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# Identifying breeding objectives of smallholders/pastoralists and optimizing community-based breeding programs for adapted sheep breeds in Ethiopia

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## Abstract

The aim of this thesis was to identify breeding objectives of smallholder and pastoral sheep keepers in Ethiopia (Afar, Bonga, Horro and Menz areas) and to design appropriate community-based breeding plans for genetic improvement of four indigenous sheep breeds. Information on genetics of adaptation in farm animals was reviewed. Two live animals ranking experiments approaches, own-flock and group-animal ranking, were used to identify sheep breeding objectives. In own-flock ranking, owners paid more attention to production and reproduction performances and behavioral traits (e.g. milk yield, temperament, lamb growth, mothering ability, body size, lambing interval). In group-animal ranking, observable attributes like coat color, tail type, ear size, body size, etc. recurred. Afar (pastoral) and Menz (sheep-barley) sheep breeders, coping with more challenging production environments, considered more attributes compared to the two crop-livestock systems (Bonga and Horro). Four scenarios of ram selection and ram use were compared via deterministic simulation of breeding plans for community-based sheep breeding programs considering the top three most important traits identified. The review work revealed the need to identify the most appropriate and adapted genotypes capable of coping with environmental challenges posed by the production systems or, wherever possible, adapt the environments to the requirements of the animals. In conclusion, both own-flock and group-animal ranking experiments can serve as tools in objective traits identification in production systems without recording practices. Strong selection and short use of rams for breeding were the preferred options. Expected genetic gains are satisfactory but rely on continuous recording.



***Keywords***: Adaptation; Breeding objectives; Breeding plan; Deterministic simulation; Ethiopia; Genetics; Group-animal ranking; Own-flock ranking; Pastoralists; Smallholders; Sheep

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## Dedication

**To**

My mother Adde Baqantu Megerssa and Adde Mulu Bayissa both who nursed me their breasts and whose steadfastness, tenacity, faith and love will always fascinate me.

My wife Ethiopia Tesfaye Urgessa

My daughters Naomi and Salem

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# CHAPTER ONE

## General introduction

In traditional production systems, sheep are kept for multiple purposes: to generate income, for food (meat and milk), manure, fiber, as insurance mainly against crop failures, as savings, socio-cultural and ceremonial purposes (Wilson, 1991; Rege, 1994; Jaitner, et al., 2001; Benin et al., 2006; Kosgey et al., 2008; Legesse, 2008). They provide both tangible and intangible benefits. Sheep production is one of the most important agricultural activities in Ethiopia. Sheep, the second most important species of livestock in the country, have an estimated population size of about 26 million (CSA, 2008) with nine identified breeds (Gizaw et al., 2007). Livestock production in general generates 30-35% of the Ethiopian agricultural GDP, 19% of total GDP and more than 85% of farm cash income (Benin et al., 2006). Sheep and goats account for 40% of cash income earned by farm households, 19% of total value of subsistence food derived from all livestock production, and 25% of total domestic meat consumption (Hirpa and Abebe, 2008).

Sheep production and productivity in the country is constrained by feed scarcity, diseases, bad infrastructure, lack of market information and technical capacity, and absence of planned breeding programs and breeding policy. Institutions that involve in research, extension and services so far failed to yield a positive influence on the traditional sheep husbandry practices. For instance, the carcass weight per slaughtered animal remained bottom low and unimproved at ~10 kg with average annual off-take rate of ~32% for the years 2000 – 2009 (FAOSTAT, 2010).

Despite the role sheep play in the economy, sustainable improvement programs targeting the species have been missing. The development of relevant breeding objectives and breeding strategies for livestock in general and sheep in particular for smallholder and pastoral production systems has been noted as an issue that has received little attention in the tropics (Kosgey, 2004). Low genetic potential among indigenous sheep is often assumed and genetic improvement plans depended on replacement of indigenous ones with exotic breeds or to cross them with temperate breeds. Such efforts have invariably been unsuccessful or unsustainable in the long term due to incompatibility of the genotypes with the breeding objectives, management approaches and environmental conditions prevailing in low-input traditional production systems (Wilson, 1986; Rewe et al., 2002; Wollny et al., 2003; Ayalew et al., 2003; Kosgey et al., 2006). Due to crossbreeding and/or replacement with exotic breeds, a large number of indigenous breeds in developing world are at risk of extinction (Hall and Ruane, 1993; Rege and Gibson, 2003; Drucker et al., 2006).

Evidences indicate that breeds and populations that have evolved over the centuries in diverse, stressful tropical environments have a range of unique adaptive traits (e.g. disease and heat resistance, water scarcity tolerance, ability to cope with poor quality feed, etc) which enable them to survive and be productive in these environments (Fitzhugh and Bradford, 1983; Devendra, 1987; Rege, 1994; Baker and Gray, 2004). Within breed selection of the adapted indigenous genotypes is a viable and promising strategy for efficient on-farm sustainable conservation (Simon, 1999; Ruane, 2000; Olivier et al., 2002; Gizaw et al., 2008) and utilization which ensure contribution to the economy of communities depending on them (Muller et al., 2002; Muller, 2006).

In developing countries where unfavorable environmental conditions are prevalent, there has been a dilemma in genetic improvement programs how to effectively organize breeding schemes involving farmers at village level and how to record such flocks and monitor progress (Kosgey et al., 2006). Community-based breeding programs have been suggested for such environments as an alternative to governmental breeding programs (Sölkner et al., 1998; Valle Zárate et al., 2010).

Formulation of acceptable and viable breeding programs for low-input traditional and subsistence production systems requires identification of breeding objectives in a participatory and comprehensive approach. The breeding objective includes all relevant characteristics of an animal such as production, reproduction, fitness and health characteristics (Kosgey, 2004). The importance of each attribute largely depends on production circumstances. Logical steps that should be followed to design and implement a genetic improvement program include (Baker and Gray, 2004; FAO, 2010):

- Understanding of the production system and identification of constraints to production
- Definition of breeding objective (i.e., the improvement goal)
- Identification of the genetic improvement strategy (e.g. matching the genotype with the environment or choosing appropriate breed, setting selection criteria, and design of breeding scheme or breeding system)
- Establish animal recording and breeding value estimation systems
- Dissemination of superior genotypes
- Review of breeding programs regularly (evaluation of progress)

This work contributes to the livelihood security of farmers and pastoralists involved in the community-based indigenous sheep improvement program through the design of alternative breeding schemes and to scientific knowledge by presenting review of information on genetics of adaptation and by testing new tools that can be used to identify sheep breeding objectives of smallholders.

**Objectives of the study**

The studies reported in this thesis were designed:

- To review the current state of knowledge on genetics of adaptation in major livestock species with emphasis on small ruminants.
- To identify smallholder farmers'/pastoralists' sheep breeding objectives in four different agro-ecological zones of Ethiopia.
- To test the effectiveness of own-flock ranking experiment approach in identifying smallholder farmers'/pastoralists' preferences for sheep attributes.
- To test the effectiveness of group-animal ranking experiment approach in identifying smallholder farmers'/pastoralists' preferences for sheep attributes.
- To simulate the most appropriate breeding plans for four indigenous sheep breeds in different agro-ecological zones in Ethiopia.

**Outline of the thesis**

Following **Chapter 1** that gives the general introduction, **Chapter 2** is devoted to the review of genetics of adaptation in domestic farm animals. The genetics and related information on breeds of sheep and goats that are resistant or resilient to a variety of disease infections, feed and water scarcity, and climatic stressors are reviewed. **Chapter 3** presents the methodological approach used to identify sheep breeding objectives of smallholders and pastoralists and results from two such approaches: the own-flock ranking and group-animal ranking experiments. In **Chapter 4,** which deals with modeling of alternative indigenous sheep genetic improvement schemes, simulation techniques and the predicted genetic gain for the various target traits are presented. Finally, **Chapter 5** presents the general discussion where some important findings and implications are discussed.

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# CHAPTER TWO

## Genetics of Adaptation in Domestic Farm Animals: A Review

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**Abstract**

*This review summarizes available information on genetics of adaptation in major livestock species focusing on small ruminants. Adaptation to humans and consequences of domestication on predator aversion, mechanisms of adaptation to available feed and water resources, severe climates and genetic evidence of disease tolerance or resistance have been presented. The latter focuses on gastrointestinal parasites and bacterial diseases. The resource allocation by the animal to production and fitness traits under both optimal and sub-optimal conditions has a genetic background. Such information would help in identifying the most appropriate and adapted genotypes capable of coping with the environmental challenges posed by the production systems or, wherever possible, in adapting the environments to the requirements of the animals.*

Keywords: Genetics; Domestication; Adaptation; Disease resistance; Review

# 1. Introduction

Adaptability of an animal can be defined as the ability to survive and reproduce within a defined environment (Prayaga and Henshall, 2005) or the degree to which an organism, population or species can remain/become adapted to a wide range of environments by physiological or genetic means (Barker, 2009). Smallholders, pastoralists and their animals often live in harsh environments which may be hot and dry, hot and humid, or high in altitude and cold. Moreover, these environments can be characterized by scarce feed and water resources and high disease pressure with large seasonal and annual variation (Sölkner et al., 1998). Adaptation to these factors is largely based on genetics, but animals can "learn" to live under such stressful conditions. In order to match genotype with the environment, breeders can follow two alternative strategies: adapt the environment to the need of the animals as is the case in industrial animal production systems or keep animals that are adapted to the respective environment as is the case in low input smallholder and pastoral systems. The physical environment greatly differs between locations and production systems based on available resources and economic conditions. Because of this, smallholders and pastoralists need different and diverse animal genotypes, species mix and types. As a result of thousands of years of adaptation to region specific conditions, a much larger variety of livestock breeds with diverse and unique traits have been created than what are currently being used in commercial agriculture (NRC, 1993).

There is ample evidence that livestock breeds and population that have evolved over the centuries in diverse, stressful tropical environments have a range of unique adaptive traits (e.g. disease and heat resistance, water scarcity tolerance, ability to cope with poor quality feed, etc) which enable them to survive and be productive in these environments (Fitzhugh and Bradford, 1983; Devendra, 1987; Baker and Rege, 1994; Baker and Gray, 2004). Marked genetic distinction between *taurine* and zebu cattle has been reported by McHugh et al. (1997) through phylogenetic analysis of microsatellite polymorphisms with estimated divergence between the two subspecies being the order of 610,000-850,000 years. It is possible that reasonable levels of functional genetic diversity exist between the two, especially with respect to adaptation (Hanotte et al., 2004). A prudent conservation and utilization of the diverse genetic resources is of special concern to livestock breeders so that their special characteristics may be adapted to unforeseen social/commercial needs, changing climate, and also to researchers who could study them and expand society's understanding of domestication, selection, genetics and evolution (NRC, 1993). The Australian beef industry provides one of the best examples of production systems where adapted zebu breeds are utilized through crossbreeding with *taurine* cattle to form synthetic breeds. Prayaga and Henshall (2005) report that this system is evolving as an efficient tool to improve the productive (meat quality) and reproductive (fertility) performances of zebu cattle adapted to the harsh tropical climatic conditions. Similarly, successful dairy and beef programs have been developed in Brazil (Madalena, 2000).

In the dairy industry, decline in average fertility and health of cows have been associated with increased genetic merit for milk yield (e.g. Pryce et al., 2004). Goddard (2009) gives two main reasons for the decline in fitness traits: (1) these traits were ignored in the construction of selection indices because they were considered to have lower heritability or not easy to record and (2) use of inappropriate breeding programs while the underlying genetic process (selection and inbreeding depression) is well understood. However, the low heritability of some fitness traits does not imply negligible genetic variance; often heritability is low because the phenotypic variance is rather larger than the genetic variance is small as evidenced by as high genetic coefficient of variation for fitness traits as for some production traits (Goddard, 2009; Hill and Zhang, 2009). Inclusion of functional traits (functional longevity, persistency, fertility, calving ease, still birth and somatic cell count) in a total merit index has been reported to have a positive effect on the annual monetary genetic gain (Sölkner et al., 1999; Willam et al., 2002; Veerkamp et al., 2002; Philipsson and Lindhe, 2003; Samore et al., 2003; Weigel, 2006).

Tick counts, fecal worm egg counts (FEC), rectal temperatures and coat scores have been used as indicator traits of adaptability of beef cattle to assess the suitability of particular genotypes to tropical environment (Prayaga and Henshall, 2005). In some cases (e.g. Silanikove, 2000) the physiological basis of adaptation has been investigated in great detail. However, more commonly such assessments are not made and information on the genetic parameters for adaptive traits in livestock populations managed in tropical environments are lacking. The purpose of this paper is to review the current state of knowledge on genetics of adaptation in major livestock species with emphasis on small ruminants. The genetics and related information on breeds of sheep and goats that are resistant or resilient to a variety of disease infections, feed and water scarcity and climatic stressors are reviewed.

## 2. Domestication

Keeping and breeding animals was practiced by ancient societies before the recorded history of animal domestication in which our present civilization has its roots. To domesticate means to adapt the behavior of an animal to fit the needs of people. Thus, domestication is defined as a process by which a population of animals becomes adapted to human and to the captive environment by some combination of genetic changes occurring over generations and environmentally induced developmental events reoccurring during each generation (Price, 1984). Domestication is the first step of selection and has to be distinguished from taming, in that domestication means that breeding (by choice of the reproducers and isolation from wild counterparts), care (shelter, food, protection against predators) and feeding of animals are more or less controlled by humans (Hale, 1969). It is believed that the most important decisive factor for selection during the early times was adaptation (live/survive, reproduce and produce) to a given environment (Gillespie, 1997). The small number of domesticated species indicates the characteristics required for domestication including traits such as diet, reproduction, social relationships and behavior toward man of which most important are a strong gregariousness, feeding regimes that can be easily supplied by humans, and precocious young (Mignon-Grasteau et al., 2005).

Consequences of domestication could be investigated using methods such as comparison of wild and domestic stocks, longitudinal analysis of wild animals kept in captivity, and molecular genetics techniques (Mignon-Grasteau et al., 2005). The consequences of domestication that resulted in modifications of many traits determining the capacity of adaptation of animals including behavior, physiology and morphology include: proportion of white color has increased in domestic population as a result of attraction to humans and relaxation of natural selection on predation (Pielberg et al., 2008); size has been increased in small species to boost meat quantity but reduced in larger species to make them easier to handle; fat location has been modified (it is stored under the skin and around kidneys in wild animals, and in muscle and around the tail in domestic animals); head or brain size has decreased in most domestic species; behavior has changed quantitatively rather than qualitatively (behavior traits did not appear or disappear, but the threshold of their expression changed (Price, 1999) indicating that if the opportunity is offered to them, domestic species can revert to behaviors observed in related wild species, as the genetic variability is still present in domesticated populations); relaxation of natural selection and natural selection in captivity are partially controlled by humans through determining environmental conditions (Mignon-Grasteau et al., 2005).

## 3. Adaptation to the environment and production system

The external environmental stimuli (physical, chemical, climatic and biological) to which animals respond interact with their genotypes to determine level of performance. All species respond to changing natural environments through altering phenotype and physiology; in livestock production the situations become more complex since human intervention influences both genotype and external environment (King, no date). The North Ronaldsay, a breed of sheep indigenous to an island in the northeast coast of Scotland possesses unique adaptive characteristics. This sheep survive exclusively on a diet of seaweed and obtain all nutritional requirements from limited freshwater and abundant kelp beds along the shore; mastered the physiological challenge of handling elements present in excess (e.g. sodium) and hence are very salt tolerant in the face of very limited supply of freshwater; and are adapted to the very low concentration of copper present in *Limnaria* (their most preferred feed). Other breeds found in Scotland, which normally feed on grass or hay, would die from lack of copper if fed *Limnaria* (NRC, 1993). Thus, preserving unique qualities in such and many other livestock breeds will ensure a wealth of genetic resources for future use in basic scientific research and the advancement of the agricultural sciences.

Ayalew et al. (2003) compared productivity of indigenous breeds of goats (Hararghe Highland and Somali) with that of crossbred (Anglo-Nubian × Somali) goats in Ethiopia and concluded the crossbred did not improve households' income in the mixed crop-livestock production system. The authors indicated that there were increased net benefits per unit of land or labor from mixed flocks (i.e. both indigenous goats and Anglo-Nubian crosses) under improved management compared with indigenous goats under traditional management. In flocks using improved management package, the crossbreds did not produce more net benefits than indigenous goats either in mixed or separate flocks. The improved management package, however, increased net benefits of farmers keeping indigenous goats; findings that explained the low adoption rate of exotic crosses by smallholder farmers and superior adaptability of indigenous goats to the prevailing production system.

Karugia et al. (2001) analyzed the impact of crossbreeding zebu with exotic cattle breeds for dairy improvement in Kenya using sector- and farm-level approaches. The agricultural sector model showed that dairy technology that involved crossbreeding and complementary nutrition and management improvements has had a positive impact on Kenyan economy and welfare but this approach ignored important social cost components of crossbreeding. The farm level approach, however, indicated that farm performance was little improved by replacing the indigenous zebu with exotic breeds. On the other hand, this analysis indicated that breeding program that concentrates on improving the local zebu breeds would improve the financial performance of the farm level with important implications for the conservation of farm animal biodiversity. Philipsson (2000) presents several case studies on limitations of crossbreeding and/or replacing indigenous with exotic cattle breeds. For instance, the Sahiwal breed currently suffers from small population size and high degree of inbreeding due to indiscriminate crossbreeding with exotic; Kenana x Holstein crossbreds with higher exotic blood levels (75 and 87.5% Holstein) did not keep up with F1 animals, rather had problems with resistance to diseases and suffered from environmental stresses in Sudan; and in West Indies, where exotic breeds were introduced, reproductive problems occurred due to tick-borne diseases and heat stress resulting in a shortage of females for herd replacements. These examples are in agreement with other studies that emphasize more use could be made of adaptive characteristics, such as parasite resistance (Preston and Allonby, 1979) and disease tolerance (Trail et al., 1988).

### *3.1 Adaptation to humans*

The process of animal domestication involves adaptation particularly to human and the environment provided. Adaptation to humans is reflected by showing low reactions to humans (short flight distance for instance) and low fear reactions; low flight times indicate animals with poor temperaments and high flight times indicate desirable docile temperament (Prayaga and Henshall, 2005). Defensive reactions against humans are still observed in domestic ruminants even though reduced fear of humans is generally considered to be a major component of domestication as routine management procedures (e.g. shearing, castration, tail docking, dehorning, vaccination, herding and transportation in cattle and sheep) can still trigger negative emotions, such as fear, which are generally considered to affect animal welfare negatively (Boissy et al., 2005). Excessive fear may reduce productivity. For instance, fear-related reactions affect sexual and maternal behaviors and social dominance ability in cattle and sheep (Boissy et al., 2005). Lankin (1997), using 467 rams and 1617 ewes of the Soviet meat-and-wool breed at various ages studied the influence of environmental factors on the manifestation and diversity of withdrawal from man in sheep, and also investigated the polymorphism of domestic behavior in 11 breeds. He found that the manifestation and population variability of withdrawal reactions in sheep are under the influence of farming factors which affect their feeding behavior. The author concluded that the common direction of development of adaptive domestic behavior in different breeds presupposes the existence of a universal physiological mechanism of ontogenetic inhibition of fear of man in animals.

Boissy et al. (2005) summarized estimates of heritability of fear in dairy and beef cattle and sheep. The estimate ranged between 0.09-0.53 for dairy cattle while a moderate heritability of 0.22 was estimated for reactions to handling in beef cattle. It ranged between 0.28-0.48 in sheep. Thus, genetic selection in ruminant livestock based on reduced fearfulness to increase their adaptive abilities could be as significant for their welfare as the systems in which they are managed. Genetic selection programs for reducing fear responsiveness to handling could be implemented without adverse effect on other desirable productive traits rather could possibly improve some other adaptive behavioral traits such as maternal behavior.

### *3.2 Behavior towards predators*

As domestication involves human protection of animals from predators, they express a lower incidence of anti-predator behaviors, probably due to relaxed selection on these traits. Consequently, it might be expected that there would be greater losses than wild animals when faced with predation (Mignon-Grasteau et al., 2005). A few studies in birds have confirmed this hypothesis. Hill and Robertson (1988) showed that captive-reared pheasants were three times more susceptible to predation than wild birds. White Leghorn chickens also showed less anti-predator behavior than Jungle Fowl.

Hansen et al. (2001) studied three breeds of sheep representing light, medium and heavy weight breeds using blind and carnivore stimuli. The light breed showed longest recovery time, the longest flight distance and the tightest flocking behavior indicating that lighter sheep breeds display stronger anti-predator reactions than heavier breeds. In a study of Anderson et al. (1998) that compared behavioral adaptation of sheep, it was found that sheep bonded to cattle from young age remained as one interspecific group when threatened by trained dog and reduced the chance of being attacked by positioning themselves among the cattle and away from the dog. On the other hand, non-bonded sheep reduced their intraspecific space by flocking together, moved away from cattle and rendered themselves more exposed to predator attack. In wild sheep (e.g., bighorn sheep), however, gregariousness or flocking together was found to increase safety though reproduction status, i.e., lactating versus barren ewes, also influenced how animals attempt to reduce predation risk (Rieucau and Martin, 2008).

### *3.3 Adaptation to available feed resources*

Adaptation to periods of feed scarcity can be in one or more of the following ways: developing low metabolic requirement, ability to reduce metabolism, digestive efficiency and ability to utilize high fiber feed, and deposition of nutrients in the form of fat as feed reserve.

#### *3.3.1 Low metabolic requirements*

Having low metabolic requirements is an advantage if feed quality and/or quantity are low. The improved temperate breeds produce more than indigenous tropical breeds if supplied with high quality feed; however, they lose weight and fail to survive when fed poor quality grass or straw, whereas adapted indigenous animals still grow, give some milk and reproduce. Adapted tropical animals recycle nutrients more efficiently than do improved temperate breeds (Bayer and Feldmann, 2003) and can also reduce their basic metabolism during periods of weight loss. The energy requirement of a mammal, a function of body mass$^{0.75}$, implies the requirement per kg weight of body tissue in small mammals is greater than that in large mammals which means their metabolic requirements cannot be met by diets rich in cellulosic matter. Thus, small ruminants have to balance their comparatively higher energy requirements by eating more food of a higher nutritional value. However, small desert breeds such as the black Bedouin goat have been found to be efficient exploiters of high-fiber low quality roughage and their energy requirement is lower than that predicted from their body mass in comparison to relatives from non-desert areas (Silanikove, 1986a, 2000). Silanikove (2000) indicated that the energy requirements of five desert goats weighing each 20 kg are at about the same level as those of goats from European breed, weighing 100 kg. Thus, the ability to maintain a larger number of animals on the same area provides an obvious advantage in terms of survival to the desert goats.

#### *3.3.2 Ability to reduce metabolism*

The ability of some mammals to maintain steady body weights under less energy intakes than their voluntary intake levels may be due to their ability to reduce metabolism. This ability may vary from species to species or among breeds. For instance, Silanikove (2000) compares the capacity of non-desert Saanen goats and Bedouin goats to maintain steady body weights when their consumption was restricted but fed on high quality roughages. Saanen goats were able to cope up to 20-30% lower than their voluntary intake while the Bedouins tolerated an intake level that was 50-55% lower than their voluntary consumption. The Bedouins had a 53% lower fasting heat production under such feed restriction. The author also reports similar capacity to adjust to a low energy intake by reducing energy metabolism in other herbivores, such as zebu cattle and llama, which are annually exposed to long periods of severe nutritional conditions in their natural habitats.

### 3.3.3 Digestive efficiency and ability to utilize high fiber feed

The digestive efficiency of ruminants and their ability to utilize high fiber feed has been extensively reviewed by Silanikove (2000). Goats have better digestive efficiency than other ruminants with high-fiber low-quality forages, and one of the main reasons is the longer mean retention time in the rumen (Devendra, 1990; Tisserand et al., 1991). Goat breeds indigenous to semi-arid and arid areas are able to utilize low quality high-fiber feed more efficiently than other types of indigenous ruminants, or exotic breeds of goats (Silanikove et al., 1993). The digestive efficiency of desert black Bedouin goats fed on roughage diets under controlled environment in comparison with Swiss Saanen goats (Silanikove et al., 1993; Silanikove 1986a) and under exposure to the full impact of their natural environment (Brosh et al., 1988) was found to be superior. Such digestive efficiency of Bedouin goats fed wheat straw (also which enables them to utilize efficiently high-fiber low nitrogen desert pastures) has been observed in other ruminants only after chemical processing of the straws (Silanikove, 1986a). This characteristic is an important asset for their capacity to exist and produce in extreme arid areas and in the face of changing climate (Rischkowsky et al., 2008; Tibbo et al., 2008a, b).

### 3.3.4 Fat deposition as feed reserve

Ruminants store energy in adipose tissues when the quality and quantity of feed is 'adequate', and mobilize it to meet energy demands during periods of scarcity (Ball et al., 1996; Ørskov, 1998; Nigussie et al., 2000; Ermias et al., 2002). In a tropical environment, where wet seasons alternate with dry seasons that are long and characterized with low quantity and quality of pasture, the ability to store fat during 'favorable' seasons, and its subsequent use for maintenance, pregnancy and lactation during 'unfavorable' season is an essential strategy for survival. The ability of sheep to survive in hilly environments had been associated with greater fat deposition in the internal fat depots (Kempster, 1980).

Nigussie et al. (2000) compared the patterns of fat deposition in Horro and Menz sheep breeds of Ethiopia and found that subcutaneous fat and gut fat were the major fat depots in Menz and Horro, respectively. Genotype variation in amount of carcass and non-carcass fat was also found: the former represented the largest proportion of total fat in Menz while the latter represented the largest proportion in Horro. However, proportion and distribution of tail fat was similar in both breeds (Nigussie et al., 2000; Ermias et al., 2002). Comparing the different stages of growth and maturity, Nigussie et al. (2000) indicated that the growth phase at six months of age that represented the period where a loss in body condition and reserves occurred in both breeds coincided with a marked reduction in the proportion of tail fat compared to all the body fat depot types, indicating its selective mobilization in order to fill the gap of prevailing energy deficiency. Both breeds probably differ less with regard to fat deposition to anticipate fluctuation in nutrient supply, but more in their adaptation to climatic factors. Both may be suited to environments where there is periodic feed fluctuation but Horro is better suited to warmer climates than Menz. As tail and rump fat depots are the most responsive ones to nutritional changes, the mass of these depots relative to the others, may be the 'best' indicator of variations in adaptation to periodic feed fluctuations in fat-tailed sheep breeds. Ermias et al. (2002) reported a heritability estimate of 0.72±0.19 for the combined weight of tail and rump fat in Menz breed indicating opportunities for selective breeding.

### *3.4 Adaptation to severe (hot/cold) climates*

When animals are exposed to heat stress the biological functions affected include depression in feed intake and utilization, disturbances in the metabolism of water, protein, energy and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites (Marai et al., 2007), resulting in the impairment of production and reproduction performances. The effect is aggravated when heat stress is accompanied by high humidity. McManus et al. (2009a) comparing Santa Inês (with three different coat colors – brown, black and white), Bergamasca and Santa Inês x Bergamasca breeds of sheep in Brazil used physiological traits (sweating, respiratory, and heart rates, rectal and skin temperatures) and blood parameters (PCV, total plasma proteins, red blood cell count, and hemoglobin concentration). The authors reported significant differences between animals due to breed, skin type and time of the day and concluded the Santa Inês (hair sheep) with white color were shown to be better adapted to higher environmental temperatures while Bergamasca, wool sheep, were least adapted. Finocchiaro et al. (2005) reported the genetic correlation between the general additive effect of milk production and the additive effect of heat tolerance to be negative ($r$ = -0.8) during all periods considered indicating that selection for increased milk production will reduce heat tolerance.

Turner (1980) extensively reviewed the genetic and biological aspects of zebu adaptability and attributed their unique suiting to hot climates to coat, hide, skin, hematological characteristics, form, growth, and physiological aspects which are unique genetic attributes of zebu compared to *Bos taurus* cattle. Zebu cattle are smooth coated, have primary hair follicles, have better developed sweat and sebaceous glands than *B. taurus* cattle and can lose more moisture by evaporation and hence have the ability to maintain thermal equilibrium that is a necessary factor for normal function and performance (Turner, 1980). McManus et al (2009b), working with five naturalized and two exotic cattle breeds in Brazil, found that the Junqueira and Nellore breeds were the most adapted to the climatic condition while Mocho Nacional and Holstein breeds were least adapted.

Adaptation to cold involves physiological responses affecting the thermoregulation of animals by making them more able to maintain euthermia during a subsequent cold challenge (Young et al., 1989). Development and retention of a long, thick-winter hair coat contributes to thermal insulation. In cattle seasonal changes in hair cover are influenced by daily photoperiod and ambient temperature (Young et al., 1989). In temperate environment, the rate of growth of new hair is inversely related to day length while the rate of shedding is associated with thermal status of the animal (Webster, 1974). Morphological modifications (shorter legs and smaller ears) were observed in growing sheep (Young et al., 1989) and swine (Dauncey and Ingrain, 1986) probably due to reduced blood flow in peripheral tissues of animals in the cold. Alterations in the distribution of body fat with enhanced subcutaneous deposition have been reported to occur during cold stress to increase peripheral insulation (Webster, 1974). Sheep originating and living in cold areas deposit more of their body fat under skin compared to those adapted to warmer areas where degree of heat load is higher (Kempster, 1980; Farid, 1991; Bhat, 1999; Nigussie et al., 2000; Ermias et al., 2002).

Nigussie et al. (2000) and Ermias et al. (2002) in their studies that compared Horro and Menz sheep breeds reported that the combined weight of tail and rump fat accounted for a large proportion of total body fat in the Horro, while the subcutaneous and intramuscular depot accounted for a large proportion of fat in the Menz confirming preferential deposition as a result of adaptation to specific environmental conditions. Hence, the greater deposits of subcutaneous and intramuscular fat in the Menz may be adaptation mechanism to the lower temperature of its typically cooler habitat compared to the warmer environment at the slightly lower altitude of the Horro habitat. Sheep adapted to arid conditions often deposit less fat under the skin; almost all of the fat deposited is on the rump and/or the fat tail (Bhat, 1999), also an adaptation strategy to overcome thermal stress since the relative positions of these depots (tail and rump fat) do not impede heat loss from the body. It has also been reported that animals adapted to cold climates have increased circulating erythrocytes and plasma concentration of substrates (glucose and free fatty acids) and hormones (catecholamines and thyroid) associated with energy metabolism (Young et al., 1989).

### *3.5 Adaptation to water scarcity*

Breeds of ruminants native to arid lands are able to withstand prolonged periods of water deprivation and graze far away from watering sites at times 50 km or more far apart (Silanikove, 1994; Bayer and Feldmann, 2003). Livestock which need little water and do not have to go back to a water point every day can access larger areas of pastures and thus get more feed during periods of drought. For example, camels can undergo as long as 17 days of water deprivation consuming dry food in the hot summer (Schmidt-Nielsen et al., 1956) or can go without drinking water for 30 to 60 days when grazing on green vegetation (Schmidt-Nielsen, 1955). There are also donkey, goat, sheep and cattle breeds that can get along without drinking for several days (Bayer and Feldmann, 2003). Such animals drink large amounts of water quickly but their overall water intake is lower than that of animals which are watered daily. Reduced water intake reduces feed intake and metabolic rate; hence, livestock can survive longer during a drought, when feed is very scarce. Desert goats have been reported to be the most efficient among ruminants in terms of ability to withstand dehydration (Silanikove, 1994). The black Bedouin and the Barmer goats, herded in the extreme deserts of Sinai (Middle East) and Rajasthan (India), often drink only once in every four days (Khan et al., 1979a, b, c; Silanikove, 2000). The Bedouin goats are also able to maintain good level of milk production under water deprivation. The small black Moroccan goats use a low water turnover as a mechanism to economize on water (Hossaini-Hilali et al., 1993); a combined strategy of maintaining a frugal water economy and the capacity to endure severe dehydration and rapid rehydration.

The physiological mechanism that enables desert goats to cope with severe water deprivation lies in their ability to withstand dehydration, and to minimize water losses via urine and feces. The water losses of Barmer and Bedouin goats by the fourth day of dehydration may exceed 40% of their body weight (Khan et al., 1979a, b; Silanikove, 2000); however, when maintained under an intermittent or a partial watering regimen during the summer, the Barmer goats usually gain in body weight at the end of the season.

### *3.6 Tolerance/resistance to disease*

In livestock, genetic diversity with respect to disease resistance is important given that disease-causing organisms evolve continuously and develop resistance to drugs. If a new strain of a disease or a new disease occurs in a country, animals with a narrow genetic base may all be affected whereas in genetically diverse livestock, the chances that some animals survive, when others die, increase. Some native livestock are less affected by ticks and worms than imported ones. In *tsetse* infested areas of Africa, for instance, indigenous cattle have developed tolerance to tsetse and *trypanosomosis* challenge, whereas imported ones die if not treated with chemicals. Similarly, local cattle, sheep and goats in West Africa are resistant to heart water, a deadly disease for imported animals or crossbreds (Bayer and Feldmann, 2003). In this review, we are limited to presenting some genetic evidences of tolerance to or resistance against parasitic and bacterial diseases.

### 3.6.1 Parasitic diseases

Resistance to infections with endoparasites involves the initiation and maintenance of responses provoked in the host to suppress the establishment of parasites and/or eliminate parasite burdens (Baker and Gray, 2004). Resilience/tolerance is the ability of the host to survive and be productive under parasite challenge (Albers et al., 1987; Woolaston and Baker, 1996; Baker and Gray, 2004). The degree of resistance to gastro-intestinal (GI) nematode parasites has usually been assessed in terms of worm counts at necropsy or fecal parasite egg counts (FEC) during an infection period in live animals. In lambs FEC are highly correlated with worm counts (Woolaston and Baker, 1996). Packed red cell volume (PCV) and mortality rates have also been used as proxies for resilience (Baker et al., 2003). Albers et al. (1987) treated both FEC and PCV as two different measures of resistance.

As extensively reviewed by Bishop and Morris (2007), genetic differences between host animals in nematode parasite resistance have been observed in all major production environments and for a variety of parasite species including *Haemonchus contortus*, *Trychostrongylus colubriformis*, *Teladorsagia circumcincta* and various *Nematodirus* species. In most cases, it is the impact of nematode parasites on the growing lamb or kid that is of interest. However, nematode infections are also problematic for reproductive females undergoing the stress of late gestation and early lactation and some attention has been given to host genetic variation in resistance during the peri-parturient period.

In Africa, several studies compared sheep breeds for resistance to GI nematodes (Preston and Allonby, 1978, 1979; ILCA, 1991, Baker et al., 1994, 1998, 1999, 2002, 2003). Main findings indicate that the Red Maasai breed is more resistant and resilient to endoparasites, particularly to *H. contortus* than Dorper lambs as reflected by their significantly higher PCV (ability to control anemia), lower FEC (lower worm burden), and lower lamb mortality (Baker et al., 1994, 1998). In another report, Baker et al. (2002) concluded that there is little difference between the two breeds in overall output or efficiency in semi-arid conditions with a low parasite challenge; however, under humid conditions where parasite (*H. contortus*) challenge is high, Red Maasai has an output per hectare three times greater than the Dorper and is five times more efficient. Baker et al. (1994, 1998) also compared four crossbred sheep genotypes and found an additive genetic breed effect for both PCV and FEC indicating that crossbreds with higher proportion of Red Maasai blood are more resistant; they found no heterosis both for PCV and FEC.

Other tropical breeds considered resistant based on anecdotal evidences that they survive and thrive in the stressful environments where they are found under severe disease challenge include the West African Djallonke sheep which may be resistant to both endoparasites and trypanosomosis (Baker, 1995; Osaer et al., 1999) and the Garole sheep in India (Ghalsasi et al., 1994). Nimbkar et al. (2003) compared the resistance to *H. contortus* of $F_1$ Garole crossbred lambs with that of Bannur, Deccani and 50% Bannur/50% Deccani lambs in India and found that lambs with 50% Garole genes were significantly more resistant than the other breeds and crosses tested. Boyce et al. (1987) found significant breed differences in FEC and fluke counts after five breeds of sheep were experimentally infected with *Fasciola hepatica*. Barbados Blackbelly sheep were the most susceptible to infection while St. Croix and Florida Native sheep were the most resistant. Wiedosari and Copeman (1990) reported relatively high resistance to *F. gigantica* in Javanese Thin Tail sheep. Roberts et al. (1997a, b) compared the resistance to *F. gigantica* of Indonesian Thin Tail with St. Croix, $F_2$, and $F_3$ crosses between these breeds and concluded that the Indonesian Thin Tail were more resistant than St. Croix. The authors also stated that resistance may be controlled by a major gene with incomplete dominance. In contrast, the Indonesian Thin Tail sheep were as susceptible to *F. hepatica* as the Merino sheep that they were compared with (Roberts et al., 1997a).

Menz and Horro sheep exposed to natural pasture challenge in the central highlands of Ethiopia showed no difference in resistance to endoparasites (Baker et al., 1994, 1998; Tembely et al., 1998; Rege et al., 2002). However, under artificial challenge there was some evidence that the Menz may be more resistant than Horro lambs (Haile et al., 2002). Asegede (1990) compared four Ethiopian sheep breeds (Afar and Blackhead Somali native to semi-arid lowlands, Horro and Arsi from humid highlands) for their resistance to endoparasites, mainly *H. contortus,* at Awassa in southern Ethiopia and found that the Blackhead Somali were the most susceptible while the Arsi were the most resistant.

The evidence for genetic variation for resistance to endoparasites among goat breeds is limited. As for sheep, it is usual that the indigenous goat breeds (e.g. the Alpine goats in France and the Small East African (SEA) goats in Kenya) are more resistant (Baker and Gray, 2004). The SEA kids were more resistant than the Borana[†] kids as evidenced by their lower FEC post-weaning but no breed difference for PCV was found (Baker et al., 1994, 1998). It is possible that the mechanisms or level of resistance may be different in sheep and goats. Goats are predominantly browsers; hence they are likely under less intense natural selection for resistance (Baker et al., 2001).

Many studies have quantified heritabilities of relative nematode resistance in sheep usually using FEC as an indicator. Appropriately transformed FEC is a moderately heritable trait in lambs and responds to selection (Morris et al., 1997a, 2000; Bishop et al., 1996, 2004; Gruner et al., 2004). FEC tends to be less heritable

[†] This nomenclature has been used in this article (the breed is so named in its home tract of Southern Ethiopia) instead of the offensive term used by the authors of the quoted article.

in kids and does (Woolaston et al., 1992; Morris et al., 1997b; Mandonnet et al., 2001; Vagenas et al., 2002) but the last authors showed that responses to selection for decreased FEC can be achieved over a short time period. In the peri-parturient ewe, FEC is also moderately heritable (Woolaston et al., 1992; Morris et al., 1998; Bishop and Stear, 2001) and is genetically correlated with resistance in the lamb (Morris et al., 1998). Resistance to different species of nematodes tends to be related, with genetic correlations between the FEC values arising from different species or genera of parasites generally being close to 0.5 (e.g. Bishop et al., 2004) or higher in some cases (e.g. Gruner et al., 2004). Douch et al. (1995), working with Romney ewes in New Zealand, studied the antibody levels against antigens from infective larvae of *C. curtecei, H. contortus, O. circumcincta,* or *T. colubriformis* and immunoglobulin $G_1$ ($IgG_1$) specific to *C. curtecei* or *T. colubriformis* and reported heritability values for antibody and $IgG_1$ ranging from 0.18 to 0.37 with average of 0.26 (for details, refer to the article). Heritabilities of $\log_e$ (FEC + 100) and dag score (measure of breach soiling) were 0.28 and 0.13, respectively. Phenotypic correlations among the 6 antibody and $IgG_1$ traits averaged 0.55, whilst the genetic correlations among them were even higher, averaging 0.83. Phenotypic and genetic correlations between antibody or $IgG_1$ and $\log_e$ (FEC+100) were all negative and generally small, with genetic correlations averaging -0.15. Antibody and $IgG_1$ were positively correlated genetically with dag score (average value 0.35).

Studies in sheep to detect quantitative trait loci (QTL) for nematode resistance or detect associations with candidate genes are now well advanced in New Zealand, Australia, Kenya, US and Europe (UK, France, Italy and Spain) although results are not readily available in the public domain (Bishop and Morris, 2007) and much success has not been achieved in this area (e.g. Marshall et at., 2009). Several studies have also looked at associations between specific genes or markers and

FEC. Coltman et al. (2001) found significant associations with a microsatellite within the interferon gamma gene in feral sheep, and various associations with microsatellites in or near the major histocompatibility complex (MHC) have been observed (Schwaiger et al., 1995; Janssen et al., 2002). The genetic variation in many aspects of host resistance to nematodes is well documented. However, the use of molecular information (mainly QTL) that has long been advocated as a promising tool to improve difficult traits, contributed little to genetic improvement in livestock breeding schemes up to now (Bijma, 2009). Reasons are that QTL have often been detected in experimental crosses, the number of QTL soon becomes impractically large, linkage phase between markers and QTL may change over time, and QTL effects may change over time. A major step forward will come from the implementation of marker assisted breeding value estimation (MA-BVE) using dense maps covering the entire genome (Meuwissen et al., 2001). Furthermore, microarray studies do have the ability to detect genes differentially expressed between 'resistant' and 'susceptible' animal, with pathways implicated in these differences including the development of acquired resistance and the structure of the intestinal smooth muscle (Diez-Tascon et al., 2005). The interest in MA-BVE approach is solely in the breeding value of the candidates with the objective to estimate the breeding value with the highest possible accuracy using all phenotypic and genomic information. There is no interest in the location or effect of individual QTL. Using a mixed model, the method gives an estimate for each marker haplotype and the breeding value of an individual is the sum of the effects of its markers or haplotypes (Bijma, 2009).

### *3.6.2 Bacterial diseases*

Mastitis is an inflammation of the mammary gland resulting from bacterial infections particularly staphylococci. Subclinical mastitis is generally diagnosed by an increase in somatic cell counts (SCC) in the milk of cows and ewes, although in goats the predictive value of SCC is less established (Bergonier et al., 2003). SCC may also be used to help select for increased resistance to mastitis though recent estimates of heritability for SCC are generally low ranging between 0.10 to 0.20 (Mrode and Swanson, 1996; El-Saied et al., 1999; Barillet et al., 2001; Rupp et al., 2003; Serrano et al., 2003; Gonzalo et al., 2003; Legarra and Ugarte, 2005; Bishop and Morris, 2007). The review by Mrode and Swanson (1996) summarized many genetic estimates, concluding that the heritability of mastitis incidence in dairy cattle is low (~0.04), as also is the heritability of SCC (0.11±0.04), but the genetic correlation between the two is high at ~0.70. Attention is now turning to the mapping of QTL for SCC in dairy ewes, in both experimental crosses and commercial breeding programs, as described by Barillet et al. (2005).

In spite of the low heritabilities, numbers of daughters per young sire are generally large enough that breeding values for SCC can be determined accurately for dairy sires, and effective selection against SCC can then be applied. In many dairy countries today, a selection index approach is used, combining various production and disease traits, including milk yield and SCC (Sölkner et al., 1999; Willam et al., 2002). Analyses of large data sets have shown that there is a small unfavorable genetic correlation between SCC and first-lactation milk yield (the weighted estimate from Mrode and Swanson (1996) being 0.14±0.04, as indicated above), but this correlation can be broken by appropriate genetic selection. Heringstad et al. (2003) reported a 0.19 percentage point annual decrease in cases of clinical mastitis in Norway since the 1990 calf crop, from using index selection, whereas clinical mastitis would otherwise increase with positive selection for milk yield alone. There have been questions about the ability of the immune system to function effectively against mastitic pathogens if SCC is selected downwards genetically. Philipsson et al. (1995) used extensive Swedish industry data to investigate this subject, testing for non-linearity in the relationship between clinical mastitis values and SCC for sires. From the size and linearity of the genetic relationship between clinical mastitis and SCC, they concluded that cell counts reflected levels of infection, and that lower cell counts did not indicate any lowered ability to fight infection.

Footrot, a bacterial disease caused by *Dichelobacter* (*Bacteroides*) *nodosus* (*D. nodosus*), is a common cause of lameness in both lambs and mature sheep, and it is considered to be one of the major welfare problems in sheep; it is also a major cause of economic loss. Currently it is estimated to have economic costs to the UK industry of £31M per annum (Nieuwhof and Bishop, 2005; Bishop and Morris, 2007). Assessing the genetic control of footrot and subsequently breeding for resistance is simple due to the fact that footrot severity is relatively easily scored under field conditions. As reviewed by Bishop and Morris (2007), Egerton and Roberts (1971) developed a footrot lesion scoring method using Australian Merino sheep which was later refined by Raadsma (2000a) into a system that separated clinical signs into 8 categories. Using this system, Raadsma et al. (1994) demonstrated substantial genetic variation in resistance both to challenge with virulent isolates of *D. nodosus*, and also to natural challenge. Heritabilities of individual assessments of severity of the disease were low to moderate; however, genetic correlations between indicators were high, approaching unity, and heritability estimates from repeated measurements approached 0.30. A practical application of this approach has been described by Patterson and Patterson (1989) who successfully bred for enhanced footrot resistance in Merinos. Additional evidence of the feasibility of selecting sheep for footrot resistance using phenotypic observations is given by Skerman and Moorhouse (1987), who report an evaluation of lines of New Zealand Corriedale ewes selected for enhanced footrot resistance. Therefore, breeding for enhanced footrot resistance using phenotypic assessment alone is possible and feasible, provided that footrot is present in the flock (Bishop and Morris, 2007). Less work has been done on QTL or genetic marker tests for footrot resistance than on phenotypic assessment of resistance; however, associations between resistance and MHC markers, particularly within the MHC class II region, have been published (Litchfield et al., 1993; Escayg et al., 1997). A specific association with the DQA2 gene has been used in New Zealand as a marker for footrot resistance (Hickford et al., 2004). This test is now commercially available (Hickford, 2000) as a tool to select more tolerant or resistant animals, without having to expose the animals to infection.

### *3.7 Resource allocation theory (production vs. fitness traits)*

Under selection within a particular environment the resources used by the animal are optimally distributed between the important traits for breeding and production within that environment (Beilharz et al., 1993) implying that any additional selection mediated increase in performance of a production-related trait, without a concurrent increase in resources, must lead to declines in other traits, due to reallocation of resources (Mignon-Grasteau et al., 2005). The decrease in these traits is proportional to the heritability of the "*resource allocation factor*", defined by the proportion of resources devoted to production vs. fitness (van der Waaij, 2004; Mignon-Grasteau et al., 2005). In animal production, negative correlations are observed between production and fitness-related traits, such as fertility and health (Rauw et al., 1998). In lactating animals, poor BCS during the period of negative energy balance results in decreased fertility (Pryce et al., 2000). It seems that energy allocated to production cannot be applied to other body functions, resulting in increased health and fertility problems (Collard et al., 2000). Apart from the balance between production and health and fertility, the selection environment influences animal performance. For example, the effect of the negative energy balance has been partly compensated for by improving the environment. However, despite these actions, negatively correlated responses to increased production are becoming stronger: environmental sensitivity increases and is especially expressed in decreased fertility. Animals tend to adapt to the environment they are selected in, which may result in the development of a G×E interaction. It is clear that selection for production, without due consideration of the concurrent undesirable effects on reproduction, leads to problems in health and fertility.

According to van der Waaij (2004), production gets first priority in contrast to what happens under natural selection in resource allocation; when selection is on observed production and resource intake is limited, selection pressure is consequently shifted toward resource intake and allocation of proportionally more resources for production and away from fitness. An insufficient proportion of resources allocated to fitness may result in decreased health, fertility, and energy available for maintenance, with consequences for reproduction rate and probability of survival. Beilharz et al. (1993) and Knap and Bishop (2000) argue that when resources become limiting, a negative correlation between production traits and fitness-related traits will result. Results of a modeling study by van der Waaij (2004) indicate that environmental sensitivity, indicated by the negative correlation between observed production and survival probability, develops as soon as there is metabolic stress. Kolmodin et al. (2002) also found a similar trend in environmental sensitivity in Scandinavian dairy cattle. Apparently, the animals with the highest observed production (trait under selection) tend to be the animals with poorer values for the *"resource allocation factor"*, and thus are those with increased environmental sensitivity. Under artificial selection, when the weighting given to production is increased, highly specialized animals will have difficulty in adapting to changes in their breeding conditions, as no buffer is left to respond to unexpected changes (and hence care must be taken in introducing highly specialized breeds in to the tropical environment) as equilibrium is expected to be reached within a given environment. If the weighting given to production is disproportionate, resources are diverted from other traits such as health or reproduction (e.g. high-producing dairy cows often have reproduction or health problems).

## 4. Conclusions

Livestock productivity remains relatively low in the tropics particularly in sub-Saharan African countries despite the crucial role of livestock in the economies of many countries in the region. Breed improvement programs serve as natural entry points for productivity increases. However, the tendency for genetic improvement programs to concentrate on one aspect, such as meat or milk, in isolation from broader livelihood system needs often results in the substitution of exotic cattle for indigenous breeds. This emanates from the view that most indigenous livestock breeds are ‘unproductive’ when traits like milk and beef are considered. This has resulted in many misguided livestock improvement programs importing exotic breeds which are assumed to be more productive based on their performances in their conducive environments of origin.

Adaptive fitness is characterized by survival, health and reproductive related traits. The wealth of knowledge generated so far indicate that genetic variation for adaptive performance particularly disease resistance is ubiquitous both within and among breeds of livestock indicating that genetic studies on adaptation of farm animals can be determined at three genetic levels: species, breed and unique genetic variation among individual animals within a breed. In the warmer tropical areas, where pathogens and epidemic diseases are widespread, climatic conditions are stressful, and feed and water are scarce, locally adapted autochthonous breeds display far greater level of resistance and adaptation due to their evolutionary roots as compared to imported breeds. There are three pathways of genetic improvement: improvement of local breeds through purebred selection, breed substitution (by other local breeds or, more frequently, by exotic breeds), and systems of crossbreeding (terminal crosses, rotations, formation of synthetic lines). Whichever pathway to follow, choice of the most appropriate breed or breeds to use in a given environment or production system should be the first step when initiating a breeding program and due attention must be given to the adaptive performance. Major limitation is that selection for less heritable traits such as fitness-related traits results in low selection response due to measurement problems and the underlying antagonistic biological relationships between productive performance and adaptive traits. The appropriate strategy for any breeding program would therefore be to set suitable selection goals, which match the production system rather than ambitious performance objectives that cannot be reached under the prevailing environment. Area-specific approach utilizing the existing resources and taking into account the prevailing constraints appears to be the only reasonable sustainable solution. Such approach would also enable *in situ* conservation of farm animal genetic resources, the only viable and practical conservation method in less developed countries compared to *ex situ* or cryopreservation approaches. Therefore, the importance of identifying the most adapted genotype capable of coping with the environmental challenges posed by any particular production system has been indicated.

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# CHAPTER THREE

## Phenotypic ranking experiments approach in identifying smallholder and pastoralists' preferences for sheep breeding objective traits in Ethiopia

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**Abstract**

*Two live animals ranking experiments approaches, own-flock and group-animal ranking, were executed in four regions of Ethiopia to identify smallholders' sheep breeding objectives from the mixed crop-livestock (Bonga and Horro), sheep-barley (Menz) and pastoral (Afar) production systems. In the own-flock ranking experiment, a total of 471 households were visited at their homesteads and were asked to choose the best, 2$^{nd}$ best, 3$^{rd}$ best and an inferior ewe in the flock. Reasons for the ranking and life history of the animals were inquired, live weight and linear measurements were taken. Ten separate group-animal ranking experiments were conducted, each involving 15 ewes and 15 rams. With exception of Afar, the ewes were chosen from the own-flock ranking experiments. Animals of same sex were randomly assigned to five groups of three animals each and put in pens. Thirty respondents belonging to the other community of the region and therefore unfamiliar with the experimental animals were invited to do the ranking. Each person ranked the three animals in a pen as 1$^{st}$, 2$^{nd}$, and 3$^{rd}$, giving reasons for the ranking order. S/he was then provided with life history of each animal and asked whether, given these additional information on each of the animals, s/he would consider re-ranking them. The procedure was repeated ten times until a respondent covered all groups of ewes and rams. It was found out that in own-flock ranking owners pay more attention to production and reproduction performances and behavioral traits (e.g., milk yield, temperament, lamb growth, mothering ability, body size, lambing interval). There was a general tendency to focus on observable attributes like coat color, tail type, ear size, body size, etc. in group-animal ranking. Differences were observed between the pastoral, sheep-barley and mixed crop-livestock systems. Afar and Menz sheep breeders, coping with more challenging production environments, considered more attributes compared to the* *two crop-livestock systems. Information on life history was found to be more influential on decisions of respondents in Bonga and Horro mainly in ewe ranking. Both own-flock and group-animal ranking experiments can serve as tools in objective traits identification in production systems without a practice of recording.*

Key words: Own-flock ranking; Group-animal ranking; Sheep; Breeding objectives; Smallholder; Pastoral

## 1. Introduction

The design of breeding programs requires that the preferences and breeding objectives of farmers/pastoralists are known and appropriately considered. Smallholder sheep farming and pastoral systems are no exceptions. Farmers/pastoralists select animals considering morphological and production characteristics. They may use more of subjective selection giving more weight to morphological selection criteria than production selection criteria (objective selection). Gavigan and Parker (1997) give examples of subjective selection of ewes and rams for improving wool and lambing performance in New Zealand. However, Harvey and Baker (1989) argue that culling of ewes on mostly performance traits was more effective than visual culling resulting in 50% greater economic returns. Smallholder farmers/pastoralists possess both practical knowledge on animal management and deep understanding of the local environments and how these influence their livestock. For instance, traditional cattle keepers in the Western Province of Zambia manipulate the genetic composition in a variety of ways: animals are selected for size, strength, color, shape of the horns, parentage and character; castration is delayed until it becomes obvious whether the bull possesses the desired characteristics (Köhler-Rollefson, 2003). However, they possess less knowledge on how genes are transmitted to the next generations and how to use information from relatives. Moreover, their breeding objectives are not empirically defined, selection criteria for optimum return are therefore not possible or used. The farmers' decision of breeding objective and selection criteria could be affected by breed, production system and herd size (Jabbar et al., 1998; Wolfova et al., 2005). In Ethiopia, information on sheep trait preferences by farmers is generally lacking and so are well defined breeding objectives.

The objective of this study was to identify smallholder farmers'/pastoralists' sheep breeding objectives in four different agro-ecological zones of the country. The methods tested here were based on the evaluation of live animals by farmers, either their own animals or groups of animals they were not familiar with.

## 2. Materials and methods

### 2.1. Study area and sheep production systems

Detailed descriptions of the study areas and the sheep breeds were given elsewhere (Getachew, 2008; Edea, 2008; Duguma et al., 2010). In brief, studies were conducted in four locations (Afar, Bonga, Horro and Menz) which represent different agro-ecologies and production systems as well as different sheep breeds/ecotypes. In each location, two communities comprising of about 60 households each were identified based on information from secondary sources and initial diagnostic surveys. Sheep population (≥ 420 breeding ewes), presence of communal grazing land, accessibility, and willingness of the community to participate in the sheep improvement project were used as criteria for selecting the target communities for implementing breeding program whereas a minimum of four breeding ewes was set for households to become members of the breeding program.

Communities in Afar are mainly pastoralists who keep Afar sheep – a hardy breed which is adapted to drought prone arid and semi-arid areas and is used for milk and meat. Bonga and Horro areas are characterized by mixed crop-livestock agriculture, and the fat-long-tailed Bonga and Horro sheep breeds which are highly valued for mutton production are kept. Menz area is a low input sheep-barley production system. The Menz breed is fat-tailed and is raised for its meat and coarse wool.

### 2.2. Own-flock ranking experiments

The own-flock ranking exercise was performed from June to September 2008. All community member households were visited early in the morning at their homesteads before the sheep were let out for grazing. The sheep owners were asked to choose the best ewe in the flock. Reasons for the ranking were inquired and recorded. Life history of the ranked animal, focusing on previous reproductive performance (number of lambings, twinning ability, number of lambs born and weaned etc.) was inquired, live weight and linear measurements were taken. The same procedures were followed for the 2$^{nd}$ and 3$^{rd}$ best ewes as well as the most inferior ewe within each monitored flock. In most cases, family members participated in the ranking process. A total of 471 households (Afar 117, Bonga 120, Horro 119 and Menz 115) were covered.

### 2.3. Group-animal ranking experiments

In Afar, Bonga and Horro, the members of one breeding community were asked to rank groups of animals from the other community in two consecutive experiments in each region. In Menz the two communities are located at about 60 km apart making it difficult to move members from one area to the other. Therefore, the two communities in Menz were subdivided into two groups in order to rank the animals owned by the members of the other group in each location. Because of high flock mobility in Afar, it was not possible to assemble animals from the member flocks to a central place for the ranking experiment. Instead, flock and facilities of Werer Agricultural Research Center were used. Life histories for milk yield and reproduction traits recorded in the own-flock ranking experiments were assigned to the station animals whereas for live-weight, dentition and birth type the true individual records were considered.

Fifteen ewes and 15 rams were selected for each ranking experiment and given unique identification numbers. With exception of Afar, the ewes were chosen from the own ranking experiment covering all ranks. For each chosen ewe, information previously obtained from the owners on her age, birth type, parity, twinning performance, number of lambs born and weaned, growth of lambs, and approximate milk yield (for Afar) was used as life history. Similarly, age, birth type, libido and temperament were obtained for rams. Furthermore, live weight measurement was taken on both sexes.

At a central location a pen with ten partitions was constructed and animals of same sex were randomly assigned to five groups of three animals each and put in pens or tied to a long wooden log. Randomization was repeated after ten consecutive rankings, i.e. random grouping was performed three times during the course of each experiment.

Thirty members belonging to the other community/sub-community of the region and therefore unfamiliar with the experimental animals were invited to do the ranking. Each person was asked to rank the three animals in a pen as 1$^{st}$, 2$^{nd}$, and 3$^{rd}$, giving his/her reasons for the ranking order. S/he was then provided with life history of each animal and asked whether, given these additional information on each of the animals, s/he would consider re-ranking them. The procedure was repeated ten times until a respondent covered all groups of ewes and rams.

### 2.4. Data preparation and analytical methods

For both own-flock and group-animal ranking experiments, reasons for ranking from the open-ended responses were first checked one by one to determine the attribute levels and then coded. Attributes mentioned less than ten times were pooled into ‘others’ category. PROC FREQ in SAS (2008) was employed and Chi-Square was calculated to evaluate the influence of attributes on decisions made by respondents. Quantitative traits provided as life history were computed with MEANS and GLM procedures of SAS (2008).

## 3. Results and discussions

### 3.1. Preferences for sheep attributes as elicited using different ranking methods

#### 3.1.1. Ewe attributes in own-flock ranking experiments

Table 1 presents lists of ewe attributes summarized from the own-flock ranking experiments. Milk yield, temperament, lamb growth, mothering ability, body size, lambing interval and coat color were the most important ewe attributes, in that order, influencing owners’ preferences in Afar. They accounted for about two-thirds of the total proportions of mentioned attributes. In Bonga, Horro and Menz, lamb size at birth, mothering ability, lamb growth, lambing interval, body size and coat color together contributed to 74.23%, 74.43%, and 68.03%, respectively, of the total proportions of attributes listed in each location, but with varying order. Other important attributes were lamb survival in Menz (11.46%) and Bonga (7.39%) and twinning in Bonga (7.64%) and Horro (6.66%).

Table 1. List of ewe attributes in own-flock ranking experiments

| Trait | Afar | | Bonga | | Horro | | Menz | |
|---|---|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | Freq | % | Freq | % |
| 1. Lamb size or vigor at birth | 113 | 4.45 | 389 | 19.43 | 320 | 18.52 | 260 | 20.68 |
| 2. Lamb growth | 237 | 9.32 | 391 | 19.53 | 279 | 16.15 | 101 | 8.04 |
| 3. Lambing interval | 194 | 7.63 | 286 | 14.29 | 239 | 13.83 | 225 | 17.90 |
| 4. Body size | 202 | 7.95 | 200 | 9.99 | 157 | 9.09 | 56 | 4.46 |
| 5. Mothering ability | 226 | 8.89 | 52 | 2.60 | 206 | 11.92 | 115 | 9.15 |
| 6. Coat color | 184 | 7.24 | 167 | 8.34 | 85 | 4.92 | 98 | 7.80 |
| 7. Lamb survival | 104 | 4.09 | 148 | 7.39 | 38 | 2.20 | 144 | 11.46 |
| 8. Milk yield | 404 | 15.89 | - | - | - | - | - | - |
| 9. Twinning rate | 18 | 0.71 | 153 | 7.64 | 115 | 6.66 | - | - |
| 10. Temperament | 245 | 9.64 | - | - | 20 | 1.16 | 10 | 0.80 |
| 11. Body condition | 93 | 3.66 | 66 | 3.30 | 51 | 2.95 | 45 | 3.58 |
| 12. Tail type | 98 | 3.86 | 19 | 0.95 | 34 | 1.97 | 24 | 1.91 |
| 13. Pedigree | 125 | 4.92 | 17 | 0.85 | 25 | 1.45 | - | - |
| 14. Drought tolerance | 49 | 1.93 | - | - | - | - | 46 | 3.66 |
| 15. Age | 24 | 0.94 | 35 | 1.75 | 29 | 1.68 | - | - |
| 16. Breed type | - | - | - | - | - | - | 51 | 4.05 |
| 17. Body length | 50 | 1.97 | - | - | - | - | - | - |
| 18. Lamb's resemblance | 12 | 0.47 | - | - | 17 | 0.98 | 10 | 0.80 |
| 19. Body width | - | - | 19 | 0.95 | 20 | 1.16 | - | - |
| 20. Body conformation | 15 | 0.59 | - | - | 17 | 0.98 | - | - |
| 21. Lamb's sex | 26 | 1.02 | - | - | - | - | - | - |
| 22. Ear size | - | - | - | - | - | - | 18 | 1.43 |
| 23. Beauty or appearance | 15 | 0.59 | - | - | - | - | - | - |
| 24. Foraging ability | - | - | - | - | 15 | 0.87 | - | - |
| 25. Homestead recognition | 14 | 0.55 | - | - | - | - | - | - |
| 26. Incidence of abortion | 13 | 0.51 | - | - | - | - | - | - |
| 27. Response to good season or feeding | 13 | 0.51 | - | - | - | - | - | - |
| 28. Physical soundness | 12 | 0.47 | - | - | - | - | - | - |
| 29. Wool | - | - | - | - | - | - | 11 | 0.88 |
| 30. Gregariousness/wandering | 10 | 0.39 | - | - | - | - | - | - |
| 31. Teat size | 10 | 0.39 | - | - | - | - | - | - |
| 32. Others | 36 | 1.44 | 60 | 3.00 | 61 | 3.53 | 43 | 3.42 |
| Sum | 2542 | | 2002 | | 1728 | | 1257 | |

Even though there was a general tendency to focus on offspring quality (size at birth and fast growth) and related reproductive attributes (lambing interval, mothering ability and lamb survival) in all production systems, we observed a conspicuous difference in trait preferences between the pastoral, mixed crop-livestock and sheep-barley systems. A higher number of attributes was mentioned for ewes in the pastoral (38) and sheep-barley systems (36) compared to the two crop-livestock systems (27 in Bonga and 29 in Horro) including those aggregated under ‘others’ (Table 1). In Afar, milk yield, temperament, and pedigree were important attributes for ranking that were of none or little importance in the other systems. In addition, body length was named quite frequently as reason for a certain rank because pastoralists associate it with higher milk yield potential. Some pastoralists also considered lamb’s sex, incidence of abortion, homestead recognition, response to good season or feeding, and gregariousness/wandering for ranking their ewes.

It is understandable that good tempered ewes are easy for handling and milking. According to the pastoralists, ewes that frequently give birth to female lambs and carry fetuses to term are preferred in order to maximize flock size. They consider homestead recognition and gregariousness as important attributes of sheep so that the flock may not wander away and hence avoid attacks by predators. Respondents claimed that some ewes play a dominant role in leading the flock back to homestead from grazing areas whereas solitary animals frequently expose themselves and their lambs to predators. Pedigree was used in the pastoral system more frequently (125 times) compared to the two crop-livestock systems (only 42 times altogether). In Afar, lineage is counted through female ancestors and all animals descending from one particular superior female are grouped together and given the same name (personal communication with clan chiefs). In general, the pastoralists attach great importance to the ancestry of their animals and memorize it in great detail up to seven generations particularly regarding those animals inherited from their forefathers. Similar practices have been observed among camel keeping pastoralists in India and the Maasai (Köhler-Rollefson, 2003)

In Bonga and Horro, owners used more frequently twinning and body width as ranking criteria than in the other two systems. The likely reason breeders in the wet humid crop-livestock systems opted for twin bearer ewes is that more lambs will be available both for replacement and marketing given the available natural feed resources almost year round. The wide bodied ewes were associated with better mothering ability, higher twinning rates and high carcass outputs. In the sheep-barley system, breed type, ear size and wool yield were additionally used for evaluation. Awassi x Menz (A x M) crossbred sheep were preferred to the indigenous Menz breed in one of the communities. Rams with 75% Awassi contribution were distributed in this area about ten years ago to genetically upgrade indigenous Menz for increased meat and wool productions. At present some households keep crossbred animals with unknown exotic blood levels (i.e., between 10 to 62.5% Awassi). Though ears are mere appearance traits and do not affect performance of the animal, respondents opted for long ears for no other apparent reason than “beauty”. Drought tolerance as an attribute was referred to in the arid pastoral and the cool tepid highland sheep-barley systems where moisture stress is prevalent and feed is scarce for most parts of the year.

Mean ± SE values for some reproduction and production traits plus dentition are given in Table 2. In all locations, the number of lambs weaned (lamb survival) and live weight of ewes significantly ($p<0.001$) influenced owners’ decisions (and hence their selection decisions) except for Afar where live weight appeared to be non significant. Milk yield and number of lambings (equivalent to number of lambs born) influenced ($p<0.001$) preferences in Afar and Menz, respectively, whereas dentition (ewe age) was important ($p<0.05$) in Bonga and Horro. For all the breeds there was clear trend for the different attributes of ewes ranked from best to inferior including those which were statistically non-significant except for number of lambings and lambs born in Horro (Table 2).

Table 2. Mean ± SE values of attributes in different rank groups of ewes from own-flock ranking experiment

| Breed | Attributes | *p* | Overall Mean | Ranks 1 | 2 | 3 | Inferior |
|---|---|---|---|---|---|---|---|
| Afar | Live weight, kg | *NS* | 25.70±0.21 | 27.80±0.38 | 26.50±0.38 | 25.70±0.43 | 22.50±0.36 |
| | Dentition | *NS* | 3.14±0.05 | 3.77±0.06 | 3.32±0.08 | 2.99±0.10 | 2.46±0.12 |
| | Number of lambings | *NS* | 3.45±0.08 | 4.60±0.16 | 3.46±0.13 | 2.74±0.12 | 2.80±0.17 |
| | Twinning | *NS* | 0.17±0.03 | 0.37±0.08 | 0.11±0.04 | 0.15±0.06 | 0.04±0.03 |
| | Number born | *NS* | 3.61±0.09 | 4.97±0.20 | 3.57±0.13 | 2.88±0.16 | 2.84±0.18 |
| | Number weaned | *** | 2.83±0.10 | 4.28±0.20 | 3.01±0.14 | 2.28±0.10 | 1.46±0.17 |
| | Milk yield, cups/d | *** | 2.28±0.07 | 3.25±0.10 | 2.77±0.10 | 2.16±0.12 | 0.63±0.08 |
| Bonga | Live weight, kg | *** | 36.30±0.28 | 40.20±0.52 | 37.20±0.46 | 35.40±0.42 | 31.20±0.50 |
| | Dentition | * | 3.00±0.05 | 3.60±0.07 | 3.20±0.09 | 2.70±0.10 | 2.30±0.13 |
| | Number of lambings | *NS* | 3.56±0.09 | 4.63±0.17 | 3.64±0.16 | 3.10±0.16 | 2.65±0.20 |
| | Twinning | *NS* | 1.13±0.08 | 2.11±0.16 | 0.99±0.15 | 0.86±0.13 | 0.36±0.09 |
| | Number born | *NS* | 4.71±0.15 | 6.78±0.29 | 4.64±0.27 | 4.01±0.27 | 3.00±0.25 |
| | Number weaned | *** | 4.53±0.15 | 6.67±0.29 | 4.52±0.26 | 3.79±0.27 | 2.70±0.24 |
| Horro | Live weight, kg | *** | 33.60±0.28 | 36.80±0.51 | 34.50±0.56 | 32.50±0.44 | 29.70±0.50 |
| | Dentition | * | 3.30±0.05 | 3.70±0.06 | 3.40±0.08 | 3.10±0.09 | 2.90±0.11 |
| | Number of lambings | *NS* | 3.90±0.10 | 4.88±0.21 | 3.61±0.18 | 3.80±0.21 | 3.12±0.20 |
| | Twinning | *NS* | 1.29±0.09 | 2.09±0.20 | 1.19±0.16 | 1.14±0.15 | 0.58±0.18 |
| | Number born | * | 5.22±0.18 | 7.03±0.38 | 4.81±0.30 | 4.98±0.32 | 3.68±0.35 |
| | Number weaned | *** | 4.71±0.17 | 6.66±0.37 | 4.47±0.28 | 4.35±0.28 | 2.91±0.33 |
| Menz | Live weight, kg | *** | 20.10±0.15 | 21.90±0.29 | 20.60±0.26 | 19.50±0.24 | 18.10±0.24 |
| | Dentition | *NS* | 3.52±0.05 | 3.84±0.06 | 3.63±0.08 | 3.48±0.09 | 3.10±0.12 |
| | Number of lambings[a] | *** | 3.59±0.09 | 4.52±0.22 | 3.63±0.14 | 3.21±0.15 | 2.93±0.16 |
| | Number weaned | *** | 3.02±0.10 | 4.39±0.22 | 3.41±0.14 | 2.67±0.14 | 1.43±0.13 |

[a]number of lambings and number born are equal since twinning is nearly absent; *NS*=$p>0.05$; *=$p<0.05$; ***=$p<0.001$.

Comparing mean values of ewes ranked as best and inferior, one can clearly observe marked differences in all attributes considered. For instance, in Afar, the magnitude of difference in live weight was 5.3kg; difference in number of lambs weaned was 2.82, and difference in milk yield was 2.62 cups/day between the two groups. In Bonga and Horro the differences were, respectively, 9.0 and 7.1 kg live weight; 1.75 and 1.51 twinning; and 3.97 and 3.75 number of lambs weaned. In Menz, they differed by 3.8 kg live weight and 2.96 number of lambs weaned. Close scrutiny of ewes ranked as 2$^{nd}$ and 3$^{rd}$ best in the flock for number of lambs born and weaned in Horro reveals to which extent farmers keep track of the performance of each animal (Table 2).

### 3.1.2. Ewe attributes in group-animal ranking experiments

Body size, coat color, tail type, body condition, conformation and body width were found to be important in Afar, Bonga, Horro and Menz the sum of which accounted for 72.62%, 88.51%, 84.49% and 72.47%, respectively, of the mentioned attributes in ewe group-ranking experiments (Table 3). Moreover, milk yield, body length, drought tolerance and assumed mothering ability each accounted for 9.71%, 6.65%, 2.99% and 2.73%, respectively, of the mentioned attributes in Afar. Hair type in Bonga (3.62%), color pattern (6.19%) and body length (2.63%) in Horro, ear size (11.18%), appearance or beauty (3.64%), body length (2.51%) and breed type (2.14%) in Menz were also identified as important ewe attributes for selection.

### 3.1.3. Ram attributes in group-animal ranking experiments

Coat color, tail type and body size were the three commonly and consistently cited phenotypic attributes which accounted for 50.65%, 66.56%, 57.56% and 51.62% of the total descriptions used by respondents in Afar, Bonga, Horro and Menz, respectively (Table 4). However, the magnitude and order of recurrence was tail type (25.59% and 21.22%); coat color (21.81 and 19.59%) and body size (19.16% and 16.75%) in Bonga and Horro, respectively, while body size assumed first priority in

Menz with 22.59% followed by tail type (14.79%) and coat color (14.24%). In Afar, the attributes appeared in the order given for all locations with proportions of 18.87, 17.59 and 14.19%, respectively. Respondents in the mixed crop-livestock production system also considered body width, age of the animal, body condition and conformation and these together contributed to 24.25% and 27.43% of the total proportions referenced in Bonga and Horro, respectively.

Table 3. List of ewe attributes in group-animal ranking experiments

| Trait | Afar | | Bonga | | Horro | | Menz | |
|---|---|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | Freq | % | Freq | % |
| 1. Body size | 378 | 12.57 | 545 | 21.23 | 509 | 18.33 | 951 | 23.38 |
| 2. Coat color | 637 | 21.18 | 460 | 17.92 | 505 | 18.19 | 735 | 18.07 |
| 3. Tail type | 479 | 15.92 | 587 | 22.87 | 516 | 18.58 | 388 | 9.54 |
| 4. Body width | 157 | 5.22 | 488 | 19.01 | 462 | 16.64 | 343 | 8.43 |
| 5. Body condition | 254 | 8.44 | 117 | 4.56 | 160 | 5.76 | 345 | 8.48 |
| 6. Body conformation | 141 | 4.69 | 75 | 2.92 | 194 | 6.99 | 186 | 4.57 |
| 7. Body length | 200 | 6.65 | 37 | 1.44 | 73 | 2.63 | 102 | 2.51 |
| 8. Ear size | 15 | 0.50 | - | - | - | - | 455 | 11.18 |
| 9. Milk yield | 292 | 9.71 | - | - | - | - | - | - |
| 10. Ewe grade | 28 | 0.93 | 84 | 3.27 | 110 | 3.96 | 29 | 0.71 |
| 11. Color pattern | 35 | 1.16 | - | - | 172 | 6.19 | 37 | 0.91 |
| 12. Beauty/appearance | 76 | 2.53 | - | - | - | - | 148 | 3.64 |
| 13. Hair type | 52 | 1.73 | 93 | 3.62 | 20 | 0.72 | - | - |
| 14. Drought tolerance | 90 | 2.99 | - | - | - | - | 56 | 1.38 |
| 15. Age | 35 | 1.16 | 46 | 1.79 | 18 | 0.65 | 21 | 0.52 |
| 16. Mothering ability | 82 | 2.73 | - | - | 14 | 0.50 | 16 | 0.39 |
| 17. Lamb size at birth | 20 | 0.66 | - | - | - | - | 80 | 1.97 |
| 18. Breed type | - | - | - | - | - | - | 87 | 2.14 |
| 19. Reproduction potential | 18 | 0.60 | - | - | - | - | 12 | 0.29 |
| 20. Wool | - | - | - | - | - | - | 34 | 0.84 |
| 21. Market demand | - | - | - | - | - | - | 30 | 0.74 |
| 22. Alertness | - | - | - | - | - | - | 12 | 0.29 |
| 23. Others | 19 | 0.63 | 35 | 1.36 | 24 | 0.86 | 1 | 0.02 |
| Sum | 3008 | | 2567 | | 2777 | | 4068 | |

In the pastoral system, alertness of the animal (as a proxy to libido), body length, and type (dairy) along with body condition, conformation and width were also important. In the sheep-barley system, attributes like horn type, ear size and appearance (beauty) were considered in addition to body width, condition and conformation. Though to a smaller extent, respondents in all locations tended to attach grades to rams ('ram grade') as an overall evaluation. Respondents in Afar and Bonga disliked rams and ewes with long and rough hair; because of susceptibility to heat stress in the former and entanglement with bush spikelet in the latter.

Table 4. List of ram attributes in group-animal ranking experiments

| Trait | Afar | | Bonga | | Horro | | Menz | |
|---|---|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | Freq | % | Freq | % |
| Tail type | 553 | 17.59 | 629 | 25.59 | 560 | 21.22 | 592 | 14.79 |
| Coat color | 593 | 18.87 | 536 | 21.81 | 517 | 19.59 | 570 | 14.24 |
| Body size | 446 | 14.19 | 471 | 19.16 | 442 | 16.75 | 904 | 22.59 |
| Body width | 122 | 3.88 | 292 | 11.88 | 169 | 6.40 | 246 | 6.15 |
| Body conformation | 123 | 3.91 | 89 | 3.62 | 257 | 9.74 | 196 | 4.90 |
| Body condition | 209 | 6.65 | 74 | 3.01 | 118 | 4.47 | 233 | 5.82 |
| Age | 79 | 2.51 | 141 | 5.74 | 180 | 6.82 | 88 | 2.20 |
| Body length | 166 | 5.28 | 16 | 0.65 | 65 | 2.46 | 103 | 2.57 |
| Libido | 261 | 8.30 | 10 | 0.41 | - | - | 41 | 1.02 |
| Ram grade | 95 | 3.02 | 50 | 2.03 | 83 | 3.15 | 55 | 1.37 |
| Horn | - | - | - | - | 72 | 2.73 | 256 | 6.40 |
| Hair type | 75 | 2.39 | 115 | 4.68 | 47 | 1.78 | - | - |
| Appearance | 52 | 1.65 | - | - | - | - | 200 | 5.00 |
| Color pattern | 49 | 1.56 | 14 | 0.57 | 101 | 3.83 | 23 | 0.57 |
| Ear size | 11 | 0.35 | - | - | - | - | 238 | 5.95 |
| Type (Dairy) | 139 | 4.42 | - | - | - | - | - | - |
| Drought tolerance | 69 | 2.20 | - | - | - | - | 20 | 0.50 |
| Market demand | 13 | 0.41 | - | - | 18 | 0.68 | 46 | 1.15 |
| Horn orientation | - | - | - | - | - | - | 77 | 1.92 |
| Wool | - | - | - | - | - | - | 49 | 1.22 |
| Breed type | - | - | - | - | - | - | 49 | 1.22 |
| Temperament | 33 | 1.05 | - | - | - | - | - | - |
| Face structure | 28 | 0.89 | - | - | - | - | - | - |
| Neck thickness | 10 | 0.32 | - | - | - | - | - | - |
| Others | 17 | 0.54 | 21 | 0.85 | 10 | 0.38 | 16 | 0.40 |
| Sum | 3143 | | 2458 | | 2639 | | 4002 | |

Like it was the case in own-flock ranking, respondents in the pastoral and sheep-barley systems used more attributes in both ewe and ram group-animal ranking experiments (Tables 3 and 4) than respondents in the mixed crop-livestock systems. Ear size, appearance, and envisaged drought tolerance were mentioned in these systems for both ewes and rams alike but with varying magnitude. Sheep owners also judge reproductive potential of a ewe and its lamb vigor from body frame. In Afar, body length was more frequently raised in both ewes and rams ranking in association with milk yield potential or type. Unlike in own-flock ranking, there was a general tendency to focus on observable attributes like coat color, tail type, ear size, body size, etc. for both sexes in all production systems.

### 3.2. Attribute levels used by farmers/pastoralists to express their trait preferences

Sheep breeders in all the studied locations used qualitative descriptions like ‘big’, ‘moderate’ and ‘small’ for size related attributes; ‘good’ and ‘bad’/‘poor’ for coat color, mothering ability, lamb survival, temperament and pedigree; ‘short’, ‘moderate’, and ‘long’ for interval between subsequent lambings; ‘fast’, ‘moderate’, ‘slow’ for lamb growth performance; ‘single bearer’ and ‘twin bearer’ for prolificacy. There was a general tendency of attaching favorable descriptions to animals ranked as best and vice versa (Figures 1, 2 and 3). However, the frequency with which they appeared noticeably varied for the different attributes and experiment types in the four study areas. For instance, in own-flock ranking, lamb size at birth, lamb growth, lambing interval and pedigree in Afar; breed type in Menz; lamb survival in Bonga; coat color in Horro were more frequently used favorably whereas poor lamb survival in Afar and susceptibility to drought in Afar and Menz were more frequently mentioned in association with inferior animals. Twin bearer ewes were also more favored in Bonga and Horro than single bearers.

In group ranking, long body and good conformation for all breeds; wide body in Bonga, Horro and Menz were more frequently used to favorably/positively describe ewes and rams whereas poor body condition in all breeds and mixed color pattern in Afar and Menz; and narrow body in Afar were frequently used to describe inferior animals. As mentioned before, in the crop-livestock system, wide body is associated with more carcass output and hence good market price. Tan, brown, red and white coat color types are preferred in all studied areas whereas black color is the most detested one followed by mixed pattern. However, black-white-headed animals are exceptionally needed for cultural rituals in Menz area.

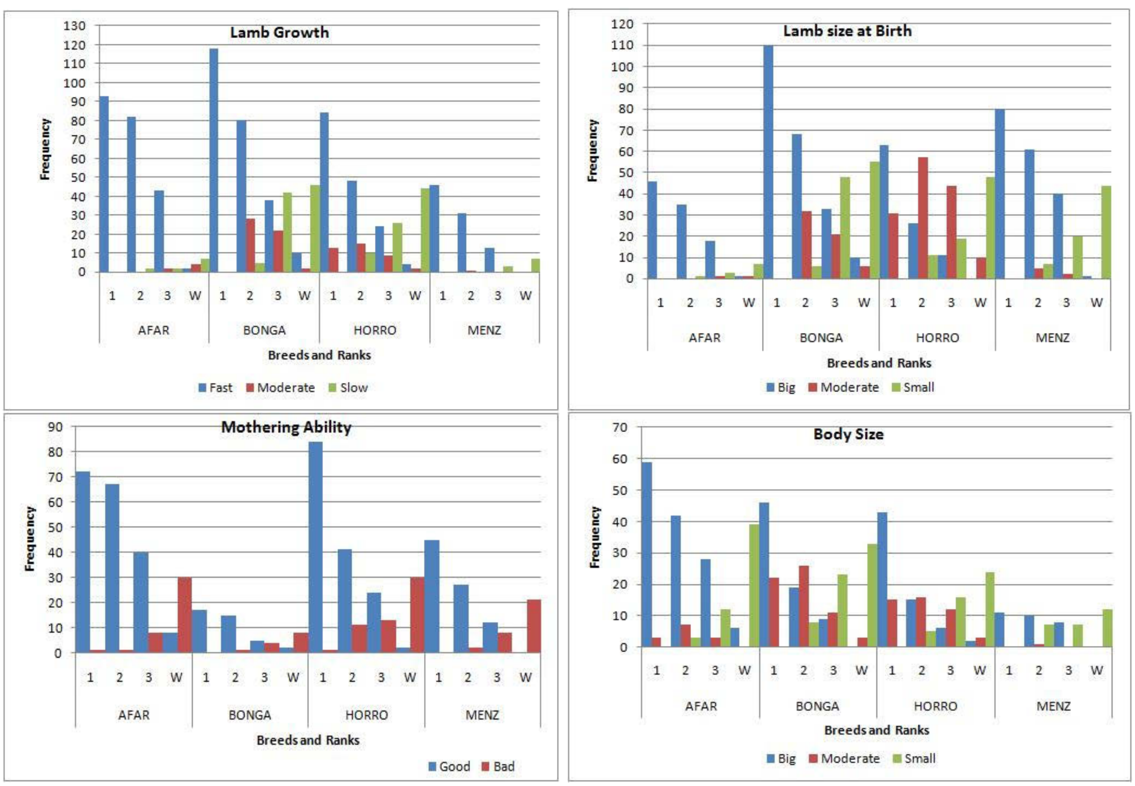


Figure 1. Selected attributes and their levels from the own-flock ranking experiments

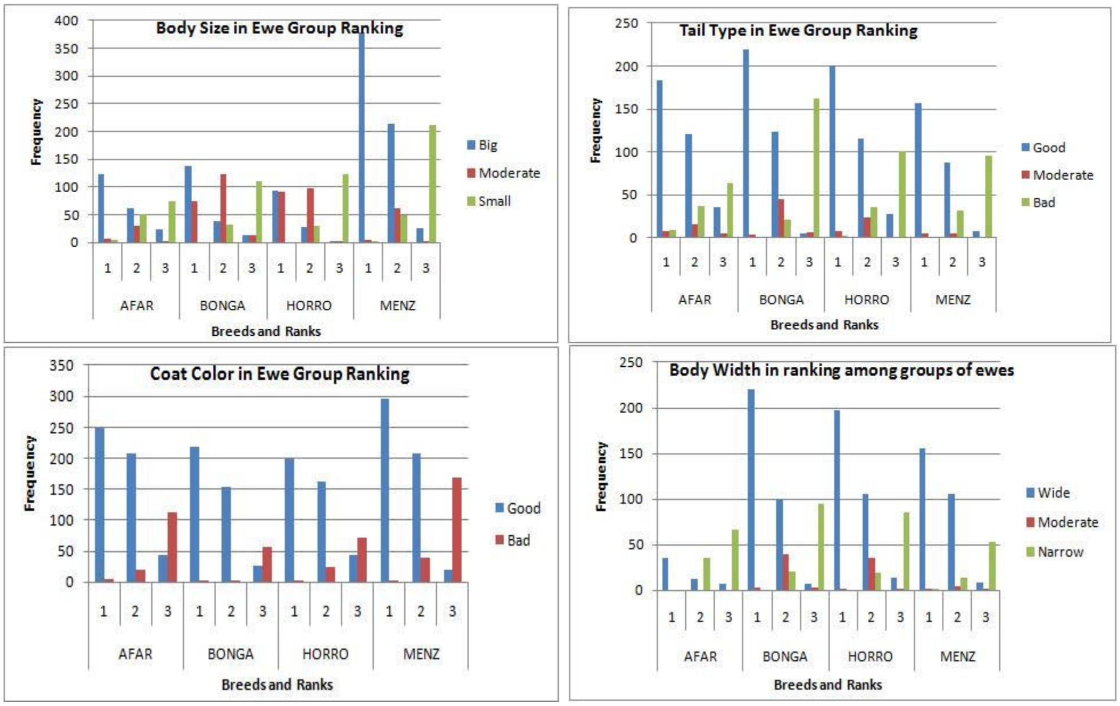


Figure 2. Selected attributes and their levels from the ewe group-animal ranking experiments

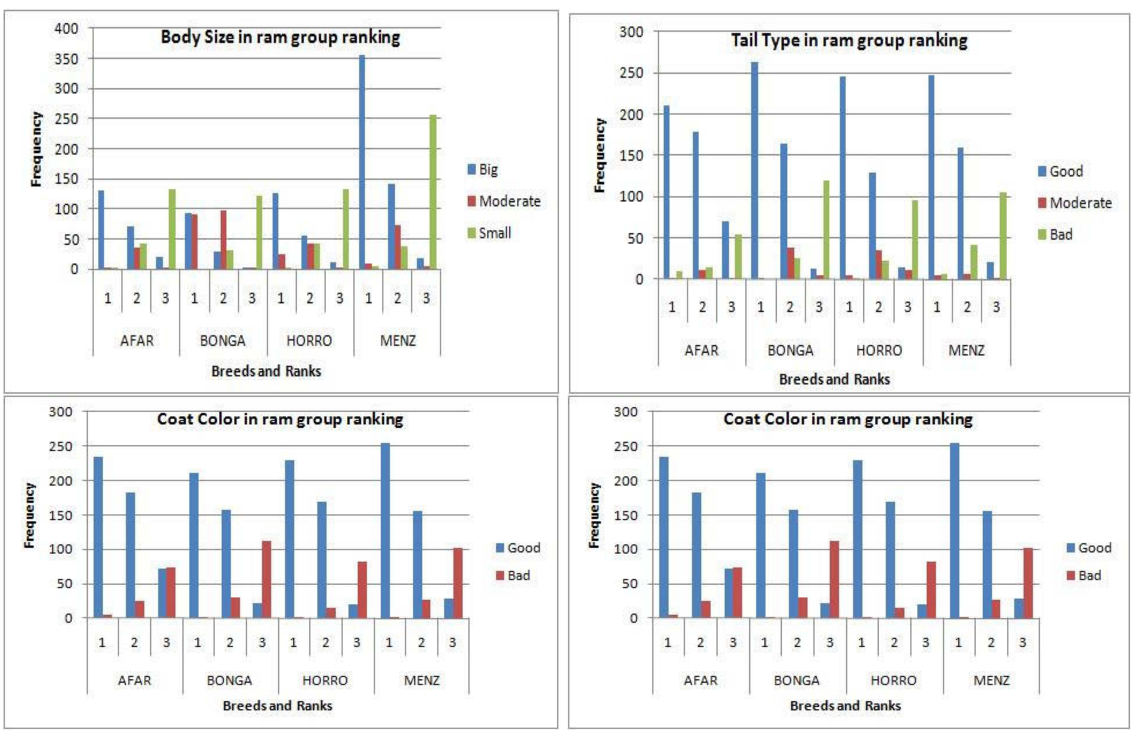


Figure 3. Selected attributes and their levels from the ram group-animal ranking experiments

### 3.3. Comparisons of rankings with and without additional information of life history

Table 5 reveals proportion of rank distribution before and following provision of information about life history. The provided information did not uniformly influence respondents' decision in all locations. For example, in Afar, of ewes ranked as first, second, and third prior to life history, 93%, 91.9% and 92.3% retained their position, respectively, after provision of life history. The likely reasons may be that 1) hypothetical life history was attached to on-station animals and 2) the pastoralists tended to rely on their own evaluation mechanisms rather than the provided information as they believe they are more knowledgeable about the type of animals. The corresponding proportions were 54.7%, 49.3% and 52.3% for Bonga; 48.4%, 49.5%, and 50.9% for Horro; and 72.3%, 68.1% and 74.9% for Menz. Presumably, information on twinning combined with mothering ability influenced respondents in Bonga and Horro to change their decisions. Unlike in ewes, life history information only minimally altered respondents' decision in ram-group ranking (Table 5) as one may expect given the types of history (birth type, live weight, age, alertness and temperament) attached to rams. Obviously, respondents can more directly judge an animal for these attributes (except for birth type) on their own from its physical appearance, dental examination and disquieting (e.g., mean values for live weight of rams ranked 1$^{st}$ to 3$^{rd}$ followed a decreasing order; data not shown). In a similar ranking experiment with Ugandan Ankole cattle keepers, performance and fitness traits attached as hypothetical life history influenced selection of cows while phenotypic appearance of an animal was important for selection of bulls (Ndumu et al., 2008).

Table 5. Number (proportions) of ranks unchanged[a] or altered following provision of information on life history

| Breed | RBLH[b] | RALH[c] Ewe | | | RALH Ram | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 |
| Afar | 1 | 265 (93.0) | 9 (3.2) | 11 (3.9) | 276 (96.8) | 4 (1.4) | 5 (1.8) |
| | 2 | 12 (4.2) | 262 (91.9) | 11 (3.9) | 4 (1.4) | 274 (96.1) | 7 (2.5) |
| | 3 | 8 (2.8) | 14 (4.9) | 263 (92.3) | 5 (1.8) | 7 (2.4) | 273 (95.8) |
| Bonga | 1 | 164 (54.7) | 85 (28.3) | 51 (17.0) | 296 (98.7) | 3 (1.0) | 1 (0.3) |
| | 2 | 60 (20.0) | 148 (49.3) | 92 (30.7) | 4 (1.3) | 291 (97.0) | 5 (1.7) |
| | 3 | 76 (25.3) | 67 (22.3) | 157 (52.3) | 0 | 6 (2.0) | 294 (98.0) |
| Horro | 1 | 138 (48.4) | 77 (27.0) | 70 (24.6) | 267 (93.7) | 14 (4.9) | 4 (1.4) |
| | 2 | 74 (26.0) | 141 (49.5) | 70 (24.6) | 11 (3.9) | 268 (94.0) | 6 (2.1) |
| | 3 | 73 (25.6) | 67 (23.5) | 145 (50.9) | 7 (2.5) | 3 (1.1) | 275 (96.5) |
| Menz | 1 | 383 (72.3) | 92 (17.4) | 55 (10.4) | 498 (94.0) | 23 (4.3) | 9 (1.8) |
| | 2 | 92 (17.4) | 361 (68.1) | 77 (14.5) | 25 (4.7) | 479 (90.4) | 26 (4.9) |
| | 3 | 55 (10.4) | 78 (14.7) | 397 (74.9) | 7 (1.3) | 28 (5.3) | 495 (93.4) |

[a]Unchanged ranks are given in the diagonal. [b]Rank before provision of life history**;** [c]Rank after provision of life history

From the attributes used in life history, sheep breeders' preferences were significantly (p≤0.01) influenced by number of lambs weaned and growth of lambs irrespective of location; live weight in Afar, Bonga and Menz and age (dentition) in Afar, Horro and Menz. Moreover, ewe birth type influenced decisions of Afar, Bonga and Horro sheep breeders (Table 6). Here reproduction and production attributes followed the logical trend in groups of ewes ranked from first to third. Linear body measurements taken on ranked animals also followed the same trend (data not shown). However, only live weight in all breeds followed a logical trend before provision of life history.

Table 6. Comparison of rank groups for various attributes before and after provision of life history

| Breeds | Attributes | Overall mean | Without life history 1 | Without life history 2 | Without life history 3 | With life history 1 | With life history 2 | With life history 3 | P value |
|---|---|---|---|---|---|---|---|---|---|
| Afar | Milk yield, cups/d | 2.54±0.05 | - | - | - | 2.81±0.07 | 2.65±0.09 | 2.16±0.10 | *NS* |
| | Live weight, kg | 28.02±0.11 | 29.07±0.18 | 28.28±0.19 | 26.70±0.18 | 29.1±0.19 | 28.26±0.18 | 26.64±0.18 | *** |
| | Dentition | 2.43±0.05 | 2.78±0.08 | 2.64±0.09 | 1.85±0.08 | 2.87±0.08 | 2.68±0.09 | 1.73±0.08 | ** |
| | Number of lambing | 3.29±0.07 | - | - | - | 3.92±0.12 | 3.47±0.12 | 2.48±0.10 | *NS* |
| | Twinning | 0.60±0.05 | - | - | - | 0.85±0.09 | 0.64±0.09 | 0.32±0.07 | *NS* |
| | Number born | 3.93±0.10 | - | - | - | 4.80±0.19 | 4.17±0.19 | 2.83±0.15 | *NS* |
| | Number weaned | 3.05±0.10 | - | - | - | 4.03±0.18 | 3.11±0.17 | 2.02±0.11 | ** |
| | *Ewe birth type (number and proportions)* | | | | | | | | |
| | Single | | 214 (25.03) | 210 (24.56) | 174 (20.35) | 208 (24.33) | 206 (24.09) | 184 (21.52) | |
| | Multiple | | 71 (8.30) | 75 (8.77) | 111 (12.98) | 77 (9.01) | 79 (9.24) | 101 (11.81) | |
| | *Lamb growth (number and proportions)* | | | | | | | | |
| | Fast | | 191 (22.34) | 146 (17.08) | 90 (10.53) | 195 (22.81) | 150 (17.54) | 82 (9.59) | |
| | Moderate | | 60 (7.02) | 67 (7.84) | 73 (8.54) | 55 (6.43) | 66 (7.72) | 79 (9.24) | |
| | Slow | | 34 (3.98) | 72 (8.42) | 122 (14.27) | 35 (4.09) | 69 (8.07) | 124 (14.50) | |
| Bonga | Live weight, kg | 40.10±0.24 | 42.80±0.47 | 39.54±0.37 | 37.96±0.32 | 42.89±0.45 | 39.93±0.38 | 37.48±0.32 | *** |
| | Dentition | 3.20±0.03 | 2.93±0.06 | 3.16±0.05 | 3.50±0.05 | 3.26±0.05 | 3.26±0.05 | 3.08±0.05 | *NS* |
| | Number of lambing | 4.07±0.06 | 3.67±0.11 | 3.94±0.11 | 4.59±0.10 | 4.15±0.12 | 4.10±0.11 | 3.95±0.10 | * |
| | Twinning | 1.43±0.05 | 1.24±0.08 | 1.08±0.08 | 1.98±0.10 | 2.11±0.09 | 1.26±0.09 | 0.93±0.08 | *NS* |
| | Number born | 5.57±0.10 | 4.94±0.15 | 5.06±0.16 | 6.70±0.19 | 6.44±0.19 | 5.36±0.16 | 4.89±0.16 | ** |
| | Number weaned | 5.40±0.10 | 4.94±0.15 | 4.91±0.16 | 6.36±0.20 | 6.44±0.19 | 5.27±0.16 | 4.49±0.16 | *** |
| | *Ewe birth type (number and proportions)* | | | | | | | | |
| | Single | | 112 (12.40) | 123 (13.70) | 155 (17.20) | 132 (14.70) | 151 (16.80) | 107 (11.90) | |
| | Multiple | | 63 (7.00) | 34 (3.80) | 23 (2.60) | 80 (8.90) | 26 (2.90) | 14 (1.60) | |
| | Unknown | | 125 (13.90) | 143 (15.90) | 122 (13.60) | 88 (9.80) | 123 (13.70) | 179 (19.90) | |
| | *Lamb growth (number and proportions)* | | | | | | | | |
| | Fast | | 235 (26.10) | 193 (21.40) | 172 (19.10) | 274 (30.40) | 208 (23.10) | 111 (13.10) | |
| | Moderate | | 39 (4.30) | 45 (5.00) | 36 (4.00) | 21 (2.30) | 52 (5.80) | 47 (5.20) | |
| | Slow | | 26 (2.90) | 62 (6.90) | 92 (10.20) | 5 (0.60) | 40 (4.40) | 135 (15.00) | |

Table 6. Comparison of rank groups for various attributes before and after provision of life history (Contd).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Horro | Live weight, kg | 36.81±0.14 | 38.10±0.23 | 36.82±0.23 | 35.53±0.25 | | 36.71±0.23 | 36.49±0.24 | *NS* |
| | Dentition | 3.60±0.02 | 3.61±0.04 | 3.69±0.04 | 3.49±0.05 | 3.94±0.02 | 3.66±0.04 | 3.20±0.05 | *** |
| | Number of lambing | 4.96±0.10 | 4.69±0.16 | 5.00±0.16 | 5.20±0.19 | 6.67±0.17 | 4.68±0.14 | 3.53±0.14 | *NS* |
| | Twinning | 2.46±0.07 | 2.67±0.12 | 2.43±0.12 | 2.27±0.13 | 4.00±0.12 | 2.05±0.11 | 1.33±0.10 | *NS* |
| | Number born | 7.45±0.16 | 7.39±0.26 | 7.48±0.27 | 7.49±0.30 | 10.76±0.27 | 6.74±0.22 | 4.87±0.21 | *NS* |
| | Number weaned | 7.05±0.17 | 7.10±0.27 | 6.98±0.28 | 7.08±0.31 | 10.71±0.27 | 6.24±0.23 | 4.20±0.21 | *** |
| | *Ewe birth type (number and proportions)* | | | | | | | | |
| | Single | | 107 (12.50) | 112 (13.10) | 155 (18.10) | 91 (10.60) | 123 (14.40) | 160 (18.70) | |
| | Multiple | | 143 (16.70) | 124 (14.50) | 102 (11.90) | 180 (21.10) | 111 (13.00) | 78 (9.20) | |
| | Unknown | | 35 (4.10) | 49 (5.70) | 28 (3.30) | 14 (1.60) | 51 (6.00) | 47 (5.00) | |
| | *Lamb growth (number and proportions)* | | | | | | | | |
| | Fast | | 160 (18.70) | 177 (20.70) | 145 (17.00) | 217 (25.40) | 171 (20.00) | 94 (11.00) | |
| | Moderate | | 115 (13.50) | 76 (8.90) | 66 (7.70) | 66 (7.70) | 81 (9.50) | 110 (12.90) | |
| | Slow | | 10 (1.20) | 32 (3.70) | 74 (8.70) | 2 (0.20) | 33 (3.90) | 81 (9.50) | |
| Menz | Live weight, kg | 21.56±0.07 | 23.05±0.12 | 21.66±0.10 | 19.97±0.10 | 22.90±0.11 | 21.6±0.11 | 20.21±0.10 | *** |
| | Dentition | 3.74±0.02 | 3.76±0.03 | 3.72±0.04 | 3.73±0.04 | 3.76±0.03 | 3.67±0.04 | 3.78±0.03 | *** |
| | Number of lambing[a] | 4.48±0.06 | 4.30±0.11 | 4.40±0.11 | 4.74±0.10 | 5.11±0.13 | 4.21±0.10 | 4.10±0.07 | *** |
| | Number weaned | 4.07±0.06 | 4.32±0.11 | 4.09±0.11 | 4.210±0.11 | 4.09±0.13 | 3.90±0.10 | 3.40±0.08 | *** |
| | *Lamb growth (number and proportions)* | | | | | | | | |
| | Fast | | 426 (27.27) | 433 (27.72) | 385 (24.65) | 484 (30.99) | 434 (27.78) | 326 (20.87) | |
| | Moderate | | 24 (1.54) | 2 (0.13) | 25 (1.60) | 18 (1.15) | 5 (0.32) | 28 (1.79) | |
| | Slow | | 80 (5.12) | 86 (5.51) | 101 (6.47) | 23 (1.47) | 77 (4.93) | 167(10.69) | |

*NS*= not significant; * = p<0.05; ** = p<0.01; *** = p<0.001; [a]Number of lambing and number born are the same in this breed since twinning is nearly absent

### 3.4. Comparisons of own-flock and group-animal rankings

The likelihood of possible associations between ranks assigned to ewes by owners and non-owners (the latter before and after getting life history) were compared and given in Table 7. About 40%, 40%, and 25% of those ewes ranked as first, second and third best by owners in Bonga were also ranked first, second and third in the group-animal ranking experiment before respondents were provided with life history. However, the corresponding proportions were in the order of about 51%, 36%, and 31%, respectively, after life history. In Horro, about 35%, 33%, and 40% of those ewes ranked as first, second and third best by owners were ranked in the same manner by respondents without life history and 48%, 32% and 50% following provision of information.

Similarly, in Menz respondents' decisions conformed to owners' ranks by 40%, 37% and 29% before life history and by 45%, 37% and 40% after life history. Ewes ranked as inferior by the owners in Horro and Menz were found to be frequently ranked third (about 64% in Horro and 49% in Menz) even before getting information on their performance. The corresponding proportions after life history were about 70% and 65%, respectively, in the two locations. The number of inferior animals that were included in the experiment at Bonga was small. These relative conformities between rankings made by owners and other community members may be good indicators that traditional breeders have good insight in selecting breeding animals. Nevertheless, the improvements in rankings made following provisions of life history emphasize that performance information (i.e. records) on each animal need be maintained and made available, and used for selection decision.

Table 7. Comparisons of own-flock and group-animal rankings[a]

| Breed | Owners' rank | Group rank RBLH[b] 1 | 2 | 3 | RALH[c] 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| Bonga | Best | 144 (36.90) | 107 (27.40) | 139 (35.60) | 200 (51.30) | 114 (29.20) | 76 (19.50) |
| | 2nd best | 72 (30.00) | 95 (39.60) | 73 (30.40) | 33 (13.80) | 87 (36.30) | 120 (50.00) |
| | 3rd best | 84 (35.00) | 95 (39.60) | 61 (25.40) | 67 (27.90) | 98 (40.80) | 75 (31.30) |
| | Inferior | 0 | 3 (10.00) | 27 (90.00) | 0 | 1 (3.30) | 29 (96.70) |
| Horro | Best | 150 (35.20) | 158 (37.10) | 118 (27.70) | 205 (48.10) | 144 (33.80) | 77 (18.10) |
| | 2nd best | 100 (39.20) | 85 (33.30) | 70 (27.50) | 75 (29.40) | 82 (32.20) | 98 (38.40) |
| | 3rd best | 25 (43.10) | 10 (17.20) | 23 (39.70) | 3 (5.20) | 26 (44.80) | 29 (50.00) |
| | Inferior | 10 (8.60) | 32 (27.60) | 74 (63.80) | 2 (1.70) | 33 (28.40) | 81 (69.80) |
| Menz | Best | 339 (39.80) | 278 (32.70) | 234 (27.50) | 383 (45.00) | 281 (33.00) | 187 (22.00) |
| | 2nd best | 66 (19.20) | 128 (37.20) | 150 (43.60) | 75 (26.80) | 127 (36.90) | 142 (41.30) |
| | 3rd best | 63 (34.80) | 65 (35.90) | 53 (29.30) | 36 (19.90) | 72 (39.80) | 73 (40.30) |
| | Inferior | 38 (20.10) | 58 (30.70) | 93 (49.20) | 19 (10.00) | 47 (24.90) | 123 (65.10) |

[a]Numbers in parenthesis are proportions; [b]Rank before provision of life history; [c]Rank after provision of life history

## 4. Conclusions

The current set of studies clearly illustrated differences between pastoral, mixed crop-livestock and sheep-barley systems. Afar and Menz sheep breeders, coping with more challenging production environments, considered more attributes compared to the two crop-livestock systems. Animals with good adaptive potential are needed in such areas adding to the number of production or functional traits demanded of animals. Moreover, the pastoral community has in-depth traditional knowledge in animal husbandry.

Both own-flock and group-animal ranking experiments can serve as tools in objective traits identification in production systems without a practice of recording. However, while in own-flock ranking owners pay more attention to production and reproduction performances and behavioral traits, there was a general tendency to focus on observable attributes like coat color, tail type, ear size, body size, etc. in group-animal ranking. Therefore, group-animal ranking experiments must be complemented with real life history information. For future studies we recommend inclusion of equal number of animals from each rank category of the own-flock ranking experiments provided one desires to execute one after the other.

We found that traditional breeders value both economic and cultural traits; the latter would have been concealed when one uses conventional valuation methods. Thus, the ranking experiments approach is useful to elicit objective traits for designing breeding plans especially under traditional production systems where recording practices have not been in place. However, given the usually large number of attributes identified in such studies, only few priority traits should be included in designing breeding plans in order to keep them as simple as possible for easy implementation under farmers' or pastoralists' circumstances.

Using results of these and other preceding studies, the research team in partnership with agricultural research institutions in Ethiopia designed community-based sheep breeding plans for four indigenous breeds in the four different regions of Ethiopia that came into effect in May 2009 with the participation of eight communities.

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# CHAPTER FOUR

## Community-based alternative breeding plans for indigenous sheep breeds in four agro-ecological zones of Ethiopia

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**Summary**

*Based on the results of participatory approaches to define traits in the breeding objectives, 4 scenarios of ram selection and ram use were compared via deterministic simulation of breeding plans for community-based sheep breeding programs in four diverse regions of Ethiopia (Afar – pastoralist, Bonga and Horro – mixed crop-livestock and Menz – sheep-barley). Strong selection and short use of rams for breeding were the preferred options. Expected genetic gains are satisfactory but rely on continuous recording.*

Key words: Deterministic simulation; Breeding plans; Smallholders; Pastoralists

**Introduction**

Institutionalized and centralized sheep genetic improvement efforts were made for the last six decades in Ethiopia and have often failed to yield significant impacts at the farm level (Duguma *et al.,* 2010). Among the many reasons, dependence on imported technological packages, absence of structured breeding plans, acute shortage of technical proficiency, and limited involvement of relevant stakeholders particularly smallholder farmers/pastoralists in the planning and implementation of sheep improvement endeavors contributed to such failures. In Ethiopia this was particularly pronounced for a crossbreeding program with imported breeds as smallholders rejected the crossbreds when distributed for further breeding purposes because of phenotypic unlikeness to the indigenous ones (Tibbo 2006). This may also be due to incompatibility of the genotypes with the breeding objectives and management approaches of the low-input production systems in these areas (Ayalew *et al.* 2003; Kosgey *et al.* 2006).

In Ethiopia, there is no organized breeding plan for any of the farm animal species both at institutional or private large-scale farms and smallholders levels. Moreover, there is no binding breeding policy. Genetic improvement efforts targeting smallholder production systems are constrained by small animal numbers per household, single-sire flocks, lack of systematic animal identification, absence of performance and pedigree recording, illiteracy, poor infrastructure, and ill-functioning public institutions. The mobility of pastoral flocks poses additional difficulties in recording and selection.

A promising option for designing breeding schemes where communal grazing and watering points are customary is to consider the village population as one large flock or a breeding unit. In this case breeding animals are being selected based on phenotypes recorded within the village population. The primary aim of a breeding program for smallholder conditions should be to minimize the risk by developing cost- and resource-saving production methods, while achieving acceptable genetic gain in important breeding traits (Sölkner *et al.* 1998).

This study simulated the most appropriate breeding plans for four indigenous sheep breeds in different agro-ecological zones in Ethiopia. The simulations were based on comprehensive studies of breeding objectives and production systems (Edea 2008; Getachew 2008; Duguma *et al.,* 2010; Mirkena *et al.,* 2010).

## Materials and Methods

### Study areas and communities

The Simulated breeding programs target four locations (Afar, Bonga, Horro and Menz) representing different production systems and agro-ecologies that are habitat to four indigenous sheep breeds named after the location or the tribe keeping them. Each location is believed to be home tract to the respective sheep breed. In-depth description of the study areas is given in Duguma *et al.* (2010). In brief, pastoral/agro-pastoral in Afar, mixed crop-livestock in Bonga and Horro, and sheep-barley in Menz are the major production systems. Participating communities were identified based on information synthesized from diagnostic surveys and secondary information from respective district agriculture and rural development bureaus. Two communities per location consisting of 60 households each were organized using the following criteria: sheep population (≥ 420 breeding ewes), presence of communal grazing land, accessibility, and willingness of the community to participate in the sheep improvement project. Households with at least four breeding ewes were included as member of the breeding program.

**Determination of objective traits**

Trait preferences of pastoralists and farmers were studied using different approaches: production system studies (Edea 2008; Getachew 2008), hypothetical choice experiments (Duguma *et al.* 2010), own-flock and group-animal ranking experiments (Mirkena *et al.* 2010). The results obtained from these approaches are summarized in Table 1 for ewes and Table 2 for rams (note that the indices and proportions do not sum up to unity because some attributes with low preferences were omitted). In the production system studies, indices were calculated based on the following formula: index = [(3*proportion of respondents that ranked a trait as first + 2*proportion of respondents that ranked a trait as second + 1*proportion of respondents that ranked a trait as third for a particular attribute)/sum of (3*proportion of respondents that ranked a trait as first + 2*proportion of respondents that ranked a trait as second + 1*proportion of respondents that ranked a trait as third for all variables in question)]. The indices and ranks in parenthesis for ewe and ram traits are indicated under column headings "PS" of Tables 1 and 2.

Proc Logistic Regression (SAS, 2003) was employed to investigate traits preferences of sheep producers in the choice experiments. The magnitude of maximum likelihood estimates reveals the importance that is attached to each trait by the farmers/pastoralists. Findings from the own- and group-animal ranking experiments were ranked based on proportions. Related attributes/traits were pooled together (e.g., size, width, length, and fast growth of lambs as body size; lamb survival and lamb size/vigor at birth as mothering ability; conformation and appearance as appearance; color type and pattern as coat color; conformation, appearance, horn size and orientation, ear size in group-ranking as appearance). Weighted rank was computed as: $y = (a+b+c+d)/n$ for ewe traits and $z = (a+b+c)/n$ for ram traits, where *a, b, c* and *d* represent the rank of an attribute in a given study and *n* is the number of independent studies.

Depending on breeders' preferences, selected measurable objective traits to be used in the simulation of alternative breeding plans for each breed were limited to only three to keep it simple, in line with the anticipated implementation plans (i.e., under smallholder farmers'/pastoralists' circumstances). The three objective trait sets were: 1) milk yield, body size, and mothering ability in Afar; 2) body size, mothering ability and twinning in Bonga and Horro; and 3) body size, mothering ability and wool yield in Menz. Smallholders attach good mothering ability of a ewe mainly to its rearing ability (i.e., viability of its lambs at least to weaning) but also to lamb size/vigor at birth. Thus mothering ability is hereafter referred to as lamb survival.

Table 1. Ewe traits preferences from different studies and their weighted ranks

| Traits | Afar | | | | | Bonga | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PS (a) | CE (b) | OFR (c) | GR (d) | WR (y) | PS (a) | CE (b) | OFR (c) | GR (d) | WR (y) |
| Body size | 0.15 (3) | 0.79 (4) | 19.24 (1) | 24.44 (1) | 2.3 (2) | 0.28 (1) | -0.68 (6) | 30.47 (1) | 41.68 (1) | 2.3 (1) |
| Milk yield | 0.22 (1) | 1.32 (2) | 15.89 (3) | 9.71 (2) | 2.0 (1) | - | - | - | - | - |
| Mothering ability | 0.16 (2) | 2.32 (1) | 17.43 (2) | 4.92 (5) | 2.5 (3) | 0.08(6) | 3.98 (1) | 29.42 (2) | 3.27 (4) | 3.3 (2) |
| Lambing interval | 0.12 (4) | -0.03 (7) | 7.63 (4) | - | 5.0 (5) | 0.08 (5) | 1.41 (3) | 14.29 (3) | - | 3.7 (5) |
| Coat color | 0.10 (5) | 0.99 (3) | 7.24 (5) | 22.34 (3) | 4.0 (4) | 0.24 (2) | -0.40 (5) | 8.34 (4) | 17.92 (3) | 3.5 (4) |
| Tail type | 0.09 (6) | 0.62 (5) | 3.86 (6) | 15.92 (4) | 5.3 (6) | 0.14 (3) | 1.80 (2) | 0.95 (6) | 22.87 (2) | 3.3 (2) |
| Twinning | 0.09 (6) | 0.51 (6) | - | - | 6.0 (7) | 0.12 (4) | -0.04 (4) | 7.64 (5) | - | 4.3 (6) |
| | Horro | | | | | Menz | | | | |
| Traits | PS (a) | CE (b) | OFR (c) | GR (d) | WR (y) | PS (a) | CE (b) | OFR (c) | GR (d) | WR (y) |
| Body size | 0.35 (1) | 0.92 (4) | 26.4 (2) | 37.6 (1) | 2.0 (1) | 0.08 (5) | 0.6 (5) | 12.5 (3) | 34.32 (1) | 3.5 (3) |
| Mothering ability | 0.05 (4) | 3.3 (1) | 32.64 (1) | 4.46 (4) | 2.5 (2) | 0.22 (2) | 2.39 (1) | 41.29 (1) | 3.36 (4) | 2.0 (2) |
| Lambing interval | 0.01 (6) | 1.04 (2) | 13.83 (3) | - | 3.7 (3) | 0.31 (1) | 1.85 (2) | 17.9 (2) | - | 1.7 (1) |
| Coat color | 0.23 (2) | -0.31 (6) | 4.92 (5) | 24.38 (2) | 3.8 (4) | 0.12 (4) | 0.23 (6) | 7.8 (4) | 18.98 (2) | 4.0 (5) |
| Tail type | 0.09 (3) | 0.73 (5) | 1.97 (6) | 18.58 (3) | 4.3 (6) | 0.05 (6) | 0.85 (3) | 1.91 (5) | 9.54 (3) | 4.3 (6) |
| Twinning | 0.02 (5) | 0.97 (3) | 6.66 (4) | - | 4.0 (5) | 0.16 (3) | 0.74 (4) | - | - | 3.5 (3) |
| Wool | - | - | - | - | - | - | - | 0.88 (6) | 0.84 (5) | 5.5 (7) |

PS = production system studies; CE = choice experiments; OFR = own-flock ranking experiments; GR = group-ranking experiments; WR = weighted ranks

Table 2. Ram traits preferences from different studies and their weighted ranks

| Traits | Afar | | | | Bonga | | | |
|---|---|---|---|---|---|---|---|---|
| | PS (a) | CE (b) | GR (c) | WR (z) | PS (a) | CE (b) | GR (c) | WR (z) |
| Body size | 0.52 (1) | 1.09 (2) | 23.35 (1) | 1.3 (1) | 0.40 (1) | 1.35 (4) | 31.69 (1) | 2.0 (1) |
| Coat color | 0.15 (3) | 1.29 (1) | 20.43 (2) | 2.0 (2) | 0.28 (2) | 1.43 (3) | 22.38 (3) | 2.7 (3) |
| Tail type | 0.21 (2) | 0.98 (3) | 17.59 (3) | 2.7 (3) | 0.27 (3) | 2.94 (1) | 25.59 (2) | 2.0 (2) |
| Libido | 0.11 (4) | 0.77 (4) | 8.30 (4) | 4.0 (4) | 0.03 (4) | 2.30 (2) | 0.41 (7) | 4.3 (5) |
| Body condition | - | - | 6.65 (6) | 6.0 (7) | - | - | 3.01 (6) | 6.0 (8) |
| Type (Dairy) | - | - | 4.42 (7) | 7.0 (8) | - | - | - | - |
| Body conformation | - | - | 6.93 (5) | 5.0 (5) | - | - | 5.65 (4) | 4.0 (4) |
| Hair type | - | - | 2.39 (8) | 8.0 (9) | - | - | 4.68 (5) | 5.0 (6) |
| Horn | 0.01 (5) | 0.67 (5) | - | 5.0 (5) | 0.01 (5) | 0.15 (5) | - | 5.0 (6) |

| Traits | Horro | | | | Menz | | | |
|---|---|---|---|---|---|---|---|---|
| | PS (a) | CE (b) | GR (c) | WR (z) | PS (a) | CE (b) | GR (c) | WR (z) |
| Body size | 0.43 (1) | 1.10 (3) | 25.61 (1) | 1.7 (1) | 0.53 (1) | 2.92 (1) | 31.31 (1) | 1.0 (1) |
| Coat color | 0.22 (3) | 0.5 (4) | 23.42 (2) | 3.0 (3) | 0.2 (2) | 0.74 (3) | 14.81 (2) | 2.3 (2) |
| Tail type | 0.28 (2) | 1.53 (2) | 21.22 (3) | 2.3 (2) | 0.18 (3) | 0.21 (5) | 14.79 (3) | 3.7 (4) |
| Libido | 0.002 (5) | 1.79 (1) | - | 3.0 (3) | 0.04 (4) | 1.7 (2) | - | 3.0 (3) |
| Body condition | - | - | 4.47 (5) | 5.0 (6) | - | - | 5.82 (7) | 7.0 (8) |
| Body conformation | - | - | 12.89 (4) | 4.0 (5) | - | - | 11.27 (4) | 4.0 (5) |
| Hair type | - | - | 1.78 (7) | 7.0 (8) | - | - | - | - |
| Horn | 0.01 (4) | - | 2.73 (6) | 5.0 (6) | 0.03 (5) | 0.64 (4) | 8.32 (5) | 4.7 (6) |
| Ear size | - | - | - | - | 0.02 (6) | - | 5.95 (6) | 6.0 (7) |
| Wool | - | - | - | - | 0.004 (7) | - | 1.22 (8) | 7.5 (9) |

PS = production system studies; CE = choice experiments; GR = group-ranking experiments; WR = weighted ranks

Wool yield in Menz sheep was included as one of the breeding objective traits because of its invaluable contribution to adaptive ability in the extremely cool tepid high altitude despite being lowly ranked. Some traits with relatively higher rank values were intentionally excluded from the breeding objectives due to various reasons. Since animals may be selected independently for desired coat color and tail types, it is not worthwhile to include them in simulations. Genetic and phenotypic parameter estimates are totally lacking regarding lambing interval, a trait highly ranked in Menz and Horro. Finally, the following selection criteria were set to be used for each breeding objective traits:

1. Yearling weight (kg) for body size (all breeds),
2. Milk yield (g) for milk yield (Afar),
3. Number of lambs born/year/ewe joined for twinning (Bonga and Horro),
4. Number of lambs weaned/ewe joined for lamb survival (all breeds), and
5. Yearling greasy fleece weight (kg) for wool yield (Menz).

**Simulation methods**

The computer program ZPLAN (Willam *et al.* 2008) was used to model the alternative breeding programs. ZPLAN is designed to optimize breeding strategies in livestock breeding by deterministic calculations. This computer program is based on comprehensive evaluation of both genetic and economic efficiencies of breeding strategies considering one cycle of selection. Important outcomes of ZPLAN include annual monetary genetic gain for the aggregate genotype, annual genetic gain for each single trait, discounted return and discounted profit for a given investment period. The gene flow method (Hill 1974; McClintock and Cunningham 1974) and selection index procedure constitute the core of the program. For the selection index part, information available for the evaluation of an individual candidate have to be defined by the number and type of relatives contributing to the index of an animal as well as records on individual's own performance (Willam *et al.* 2002). For the current simulation, proportions chosen were based on individual performance (yearling weight for all breeds and yearling greasy fleece weight for Menz) and maternal information (lamb survival in all breeds, milk yield in Afar, and twinning in Bonga and Horro). For further information on ZPLAN, see Nitter *et al*. (1994).

For each breed, a breeding unit consisting of four selection groups was defined. Both generation and dissemination of genetic gain occur within this single unit. The selection groups are defined as: 1) rams to breed rams (RM>RM), 2) rams to breed ewes (RM>EW), 3) ewes to breed rams (EW>RM), and 4) ewes to breed ewes (EW>EW).

Essential input parameters for ZPLAN are given in Table 3. The average population size of breeding ewes and lamb survival to weaning (the latter used to approximate survival to yearling) were based on flock inventory taken from each community member household during the 'own-flock ranking experiment' while information on reproductive performance were mainly obtained from the production system studies (Edea 2008; Getachew 2008). In addition, published reports based on on-station and on-farm studies (Galal 1983; Abegaz 2002; Matika *et al.* 2003; Gizaw *et al.* 2007; Afolayan *et al.* 2009) were consulted for the phenotypic and genetic parameter estimates (Table 5).

ZPLAN cannot consider reduced genetic variance due to selection (Bulmer effect) and inbreeding. Rates of inbreeding per generation (ΔF) were estimated using a formula $\Delta F=(1/(8N_m))+(1/(8N_f))$, where $N_m$ and $N_f$ refer to number of male and female breeding animals, respectively, relating to the effective population size

(Falconer and MacKay 1996). During the simulation, we first defined and evaluated a breeding program considering a ten percent selection proportion and two time units (TU) of ram use for breeding. One TU is usually one year for sheep (Nitter *et al.* 1994). Then alternative testing schemes with regard to variation of these two factors (either 10% or 15% selection proportion and either 2 or 3 years of ram use) were run and evaluated. Thus the following four alternative schemes were simulated.

Scheme 1: 10% selection proportion and 2 years of ram use for breeding

Scheme 2: 10% selection proportion and 3 years of ram use for breeding

Scheme 3: 15% selection proportion and 2 years of ram use for breeding

Scheme 4: 15% selection proportion and 3 years of ram use for breeding

Flock projection for each breed was done considering the population and biological parameters given in Table 3. For instance, in Afar, given a population of breeding ewes of 670 with 90% fertility, 85% lambing rate, 1.06 twinning rate, a lambing interval of 0.75 years (1.34 lambing per TU), 75% lamb survival to yearling and a sex ratio of 50%, the projection yields 273 yearling candidate rams (i.e., 670*0.9*0.85*1.06*1.34*0.75*0.5 = 273).

Table 3. Input parameters for simulation of alternative breeding plans

| Parameters | Afar | Bonga | Horro | Menz |
|---|---|---|---|---|
| *Population parameters* | | | | |
| Population size (ewes) | 670 | 650 | 650 | 650 |
| Number of proven males/year | 273 | 352 | 362 | 260 |
| Proportion of rams selected | 0.15; 0.10 | 0.15; 0.10 | 0.15; 0.10 | 0.15; 0.10 |
| *Biological parameters* | | | | |
| Breeding ewes in use (years) | 5 | 5 | 5 | 5 |
| Breeding rams in use (years) | 2; 3 | 2; 3 | 2; 3 | 2; 3 |
| Mean age of rams at birth of first offspring (years) | 1.5 | 1.5 | 1.5 | 1.5 |
| Mean age of ewes at birth of first offspring (years) | 1.5 | 1.5 | 1.5 | 1.5 |
| Fertility (conception rate) | 0.90 | 0.90 | 0.90 | 0.90 |
| Lambing rate | 0.85 | 0.85 | 0.85 | 0.85 |
| Mean time period between subsequent lambings (years) | 0.75 | 0.71 | 0.61 | 0.71 |
| Mean number of lambs per litter (litter size) | 1.06 | 1.34 | 1.34 | 1.02 |
| Mean number of lambs/ewe/year | 1.34 | 1.41 | 1.45 | 1.40 |
| Lamb survival to yearling (%) | 75 | 75 | 75 | 75 |
| *Cost parameters* | | | | |
| Animal identification and drugs (€)/ewe/year† | 2.80 | 2.89 | 2.93 | 2.87 |
| Performance recording and monitoring (€)/ewe/year | 0.63 | 0.65 | 0.65 | 0.65 |
| Interest rate return (%) | 0.03 | 0.03 | 0.03 | 0.03 |
| Interest rate costs (%) | 0.075 | 0.075 | 0.075 | 0.075 |
| Investment period (years) | 15 | 15 | 15 | 15 |

†1€ = 18.36705 Ethiopian Birr (ETB) based on exchange rate on December 29, 2009

Following Nitter *et al.* (1994), only costs that are additional to normal husbandry practices of smallholder farmers/pastoralists were assumed. These were costs of enumerators to do the performance and pedigree recording as well as items used for animal identification per individual breeding ewe. The costs were computed as follows taking one of the communities at Afar with 670 breeding ewes as an example:

- Enumerator: 27.22€/month = 326.67€/year; 326.67€/670 ewes ≈ 0.49 €/ewe
- Stationary items for 60 members = (60*1.6333€)/670 ewes ≈ 0.14€/ewe/year
- Identification: 2 tags/animal/year (a ewe and her 1.34 lambs/year) = 2*2.34*0.2722 ≈1.27 €/year
- Drugs: 0.6533€/animal/year = 2.34 (a ewe plus 1.34 lambs/year)*0.6533 ≈1.53€/ewe/year

Information on economic values of sheep traits as well as marketing is generally lacking in the country. Relative economic weights given in Table 4 for all traits in Afar and Menz breeds and yearling weight in Bonga and Horro breeds were computed by standardizing the indices calculated based on breeders' preferences with the additive genetic standard deviation ($\sigma_A$) whereas estimates by Gebre *et al.* (2010) were used for the rest. However, it should be borne in mind that these values are approximations but can serve as fair economic estimates where information is lacking.

Table 4. Selection criteria and their relative economic weights, phenotypic ($\sigma_P$) and genetic ($\sigma_A$) standard deviations

| Objective traits | Selection criteria† | Unit | Economic Weight (€) | $\sigma_P$ | $\sigma_A$ | $\sigma_P / \sigma_A$ |
|---|---|---|---|---|---|---|
| *Afar* | | | | | | |
| Body size | YWt | kg | 0.31 | 3.486 | 1.85 | 1.88 |
| Milk yield | MiY | kg | 1.14 | 0.67 | 0.211 | 3.17 |
| Lamb survival | NLW | % | 2.12 | 0.379 | 0.085 | 4.46 |
| *Bonga* | | | | | | |
| Body size | YWt | kg | 0.163 | 6.36 | 3.6535 | 1.741 |
| Twinning rate | NLB | % | 3.60 | 0.37 | 0.1433 | 2.582 |
| Lamb survival | NLW | % | 3.16 | 0.66 | 0. 132 | 5.00 |
| *Horro* | | | | | | |
| Body size | YWt | kg | 0.235 | 6.36 | 3.6535 | 1.741 |
| Twinning rate | NLB | % | 3.60 | 0.37 | 0.1433 | 2.582 |
| Lamb survival | NLW | % | 3.16 | 0.66 | 0. 132 | 5.00 |
| *Menz* | | | | | | |
| Body size | YWt | kg | 0.32 | 3.486 | 2.205 | 1.58 |
| Wool yield | GFW | kg | 0.10 | 0.167 | 0.105 | 1.59 |
| Lamb survival | NLW | % | 3.14 | 0.379 | 0.085 | 4.46 |

†YWt = yearling weight; MiY = milk yield; NLW = number of lambs weaned/ewe; NLB = number of lambs born/ewe/lambing; GFW = greasy fleece weight.

Table 5. Phenotypic (upper triangle), genetic (lower triangle) correlations and heritabilities (diagonal, in bold) of the traits of the four sheep breeds

| Variables | Afar | | | Bonga | | | Horro | | | Menz | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | YWt | MiY | NLW | YWt | NLB | NLW | YWt | NLB | NLW | YWt | GFW | NLW |
| YWt | **0.28** | 0.10 | 0.10 | **0.33** | 0.00 | 0.10 | **0.33** | 0.00 | 0.10 | **0.40** | 0.42 | 0.10 |
| MiY/NLB/GFW | 0.20 | **0.10** | 0.07 | 0.00 | **0.15** | 0.15 | 0.00 | **0.15** | 0.15 | 0.46 | **0.39** | 0.00 |
| NLW | 0.30 | 0.53 | **0.05** | 0.30 | -0.20 | **0.04** | 0.30 | -0.20 | **0.04** | 0.30 | 0.00 | **0.05** |

**Results and Discussion**

The predicted annual genetic gain for each selection criterion used is presented in Table 6. The highest annual genetic gains in yearling weight were obtained from scheme 1 (10% selection proportion and 2 years of ram use for breeding) whereas the lowest from scheme 4 (15% selection proportion and 3 years of ram use for breeding) for all breeds. The responses from all schemes may be considered satisfactory and can result in appreciable genetic improvement of these sheep breeds under smallholder breeders' management practices. Literature reports on similar sheep breeding schemes under tropical conditions are generally lacking. Gizaw *et al.* (2009) predicted an annual aggregate response of 0.492 to 0.704 kg for yearling weights of Menz sheep under village-based breeding schemes applying selection proportions ranging from 5 – 20%. In another report from on-station selection experiment conducted between 1998 and 2003, Gizaw *et al.* (2007) indicated average annual genetic response of 0.67 kg in yearling weight for selected group in Menz flock.

The genetic gain in milk yield was in the range of 18 g in scheme 4 to 20 g in scheme 1 per year for Afar breed. Afar breed was reported to have a lactation length of about 114 days, a milk yield of 224 ml/day which translates to a lactation yield of 25.53 kg (Galal 1983; Getachew 2008). The predicted annual genetic gain, if realized, will result in 2.28 kg milk per lactation. In their extensive review on Awassi sheep, Galal *et al.* (2008) indicated the difference between the milk line and control line to be 19.6 kg (=13.5%) in 1977 and 100.6 kg (=78.6%) in 1995. However, the level and duration of Awassi improvements were different for the countries that implemented the programs. For instance, the phenotypic average lactation milk production increased from 297 kg in 1940's to over 500 kg in 1990's in Israel, a selection program in Syria succeeded to increase lactation milk yield from 128 kg in 1974-76 to 335 kg in 2005, while it increased from 67 kg to 152 kg in a selection/crossing program that run for seven years in Turkey (Galal *et al.* 2008).

Table 6. Genetic gain year$^{-1}$ for the breeding objective traits in different schemes

| Schemes and traits | Afar | Bonga | Horro | Menz |
|---|---|---|---|---|
| *Scheme 1 ($r_{IH}$)* | *0.263* | *0.214* | *0.222* | *0.297* |
| Yearling weight | 0.440 | 0.894 | 0.940 | 0.699 |
| Milk yield/Number born/GFW‡ | 0.020 | 0.010 | 0.010 | 0.009 |
| Number weaned | 0.009 | 0.010 | 0.011 | 0.011 |
| *Scheme 2 ($r_{IH}$)* | *0.264* | *0.214* | *0.222* | *0.298* |
| Yearling weight | 0.422 | 0.854 | 0.896 | 0.669 |
| Milk yield/Number born/GFW | 0.019 | 0.010 | 0.009 | 0.009 |
| Number weaned | 0.009 | 0.010 | 0.010 | 0.010 |
| *Scheme 3 ($r_{IH}$)* | *0.263* | *0.216* | *0.222* | *0.293* |
| Yearling weight | 0.413 | 0.871 | 0.885 | 0.639 |
| Milk yield/Number born/GFW | 0.019 | 0.009 | 0.009 | 0.006 |
| Number weaned | 0.009 | 0.010 | 0.010 | 0.010 |
| *Scheme 4 ($r_{IH}$)* | *0.264* | *0.214* | *0.222* | *0.294* |
| Yearling weight | 0.399 | 0.813 | 0.850 | 0.616 |
| Milk yield/Number born/GFW | 0.018 | 0.009 | 0.009 | 0.006 |
| Number weaned | 0.008 | 0.009 | 0.010 | 0.010 |

‡Milk yield for Afar breed; Number born for Bonga and Horro breeds; Greasy fleece weight (GFW) for Menz breed

The predicted responses year$^{-1}$ and generation$^{-1}$ for number of lambs born per ewe joined ranged from 0.9 to 1.0% and 2.34 to 2.90%, respectively, were of the same magnitude for the two breeds in the mixed crop-livestock systems. These levels of improvements may be considered encouraging under farmers' management conditions in the tropics. Cloete *et al.* (2004) reported genetic changes that were in the order of 1 – 2% year$^{-1}$ for selected Merino lines as substantial.

Regarding response in number of lambs weaned per ewe joined, it was similar in the sheep-barley system and the two crop-livestock systems except in schemes 1 and 4 of Bonga. The gain was relatively low in the lowland pastoral system. The values were in the range of 0.9 –1.1% in the former systems and 0.8 – 0.9% in the latter. Gains in both numbers of lambs born and weaned per ewe joined may appear very insignificant; however, the slightest improvements in these aggregate traits (number born and weaned) would lead to sizable gain in terms of overall change.

Genetic gain per generation for greasy fleece weight (kg) was 0.024, 0.026, 0.016 and 0.017 in schemes 1 – 4, respectively. Comparable gains (0.016 – 0.022) were predicted for the same breed under village-based breeding schemes applying selection proportions ranging from 5 – 20% (Gizaw *et al.* 2009). A 0.012 kg mean annual genetic response to selection was also reported by Gizaw *et al.* (2007) in an on-station study conducted over 5 years period.

The accuracy of selection for Afar, Bonga, Horro and Menz was 0.263 – 0.264, 0.214 – 0.216, 0.222, and 0.293 – 0.298, respectively. Comparable accuracy values of 0.208 and 0.209 for male and female selection groups, respectively (Nitter *et al.* 1994) and values ranging from 0.21 to 0.34 (Graser *et al.* 1994) were reported for breeding schemes of Australian beef cattle. The latter indicated accuracy increased with increased intensity of recording.

The monetary genetic gain (mΔG), selection intensity, mean generation interval, and number of selected and replaced rams year$^{-1}$ for the different schemes are given in Table 7. mΔG, measure of the monetary superiority year$^{-1}$ of the progeny of the selected animals of one selection cycle, was comparatively high in scheme 1 and low in scheme 4 for all breeds. Genetic gain is influenced by accuracy of selection, selection intensity, generation interval, and heritability of the trait under consideration. Accuracy, as indicated above, was nearly similar among the schemes. One would expect a higher mΔG in scheme 2 given the highest selection intensity of about 2.21 in all breeds. However, the longer generation interval in this scheme resulted in less gain year$^{-1}$ compared to scheme 1, both with 10% selection proportion but differing in years of ram use.

The approximated rates of inbreeding, in percentage, at 10 and 15% selection proportions were 0.48 and 0.32 for Afar, 0.39 and 0.26 for Bonga, 0.37 and 0.25 for Horro and 0.50 and 0.33 for Menz. Gizaw *et al.* (2009) estimated an inbreeding rate of 1.35% under 10% proportion of selection for village-based sheep breeding scheme. Wurzinger *et al.* (2008) reported slightly lower values in a breeding program designed for Bolivian llama.

The discounted profits ewe$^{-1}$ in schemes 1 – 4 were: 2.366, 2.142, 2.165, and 1.978€ for Afar; 2.662, 2.392, 2.344, and 2.221 for Bonga; 2.888, 2.595, 2.645, and 2.400 for Horro; and 2.825, 2.556, 2.532, and 2.312€ for Menz. However, these values must be seen with caution since economic weights attached to the selection criteria and the costs were only approximation.

Even though the selection to genetically improve the sheep breeds considered in these simulations envisages selection on rams, the predicted returns are not entirely from the ram selection groups alone. Young ewes selected as replacements also contribute to the returns. Relative contributions from the ram and ewe selection groups or pathways to returns from selections differed little among schemes ranging between 72.74 – 76.55 and 23.45 – 27.26 % in Afar, 67.92 – 70.04 and 29.96 – 32.08% in Bonga, 67.24 – 69.53 and 30.47 – 32.76% in Horro, and 72.48 – 76.46 and 23.54 – 27.52% in Menz for rams and ewes, respectively.

Table 7. Monetary genetic gain year$^{-1}$, selection intensity, mean generation interval, and number of selected and replaced rams year$^{-1}$ for the different schemes

| Schemes | Afar | Bonga | Horro | Menz |
|---|---|---|---|---|
| *Scheme 1* | | | | |
| mΔG (€) | 0.410 | 0.531 | 0.557 | 0.501 |
| Selection intensity | 2.048 | 2.049 | 2.052 | 2.053 |
| Generation interval | 2.675 | 2.627 | 2.602 | 2.627 |
| Number selected | 27 | 34 | 36 | 26 |
| Number replaced | 14 | 17 | 18 | 13 |
| *Scheme 2* | | | | |
| mΔG (€) | 0.393 | 0.507 | 0.531 | 0.479 |
| Selection intensity | 2.207 | 2.210 | 2.211 | 2.210 |
| Generation interval | 2.946 | 2.897 | 2.873 | 2.897 |
| Number selected | 27 | 34 | 36 | 26 |
| Number replaced | 9 | 12 | 12 | 9 |
| *Scheme 3* | | | | |
| mΔG (€) | 0.385 | 0.486 | 0.525 | 0.464 |
| Selection intensity | 1.875 | 1.883 | 1.871 | 1.874 |
| Generation interval | 2.675 | 2.627 | 2.602 | 2.627 |
| Number selected | 41 | 52 | 55 | 40 |
| Number replaced | 21 | 26 | 28 | 20 |
| *Scheme 4* | | | | |
| mΔG (€) | 0.372 | 0.482 | 0.503 | 0.447 |
| Selection intensity | 2.043 | 2.055 | 2.042 | 2.042 |
| Generation interval | 2.946 | 2.897 | 2.873 | 2.897 |
| Number selected | 41 | 52 | 55 | 40 |
| Number replaced | 14 | 17 | 18 | 13 |

We designed alternative community-based breeding programs to be implemented in different production systems. The choice of specific scheme for implementation entirely depends on the decision of each community. However, even though the breeding program will be owned and managed by the community, technical assistance will be provided from national and international research institutions involved in the initiation and planning of the alternative breeding schemes. The need to form ram-groups based on settlements and social networking is believed crucial to facilitate use of selected rams for breeding. The communal grazing management system in all studied areas except Bonga may also enhance transmission of genes from selected rams despite associated risks of inbreeding. Rams should be used only for a single year in a given ram-group flocks and then exchanged with a distant ram-group. This will serve at least two major purposes: it minimizes inbreeding and creates genetic links across different flocks. Selection of a breeding ram is based on information sources such as individual growth performance and dam's rearing ability (number of lambs weaned/ewe joined) for all breeds, milk yield of dam in Afar, maternal prolificacy (twinning) in Bonga and Horro and own greasy fleece weight in Menz. Only rams born to second or higher parity ewes are selected for breeding.

Recording is a prerequisite for any planned genetic improvement endeavors but it has to be simple with limited number of traits for smallholders' management conditions. We propose recordings be taken on birth, weaning and yearling weight parameters, number born and weaned per ewe joined for all breeds and additional milk and greasy fleece yields for Afar and Menz breeds, respectively.

**Conclusion**

Different approaches were used to determine breeding objective traits of smallholder farmers/pastoralists in four different production environments of Ethiopia. Production system studies, choice experiments, and own-flock ranking experiments can independently depict smallholders' preferences for sheep breeding traits with slight variations.

The responses year$^{-1}$ and generation$^{-1}$ in yearling weight, number of lambs born and weaned per ewe joined, milk yield, and greasy fleece weight obtained from the simulated schemes, though slightly different, may be considered satisfactory and can result in reasonable genetic improvements of these sheep breeds under smallholder breeders' management practices. Realization of these predictions, however, largely relies on accurate recording and record keeping, estimation of reliable breeding values, monitoring and/or guidance, and motivation of the smallholder breeders.

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# CHAPTER FIVE

## General discussion

Sheep breeding objectives of smallholder farmers in Bonga (Southwestern), Horro (western), and Menz (central north) and of pastoralists in Afar (eastern) areas of Ethiopia were studied. These areas represent different agro-ecological zones and production systems. The objective traits were studied using two types of phenotypic ranking of live animals, own-flock and group-animal ranking experiments, as described in Chapter 3. Findings from these studies were combined with those from preceding studies (production systems and sheep breed characterization (Edea, 2008; Getachew, 2008) and choice experiments (Duguma et al., 2010a)) to derive weighted values for traits. Then traits were ranked and prioritized to decide which ones to include in the simulation of production system specific alternative breeding plans (Chapter 4).

Local breeds have irreplaceable cultural, historical, socio-economic, and environmental values, in addition to be important sources of genetic variation both for production and adaptive qualities (Hiemstra et al., 2010). Genetic improvement program can serve as a vehicle to improved livestock production in the broader sense (Olivier et al., 2002). Adaptive fitness is characterized by survival, health and reproductive related traits (Chapter 2). In tropical areas, where pathogens and epidemic diseases are widespread, climatic conditions are stressful, and feed and water are scarce, locally adapted autochthonous breeds display far greater level of resistance and adaptation due to their evolutionary roots as compared to imported breeds. Strategies for livestock improvement schemes in low- and medium-input production systems should focus on the use of such adapted indigenous populations.

Another equally important point to note is the need to integrate breeding intervention with the needs and demands of local communities. Numerous genetic improvement programs in the tropics failed to reach their intended targets mainly because breeding goals of the farmers were poorly understood and the interventions were imposed upon the farmers in a top-down approach. Technical competence of the executing agencies has been inadequate also. In Ethiopia, sheep improvement for meat and wool production was attempted for long time through crossbreeding (e.g. local Menz with Corriedale, Hampshire or Romney at different times) but failed because the crossbreds did not meet farmers' phenotypic preferences for horns and tails (Tibbo, 2006; Gizaw and Tesfaye, 2009). In the Andean region of the Americas, genetic improvement intervention was focused on wool production by crossing naturalized Criollo that lambs year round with a seasonal Corriedale sheep. The program frustrated the community of farmers when many of the crossbreds failed to reproduce under the usual pattern and therefore did not produce lambs when price was higher or milk for highly demanded cheese through extended lactation (Iniguez, 1998). According to the author, Criollo sheep have accelerated lambing and extended lactations indicating that both the introduced and native breeds were not appropriately evaluated for their comparative merits. In Republic of Korea, Boer goats were used for crossbreeding with the native black goats to satisfy increased demand for meat in the 1990s. However, the crossbreds failed to become popular despite their better growth rates because they did not have the same black coat as the local goats (FAO, 2010). Mismatches between breeding objectives of such programs and those of farmers could have been avoided by involving farmers in the planning and implementation procedures.

The phenotypic live animal ranking approaches (Chapter 3) were found to be effective in eliciting breeding objectives of smallholders and pastoralists as the techniques enabled respondents to exhaustively describe an animal. Nevertheless, it was observed that in group-ranking experiments respondents mainly focused on attributes that can visually be judged. In own-flock ranking, owners gave more attention to production, reproduction and behavioral attributes. These approaches can further be refined in the future. For example, respondents may be asked to attach value or price to each attribute of an animal or an aggregate price to the animal itself. Obtaining estimates of economic values of traits is one of the hurdles to model genetic improvement programs in the tropics. We standardized the relative weights attached to traits by farmers/pastoralists with the additive genetic standard deviation of the trait for the current simulations. Such weighted and standardized values may serve as a bench mark. Alternatively, panel of professionals who are familiar with the cost and return structure of the enterprise may assign relative weights to traits, in percentage or proportion, as described in FAO guidelines for development of breeding strategies in low input production systems (FAO, 2010). Under smallholders' conditions, the returns may be the relative contribution of traits to household's livelihood.

Genetic and phenotypic parameter estimates (heritability, variance/standard deviation, and correlation) of traits are not widely available for many of the breeds of livestock in Ethiopia as elsewhere in developing countries. Published reports on other tropical sheep breeds were consulted and weighted estimates were derived whenever breed specific information was unavailable for the current simulation studies (Chapter 4). Results of the simulations predicted satisfactory genetic gains that will enable to achieve reasonable genetic improvements in the target sheep breeds under smallholder breeders' management practices.

The designed alternative breeding plans were presented to each community for decision which specific scheme to implement. As of May 2009, the selected scheme is being translated into practical selection activities. Werer, Bonga, Bako, and Debre Berhan Agricultural Reseach Centers follow up the routine implementation activities at Afar, Bonga, Horro, and Menz, respectively. Details of implementation procedures are given in Duguma et al. (2010b).

Implementation of a community-based livestock breed improvement has not been attempted widely beyond theoretical explanations and hence only very few field reports exist. One such example is alpaca breeding in Peru by communities (Iniguez, 1998); a report that indicated community farmers can be successful in applying breeding technologies. Still it is possible to draw lessons from experiences of some successful genetic improvement programs from the tropical areas (e.g. dairy and sheep improvement in Brazil (Mariante et al., 2010); Boer goat and Doprer sheep development in South Africa (Ramsay et al., 2000)). Similar to our studies, overriding trait in the breeding programs of Boer and Dorper development was adaptability, i.e. ability to survive unfavorable conditions, ability to reproduce regularly and ability of lambs to grow rapidly to a marketable size (Ramsay et al., 2000).

For improvement programs to be sustained by producers, the benefits from improved production must be tangible in the short-term and preferably experienced all year round (Olivier et al., 2002). Thus increasing the current off-take rate through enhancing access to market will be of principal importance. It will be advantageous to further characterize not only the breeds used for the current studies but also other sheep genetic resources in the country to identify their unique qualities and fill market niches. Ermias et al. (2002) compared Menz and Horro sheep breeds and concluded that Menz had stronger genetic tendency to fatness (in storing marbled fat) than Horro. Though further investigations are needed to substantiate such conclusions, it may be speculated that Menz sheep might have better acceptance from consumers with good taste for fat or marbled meat whereas Horro sheep might be preferred by consumers who need leaner meat. Gizaw et al. (2008) prioritized sheep breeds in Ethiopia based on analysis of current merit and found that sub-alpine (a cluster that includes Menz sheep) and arid lowland (Afar and Black Head Somali) breeds contribute most to farmer/pastoral livelihoods in comparison to other breeds. Organizing the communities into breeder or producer cooperatives would empower them to access inputs and marketing opportunities. Moreover, creation of market systems that pay premium price for breeding animals is highly essential.

To realize the full benefit of genetic improvement, all aspects of animal husbandry such as nutrition, health and marketing should be recognized and addressed in a comprehensive approach. Integration of balanced approaches into improvement interventions ensures response to the needs of producers as well as the markets. The effects of climate change, land degradation and recurrent drought have become so immense in Afar and Menz. Shift in production system from a mixed crop-livestock to sheep-barley has already occurred in Menz as a consequence. Policy intervention that promotes specialization in livestock (sheep) production in areas like Menz is expected to safeguard both the community and the environment. Indeed, land use policy must be developed and ratified for the whole country. Equally urgent is the preparation and enforcement of livestock breeding policy addressing major species of farm animals.

The consequence of genetic improvement on the adaptive ability of the animals as gain in target traits progresses (e.g. ability to move in extensive grazing conditions, possessing and maintaining the required adaptive traits, and ability to graze efficiently without becoming voraciously destructive to the environment) should be closely monitored.

Finally, launching a national recording and evaluation schemes for the different species of livestock is suggested. Lessons from the current community-based breeding programs should be used to up- and out-scale in other areas and species. Government must be committed to establish an institute (e.g. Ethiopian Institute of Animal Genetic Resources) responsible for such tasks.

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# Summary

In traditional production systems, sheep are kept for multiple purposes such as income, food, manure, fiber, insurance mainly against crop failures, savings, socio-cultural and ceremonial. Predominantly indigenous breeds are kept in Ethiopia and level of production and productivity has generally been too low. Genetic improvement efforts focused on importation of exotic breeds for crossbreeding with local ones but invariably failed to boost performance.

Information on genetics of adaptation in major livestock species was reviewed as presented in **Chapter 2**. Adaptation to humans and consequences of domestication on predator aversion, mechanisms of adaptation to available feed and water resources, severe climates and genetic evidence of disease tolerance or resistance were covered. For genetic improvement programs to be successful, the review concluded the importance of identifying the most appropriate and adapted genotypes capable of coping with environmental challenges posed by the production systems.

Participatory approaches were used to study smallholders' sheep breeding objectives **(Chapter 3)**. Live animals ranking experiments, own-flock and group-animal ranking, were carried out. For the own-flock ranking experiment, a total of 471 households were visited at their homesteads and were asked to choose the best, 2nd best, 3rd best and an inferior ewe in the flock. Reasons for the ranking and life history of the animals were inquired, live weight and linear measurements were taken. Ten separate group-animal ranking experiments were conducted, each involving 15 ewes and 15 rams. Animals of same sex were randomly assigned to five groups of three animals each and put in pens. Thirty respondents belonging to the other community of the region and therefore unfamiliar with the experimental animals were invited to do the ranking. Each person ranked the three animals in a pen as 1st, 2nd, and 3rd, giving reasons for the ranking order. The person was then provided with life history of each animal and asked whether, given these additional information on each of the animals, s/he would consider re-ranking them. The procedure was repeated ten times until a respondent covered all groups of ewes and rams. In own-flock ranking, owners paid more attention to production and reproduction performances and behavioral traits (e.g., milk yield, temperament, lamb growth, mothering ability, body size, lambing interval). In group-animal ranking, observable attributes like coat color, tail type, ear size, body size, etc. recurred. Afar and Menz sheep breeders, coping with more challenging production environments, considered more attributes compared to the two crop-livestock systems. Information on life history was found to be more influential on decisions of respondents in Bonga and Horro mainly in ewe ranking. Both own-flock and group-animal ranking experiments can serve as tools in objective traits identification in production systems without a practice of recording.

In **Chapter 4**, four alternative schemes of ram selection and ram use were compared via deterministic simulation for each breed. Three most important target traits were determined for each breed based on results of the participatory tools and previous production system studies. The responses year$^{-1}$ and generation$^{-1}$ in yearling weight (all breeds), number of lambs born per ewe joined (Bonga and Horro), number of lambs weaned per ewe joined (all breeds), milk yield (Afar), and greasy fleece weight (Menz) from all simulated schemes were reasonable; though slightly different. Strong selection and short use of rams for breeding were the preferred options. Realization of these predictions relies on continuous recording.