# Genetic resources for production of commercial lambs

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## Abstract

With the high demand for lamb and its products on the Brazilian market, there is a need to improve efficiency within the production system. Genetic resources play an important role in this process. This paper discusses the role of these in the various stages of lamb production, looking at environmental adaptations, disease resistance, choice of ram and dam, through conception, lambing, survival, pre and post weaning growth as well as quality issues linked to carcass quality and traceability. We look at the use of both pure and crossbred sheep in rearing systems, as well as the use of molecular markers for parentage identification, reproduction, development and carcass quality. The overall suitability of the genetic resource depends on the breeding/rearing system, markets demands as well as genotype availability. At the end of the day, the most important factors are animal and farmer well-being and sustainability as well as the profit within the enterprise which may change as farm environment and circumstances change.

## Introduction

After severe reductions in sheep production in Brazil during the 1980s, there has been a recent increase in lamb production especially in the Center West and South East of Brazil (Hermuche et al., 2012). There has also been a resurgence of sheep production in the Southern region, but Brazil still imports a large quantity of lamb, represented by stagnation in the north-eastern movement of sheep production in recent years (Figure 1). In 2012 the lamb meat demand remained firm in the internal market and Brazil lamb meat imports from Uruguay and Argentina increased 11 e 123%, respectively (MDIC,

2012). For Brazil to become an exporter of lamb on the world market, as well as to meet internal demand for the product, as happens with cattle, chicken and pig production, changes in present production systems are necessary to produce animals with both the quality and quantity required by international buyers. Lamb production to meet market demands requires efforts to reduce production costs and increase profit for the farmer with use of improved technologies for sheep production systems (Reis et al., 2012).

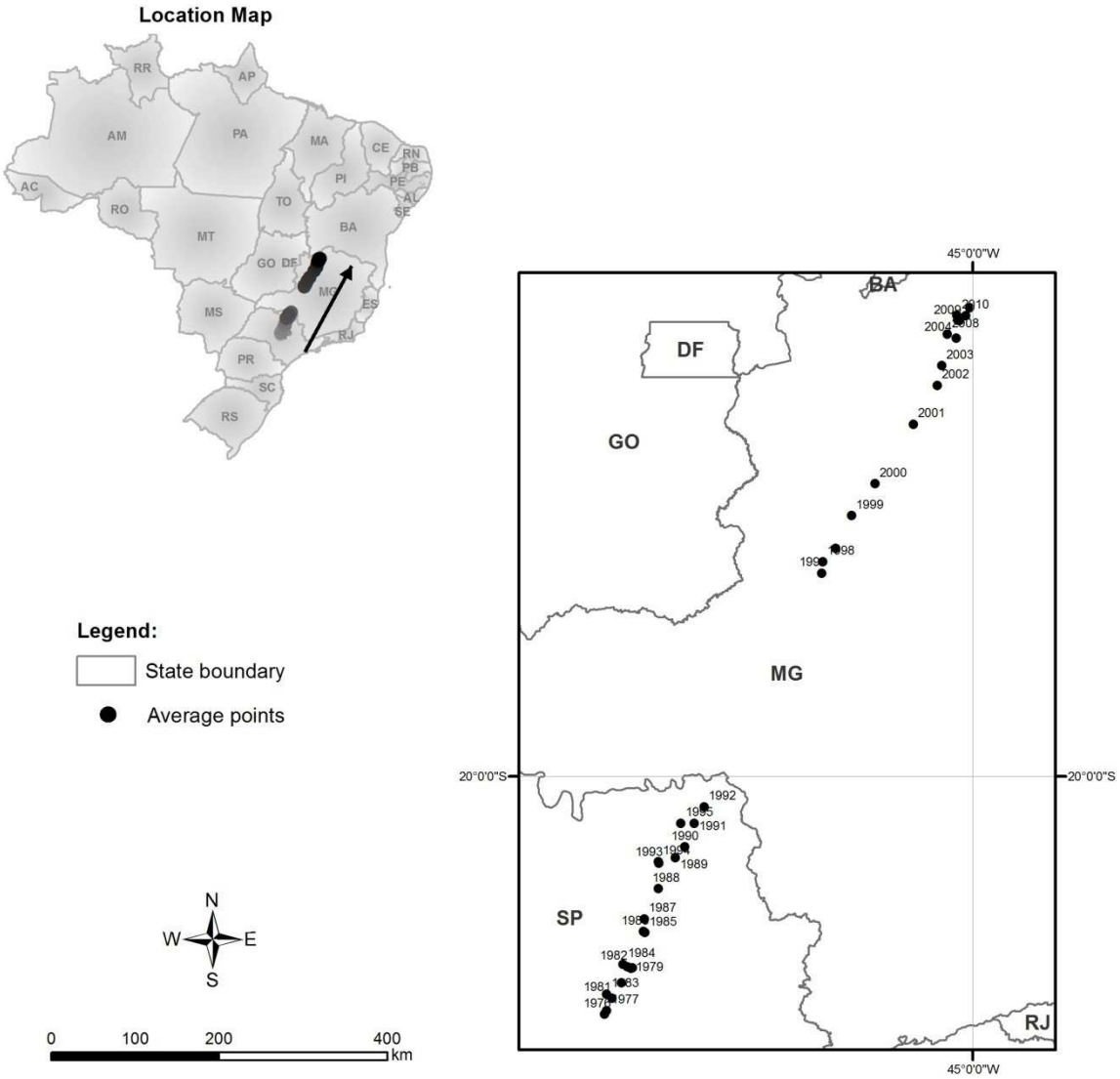


Figure 1. Center of sheep production in Brazil from 1976 to 2010.

Ben Salem and Smith (2008) point out that livestock are fundamental for financial security for many smallholder farmers in the developing world. These authors highlight that breeding is a major factor where local breeds have desirable traits such as their

small size and high disease resistance but also have low milk production and their offspring are slow to grow. Crossbreeding schemes have been designed between tropical hair sheep and meat specialized breeds to improve meat production and growth rate (Bores et al., 2002) but the larger progeny require better nutrition and more inputs to withstand harsher environmental conditions.

According to McManus et al. (2005) the establishment of an economically viable production system in any region requires the choice of breeds or crosses that are adapted to local conditions. The introduction of specialized exotic breeds for meat production such as Hampshire Down, Ile de France, Suffolk, Texel, and more recently Dorper is well documented. However, Gouveia et al. (2006) state these breeds lack a production system that is coherent with their potential as well as breeding programs that evaluate their progeny with objective selection criteria.

High production costs, especially those related to feed, are determining factors in the choice of production system (Oliveira et al., 2002). Canton et al. (2009) have shown that several factors such as energy level in the food and heat stress can affect food consumption in different genotypes. Efforts to improve efficiency in sheep production should concentrate on reducing feed costs, or breeding ewes to produce more without increasing maintenance (Ferguson et al., 2011). These authors indicate several selection traits that should be considered to improve efficiency such as number of lambs weaned, resilience to restricted nutrition and total weight of lamb weaned per ewe lamb weight. As well as productive efficiency, genetic tools are required to improve carcass quality and explore lamb carcass characteristics necessary to ensure consumer health, such as fatty acid profile, conjugated linoleic acid concentration as well as monounsaturated and polyunsaturated fatty acid ratio, which can aid in the reduction of risk of cancer and cardiovascular diseases (Wood et al., 2008).

This paper looks at issues related to lamb production in Brazil and how breed resources can to be to increase both quantity and quality of the lamb produced to meet consumer demands.

**Environmental Issues**

The adaptation of animals to the breeding environment is essential to the success of any livestock enterprise. In Brazil, over many decades, several breeds from various species of farm animals were imported, these mainly originated in temperate climates and whose progeny were evaluated and selected taking into account only the productive

aspects (Façanha et al., 2013). McManus et al. (2011b) state that animal production is not related to a single trait, but includes adaptation to the environment, disease and parasite resistance, nutritional parameters, production and body indices as well as reproductive traits, among others. The choice of location as well as breed or breed crosses for the production system is of vital importance to ensure success in the farming enterprise and adaptive aspects need to be considered, mainly in Brazil, which has a wide range of different biomes and climate conditions. Hermuche et al. (2012) have shown that over the last 40 years the dynamics of sheep production in Brazil by region has changed radically; some areas showing continued growth while other show wide variations in sheep populations (Figure 2).

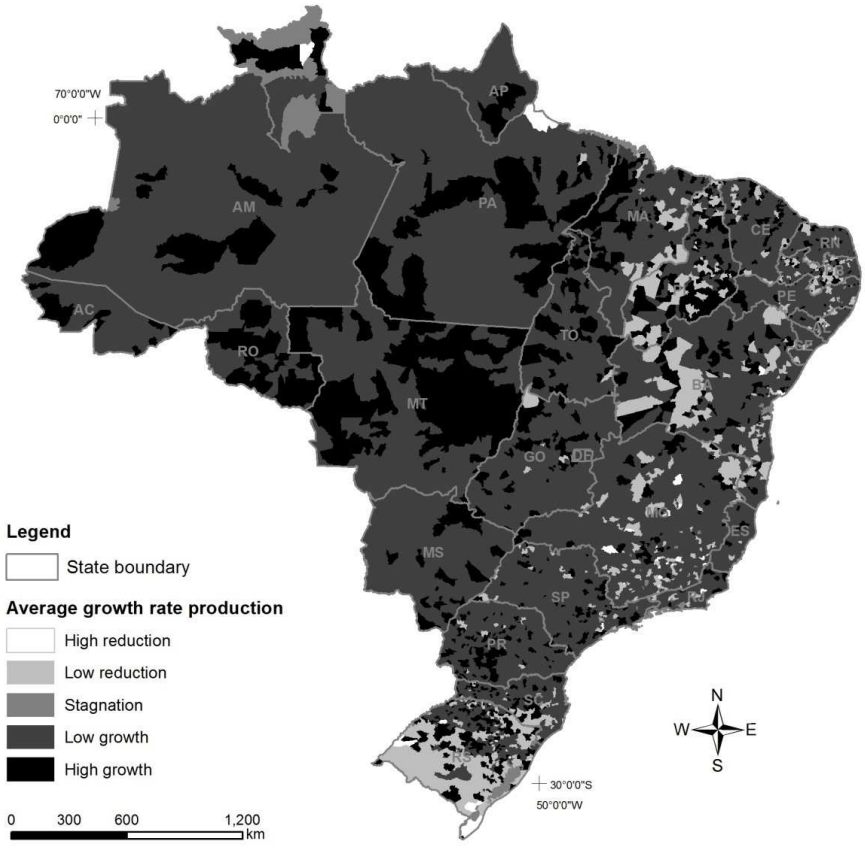


Figure 2. Average growth rate of sheep production in Brazil between 1976 and 2010.

This latter leads to insecurity for investments in production, slaughter facilities and logistics. With changes in the environment, breeds and breed crosses become important. Breeds in Brazil are generally found within 500 km of their midpoint and most are found within distinct environmental conditions. Spatial distribution of breeds is highly correlated with environmental controls. The exceptions are the Dorper and Santa Ines which are widespread. Whether these breeds are in fact adaptable to all

conditions is questionable. Studies (McManus et al., 2009b, Castanheira et al., 2010, McManus et al., 2011a, Correa et al., 2012, Paim et al., 2013b) have shown that there are large differences within breeds for heat tolerance and this is directly linked to production and quality traits.

Blackburn et al. (1998) state that the production with a certain environment depends on the stress to which the animal is subjected to within that system. The localization of the breeds (Figure 3 for naturalized breeds and Figure 4 for commercial breeds) leads to questions of adaptation to the environment and local disease conditions. Paim et al. (2013b) found significant breed differences in terms of tolerance to heat and cold while McManus et al. (2009a) found the same for gastrointestinal resistance. In addition, genotype and environment interactions have also been seen to be important in determining an animal´s response to stressful conditions (McManus et al., 2013), although this is not always evident (McManus et al., 2012).

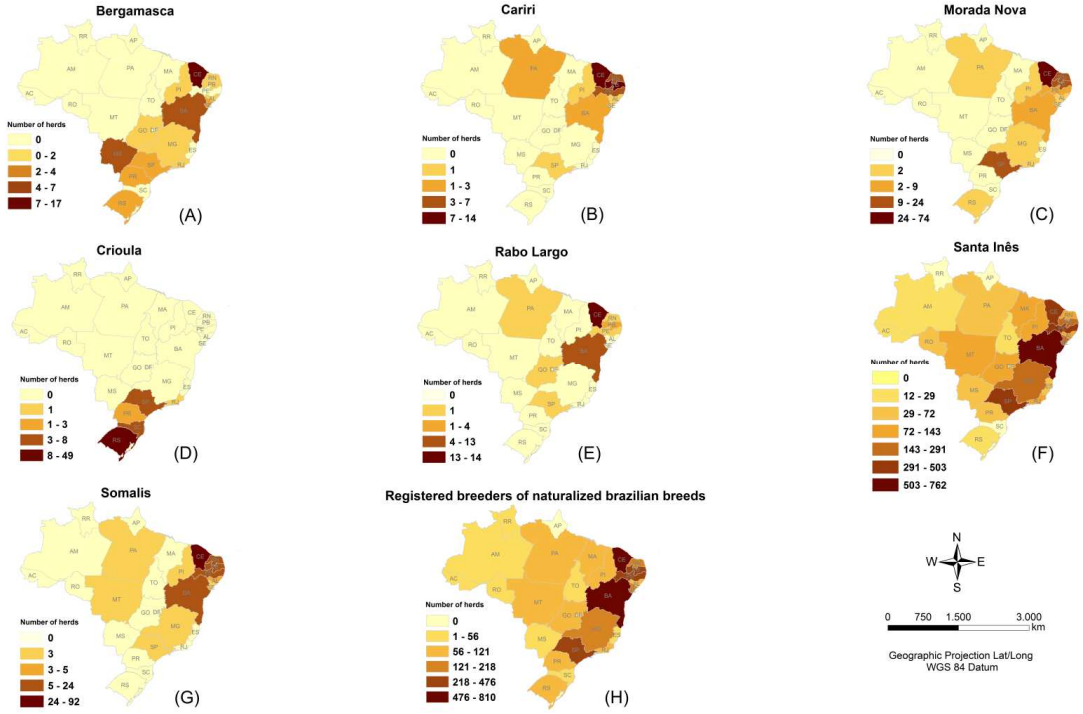


Figure 3. Distribution of registered breeders of Naturalized Brazilian breeds (adapted National Sheep Breeder´s Association- ARCO). Sheep Breeds: A – Bergamasca; B- Cariri, C – Morada Nova; D – Crioula, E – Rabo Largo, F – Santa Inês, G – Somalis, H - Total

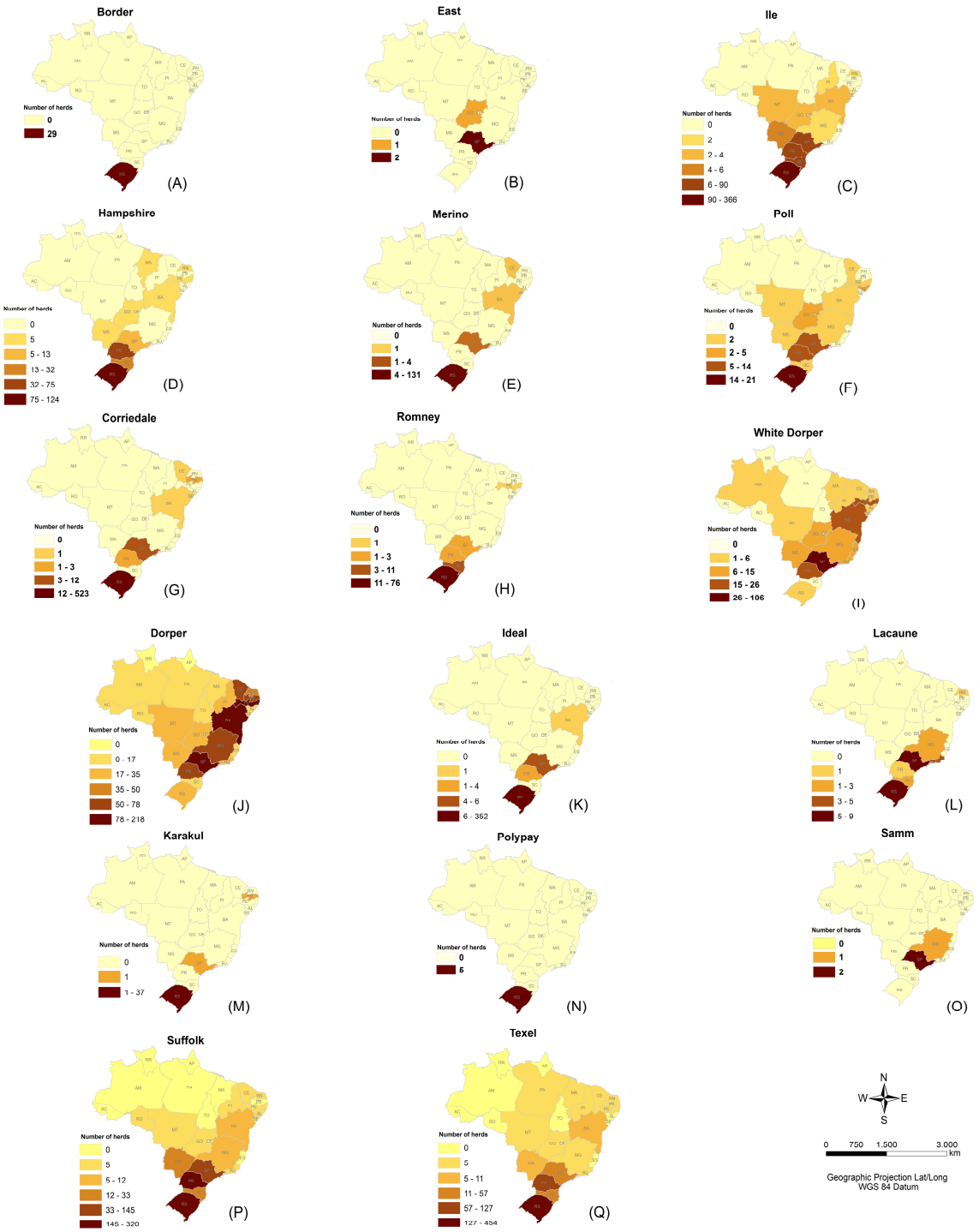


Figure 4. Distribution of Commercial Sheep Breeders in Brazil.

Heat stress can significantly affect production and reproduction indices in sheep (Veríssimo et al., 2009), as one of the first responses to heat stress is the decrease in dry matter intake. Finocchiaro et al. (2005) found antagonisms between milk production and heat tolerance, since selection for greater production and growth leads to higher metabolism. According to Sejian et al. (2010), animals reared in semiarid regions

exposed to various stressors can adapt by thermoregulation at the expense of other bodily functions, especially those related to the production and reproduction.

Paim et al. (2013b) showed that lambs in tropical countries can suffer from both heat and cold stress in the same day. These authors found that the three main phenotypic traits that influenced genetic group separation were hair density, height of coat, and length of hairs. Cold stress is a significant source of discomfort for the neonatal lamb and is also a critical factor in lamb survival, even in tropical countries. The starvation/hypothermia complex is the most important cause of death in lambs, ranging from 40.6% to 78.5% of deaths (Nóbrega Jr et al., 2005), and it is directly influenced by adverse weather conditions, such as extreme temperatures, precipitation, and wind (Alexander et al., 1980, McCutcheon et al., 1981). Perinatal lambs lose a great quantity of energy trying to maintain the homeostasis, which leads to the depletion of the already limited energy reserves, culminating with animal death (Nóbrega Jr et al., 2005).

In tropical areas, one of the main problems for sheep production is the dissipation of body heat to environment. However, this factor is not just related to high temperatures but also to their association in some cases with high relative humidity and the low air movement, which reduces the efficiency of body heat loss and, with it, increases the stress of the animal, limiting development, production and reproduction (Silva et al., 2006). Quesada et al. (2002) studied the effects of genetic and phenotypic characteristics of production and reproduction of hair sheep in the Federal District of Brazil and observed that, although rams were kept with the ewes year round and births were distributed throughout the year, 77% occurred between March and September, indicating a possible influence of food availability and quality on reproductive traits.

Some studies carried out in Northeastern Brazil evaluated adaptive aspects for naturalized and/or crossbreds. Santos et al. (2006), evaluating physiological parameters (respiratory and heart frequency as well as rectal temperature) and thermal variation of Santa Ines and Morada Nova sheep and their $F_1$ crosses with the Dorper sheep, under to the climatic conditions of the semi-arid, concluded that these animals showed high adaptability in this region of Brazil. Studying thermal comfort indexes, physiological parameters and the thermal gradient of four sheep genetic groups (Cariri, Morada Nova, Barriga Negra and Cara Curta) in the semi-arid region of the Paraiba state, Ribeiro et al. (2008) conclude that, except for the Cariri, animals showed high tolerance to heat, showing adaptation to the tropical environment, with the Morada Nova considered the best adapted group. In addition, Bezerra et al. (2011) evaluated the physiological

behaviour of different genetic groups of sheep reared in the semi-arid conditions in the dry and rainy seasons and observed that the Santa Ines, Cariri and offspring resultant from crossing ½Dorper and ½Damara with sheep without defined breed (SRD) resemble each other in adaptation terms to the conditions of the semi-arid. Therefore knowledge of the breed and its adaptation to the proposed environmental conditions is important for success in the rearing of sheep. Carneiro et al. (2010) looking at naturalized and commercial breeds of sheep in Brazil, Uruguay and Colombia found that the breed was the most important factor to differentiate between the animals measured, and adult weight was more influenced by the environment.

**The Ram**

While crossbreeding is becoming increasingly popular for commercial lamb production, several issues must be addressed before choosing the ram breed. As stated above, adaptation to environmental conditions and capability to produce and survive in stressful conditions is important. To increase lamb production the ram should be genetically superior for important characteristics for meat production such as fertility, precocity and weight gain, but in Brazil these are frequently selected for external appearance (Reis et al., 2012).

Several traits are of interest when selecting rams. These include the ability to produce viable sperm and make the ewes pregnant as well as produce quality lambs that produce well within the production system, which will be discussed below.

Puberty in rams is affected by the season of year (Alves et al., 2006, Carrijo Junior et al., 2008), with the end of the rainy season being shown to the best season for births of sheep in the Central region of Brazil, with histological testicular traits at puberty being superior to the other groups (McManus et al., 2010b). This is also affected by the breed of ram. Puberty is seen to be linked to growth rates, so ram lambs that grow faster enter puberty earlier, under adequate feeding conditions.

Few studies are available in Brazil comparing ram fertility between breeds in the same production systems. Machado and Simplicio (1998) found that breed affected some reproductive indices such as birth rate, and that Suffolk and Texel were more affected by heat than other breeds tested. Cruz Jr et al. (2011) and Ribeiro et al. (2011b) also found that breed had a strong effect on recovery of semen quality and scrotal integrity after heat stress when evaluating semen quality in six breeds of rams using scrotal insulation.

Many rams are acquired in agricultural fairs and Maia et al. (2011) showed that these had lower quality semen than those on-farms, with over 60% being unsuitable for breeding, this being attributed to over-feeding. These authors also found that mixed breed rams showed fewer abnormal sperm cells than purebred Dorper and Santa Ines rams in Northeastern Brazil.

Studies in different breeds showed a lack of cyclicity linked to photoperiod in Northeastern and Central Brazil as day length varies little throughout the year, but differences may be due to nutrition (Martins et al., 2003, Alves et al., 2006) or climate (Coelho et al., 2008, Soares and Guerra, 2009, Silva et al., 2011b). This is not the case in Southern regions where photoperiod has a more pronounced effect on sheep breeding.

Rams are mainly selected to breed lambs with higher growth rate and improve carcass quality. Genetic tests for sheep are commercially available worldwide (Dodds et al., 2007) including Parentage testing, Scrapie, Spider Lamb Syndrome (SLS); Ovine Progressive Pneumonia Virus (OPPV); Johne's Disease, Brucellosis, Inverdale locus as well as for carcass quality LoinMAX - a mutation at the *Carwell* locus, originally identified in Poll Dorsets and mapped to chromosome 18 near the *Callipyge* locus, causes an 8% increase in *L. dorsi* weight and a 10% increase in cross sectional area (Nicoll et al., 1998); MyoMAX, a QTL affecting carcass yield, closely linked to the GDF8 (myostatin) locus on chromosome 2 has been recorded in the Texel breed in New Zealand by Johnson et al. (2005) and in Belgium by Laville et al. (2004). This mutation is associated with a 3% increase in leg muscle and a 10% decrease in leg fat and is common in the Texel breed.

Few studies are found on this topic in Brazil, but Lobo et al. (2012) found that 23 transcripts among which those involved in skeletal muscle development (MyoD1 and IGFBP4), lipogenesis and adipogenesis (C/EBPδ, PPARγ and PGDS) were differentially expressed between four groups of sheep (Morada Nova, Brazilian Somali, Santa Ines and ½Dorper×½Morada Nova).

Genetic diseases in rams also require special attention and a list may be found at Online Mendelian Inheritance in Animals (OMIA; http://omia.angis.org.au). While virus and bacterial diseases are generally controlled by import legislation, genetic factors such as scrapie susceptibility are not. While scrapie is not a problem in Brazil several prion diseases have been reported and levels of susceptibility are high in Brazilian breeds (Sotomaior et al., 2008, Ianella et al., 2011, Ianella et al., 2012).

Selection within flocks depends on accurate pedigree recording. When this is lacking or there exists a need for confirmation of parentage, molecular markers have been be used for parentage testing. In 2012, Souza et al. (2012) found that the markers used by the Ministry of Agriculture (MAPA, 2004) could be replaced by others that were more informative. In August of the same year MAPA updated this list (MAPA, 2012), part of which are contained in the list published by ISAG of 14 markers (*http://www.isag.us/Docs/AppGenSheepGoat2012.pdf*) and FAO (*ftp://ftp.fao.org/docrep/fao/010/a1250e/a1250e17.pdf*) with 22 markers. This new panel of markers still contains markers shown to be uninformative (Souza et al., 2012) in Santa Ines sheep (the largest sheep breed in Brazil) such as OarAE129 and OarFCB20, as well as OarAE129 showing high discrepancies between laboratories (ISAG, 2012). Nevertheless other markers such as DS52 (ETH152), ILSTS87 and MAF 065 are seen to be highly informative with this group of animals.

Paiva et al. (2011) showed that molecular marker technologies, especially those based on genotyping microsatellite and mtDNA loci, can be used in conjunction with pedigree analysis for the maintenance of genetic variation in herds, while Carneiro (2012) showed how they can be used for risk analysis in sheep conservation programs. Both concluded that Brazilian breeds such as Brazilian Somalis and Bergamasca are in risk of extinction and conservation measures are needed maintain these genetic resources. This is in line with the spatialization of purebred sheep breeds in Brazil and found that most lie within 500km of their centerpoint (unpublished data). This has implications for conservation, exchange of germplasm and sanitary issues. Carneiro et al. (2010) showed that phenotypic characterization was an accessible and easy to use tool in conservation and breeding programs.

**The Dam**

The decision to use purebred or crossbred dams is very important. Questions linked to feed efficiency, maintenance and development as well as reproductive issues such as age at puberty, prolificy and lamb survival are important. Productive efficiency is the goal of any production system and reproductive performance is of primary importance. High reproductive efficiency enables higher intensity of selection due to the increased number of animals available for selection and, ultimately resulting in greater genetic gains. Measures of reproductive efficiency include, among others, ages at puberty, 1$^{st}$ ovulation, 1$^{st}$ conception, 1$^{st}$ lambing, regularity of estrous cycles, number

of offspring produced throughout life, ease of lambing, service period (from lambing to the beginning of a new pregnancy), lambing intervals, among others. Variations in these indices result from actions involving genetic and environmental factors (Lôbo and Lôbo, 2007).

In some studies carried out in Central-Brazil (McManus et al., 2011d, Paim et al., 2011), sheep farming has been seen not to be a profitable enterprise, with ewe feeding costs being responsible for up to 70% of the variable costs in the system (Lobo et al., 2011, McManus et al., 2011c). Studies are therefore necessary to increase efficiency within the system.

Selection of dams, particularly for high prolificacy is important as the birth of a large number of offspring is one of the aspects that can contribute to flock profitability (Paim et al., 2011). Thus, multiple births favor higher productivity per dam or per area compared to single births. However, it is essential to ensure the survival and development of offspring which implies analyzing the conditions of the environment and, if necessary, how much it costs to improve it.

Nevertheless the claim that Santa Ines is a prolific breed should be questioned. Mean litter size is seen to be about 1.25 in stressful environments (Rajab et al., 1992, Silva and Araújo, 2000). This is in contrast with other naturalized breeds raised in the same region such as the Morada Nova (Selaive-Villarroel and Fernandes, 1994, Machado et al., 1999, Quesada et al., 2002) or Crioula (Silva and Araújo, 2000) where although prolificacy was approximately the same, weaning rate was almost half in Santa Ines. This may be because of the environment, as litter size in Santa Ines can reach 1.5 or more in more intensive systems (Saunders et al., 2012).

The Santa Ines breed has increased in numbers in various regions of the country, due to its perceived great adaptability and production potential. However, some authors report that this genetic group has lower performance in intensive production systems so its use in these systems should consider crossing with specialized breeds for meat production (Oliveira et al., 2010). The definition of the best use of Santa Ines within breeding systems is still unclear, the same being extensively used as both dam and ram breed in crossbreeding systems (McManus et al., 2010a). Their use therefore may depend on the production system and environmental conditions.

Silva et al. (1988) showed that Morada Nova lambs were younger at puberty and Santa Ines were significantly heavier than Morada Nova and Somali at puberty while Mexia et al. (2004) found prolificity to be 1.32 in Santa Ines in the South of Brazil and

Selaive-Villarroel and Fernandes (1994) found prolificity in Morada Nova to be 1.5. In ten properties in Brazilian Northeast fertility was found to be 42% in Santa Ines and 75% in animals with no fixed breed. Silva and Araújo (2000) also showed reduced lower fertility, prolificacy and weaning rates in crossbred Santa Ines vs Crioula sheep in Ceará, with no significant differences between genetic groups for lamb growth rates. Ferra et al. (2010) found that ewe lambs that entered puberty earlier grew faster than those that did not enter puberty. This depends on season of birth, nutrient availability as well as breed (Silva et al., 1988).

According to Ribeiro et al. (2011a) some of the causes limiting productivity in sheep flocks are linked to reproductive losses, these being associated with a low conception rate (81.6%), prolificacy (6%) and high perinatal mortality of lambs (38%), conditions that can be minimized by optimization of labor and improving the reproductive efficiency, which are the main factors that contribute to improving the performance and profitability of commercial herds (Vasconcelos and Meneghetti, 2006). Silva et al. (2011a) found that homozygote Santa Ines ewes presenting the $FecG^{E}$ allele showed an increase in their ovulation rate (82%) and prolificacy (58%).

Most feed consumption studies in Brazil are based on lamb growth but few look at maintenance of the ewe and efficiency of production due to dam size. Kenyon et al. (2011) found that ewe size had no effect on size or development of singleton-foetuses at 140 days of pregnancy but Blair et al. (2011) showed that small ewe size constrained twin foetuses in late gestation, but not in early or mid-gestation. These authors did not show the effect on lamb development or overall efficiency. Kenyon et al. (2009) concluded that heavier weaning weights of lambs from heavier ewes may not be compensated by the greater nutritional demands of the dams.

Gomes et al. (2013) found that Small Santa Ines ewes were economically more viable as they produced more lamb per kilo of food consumed by the dam than Large Santa Ines, Bergamasca and crossbred Santa Ines x Dorper ewes. The smaller animals ate less and produced the same amount of lamb as larger animals, thereby showing a greater production of lamb per kg of feed consumed. For Paim et al. (2011), this difference has an important influence on the profit of the system as dam feed costs are the most important source of costs in the production of lambs for slaughter. This author found that crossbred lambs were economically more viable in the Brazilian Center-West than purebred Santa Ines lambs. Nevertheless farmers do not always slaughter all $F_1$

lambs, using the females as replacements within the herd. This may negatively influence the profitability of the enterprise as these are less efficient.

Whereas animals from crosses are usually destined for the meat market, it is possible that females from these may be used for reproduction and used to increase the economic viability of production through the production of a lamb before slaughter (Keeling et al., 1991, Khadem et al., 1995). As the ewe is a major cost factor in lamb production, if the ewe lamb can also produce a lamb and both can be slaughtered at a young age, this may increase the efficiency of the system. Meneghini (2010) compared Santa Ines and their crosses with specialized meat breeds and observed weaning rates of 35.5% for purebred Santa Ines vs 79.8; 68.0; 51.7 and 83.1 for crossbred Santa Ines with Dorper, Ile de France, Suffolk and Texel, respectively. In addition, this author found that ewes Santa Ines x Texel weaned more lambs in kilograms (27.2 kg) than Santa Ines (17.3 kg).

**Pregnancy Levels and Birth Rates**

Silva (2012) found differences between Santa Ines, Texel x Santa Ines, Dorper x Santa Ines and Ile de France x Santa Ines for traits such as weight and age at first oestrus, service, conception, fecundity, ewe weight at weaning, days to return to oestrus and lambing rates. For this author there was no significant difference in age at first oestrus in the different groups, but conception rates were higher in Ile de France x Santa Ines and Dorper x Santa Ines crosses compared to Santa Ines.

Casas et al. (2004), when studying the reproductive behavior of four genetic groups of ewes during the first three years of life, also observed average reduced fertility in the first year (40.1%), which rose in the second (83.6%). The groups with the best performances in the first year maintained their position in later years. High fertility rates are generally associated with weight gain and high body weights. Silva (2012) found that Ile de France dams were heavier when compared to the Santa Ines and therefore had a higher conception rate.

Several genes with a large effect on fecundity and prolificacy have been detected. These include the Booroola, Inverdale, Hanna, Belclare, Galway, Woodlands, Lacaune and Thoka (Davies, 2005). Molecular markers are also available for prolificacy and ovulation rate (Silva et al., 2011a, Lacerda et al., 2012) in Brazilian breeds of sheep. Major genes for prolificacy with differing sizes of effect on ovulation rate and litter size have become an option for sheep farmers aiming to significantly increase lambing

percentages, but this needs to be used within a production system which assures survival and growth of the extra lambs. The incorporation of a major gene for prolificacy into a flock using marker assisted selection allows increased selection pressure on other traits leading to increased genetic gain.

**Lamb Survival**

There are reports in the scientific literature of breed differences for lamb survival, which is a good indicator that lamb survival is determined, to some extent, by the genotype of the lamb and/or the dam. Lamb survival exhibits a high degree of individual and maternal hybrid vigor. Therefore, the greatest opportunities to genetically improve lamb survival are to utilize breeds known for this trait in mating systems that produce crossbred lambs from crossbred ewes (Thomas, 2011).

The formation of maternal lineages with focus on maternal ability and sire lines focused on performance is important for the production of crossbred animals. Crossbreeding uses complementarity between breeds which combines desirable features of each and exploitation of heterosis. However, more information is needed on the evaluation of crosses between different breeds of sheep (McManus et al., 2010a). In addition, according to Thomas (2011) to evaluate the effect of a lamb's genes on its survival, consideration also needs to be given to the effect of the dam on the lamb's survival through the maternal environment that she provides. This includes the uterine environment provided to the fetus, the maternal care at lambing, and her milk production.

Lamb survival depends on factors linked to both the lamb and its dam, but also be linked to the ram breed. Silva (2012) did not find any differences in lamb survival in four genetic groups of first lambing ewes. In contrast, Paim et al. (2013a) found large differences between crossbred dams for performance and survivability. Texel cross lambs had similar growth rate and survivability compared to Dorper and Ile France crosses and animals born as twins showed higher mortality rates than singles. Therefore selection of genetic groups for increased prolificacy may have some negative side effects.

In the same study, Paim et al. (2013a) related that Hampshire Down crosses showed the highest mortality rates. The causes of death were not known, but this showed the lower adaptation degree of this breed to the environment conditions of the above study. Machado et al. (1999) also found a lower survival rate (71.4%) for

Hampshire Down crossbred compared to Santa Ines purebred, Suffolk and Texel crossbred lambs (89%, 84.8%, 90.2%, respectively). Other studies also found negative results for survivability of Hampshire Down (Barros et al., 2004). Therefore, these results do not support the recommendation of it as a paternal breed for crosses with Santa Ines dams.

Crossbred dams tend to produce more milk than purebred, whereas the duration of lactation and increasing day length to the end of winter increases production and the levels of milk constituents (Corrêa et al., 2006, Morrissey et al., 2008, Ferreira et al., 2011). In general, sheep which produce more milk tend to produce heavier lambs at weaning, thus contributing to the economy and efficiency of the production system. In this context, Ferreira et al. (2011) and Corrêa et al. (2006) describe that $F_1$ females have higher milk production than their maternal breeds. This is important, since the viability of the lamb and subsequent weight gain until weaning is a reflection of maternal ability including milk production (Snowder and Knight, 1995). Factors that influence sheep milk production include the paternal genetic group of the dam, the number of lambs born and reared, the season, weight gain of the dam through pregnancy until weaning (Morgan et al., 2006).

Besides the quantity, quality aspects of milk also influence the performance of lambs. The genetic group is cited as one of the factors that can alter the composition of sheep milk, in addition to age, stage of lactation, nutrition, milking frequency and level of health (Morand-Fehr et al., 2007). Assuming that the production of dam milk influences the performance of their lambs, it is possible that the physicochemical characteristics also play an important role on this condition. Wilson et al. (1983) suggest that the concentration of glucose in sheep milk may important and consequently influence the growth rate of the lamb. Compared to cattle, sheep milk has similar levels of lactose, yet higher fat and protein. The concentration of protein in sheep milk (5.8%) is greater than observed in the goats (4.6%) and cattle (3.3%). However, the concentration of protein can undergo change according to genetic group, stage of lactation, feeding, climate, calving season and udder health status (Park et al., 2007).

Low postnatal performance is associated with perinatal mortality (from 60 days of gestation to 28 days postpartum). Much of the lamb mortality occurs in the first weeks of life (Nowak and Poindron, 2006), where survival depends on the complex interaction between the ability of mother to care for it and lamb viability.

Silva (2012) found no difference for any physical-chemical characteristic of the milk for Santa Ines and its crosses with Dorper and Ile de France but milk from Texel cross females had significantly lower values for fat, protein, lactose and non-fat dry matter as well as lower density and cryoscopic index when compared to the pure Santa Ines group. On the other hand, Peeters et al. (1992) reported that the composition of milk from three genetic groups (Flemish milksheep, Suffolk and Texel) did not affect the weight gain of their lambs, and this condition is affected by its own genotype, birth weight and number of lambs competing during lactation.

**Pre and post weaning growth rates**

Crossbreeding studies in Brazil show a wide range of breeds used. The dam breed varies according to region with wool breeds being used in the South and Southeast and hair breeds being used in the Northeast and Center-West, although hair breeds are also becoming more common in the Southeast (Furusho-Garcia et al., 2004). In this present revision, we decided to focus in summarized the recent results evaluating the Santa Ines breed as dam, due increasing importance of this breed to a great range of regions of the country. Paim et al. (2013a), evaluating crossbred lambs from five paternal breeds with Santa Ines ewes, found that Santa Ines animals did not differ in growth from birth until slaughter compared to crossbred animals. These results showed that local breed in highly challenging environment, can have similar performance compared to crosses because the losses in adaptation may outweigh the benefit of heterosis. In the same study, the crossbred Texel lambs had similar growth rate and survivability compared to crossbred Dorper and Ile de France and had better carcass traits than these genetic groups.

There is a large number of different management systems and environments used for sheep production in Brazil. Crossbreeding may be an alternative to increase the efficiency in some high input systems. Barbosa Neto et al. (2010) evaluated the additive and non-additive genetic effects on growth, reproductive and maternal traits in sheep of Santa Ines, Brazilian Somalis, Dorper and Poll Dorset breeds and concluded that the use of F1 dams (Santa Ines × Brazilian Somalis) with ram from Poll Dorset or Dorper can improve the productive efficiency in tropical environment. Studies have shown that Santa Ines animals did not differ in growth from birth to slaughter compared to crossbred animals, which highlights the potential of this naturalized breed for meat production (Meneghini, 2010, Paim et al., 2013a). Moreover, there is a great variability

inside this breed for carcass and growth traits which may respond well to selection through structured selection programs (McManus et al., 2010a). On the other hand, rearing purebreds or naturalized animals without defined breed that are well adapted to stressful environments may be the most efficient choice in low input systems. Batista et al. (2012) evaluated the performance lambs from crossing sheep without a defined breed (SRD) with Santa Ines and Brazilian Somalis hair breeds and concluded that the Santa Ines sheep showed advantages over the Somalis in the northeast Brazil, especially for weight gain.

The farmer often has to choose between a less productive breed that is well-adapted to the local environmental conditions and resistant to parasites or a highly productive breed that is not well-adapted to the climate and is more susceptible to parasites (McManus et al., 2009a). A third option is the use of crossbreeding of a susceptible breed, of elevated productivity, as the sire breed with a resistant, but less productive maternal breed (Amarante et al., 2009). According to Maniatis and Pollott (2002), Quesada et al. (2002) and Matika et al. (2003) with several sheep breeds have shown that direct and maternal influences are important for birth and weaning weights.

Most crossbreeding studies in Brazil have been carried out with Santa Ines as the dam breed and Texel is the most popular sire breed but the majority of these studies evaluated only two or three genetic groups (McManus et al., 2010a). Interaction between maternal and paternal genotype for birth weight have been described (Freking and Leymaster, 2004). Paim et al. (2011) found that breed used significantly affected the economic return to the sheep enterprise, but this had a significant interaction with slaughter weight. These authors found that Texel cross lambs gave higher profit than Santa Ines in the Distrito Federal.

In terms of dam breed, Carneiro et al. (2007) found that lambs from the genetic group Dorper x Santa Ines presented a faster growth rate, as estimated by weight at maturity and maturity rate, followed by the Dorper x Morada Nova and Dorper x Rabo Largo. Fernandes et al. (2007) reported weight gains for pre-weaning lambs Suffolk, SI, ½ SI x Suffolk, ½ Suffolk x SI of 0.256, 0.162, 0.212 and 0.255 g/day. Thus, comparisons with the literature are difficult because of different production systems, environments and genotypes involved.

**Slaughter traits and Carcass quality**

For lamb production quantitative aspects of the carcass should be emphasized, as knowledge of weights and yields of the main carcass cuts is important for the evaluation of animal performance. Furthermore, lamb meat consumption and demand depends of the carcass composition, for example, increased size of cuts and decreased fatness are two factors that affect lamb meat acceptability.

There are several factors that determine carcass value: carcass weight, composition of carcass (% lean, fat, and bone), pelt condition, animal health, etc. Carcass weight and composition are influenced, in the short term, by choice of feeding regimen, and, in the long term, by choice of breeds and animals within breeds. However, selection for animals that will produce a heavier carcass while maintaining desirable composition can be accomplished with the use of multiple-trait selection. The response to selection for any one trait depends on the extent to which the trait is under genetic control, the amount of variation, as well as the accuracy of predicting genetic merit for the trait from the available phenotypic measurements. The issue of genetic improvement of carcass composition involves not only genetics and measurement of body composition, but also economics. The most important issue for the farmer at the end of the day is his profit within the production system he has adopted.

In Brazil, although adapted to the environment, naturalized breeds show low capacity for growth and fat deposition (Lobo et al., 2011), producing lambs with high age at suitable slaughter weight compared to specialized breeds for meat production. Researchers and farmers therefore use specialized breeds for meat production to reduce the slaughter age and increase the quality of meat and carcass. Even though, there are beneficial for growth performance of lambs, some studies showed that no differences were found for kill out percentage (Garcia et al., 2000, Selaive-Villarroel et al., 2006, Landim et al., 2007) when is used Texel ram. Paim et al. (2013a) evaluated crossbred lambs from five paternal breeds with Santa Ines ewes and found that the crossbred Texel lambs had better carcass traits compared to crossbred Dorper and Ile de France. With regards to fat deposition, meat breeds are efficient in increasing this characteristic when crossed with naturalized breeds. For example, when crossed with Santa Ines ewes, Texel and Dorper contributed to increased fat deposition (Garcia et al., 2000, Cartaxo et al., 2011).

In addition to the carcass qualitative aspects, the quality parameters are essential to ensure meat quality and increase the acceptability of lamb meat, such as pH, colour,

flavor and, more recently, fatty acid profile. Siqueira et al. (2002) found that meat from crosses of Hampshire Down, Santa Ines and Bergamasca x Corriedale were similar in colour but not flavour or tenderness. Bonagurio et al. (2003) evaluated the pH of the Semimembranosus muscle post mortem and found that Santa Ines had higher pH and more fat cover than Texel x Santa Ines, and purebred Santa Ines had darker meat than Texel x Santa Ines.

For the fatty acid profile, studying the influence of genotype and diets with different energy levels on the lipid profile of sheep, Costa et al. (2009) concluded that genotype influenced the saturated fatty acids (SFA) concentration, desirable fatty acids (DFA), atherogenicity index as well as PUFA:SFA, MUFA:SFA, (C18:0 + C18:1):C16:0 ratios. Additionally, Maia et al. (2012) investigated the effects of genotype on the fatty acid profile in the *Longissimus dorsi* muscle of feedlot ewe lambs and found that Oleic (C18:1cis), palmitic (C16:0), and stearic (C18:0) were the fatty acids found in largest amounts in the intramuscular fat. The genetic group Ile de France × Santa Ines showed smaller ratio between polyunsaturated fatty acid (PUFA) and saturated fatty acid (SFA) when compared with Santa Ines and Suffolk × Santa Ines ewe lambs. These authors concluded that Santa Ines and Suffolk × Santa Ines crossbred animals showed potential to produce meat with higher nutritional value due to lower fat content and better ratio between polyunsaturated and saturated fatty acids.

Genetic strategies to improve the profitability of sheep operations have generally focused on traits for reproduction. Natural mutations exist in sheep that affect muscle growth and development, and the exploitation of these mutations in breeding strategies has the potential to significantly improve lamb-meat quality (Cockett et al., 2005). Genes with large effect affecting meat production in sheep have been found including was the *Callipyge* gene (Cockett et al., 1994). This gene post-natally increases the size of some muscles, mainly in the hindquarters, reduces fat content (Jackson et al., 1997) but may also make meat tougher (Koohmaraie et al., 1995). This has prevented widespread use of the gene in breeding programs. Cockett et al. (2005) pointed that actual mutations responsible for the muscular hypertrophy phenotypes in sheep have yet to be identified, and further characterization of the genetic basis for these phenotypes will provide insight into the biological control of muscle growth and body composition.

In the future considerations such as traceability may become important in the sheep industry (Dodds et al., 2007). This is normally used to ensure that food safety regulations are being complied to, trace the origin of desirable (or undesirable) products

to enable the selection of living relatives or protect genetically distinct brands of products (Arana et al., 2002). Studies in meat processing plants identify that up to 10% of animals are mislabelled (Heaton et al., 2005). Paiva et al. (2012) and Vasconcelos (2012) found that for traceability purposes only 20 and 21 SNPs are necessary to identify individuals with 99.9999% precision, in Brazilian Crioula, Morada Nova and Santa Ines breeds. On validation with other Brazilian breeds and groups (Crioula; Bergamacia; Corriedale; Pantaneira; Rabo Largo; Santa Ines) these SNPs were seen to be efficient in separating populations except Pantaneira and Crioula. The authors suggested that the proposed reduced panel represented a useful tool for breed-certification of live animals and derived products. Parentage identification in the same studies showed that about 120 SNPs are necessary.

**Final Considerations**

The choice of genetic resource to use of commercial production of lambs depends on environmental conditions, parasite and disease challenge and management system. Therefore, it is necessary to know the potential of genetic resources available, to choose the best option to each sheep production system. Crossbred animals, in general, demand more nutrients and better environmental conditions than purebred naturalized breeds. The cost of maintenance of crossbred dams can be higher than that of local hair breeds, as it represents a heavier animal, which should be considered in the design of the breeding system.

Marai et al. (2007) highlighted the need to look at the efficiency and overall productivity of the farming system and not just individual production levels. It is important to remember that, depending on the system used, crossbreds are not necessarily better than purebreds (Mendes et al., 2009). According to McManus et al. (2010a) breeders and farmers need to improve production and quality traits taking into consideration welfare related fitness, as well as heat and disease resistance. As many of these traits are difficult or expensive to measure, the combination of gene mapping and sequencing technologies, gene expression studies in target tissues, production data and modern bioinformatics tools are needed to determine the origin of genetic variation in important traits.

According to van der Werf (2007) the number of detected and confirmed QTL is low for sheep and goats and gene mapping is less advanced than in other livestock

species. This shows the need for increased efforts in this area, especially to try and implement breeding schemes that bring real benefits to farmers.

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