replicated under on-farm management (Workneh et al., 2003). Hence, the adoption rates of exotic and crossbred genotypes by smallholder farmers were found to be very low (Teressa, 2004; Kosgey et al., 2006; Oumer and Firew, 2017) and their number remains insignificant (0.31%) (CSA, 2016). This indicates that small ruminant crossbreeding program in Ethiopia did not deliver the anticipated benefit and the smallholder farmers did not benefit more from crossbreds than from indigenous breeds (Workneh et al., 2003). As a result, most of the crossbreeding programs were not successful; rather they caused erosion and dilution of the adaptive features of the indigenous breeds.

Following the fruitless ending of various crossbreeding programs, centralized nucleus-based selection programs were then applied in the country. The programs were implemented on Afar, black head Somali, Horro, Menz, and Washera sheep breeds (Gizaw et al., 2013) and Arsi-Bale goat populations (Abegaz et al., 2014). The selection criteria were post-weaning growth rates, Pre-weaning weight gain, litter size and yearling weights (Gizaw et al., 2013). Nevertheless, the improvements obtained from these nucleus-based selection programs, except the Menz program, were found to be unsatisfactory and improving the performance of small ruminants through such programs is still a challenge in Ethiopia.

The failure of the small ruminant crossbreeding and nucleus-based selection programs in Ethiopia initiated the implementation of a very recent approach called community based breeding program (CBBP) on the adapted local breeds. Due to its multidimensional benefits and fitness to the existing low input production systems, CBBP is a feasible alternative for Ethiopian smallholder farmers (Haile et al., 2011; Wurzinger et al., 2011). The program was employed in the country as early as 2003 on Afar, Bonga, Horro and Menz sheep breeds (Gemeda, 2011; Mirkena, 2011) and Abergelle goat populations (Solomon, 2014) by the national agricultural research centers in collaboration with the international research institutions (Gutu et al., 2015).

Overall, large number of sheep and goats in Ethiopia are reared in diverse production systems and several crossbreeding, nucleus-based selection and community-based breeding programs, directed towards improving the performance of indigenous breeds, were executed in the past several years. However, there is lack of organized and up-to-date information on small ruminant production systems and breeding programs in Ethiopia. This paper, therefore, aims to review and discuss the achievements recorded so far, challenges encountered and lessons learnt in the Ethiopian small ruminant production systems and breeding programs.

DISCUSSION

Role and productivity of small ruminants in Ethiopia

Small ruminants in Ethiopia play very crucial role in terms of meat, milk, manure, skin, wool, horn, bone, security, gifts, religious rituals, medicine and incentives (Legese and Fadiga, 2014; Zahra et al., 2014). Currently, small ruminants in Ethiopia contribute 154,000 tons of meat (Mourad et al., 2015), about one-fourth of the domestic meat consumption; half of the domestic wool requirements; 40% of fresh skins and 92% of the value of semi-processed skin and hide export trade. At optimum off-take rates, Ethiopia can export 700,000 sheep and 2 million goats annually, and at the same time supply 1,078,000 sheep and 1,128,000 goats for the domestic market (Adane and Girma, 2008).

Given their multiple roles, the current level of indigenous small ruminants' productive performance is however reported to be very low. For instance, carcass yield has been flat for the past several years and will remain so in the

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future. For the years (1999-2008), the average carcass weight produced from yearling sheep and goat in Ethiopia was only 10 and 8 kg, respectively and it was one of the lowest compared to all countries and the world average (16 kg for mutton and 12 kg for goat meat) (FAO, 2005). Therefore, the future growth in Ethiopian small ruminant meat production will come from increase in the number of slaughter animals or slaughter volume (Legese and Fadiga, 2014). Likewise, the dressing percentage (DP) of indigenous small ruminants at one year of age is also very low. The average dressing percentage of Ethiopian sheep were reported to be 42.5% (Berhe, 2010) while the same varied between 42 and 45% for goats.

The average annual off-take rate, defined as the proportion of animals sold or consumed in a year, for sheep and goats in Ethiopian smallholder farmers and pastoralists was also very low over different time periods (Asfaw and Jabbar, 2008). For the year 1999/2000, the average net commercial off-take rates of sheep and goats in the highland areas of Amhara, Oromia and Tigray regions were 22 and 18%, respectively while in the year 2004/05, the average net commercial off-take rate were 7 and 8%, for sheep and goats, respectively (Workneh, 2006). In the case of Borana pastoral production system, the average net commercial off-take rate of small ruminants was 7% (Asfaw and Jabbar, 2008). Ethiopian Privatization Agency (EPA, 2002) and Adane and Girma (2008) also reported that the annual off-take rate of indigenous sheep and goats were only 33 and 35%, respectively. Recent estimate of average off-take rate from sheep and goats, between 2008 and 2010, was 30-38% (ILRI, 2014, unpublished report; cited by Mourad et al., 2015). In parallel, the demand for animal products has increased due to a growing human population and urbanization. There is, therefore, an urgent need to improve productivity of small ruminants in order to raise smallholders' incomes and meet the demands of the growing human population (Haile et al., 2011).

The low productivity of small ruminants could be attributed to complex interaction of numerous technical, institutional and socio-economic factors such as: poor nutrition, inadequate veterinary services, persistent drought, disease, poor infrastructures, low levels of technologies, insufficient financial services and poor genetic performance (Aklilu, 2008; Solomon et al., 2010). Along with these factors, uncontrolled mating, negative selection practices through sale of best performing young animals (Getachew et al., 2010; Mirkena, 2010; Haile et al., 2011; Gizaw et al., 2013) and inappropriate livestock development policies (Aleme and Lemma, 2015) are becoming major factors for the poor performance of small ruminants. Lack of suitable policy in one hand and implementation of inappropriate policies on the other hand hindered the smooth progress expected of the livestock sector.

Therefore, for the Ethiopian small ruminants to be more productive and entirely play their role as a pathway for the development of the country, any intervention that improves their productivity is important in creating wealth and improving the standard of living of resource-poor farmers. For example, alleviating the challenges and constraints that determine and hamper their productivity could be one possible mechanism. Moreover, designing and implementing appropriate genetic improvement programs that can boost productivity per animal is another possible option in order to meet the ever increasing demand of small ruminant meat in the ever growing human population. This is especially so when one considers that the demand for animal products is expected to double over the next 33 years as a consequence of urbanization, population growth and increased income (Westhoek et al., 2011).

Reproductive performances of Ethiopian small ruminants

Good reproductive performance is a precondition for any successful genetic improvement program and it determines production effectiveness (Zewdu, 2008). Reproductive performance of sheep and goats depends on various factors including age at first lambing/kidding (AFL/AFK), lambing/kidding interval (LI/KI), litter size (LS) and twinning rate (TR). For example, AFL/AFK is a good indicator of early sexual maturity in ewes/does and it is an economically important trait as greater population turnover and more rapid genetic progress can be obtained when sheep or goats produce their first progenies at an earlier rather than later age. Early maturing females are also known to have a relatively long and fruitful reproductive life. Similarly, total life time production (life time lamb/kid crop) can be increased by encouraging first lambing/kidding at an early age (Amelmal, 2011).

The reported average AFL of Ethiopian indigenous sheep breeds ranges between 11.5 and 23 months (Zelalem, 2016) whereas the average AFK of most indigenous goats is between 12 and 14 months (Dereje et al., 2015). The present review shows that most indigenous sheep/goat breeds of Ethiopia tend to have their first lambs/kids before they are two years old. This indicates that the existing uncontrolled breeding practice in the traditional production system is in favor of early lambing/kidding of indigenous goats than the controlled breeding practices in the improved system. In fact, there is variation among indigenous sheep/goat breeds in AFL/AFK due to various factors like genotype, nutrition, disease or parasitic burden, year and season of birth in which the ewe and doe were born (through their effect on feed supply and quality during different seasons) In addition, lambs and kids born for twins had longer age at first lambing and kidding than their counterpart single born lambs and kids.

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Lambing/kidding interval (LI/KI), which is the interval between two consecutive parturitions, is another main component of reproductive performance. Available evidences show that the average LI for indigenous sheep breeds is between 6.6 and 13.6 months (Zelalem, 2016) while the average KI for indigenous goat breeds is within the range of 8.5 and 12 months (Dereje et al., 2015). However, there are variations in LI/KI among indigenous sheep/goats that may be due to variations in breed, season (Mengiste, 2008), year of lambing/kidding, nutrition, type of mating, parity of ewes/does, post-partum body weight and management practice (Gbangboche et al., 2006). In conditions where good management, adequate nutrition and breeding males are available in the flock for most time of the year, shorter LI/KI can be achieved whereas longer LI/KI are mainly due to the result of controlled breeding, poor management and nutrition.

On the other hand, litter size (LS), a trait largely determined by ovulation rate, is reported to be between 1.02 and 1.51 for indigenous Ethiopian sheep (Zelalem, 2016) and between 1.07 and 1.5 for goats (Dereje et al., 2015). Ovulation rate is in turn dependent on age of the dam, level of nutrition, type of breed, season and dam body weight at mating (Mukasa-Mugarwa and Lahlou-Kassi, 1995) and management system (Mekuriaw et al., 2013). For instance, age of the dam has an effect on the number of lambs/kids born per lambing/kidding in such a way that LS is increased with an increase in parity and the highest LS is attained at six years of age or the fifth parity (Berhanu and Aynalem, 2009). Peak prolificacy is generally achieved between 4 and 8 years of the dam (Notter, 2000). Similarly, level of nutrition has an effect on LS in that, poor nutrition during service period lead to reduced ovulation rate and increased embryonic mortality and consequently decreased LS.

Moreover, most indigenous goats have twining rate (TR), the percentage of ewes/does having twins, below 20% varying from less than 5% for pastoral goats in arid areas to 36% for goats in the humid areas of the country (Dereje et al., 2015). Overall, LS and TR are the most variable traits reported for indigenous sheep and goats in Ethiopia. This shows the presence of huge opportunity to improve these traits through selection and improved management focusing on breeds having better potential for the traits. It is also found that LS and TR of some indigenous sheep and goat breeds are found to be lower than the values reported for most of the indigenous breeds in Ethiopia even under traditional systems which appear to be one mechanism of adaptation to the harsh environmental conditions of the rangelands and to the seasonal scarcity of feed resources.

Small ruminant production system in Ethiopia

Describing the production system in a holistic manner is a pre-requisite to design and implement a breeding program that can address the trait preferences and breeding objectives of smallholder farmers. To this extent, many studies were undertaken to describe the small ruminant production systems in Ethiopia since the mid-1980s (Samuel, 2005; Belete; 2009; Tesfaye, 2009; Zewdie, 2010; Alubel, 2015; Tsigabu, 2015; Zergaw et al., 2016) following the adoption of farming system research approach by the then EARO (Ethiopian Agricultural Research Organization) and now EIAR (Ethiopian Institute of Agricultural Research). Some of the reports were published in different journals, yet many more are neither reported nor accessed (Gizaw et al., 2013). Based on the level of the small ruminant production, their contribution to the community and the type of crop production enterprises, there are two major small ruminant production systems in Ethiopia: mixed crop-livestock and pastoral and agro-pastoral (Alemayehu, 2006) that can be distinguished mainly through the three production factors: land, labor and capital.

Mixed crop-livestock production system. Crop-based mixed farming system is often found in the highland agro-ecological zones where the altitude ranges between 1500 and 3000 masl and the climate is favorable for farming of crops and raising of livestock. In this production system, livestock production is secondary to crop production and it usually comprises of small ruminants with very small flock sizes as a means to generate cash income from sale of animals and produce meat (Tesfaye, 2004; Solomon et al., 2014). Sometimes, manure is returned to the system (nutrient cycling) to benefit vegetable gardens, food and cash crops. Here, mixed species (cattle, sheep, goats and other livestock) grazing system has been predominantly practiced (Lebbie, 2004) and livestock were freely grazed on communal pastures and seasonally on fallow crop lands with no extra-supplement. However, due to human population growth and urbanization, there is shrinkage of grazing lands from time to time (Workneh, 2000). Hence, in some areas, free grazing is limited and small ruminants are now tethered (Kidus, 2010) though they are herded in others to graze and browse on communal lands (Deribe, 2009; Tegegne, 2012). In addition, due to a gradual shift from keeping large to small ruminants, the relative importance and population of small ruminants is increasing and feeding animals in a limited available grazing lands, crop residues, forages, bushes and shrubs, home left overs and industrial by-products are becoming the features of mixed crop-livestock production system. Accessibility of water is not a limiting factor in most areas under this production system and goats are housed within the family house (Endeshaw 2007; Deribe 2009; Kidus, 2010) or in separate housing (Belete, 2009; Kidus, 2010; Dhaba et al.,

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2012). However, the system is characterized by low productivity due to recurrent drought, nutritional stress, severe resources degradation and internal and external parasites (EARO, 2000; IBC, 2004).

Pastoral and agro-pastoral Production system. The majority of small ruminants (40% of sheep and 40% of goats) are concentrated in the pastoral and agro-pastoral areas (Asfaw and Jabbar, 2008) kept under extensive systems which make them major sources of livestock products for the Ethiopian export market (Legese and Fadiga, 2014). In this production system, there is relatively lighter human pressure on natural resources and higher land holding per households than that observed in the mixed farming system. As the arid and semi-arid agro-ecological zones, within altitudes below 1500 masl, receive low moisture in most of the time and feed is scarce in the dry season, pastoralists and agro-pastoralists travel long distances with their animals in search of feed and water. The system is either transhumant (the whole system moving periodically) or sedentary (limited movement) (Solomon et al., 2008). The pastoral production system is based on wide-ranging communal grazing lands primarily using natural vegetation where thorny enclosures are common while the agro-pastoralists, on the other hand, are characterized by a combination of pastoral and mixed crop-livestock production systems with periodic use of crop residues (Grum, 2010; Legese and Fadiga, 2014).

Selection criteria and breeding objectives of small ruminants in Ethiopia

In designing breeding programs for most livestock species, selection is based on breeding values estimated using either selection index or, if possible, best linear unbiased prediction (BLUP). Based on the traits under consideration, these techniques require recorded information on the performance of the individual animal and its relatives (Mbuku et al., 2006). Such techniques are however too complex for the resource-poor farmers to apply, as they do not have records on the performance of individuals and their pedigree. Conversely, this does not mean that they do not consider the performances of the individual and its relatives when selecting animals to be parents of the next generation though no effective selection and breeding programs can be applied in the absence of records (Semakula et al., 2010).

Selection criteria of smallholder farmers reflect their breeding activities and farming philosophies and the criteria do vary among different production systems and species (Roessler et al., 2008). The criteria are also different between sexes. For instance, for males, appearance (Getachew, 2008), body size (Zewudu et al., 2012), tail type, color and height (Gizaw, 2008) are given due emphasis during selection. On the contrary, rams and bucks with black color, poor body condition and small size are not preferred for breeding purpose and male animals of such character are usually culled at a young age or sold or slaughtered at home. Similarly, in selecting ewes and does, appearance, coat color and lamb survival (Getachew, 2008; Niggussie et al., 2013) and liter size and lamb growth (Gemeda et al., 2011) were reported as the most important selection criteria, yet those of which are black colored, old aged, poor conditioned and those having long lambing interval are culled (Zewudu et al., 2012 and Yenesew et al., 2013).

Despite the variation in production system and sex, the small ruminant selection criteria in Ethiopia usually focused on a single market driven trait. For instance, fast growth rate, to produce sheep and goats that can fetch higher market price, was the primarily preferred trait in the crop-livestock mixed production system (Arse et al., 2013; Niggusie et al., 2013; Ahmed et al., 2015; Alubel, 2015; Tsigabu, 2015; Zergaw et al., 2016) while milk yield and meat production was the most preferred traits in pastoral and agro-pastoral areas (Getachew, 2008; Zewdu, 2008; Belete, 2009; Kahsa, 2009; Getachew et al., 2010; Gizaw et al. 2010; Alefe, 2014; Feki and Berhanu, 2016). Social and cultural functions were also ranked as other important aspects of small ruminant production (Mengistie et al., 2010; Assen and Aklilu, 2012; Fsahatsion et al.; 2013 and Solomon, 2014). However, the adaptive attributes that small ruminants would assume were not considered in the improvement programs and not captured in the economic analysis. This might lead to genotypes that are neither well adapted to the environment nor capable of performing multiple roles (Haile et al., 2011).

Hence, identifying the selection criteria of farmers and their breeding objectives, in a particular production system and environment, is very crucial to design and implement effective small ruminant genetic improvement programs (Jaitner et al., 2001; Jimmy et al., 2010; Wurzinger et al., 2011; Niggusie et al., 2013). In this state of being, the multiple values of indigenous small ruminants and non-tradable attributes such as adaptive features, tolerance to diseases and feed shortage would not be overlooked by giving rise to misplaced objectives. Furthermore, it is possible to extract more than just milk and meat and get the most out of these animals that can survive and reproduce under the harsh environmental conditions. In general, for developing countries like Ethiopia, where indigenous small ruminants are the most important livestock species in the livelihood of smallholder farmers, the development of single purpose specialized breeds is not an appropriate option.

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Small ruminant crossbreeding programs in Ethiopia

Adapted to the local environment, the indigenous small ruminants represent a unique genetic resource for the smallholder farmers. However, the need for increased economic gains and the belief that crossbred genotypes have better overall performance than the indigenous breeds led to indiscriminate crossbreeding of the indigenous breeds with exotic breeds (Workneh et al., 2003; Tesfaye, 2004). The small ruminant crossbreeding program based on exotic sires was therefore started in Ethiopia in 1944 with the introduction of the Merino sheep breed from Italy (DBSBMC, 2007). Since then, small ruminant crossbreeding has been the major component of the livestock genetic improvement endeavors and several on-station and on-farm efforts have been made on sheep (Tibbo, 2006; Gizaw et al., 2013) and goats (Abegaz et al., 2014).

For instance, Romney, Corriedale, Hampshire and Rambouillet sheep breeds were imported from Kenya in 1967 (BoA, 2000) and were crossed with local Menz breed to produce and supply finer and longer wool fiber for Debre Berhan blanket factory (DBHBMC, 2007; Gizaw and Getachew, 2009). The breeds and their resultant crosses had good growth and wool production performance under on-station and on-farm conditions. But, except Romney, the rest of the three breeds were not accepted by the local farmers due to their phenotypic characteristics (face covered with hair, absence of horn in males, thin tail, fatty nature of the wool making it difficult to spin in the traditional way and poor skin quality) (Getachew et al., 2016).

Later in 1980, pure Awassi rams were imported from Israel (DBHBMC, 2007) and were crossed with the local Menz ewes in Debre Birhan and Amed Guya multiplication centers. The resultant crossbred rams were then distributed to villagers when they were six months old. Finally, upgrading of the village flocks to 75% Awassi were undertaken (Gizaw and Getachew, 2009). The purebred Awassi and their crosses (Awassi x Menz) were accepted very well by Ethiopian farmers due to their similar physical appearance with the local Menz breed. However, the strategy to disseminate improved genotypes to the farmers and the scheme to sustain the crossbreeding at the community level were not well defined. As a result, indiscriminate crossbreeding and extensive distribution of crossbred rams across the country, in the last three decades, yielded virtually no impact on the sheep industry (Gizaw and Getachew, 2009; Gizaw et al., 2013). In addition, the rates of inbreeding per generation derived from the number of breeding males and females (BoA, 2001) were well beyond the acceptable level of 1.0% (6.1% at Debre Birhan and 32.5% at Amed Guya). This could be attributed due to small flock sizes which lead to mating of related individuals and inbreeding depression; 67 pure breed rams and ewes at Debre Birhan and 13 at Amed Guya ranches were kept by the end of 2004 (Gizaw and Getachew, 2009).

In the late 1980s, Dorper sheep were introduced into Ethiopia though they were looted during the political instability in 1991 (Awgichew and Gipson, 2009). In 2006, they were imported again from the Republic of South Africa by the Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) (ESGPIP, 2006; Gizaw et al., 2013) with a financial support from USAID. After the importation of the breed, two nucleuses and ten Breeding, Evaluation and Distribution (BED) centers were established in different parts of the country by the ESGPIP in collaboration with local universities and research centers. However, the promising start faced the common tragedy of sheep crossbreeding programs in Ethiopia following the termination of funding and phasing-out of the ESGPIP in 2011 (Getachew et al., 2016). Currently, the various Dorper centers are being run with little national coordination. Despite this fact, there are encouraging regional Dorper sheep researches and development projects with rational crossbreeding schemes (Gizaw et al., 2013). A detail report on the on-station and on-farm research results on growth, reproductive and carcass performances of different sheep crossbreeding programs, based on exotic sires, in Ethiopia is presented in Getachew et al. (2016).

Crossbreeding among the local sheep breeds has also been practiced in many areas of the country. For example, the indigenous Washera rams were distributed to the highlands of North Shewa, South Wollo, North Wollo, and Gondar areas by Debre Berhan Agricultural Research Center as an alternative to the use of exotic sires for crossbreeding (ANRSBoARD, 2004; Getachew et al., 2016). In 2005, a village-based Farta × Washera sheep crossbreeding program has also been started by Andassa Livestock Research Center in Lay Gaint and Farta districts of South Gondar (Mekuriaw et al., 2013) with the aim to increase the productivity of medium sized Farta (Gizaw et al., 2008) by crossing with male and female Washera sheep. Improvement program on indigenous Farta sheep using indigenous Washera breed indicated that the growth performance of crossbreds was better than the pure Farta sheep (Mekuriaw et al., 2013).

Like that of the sheep, several goat crossbreeding programs have been implemented in Ethiopia to improve the meat, milk and fiber productivity of the local goat breeds. Introduction of exotic goats such as Saanen, Anglo-Nubian, Toggenberg and Boer was among the efforts made so far. Several comparison studies documenting the performance of different indigenous goat breeds and different blood levels of crossbreds were also reported by various scholars. The following are summarized reports.

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A study by Galal et al. (1982) on crossbreeding of Ethiopian highland goats with Saanen indicated a substantial increase in milk production from 19 to 52 kg in half-bred Saanen does (from a 12-week lactation), with a slight reduction in reproductive performance and a marginal increase in the growth potential of crossbreds. However, there have been adaptation problems for first crosses of Saanen and lowland goats in harsher areas, indicating that a lower level of exotic genotype might be more suitable.

A comparative study was also conducted on the productivity of indigenous purebred Adal and quarter-bred Saanen goats in Melka Werer Research Center (Awgichew et al., 1989). The same authors reported that crossbred does produced more milk than purebred Adal does and their progenies were heavier than purebred Adal goats at 3 and 6 months. However, breed had no significant effect on birth weight and 12 months weight. Further, there were no differences between purebred Adal and quarter-bred Saanen does in any of the reproductive traits recorded. It was thus concluded that, for the nomadic pastoralists around Melka Werer, the quarter-bred Saanen x Adal doe has much to offer.

Similarly, on-station comparison made between local goats and crossbreeds (local x Anglo-Nubian) in the FARM-Africa's dairy goat development project (DGDP) (FARM Africa, 1996) showed an increment in milk and meat outputs in crossbred goats, resulting an average increase in gross per capita income of 19% for the beneficiaries (Wagayehu and Habtemariam, 1994). The same authors noted, however, that the long-term success of local goats' genetic improvement program based on crossbreeding with exotic genotypes remains unproven. In similar study but with a different approach and after the completion of the DGDP, Workneh et al. (2003) found that crossbred goats (local x Anglo-Nubian) did not perform better than indigenous goats on comparisons based on land, metabolic weight and labor inputs.

Generally, given the host of examples available in the sheep and goat crossbreeding programs in different parts of the country, the on-station crossbreeding programs were successful with various achievements and crossbreds have superior performance than local breeds. However, such superiorities were not replicated under on-farm conditions and the resultant crossbreeds did not perform better than indigenous breeds. As a result, the adoption rates of crossbred genotypes by resource-poor farmers were found to be very low because crossbreds have no significant effects on their livelihoods and the national economy at large. On the other hand, the crossbreeding programs in Ethiopia caused erosion and dilution of the adaptive features of the local breeds and thus most of the small ruminant crossbreeding programs were unsuccessful and failed.

The major reasons for the failure of the small ruminant crossbreeding programs in Ethiopia are associated with the following documented reasons. Absence of a clear and documented livestock breeding policy except attempts to develop small ruminant breeding guidelines in the regional states to some extent (Getachew et al., 2016) is the premier reason. Very little consideration of the needs, perceptions and indigenous practices of the farmers and their limited or no participation from planning to execution of the breeding programs is also another reason (Gizaw et al., 2013). In developing countries like Ethiopia, acceptance of new breeds is influenced not only by their productive performances but also by non-production traits like coat color, tail type, horn and ear size and appearance of the animal (Ndumu et al., 2008) and cultural values (Leroy et al., 2015). Absence of effective strategies to sustain the crossbreeding programs at the research centers, at community and household level (Gizaw et al., 2013), mismatch between the genotypes and the environment (Getachew et al., 2015), indiscriminate and unplanned distribution of the improved genotypes and their incompatibility with the farmers' breeding objectives, poor management and low input production systems were also among the reasons for the failure of small ruminant crossbreeding programs in Ethiopia (Gizaw et al., 2013).

Therefore, in order to maximize the benefits that will be obtained from small ruminant crossbreeding programs in the future, the previous recorded achievements should be strengthened and the gaps identified so far must be addressed and filled before the introduction of any exotic breed for crossbreeding. Moreover, lessons should be learnt from the already implemented yet unsuccessful crossbreeding programs, the adaptive features of indigenous small ruminants have to be conserved and the on-farm management must be improved for a better productivity since the indigenous small ruminants have good growth and reproduction performance under on-station conditions indicating their potential. Moreover, the quick fix short cut solution through crossbreeding may be a recipe for genetic progress but such attempts may endanger the adapted indigenous animal genetic resources in the face of climate change. Instead, genetic progress could be achieved through designing a sustainable within breed selection program such as nucleus-based or community-based selection for moderately heritable traits like body weight gain and milk production.

Small ruminant nucleus-based selection programs in Ethiopia

Nucleus-based small ruminant selection programs in Ethiopia, in which flocks were maintained exclusively in agricultural research centers, were mainly employed on sheep breeds like Afar, black head Somali (BHS), Horro,

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Menz, and Washera (Haile et al., 2011; Gizaw et al., 2013). To this end, Werer research center was working on Afar and BHS sheep breeds whereas Bako, Debre Berhan and Andasa research centers applied the program on Horro, Menz and Washera breeds, respectively. The selection criteria were post-weaning growth rates (for Afar and BHS sheep breeds), Pre-weaning weight gain and litter size (for Washera sheep breed) and yearling weights (for Horro and Menz sheep breeds) (Gizaw et al., 2013). Nevertheless, similar to other developing countries with large livestock population, genetic improvement of indigenous breeds in Ethiopia through nucleus-based selection is generally considered too slow and most of the selection programs, except the Menz program, yielded unsatisfactory results (Abegaz et al., 2000). For instance, the Horro nucleus-based selection program shows no progress and the nucleus flock did not result in appreciable genetic improvement (Abegaz et al., 2000; Temesgen, 2010). Moreover, the results of the Afar and BHS programs also remain unreported and the Washera program is yet to be evaluated.

Hence, the selection programs were discontinued, with whatever genetic improvement achieved being lost with the disposal of the flocks. Fortunately, the Washera and Afar breeding programs were re-initiated with new flocks in 2004 and 2011, respectively (Gizaw et al., 2013). Moreover, an elite nucleus flock of Menz sheep has been established with genetic superiority in yearling weight of about 7 kg above the average, and improved rams are being disseminated to village flocks (Gizaw et al., 2011). This may be due to the fact that the Menz sheep genetic improvement is carried out in a controlled environment at the nucleus centers with advanced selection tools such as the best linear unbiased prediction (BLUP) (Gizaw and Getachew, 2009).

Lack of documented selection procedures, high turnover of breeders managing the nucleus flocks, lack of skilled manpower in quantitative genetics particularly the accurate estimation of breeding values, budgetary constraints, lack of vision and commitment from researchers, and bias in the livestock development strategy towards crossbreeding with less emphasis on selection programs could be the possible reasons for the failure of many of the nucleus-based selection programs (Gizaw et al., 2013). Moreover, the farmers were not fully engaged in the selection program, thus their preferences were not fully addressed (Gizaw et al., 2011) and the different intangible, socio-economic and cultural roles that small ruminants could play were not considered (Wollny, 2003; Kosgey, 2004; Kosgey et al., 2006; Kosgey and Okeyo, 2007). A new approach was therefore required and attempts have been made to transform the conventional nucleus-based selection approach into a sustainable participatory breeding program (Haile et al., 2011). One such approach that has recently stimulated global interest is community-based breeding program.

Community based small ruminant breeding programs in Ethiopia

Failure of the crossbreeding and nucleus-based selection programs initiated the development of participatory breeding program called community based breeding program, CBBP (Mueller, 2006; Gizaw et al., 2011; Haile et al., 2011). It is a village based breeding activity planned, designed, and implemented by smallholder farmers, either individually or in cooperatives, to effect genetic improvement in their flocks and conserve indigenous genetic resources. The program would be coordinated and assisted by stakeholders like development and research experts in government and non-government institutions (Gizaw et al., 2013). Unlike the conventional crossbreeding and nucleus-based selection, CBBP involves the local community at every stage (from planning to operation) and takes their indigenous knowledge of breeding practices and objectives in to account. Moreover, it considers the production system in a holistic manner and is a recently advocated option for tropical countries like Ethiopia characterized by low input traditional livestock production system (Solkner-Rollefson, 2003; Baker and Gray, 2004; Wurzinger et al., 2011).

Solomon (2014) documented the summarized advantages of the small ruminant CBBP as follows: the breeding flocks are located within the production environment and potential genotype-environment interactions are therefore minimized, direct participation of farmers is possible and accordingly they could have a sense of responsibility for the targeted breed, the farmers are owners of the initiative and benefits from it, keeping the targeted breed is economically important, utilization of available feed resources is possible, maintenance is labor-intensive and not capital intensive and the initiative is self-administered by the community, but is supported by government and other organizations.

In order to design an appropriate and feasible small ruminant CBBP, the basic steps involve selection of the communities and breeds, analysis of production system (including livelihood strategies), characterization (phenotypic and molecular) of the breeds, definition of the breeding objectives and evaluation of the breeding programs (Kosgey et al, 2006; Haile et al., 2011). However, designing and implementing a sustainable CBBP that would benefit the owners of the small ruminants and the national economy at large is not an easy task, rather it is demanding and worthwhile (Wurzinger et al., 2011). In Ethiopia, attempts were made to develop effective and sustainable community-based small ruminant breeding programs as early as 2003 with Washera and later with

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Gumz sheep (Amhara region agricultural research institute (ARARI) research directory), but failed due to lack of proper knowledge among researchers on the new approach (Gizaw et al., 2013).

Very recently, different community based sheep breeding programs were implemented in Ethiopia by the national agricultural research centers (Bako, Bonga, Debre Berhan, and Worer), in collaboration with the international research institutions (ICARDA-ILRI-BOKU) (Gutu et al., 2015) in four sites (Horro, Bonga, Menz and Afar) and detailed (Gemeda, 2011; Haile et al., 2011; Mirkena, 2011). Unfortunately, the Afar community based sheep breeding program was not successful. On the other hand, the more successful breeding programs in Bonga, Horro and Menz were scaled-out in to two new sheep sites (Doyogana and Atsbi) and one goat breeding site (Abergelle goats) (Solomon, 2014; Gutu et al., 2015). In 2015, the community based breeding programs in Bonga, Horro and Menz were evaluated and realized several achievements (Gutu et al., 2015).

The following were some of the major achievements of the community based sheep breeding programs in Bonga, Horro and Menz: body weights at birth, 3 and 6 months of age and the number of births were increased and thus the market outlet was improved, lambs with bigger size and attractive color were obtained and fetch a better market price, the mortality rates were reduced due to the combination of breeding with improved health care and feeding, better awareness about inbreeding and the need for breeding rams were created and well-functioning cooperatives were formed. In addition, the negative selection, exercised by the local community, has been reverted as fast growing lambs are being retained for breeding purpose instead of ending up in markets. In general, the overall performance of sheep and goats was improved and there was commercialization of breeding rams and bucks (Haile et al., 2011; Gizaw et al., 2013; Gutu et al., 2015). Farmers, who were involved in Menz community-based sheep breeding program and invited to participate in the workshop and field visit held on January 15, 2014, also evidently mentioned that they are benefiting from the community based pure breeding program and explained the adaptation problems of the already introduced exotic breeds (Getachew et al., 2016).

Despite the achievements, the programs had been constrained by several challenges. The challenges include, but not limited to: disease prevalence, feed shortage, poor access to market, selling of selected breeding males, poor cooperation with district extension system, delaying selection of breeding males and mating of females by unselected males (Gutu et al., 2015). Alleviating these challenges and sustainably supporting the programs necessitates the development of operational mechanisms. One such mechanism would be creating a strong link between the programs and the nearby higher education institutes and research centers. Hence, the institutes and the research centers would maximize genetic gains in the breeding programs through their research and community service endeavors. The financial, social and economic feasibility of the breeding programs should also be assessed. The successful community based sheep breeding programs in Bonga, Horro and Menz areas would serve as a model to design and implement similar breeding programs for other breeds. The reasons for the fruitless ending of the Afar community based sheep breeding program should also be pinpointed in order to learn lessons from the failure and revisit the program.

CONCLUSIONS AND RECOMMENDATIONS

Small ruminants in Ethiopia are raised in two major production systems: mixed crop-livestock and pastoral/agro-pastoral production systems. To date, the country has more than 60 million heads of sheep and goats playing a crucial role in terms of meat, milk, income, manure, wool and saving. The existing populations are adapted to the prevailing harsh environmental situation which is characterized by low levels of input and technologies, feed scarcity and disease challenge. However, there is a belief that the productivity of indigenous breeds is very low and they are unlikely to satisfy the fast growing demand for meat and milk that is created due to rapid human population growth, urbanization and increased income. Crossbreeding, nucleus-based selection and community-based breeding programs were the different options implemented in Ethiopia to improve the productive performance of local breeds. Due to its quick benefits, as the result of breed complementarity and heterotic effects, crossbreeding was applied in Ethiopia in the past seven decades. However, the smallholder farmers did not benefit more from the crossbred genotypes than the indigenous breeds and hence most of the crossbreeding programs were failed. Failure of the crossbreeding programs gave rise to the development of nucleus-based selection. But, the selection programs in many nucleus centers exclusively focused on sheep. Moreover, the genetic improvement through such selection programs was too slow and yielded unsatisfactory results. To curve the situation, community based breeding program (CBBP) was introduced and implemented in Afar, Atsbi, Bonga, Doyogana, Horro and Menz areas on sheep and Abergelle goats. The program had a promising start and by now it realized several achievements, though constrained by various challenges. CBBP is therefore a viable option for developing countries like Ethiopia characterized by low input traditional production systems and breeding objectives. However, long-term commitment of all stakeholders is vital as successful and tangible results of the program will only be achievable

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after several generations and many years of consistent collaboration among the key actors. In addition, the program should be part of the national livestock breeding policy.

DECLARATIONS

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Ethics approval and consent to participate

The review paper meets all applicable standards with regard to ethics and integrity. As a researcher and educator in animal breeding and genetics and along with the co-author, the paper has been submitted with full responsibility, following due ethical procedure, and there is no duplicate publication, fraud or plagiarism.

Authors' contributions

Mr. Oumer Sheriff drafted and organized the manuscript while Dr. Kefyalew Alemayehu participated in coordination and helped to draft the manuscript. Both the authors read and approved the final manuscript.

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