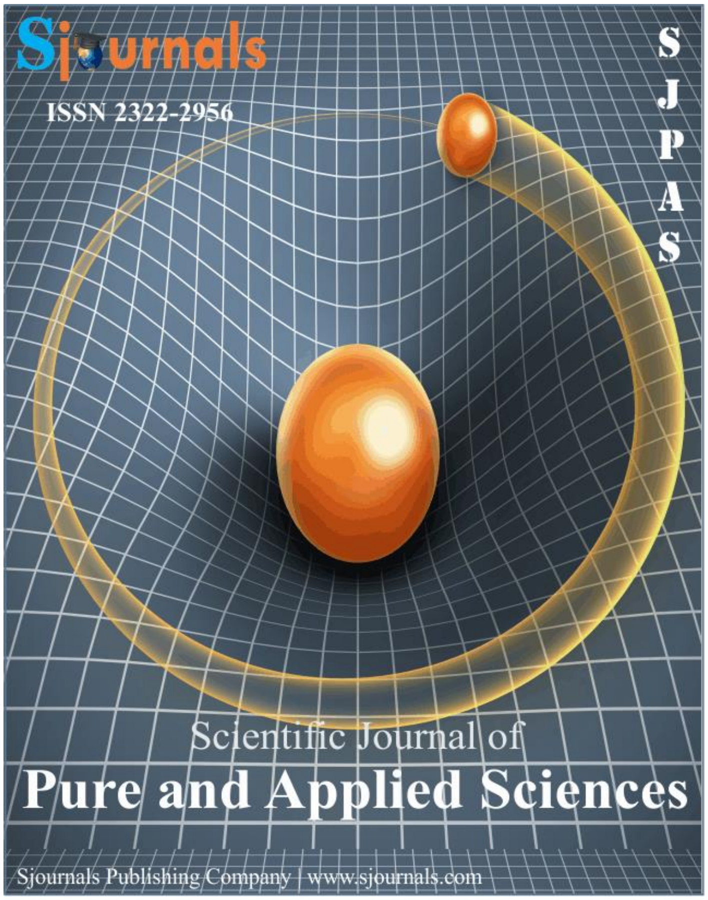
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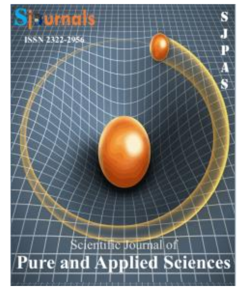

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Review article

Growth, carcass and meat performance in goat and sheep breeds and their crosses

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ABSTRACT

The growth performance, carcass and meat properties are the driving factors for efficiency and overall viability of goat and sheep meat production systems. These performance factors are much dependent on genotype, although the overall productive capacity will be influenced by other factors such as nutrition, management, health and other animal related factors as age, slaughter weight and sex. Goats and sheep breeds are diverse and populated all around the worlds' agro ecological regions culminating in distinctive performances. Some agro ecological regions usually use both pure breeds and assorted crossbred goats and sheep that include characteristics from more than one breed, which might be locally available or exotic breeds. Breed differences in performance characteristics proffer contingency to improved efficiency of goat and sheep meat production as a consequence of growth, carcass and meat performance. Different production systems have taken advantage of various goats and sheep breeds and their crosses for meat production and have designed their management specifically to maximize production on targeted breeds. Pure breeding and crossbreeding have been the most used mode of production to promote growth performance, carcass and meat parameters to serve specific commercial meat market expectations and consumer appeal. Straight breeding has its own share of benefits and shortcomings, on the other hand goat and sheep breed diversity and genetic distance have acted as valuable ingredient which has been exploited in crossbreeding systems in improving growth performance, carcass and meat parameters. Different forms of systematic crossing strategy to improve growth performance, carcass and meat production have been designed based on specialized terminal sires breeds to complement performance characteristics of known maternal breeds lines. In this case, appropriate choice of breed to attain optimal growth, carcass and meat parameters as expected by specific markets and meat products acceptable to consumers becomes critical. Unlike pure breeding accomplishment of breeds and their crosses utilization is dependent on their genetic distance among them, as well as breed complementarity, individual, maternal and paternal heterosis that make the proper choice of breeds employed in a crossing system of great importance. Therefore, it is recommendable for goat and sheep producers to acquaint themselves with the production potential of available goat and sheep genetic resources in order to get maximum meat production utility. The present review gives an insight on the performance of goat and sheep breeds and their crosses in terms of growth, carcass and meat production.

1. Introduction

There is evidence that overall efficiency of goat and sheep meat production count largely on desirable growth performance, carcass characteristics and meat quality properties of kids/lambs (Caro-Petrović et al., 2015). However, determinants of growth and carcass and meat quality include factors such as slaughter age, breed, genotype, gender, diet and treatment during slaughter (Costa et al., 2008; Toplu et al., 2013; Cobanovi'c et al., 2019). The effect of goat and sheep breed on growth (Dvalishvili et al., 2015; Simeonov et al., 2014) and carcass (Tesema et al., 2018; Komprda et al., 2012) parameters have been extensively evaluated. In a number of studies genetic and non-genetic factors have shown to influence growth performance, carcass and meat attributes with pure breeds and crossbreds exhibiting foremost distinction (Burger et al., 2013; Cloete et al., 2012; Cloete et al., 2008). Goat and sheep meat production has been exploited mainly through pure breeding and/or crossbreeding strategies for enhancing growth performance, carcass characteristics and meat quality properties (Oman et al., 2000; Rastogi et al., 1982). Breed diversity has acted as a valuable aspect of crossbreeding systems to enhance growth performance, carcass and meat parameters relative to purebred flocks. Purebreds of any breed would need more time to attain destined carcass weights with reference to crossbreds (Carson et al., 1999). Production capacity of sheep to meet market demands can be improved by using breeds that are more adapted to the production system and exploring desirable characteristics of each breed (McManus et al., 2010). Success of crossing depends on the breeds used and the genetic distance among them, as well the combining ability of maternal and individual heterosis to make the proper choice of breeds employed in a crossing system (Caro-Petrović et al., 2015). Crossbreeding systems utilize breed diversity to increase productivity comparable to purebred flocks (Petrovic et al., 2011; Fathala et al., 2014). Issakowicz et al. (2018) the use of lambs from crossing of local with specialized sheep breeds for meat production may lead to higher meat deposition and a smaller fat amount in the carcass, with a more adequate nutritional profile for human consumption. The relationship of lean meat, fat and bone in the carcass establishes the proportionate merit of various breeds for meat production (Mohapatra et al., 2018). In comparative review by Van Niekerk and Casey (1988) it was noted that Boer goats had remarkable inferior weight apportionment in the hind limb than sheep breeds including the Dorper. Maximum benefits in meat production are accrued in terminal crossbreeding systems where specialized sire breeds are utilised to complement traits of crossbred ewes (Leymaster, 2002). The present review gives an insight on growth performance, carcass and meat parameters in goats and sheep breeds and their crosses.

2. Growth performance in goat and sheep breeds and their crosses

Genotype and crossing system have significant effect on body weight and average daily gain of lambs. St. Croix and Barbados Blackbelly displayed inferior average daily gain as compared with wool sheep breeds, while the St. Croix were superior than the Barbados Blackbelly lambs (Wildeus, 1997). The same author observed that hair x wool crosses had better performance against purebred hair sheep and exhibited comparatively average daily gain to wool breeds. Comparable post weaning growth rate were reported for Boer * Spanish and Boer × Angora wethers, however it was superior for Boer crossbreds against Spanish wethers (Cameron et al., 2001). Crossbreeding in isolation is not the resolution to address growth rate and carcase composition desirability, among others the type of crossbred ought to be matched to production condition, (Fogarty, 2006) or else the targeted performance might not be attained. Sire selection within breeds apart from imparting carcass composition or yield in slaughter animals, it is also an important component that enhance growth rate in either purebreds or crossbreds (Afolayan et al., 2007; Fogarty, 2006). Dorper sheep has featured prominently in meat production, which makes it a suitable candidate as a terminal sire for crossing with local breeds (König et al., 2019). Sire breed effect was conspicuous for initial and final live weights, hot carcass and cold carcass weights, along with dressing percentage, fat thickness, yield grade and rib eye area with crossbreds outclassing Merino purebred lambs (Flakemore et al., 2015), and sire breed impact is sustained despite other non-genetic effects such as nutrition. It has been established that Merino is characteristically a slower growing, leaner sheep breed, experiencing delayed maturity and for that reason market slaughter weights (Warner et al., 2010; Ponnampalam et al., 2008). The inferior performance of Merino has been explanation by its greater affinity for genetic predisposition for wool growth than muscle development. This has been compared with Dorset and White Suffolk sheep breeds has an increased genetic potential for growth and muscling (Warner et al., 2007). In a comparative study where purebred Merino lambs are slaughtered at the same age as other breeds, Merino exhibits inferior carcass performance characteristics (Fogarty, et. al. 2003). In a comparative study on body weight of purebred and crossbred Mecheri sheep at different ages from birth to 12 months, Thiruvenkadan et al. (2009) reported comparable birth weight of crossbred and purebred Mecheri sheep. Nevertheless, the trend was altered as age advanced the differences were insignificant. It was also noted that variation in body weight was not important between purebred and crossbred Mecheri sheep up until nine months of age. The interesting period was at 12 months of age when crossbred Mecheri had superior body weight than their purebred contemporaries. Previously improved body weights of crossbreds than the purebred sheep were reported in various studies (Ulaganathan et al., 1989; Prasad et al., 1991; 1993). Based on the results obtained, it shows an advantage effect of crossing system (Pirot pramenka x Wurttemberg sheep) x Ile de France when it comes on growth and daily gain of lambs. Issakowicz et al. (2018) working with crossbred of Dorper × Santa Inês and Dorper × Morada Nova lambs reported that the crosses had much the same daily live weight gains and feed conversion, comparatively higher as observed in Morada Nova lambs, consequently in a reduction of slaughter age of the former crosses. Morada Nova pure bred lambs showed lower performance compared to the other genetic groups (Dorper × Santa Inês versus Dorper × Morada Nova) lambs resulting in a higher age at slaughter. The variation in performance between crosses and pure lambs were ascribable to greater genetic distance between Morada Nova and Dorper genotypes, and this influence was more conspicuous following weaning, possibly because milk supply had no longer had an effect on performance of weaned lamb. Tesema et al. (2018) average daily gain for Central Highland and Boer* Central Highland goats increased with supplementation levels and the increment was greater for crossbred Boer goats, than for pure Central Highland goats. Growth performance of Menz sheep and their crosses with either indigenous Bonga or Washera sheep were studied by Lemma et al., (2014). The Bonga × Menz coss displayed superior growth performance against pure Menz and Washera × Menz, at the same time the latter two genotypes were comparable. Dvalishvili et al. (2015) reported that crossing of the purebred Romanov ewes with crossbred Romanov rams (3/4 R X ¼ A) had positive influences on growth performance and muscularity of the newborn lambs (7/8 R: 1/8 A). Performance was favourable for crossbreed Boer goats in comparison with other genotypes determined by high quality diet, but comparable on diets with low to moderate quality (Joemat et al., 2004; Negesse et al., 2007; Ngwa et al., 2009). This observation point to the fact that selection for improved goat performance should consider unfavorable environment as expected in the standard commercial production condition. This could be done in order to avoid animals ranked for superior growth rates in favourable environment especially based on nutrient rich diets, to lose fitness hence experiencing challenges when raised in unfavourable production environment (James, 2009; Wilson, 2009).

3. Carcass parameters in goat and sheep breeds and their crosses

Purebred lambs of any breed would need more time to attain destined carcase weights with reference to crossbreds (Carson et al., 1999). This suggests that choice of appropriate breed combination to produce the crossbred progeny is critical. Carcass traits, besides total edible proportion as a percentage of slaughter weight and fat thickness, were superior for crossbred Boer goats against Central Highland goats (Tesema et al., 2018). Dvalishvili et al. (2015) working with Romanov ewes with crossbred Argali Romanov rams on male progeny performance and carcass traits, reported superior parameters of controlled slaughter and deboned carcass than purebred animals. The variation on pre-slaughter weight, hot carcass weight (doubles), slaughter weight and cold carcass weight was important, whereas visceral fat and carcass fat fraction was not significant. Dorper have been characterised as early maturing with the potential of depositing fat at an early age (Cloete et al., 2000). Due to genetic influence of Dorper in their crosses, cross lambs have displayed superior fraction of carcass weight in the hind saddle against Suffolk and Columbia lambs, comprising exceptionally superior loin weights (Snowder and Duckett, 2003). Previously. Means et al. (1999) working with Dorper sheep, reported that Dorper-sired lambs displayed greater leg scores than wool breeds. This result was in conformity with a similar study by Moss et al. (2000). Crossbred Romanov lambs increased significantly the pre-slaughter weight, hot carcass weight, slaughter weight and cold carcass than the purebred ones. Dressing percentage predicted on the hot carcass weight, was not important between crossbred Argali *Romanov and purebred Romanov lambs. Genotype had a significant effect on carcass parameters, where higher carcass measurements where obtained in larger breeds and genotypes (Kadim et al., 2003; Santos et al., 2007). Turkyilmaz and Esenbuga (2019) crossing Turkish indigenous Morkaraman ewes with prolific Romanov rams on performance traits, growth traits, slaughter and carcass characteristics under semi-intensive production systems, purebreds Morkaraman as compared with Morkaraman*Romanov crossbred lambs had superior weight at slaughter, hot and cold carcass, tail fat, and organs (testis, heart and lung). In addition, Morkaraman lambs had greater longissimus dorsi area with reference to Morkaraman* Romanov lambs. It was evident that the Morkaraman lambs had higher growth and slaughter values and some carcass characteristics than Morkaraman*Romanov crossbred lambs. In a similar study De Sousa et al. (2012) reported that Dorper × Santa Inês lambs' crosses were superior to purebred Santa Inês lambs because the crossbred animals had 50% of a breed specialized for meat (slaughter) in their genotype composition.

Dorper × Santa Inês crossbred lambs were superior on fat cover and, resultant higher corporal condition scores. Dorper × Santa Inês (DS) crossbred had desirable fatty acid profile with likely acceptable for healthy human consumption as compared to Dorper × Morada Nova (DM) crossbred lambs, even though both exhibited inferior intramuscular lipid content (as measured by ether extract levels from Longíssimus lumborum) as against purebred lambs (Issakowicz et al., 2018). The displayed elevated fraction of linoleic acid (C18:2C9C12) and arachidonic acid (C20:4n6) and, comparatively, enhanced PUFAs and higher PUFA: SFA ratio of the meat from DS lambs with reference to DM lambs displayed acceptable quality for human consumption. In the same study crossbreds of Dorper × Santa Inês and Dorper × Morada Nova lambs exhibited superior meat characteristics with improved conformation coupled with leg and carcass compactness index. In comparative review by Van Niekerk and Casey (1988) it was noted that Boer goats had remarkable inferior weight apportionment in the hind limb than sheep breeds including the Dorper. In the same review Boer goats posted superior dressing percentage against wool sheep but comparative to the Dorper. Crossbreeding of indigenous Hair Goat with Saanen on carcass quality characteristics of kids under an intensive production system observed that the variation in dressing percentages and other carcass measurements were not important (Yilmaz et al., 2010). A simalr trend was experienced in M. longissimus dorsi area, fatness parameters, subcutaneous fat colour, carcass joint weights and percentages and dissected leg compositions of kids. Kosum et al. (2003) also observed that the influence of genotype was not important for conformation and fatness scores and majority of the carcass characteristics of Saanen and Bornova kids.

Improved dressing percentage were exhibited in crossbred lambs which translated into enhanced proportion of wholesale cuts (Kashan et al., 2005). Cameron et al. (2001) observed non-important variation in dressing percentage between Boer x Spanish, Spanish and Boer x Angora kids in intensive fattening. A dressing percentage range of 46.47 to 47.55% was experienced in crosses of Hair Goat and Saanen x Hair Goat crossbred kids, this was predicted on empty body weight. The non-significant effect of genotype on dressing was also found by Santos et al. (2007) for Capretto carcasses as part of empty body weight. The differences in the importance of genotype on dressing percentages may be explained by variation in slaughter within studies (Ekiz et al., 2010; Kosum et al., 2003). Dorper and Blackhead Ogaden crossbreds had superior dressing percentage as compared with the individual purebreds (Tsegay et al., 2013).

4. Meat quality properties in goat and sheep breeds and their crosses

Genetic and non-genetic factors influence meat attributes with pure breeds and crossbreds exhibiting important distinction in genetic variation (Burger et al., 2013; Cloete et al., 2012; Cloete et al., 2008). Ponnampalam et al. (2007) observed that at the age of 8 months carcases lambs had inferior lean meat and those from Merino lambs were comparable to Poll Dorset x Merino lambs. Oman et al. (2000) observed that genotype influenced muscle, fat and bone percentages in long leg in different goat breed types. However, the lower fat deposition in the organs, the lower total fat percentages in the long leg was an indication that the total fat deposition in different goat breed types might be low in intensive fattening alike. Taylor (1985) reported that advanced animal maturity promotes an increase in fat fraction, a decrease in bone percentage and minimum change in muscle fraction. The different state of physiological maturity of the genotypes utilized in different production environment appeared to be liable for variations in carcass composition. For this reason, animals with higher carcass fat cover assumed higher degree of maturity, leading to a higher length of time to reach the predetermined slaughter weight. The maturity degree may be responsible for carcass composition, since the animals were slaughtered with similar weights as determined by market demand, such as standardized carcasses and cut weights. Breeds differences exist in proportions and distribution of carcass muscle, fat and bone (Bourden, 2000) however their magnitude are also dependent on other factors such as nutrition, age and weight at slaughter. Hopkins et al. (2013) observed that Merinos had inferior sensory indicators than Border Leicester x Merino (BLM) lambs in different location of muscles, which might be probably explained by a slower rate of pH downturn in the Merino lambs. One major challenge of crossing is that it may expedite fatter carcases subject to slaughter weight targets and consequently reduction in lean or saleable meat. A number of studies failed to ascertain variation of meat tenderness amongst breeds and their crossbreds (Dransfield et al., 1979; Hopkins and Fogarty, 1998; Hopkins et al., 2005), in addition to contradictions it was not clear on variation in other traits that determine tenderness, such as pH, sarcomere length, carcass weight or fat levels (Purchas et al., 2002).

Farid et al. (1991) reported differentiated high proportion of kidney and tail fat, omental and mesenteric fat and subcutaneous fat in Baluchi, Karakul and Mehraban sheep, respectively. In contrary, Canton et al. (1992) did not observe differences in fat growth and deposition in pure and crossbred Black Belly genotypes, however, noted that the hair sheep deposited more non-carcass fat in the internal organs than subcutaneous fat in wool sheep. Merino and Border Leicester x Merino crossbred lambs had superior intramuscular fat fraction in such way as to cover both ewes and wethers, and even in comparison with other genotypes (McGhee et al., 2008). Sire influence on fat deposition in carcasses was predominant as measured by subcutaneous fat depth with lambs sired by Border Leicester rams beign superior against those sired by Dorset Horn rams (Atkins and Thompson, 1979). There was evidence of superior dissected hind leg fat content indicated by Border Leicester x Merino carcasses attaining an average of 2.4 and 2.7% for ewes and cryptorchids, respectively, as compared with Dorset x Merino carcasses (Hopkins et al., 1997). The variation in primal cuts as a proportion of whole carcass were comparable among Boer × Spanish, Boer × Angora, and Spanish goats, and there were few differences in fraction of split lean, bone, and fat in primal cuts (Cameron, et al. 2001). Fat deposition and distribution sequence differ with breeds, Negussie et al. (2003) working with Menz and Horro sheep, the former had a tendency to deposit more fat into the carcass as contrasted with the latter, which deposit more fat into non-carcass fat depot or body cavities. The major human health concern on red meats is the content and nature of saturated fatty acids by the side of cholesterols, which has been associated with the deposition of plaques walls and in accord with the rise in cases of heart disease (Penfield, 1990). Fatty acids have been targeted in number of studies in goat and sheep meat production to amass knowledge their effects on human health and association with certain diseases. Superior muscle ultimate pH for Merino and Border Leicester x Merino lambs against terminal sire second cross lambs was observed in more than one studies (Hopkins et al., 2007; Fogarty et al., 2000; Gardner et al., 1999). Cameron et al. (2001) working with Boer × Spanish, Boer × Angora, and Spanish goats observed that non-carcass fraction were comparatively higher for Boer crossbreds against Spanish goats, based on empty body weight, however, non-carcass component weights did not differ in the ranks of genotypes. As excepted, carcass traits were essentially associated with variation in final body weight.

5. Highlights

- ✓ Goats and sheep breeds are diverse and populated all around the worlds' agro ecological regions culminating in distinctive performance, hence it is recommendable that producers are acquainted with the performance parameters of some of the more popular breeds and their crosses within regions.
- ✓ Growth performance, carcass characteristics and meat quality properties of kids/lambs which meet specific market demands are dependent on genotype of breeds and their crosses.
- ✓ Pure breeding and crossbreeding are both acceptable modes of production to promote targeted growth performance, carcass and meat parameter.
- ✓ Individual breed and crossbred performance characteristics have a genetic foundation that determine its success in both straight breeding and/or structured crossbreeding systems
- ✓ Goats and sheep breeds diversity and genetic distance are the basis for enhanced crossbred growth performance, carcass and meat parameters proportionate to purebred flocks.
- ✓ Maximum benefits in growth performance, carcass and meat parameters are accrued in systematic terminal crossbreeding systems where specialized sire breeds are utilized to complement traits of crossbred dams.
- ✓ Accomplishment of crossing depends on the degree of combining ability, maternal, paternal and individual heterosis as determined by choice of breeds, hence goats and sheep breeds can be bred as specialized paternal and maternal lines for utilization in crossbreeding systems.
- ✓ Performance parameters are much dependent on animal genotype, although the overall productive capacity of breeds and their crosses will be influenced by other factors such as nutrition, management, health and animal factors of age, slaughter weight and sex.
- ✓ Overall performance of goats and sheep breeds and their crosses will vary according to production conditions, as a result affecting the extent of growth performance, carcass and meat properties one way or another.

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