

Goat meat production, composition, and quality

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Implications

- Goats are prolific and resilient small ruminant livestock with a wide ecological adaptation. Production and consumption of goat meat are low despite the importance of the species, but this sector has huge potential to supply food for a growing human population.
- Goat meat serves as a major source of meat in developing countries while it is less popular in western countries. Nevertheless, the perceptions about goat meat are changing due to the health benefits of the consumption of lean meat with reduced fat and cholesterol content.
- Scientific research has been conducted on the quality and composition of goat meat as well as management, feeding, and genetic aspects of goat meat production.
- It is clear that, in future, goat production will have to focus on the use of technologies to improve productivity and efficiency.
- Improved transportation, pre-slaughter management, and optimum slaughter weights and conditions are essential to ensure consistently high quality meat from goats. The purpose of this article is to review goat meat production, composition, and quality.

Key words: goat, meat production, meat quality

Introduction to Goat Meat Production

Domesticated goats descended from the bezoar or wild goat, *Capra hircus*, in the hills of western Asia. These small ruminants represent one of the earliest species of livestock domesticated by pastoralist humans approximately 9,000 years ago (Casey et al., 2003). Goats are now widely distributed around the world, totaling more than 850 million and representing about 1,156 different breeds (Devendra, 2010). On a global scale, goat meat consumption is less than beef (Madruga and Bressan, 2011), but goats undoubtedly serve as a staple source of red meat to humans (Webb et al., 2005), especially in developing countries. It is estimated that 98% of the goat population is in developing countries where more than 30 improved or indigenous breeds exist that are under-utilized (Devendra, 2010). In India, goat meat is preferred above mutton (Sen et al., 2004).

Commercial farming for metropolitan markets is increasing in Asia, Africa, and in Central and South America (Casey et al., 2003). In New Zealand, the focus of goat production is primarily on fiber, and meat is a by-product

(Hogg et al., 1992). The exploitation of unconventional livestock like goats is advocated in developing countries to meet the increasing demands for meat consumption (Babiker et al., 1990) and to ensure food security.

The quantity and quality of goat meat are affected by genetic and environmental factors (Goetsch et al., 2011). The effects of breed, age, sex, and nutritional factors on growth, carcass, and meat quality have been reviewed (McMillin and Brock, 2005; Webb et al., 2005; Casey and Webb, 2010; Goetsch et al., 2011). Domesticated goats are characterized by notable genetic variation in morphological and production characteristics (Shrestha and Fahmy, 2005). There is a growing tendency in many countries to import more prolific breeds to increase the growth characteristics and meat yields of local goats by crossbreeding and breed improvement programs. In Italy and other countries, the demand for goat meat is seasonal with notably greater demands for the product at Christmas and Easter (Carlucci et al., 1998). Similar trends in terms of seasonal fluctuations in producer prices for goats are noticeable in the USA. The demand and producer prices of goats generally increase from November and December to Easter, followed by a decrease in demand and producer prices from July to October. Although goat meat production holds promise in terms of supplying the protein needs of an increasing human population, there are concerns about the productivity of goats in developing countries due mostly to inefficient feeding and management, inadequate exploitation of genetic resources, and disease constraints (Devendra, 2010). These concerns will be discussed in the next sections.

Popularity of Goat Meat

The popularity of goat meat is subject to the common culture of communities and the forces of civilization (Webb et al., 2005). Consumers in the Western world do not favor goat meat (Babiker et al., 1990), although the perceptions of Western consumers are changing because of its low fat and cholesterol contents and favorable sensory characteristics (Webb et al., 2005; Madruga and Bressan, 2011). Globally, goat meat consumption increased during the past 20 years (Madruga and Bressan, 2011). Ibrahim (2011) recently reported an increase in the importation of chevon from Australia and New Zealand to the USA due to an increasing immigrant population. The increasing awareness of Western consumers in relation to a variety of environmental issues and traceability has caused a greater demand for animal products from organic or natural production systems, which are compatible with extensive goat production systems.

Goat Carcass Characteristics

The phenotypic characteristics and production potential of goats are highly variable, with subsequent effects on carcass and meat quality.

Table 1. Comparison of carcass characteristics of Boer goats, Nubian × Florida Native goats, Spanish × Florida Native goats, and Florida Native goats at representative commercial slaughter weights.

Variables	Boer goats*	Nubian × Florida Native†	Spanish × Florida Native †	Florida Native†
Cold carcass weight, kg	14.0	10.9	9.6	9.5
Dressing, %	55.7	50.0	51.1	51.9
Total meat, %	76.5	69.0	68.3	68.0
Total bone, %	20.5	21.7	21.2	20.4

*Tshabalala et al. (2003).

†Johnson et al. (1995).

Carcass characteristics of Boer goats, Nubian × Florida Native goats, Spanish × Florida Native goats, and Florida Native goats at representative commercial slaughter weights are presented in Table 1. Goats are generally sub-divided in three categories based on frame size, namely, dwarf breeds, small breeds, and large breeds. The body weights of goats with a small frame size vary between 15 and 30 kg at about 15 months of age, while large-framed breeds may weigh up to 55 kg body weight at a similar age. By contrast, dwarf goats seldom weigh more than 25 kg at 15 to 24 months of age. Mature animals above 2 years of age tend to dominate

goat markets in developed countries and formal markets in developing countries, while appreciably younger animals are traded in the informal, subsistence, and small-scale agricultural systems.

Slaughter weights are influenced by the production system, mature frame size or type, environmental factors like the availability of feed and water, as well as cultural factors and rituals. “Cobrito meat” from relatively small carcasses of 6 to 8 kg is popular in Mediterranean countries, Latin America, and western parts of India (Madruga and Bressan, 2011). Optimum carcass weights vary between 12 and 15 kg due to the increasing emphasis on lean meat yield. Indications are that carcasses from older animals that weigh more than 20 kg are more likely to be perceived as stringy, tough, and strongly flavored (Webb et al., 2005; Casey and Webb, 2010). This is reminiscent of the practice in marginal agricultural systems to retain castrates that will survive droughts and to trade such animals at an older age.

The dressing percentage of goat carcasses tend to be less than that of sheep, mainly due to the reduced carcass fat content of goats (Webb et al., 2005). Average dressing percentages varies between 50 and 55%. An important feature of goat carcasses is that almost all parts of the carcass are consumed, which makes the practical use of dressing percentage in goats dubious (Lebbie, 2004). Carcass fat content of goats is generally low, and fat accretion occurs much later in the growth process compared with other domesticated ruminants. It should be noted that in some countries, the head is not removed from goat carcasses, which influences the dressing percentage. Values quoted in this paper are with the head removed from the carcass. In addition, moisture and drip losses from goat carcasses are sometimes quite high (up to 8%), which may result in lesser dressing percentage values.

Carcass fat content and composition are influenced by age, sex, breed type, body weight, and dietary factors (Casey et al., 2003). The relatively low carcass fat content in goats has implications on the conversion of muscle to meat and ultimately meat quality (Webb et al., 2005). In this regard, the relatively poor subcutaneous fat cover appears to be the most limiting factor since subcutaneous fat is used to estimate carcass yield in sheep and other ruminants. It follows that most sheep grading and/or classification systems that are at least partly based on subcutaneous fat thickness or cover, cannot be employed in goats (Simela et al., 2004a). Goat carcasses with less subcutaneous fat are more prone to moisture losses and cold shortening subsequent to chilling. Cold shortening in lean goat carcasses can be better managed or prevented by electrical stimulation of the carcasses as well as post-mortem ageing or blade tenderization (Kannan et al., 2002, 2006; McMillan and Brock, 2005).

Goat Carcass Composition and Retail Cuts

The use of the various cuts of a goat carcass differs among countries; for instance, the cuts from the loin region, dorsal trunk (dorsal part of the thorax), and hind limb are the most sought after ones in Western countries. By contrast, a high preference for cuts from the breast region has been shown in some African and Asian studies (Casey, 1982; Simela, 2005). These aspects have important implications in terms of the marketing of goats in different countries. Cuts from the hind limb are associated with high value due to the low carcass fat and high lean content (Casey, 1982; Simela, 2005). Cuts from the dorsal trunk have a low fat content, but they are perceived to contain a percentage of bone (Table 2). The practical implications are that the rib and loin cuts from goat carcasses are less meaty compared with similar cuts derived from the dorsal trunk of sheep.



Goat Meat Quality

Goat meat is internationally regarded as a lean red meat with favorable nutritional characteristics (Babiker et al., 1990; Hogg et al., 1992; Webb et al., 2005). Goat meat has a somewhat darker red color, coarser texture, and characteristically different flavor and aroma compared with lamb or mutton (Schönfeldt et al., 1993a,b; Casey et al., 2003). The results of sensory studies indicate that goat meat is different but certainly not inferior to lamb (Webb et al., 2005). Goat meat and meat products also tend to be less juicy than mutton (Schönfeldt et al., 1993b; Tshabalala et al., 2003) predominantly due to their reduced fat content.

Flavor and aroma are complex attributes of goat meat. These sensory attributes are affected by species, age, fatness, and anatomical location, gender, diet, and method of cooking. Consumers can easily detect the aroma and flavor of meat and can grade the acceptability of these attributes. Goat meat flavor is either as acceptable (Babiker et al., 1990; Griffin et al., 1992) or less desirable (Pike et al., 1973a) than that of lamb or mutton.

Branched chain fatty acids may contribute to the typical sheep and goat species flavor (Wong et al., 1975; Johnson et al., 1977; Ha and Lindsay, 1990). The strong goat odor has been associated with 4-ethyloctanoic acid in goat meat, lamb, and mutton (Brennand, 1989 as cited by Madruga et al., 2000; Ha and Lindsay, 1990). Shear force values and tenderness ratings of goat meat are generally acceptable, especially meat from young animals (Webb et al., 2005). Factors such as the treatment of the animals before slaughter (Simela et al., 2004a, b) and of the carcass (like electrical stimulation of carcasses with high or low voltages) influence meat tenderness (King et al., 2004).

One of the important recent contributions to our current knowledge on goat meat quality concerns the sensitivity of goats to peri-mortem stress and the related effects on the conversion of muscle to meat (Webb et al., 2005). Ultimate pH values (pHu) in goat carcasses generally range between 5.8 and 6.2 (Nuñez Gonzalez et al., 1983; Kannan et al., 2001, 2003; Simela et al., 2004a,b). These high-pHu values of goat meat suggest that goats are generally more prone to stress. Peri-mortem concentrations of glycolytic metabolites in muscles support these findings (Simela et al., 2004b). A glycogen concentration of approximately 50 $\mu\text{mol/g}$ is regarded as the minimum concentration required for sufficient lactic acid production to attain a satisfactory pHu. Simela et al. (2004b) reported muscle glycogen concentration as low as 33 $\mu\text{mol/g}$ for samples from a goat herd of mixed sex and age.

Goat carcasses with a lower pHu tend to be more tender, with lower shear force values and better colorimetric values (Simela et al., 2004a) than those



with a high pHu. The susceptibility of goats to peri-mortem stress is apparently associated with the excitable nature of goats, which predisposes them to this condition (Hopkins and Fogarty, 1998). Much of the variation in meat quality due to peri-mortem stress appears to be associated with transportation stress, and it was shown in Omani goats that electrical stimulation of carcasses reduces the effects of transportation stress (Kadim et al., 2010) by increasing the anaerobic metabolism of glucose to lactic acid, reducing cold shortening and improving the conversion of muscle to meat.

Nutrient Composition

A summary of the proximate composition of goat meat is presented in Table 3. Goat meat protein also has a high biological value of

Table 2. Approximate mass distribution of major primal cuts in Boer goat carcasses (expressed as a percentage of carcass weight) at a representative commercial carcass weight of ca. 14 kg (adapted from Casey et al., 2003).

	Boer goat
Fore limb, %	17.3
Neck, %	9.3
Ventral trunk, %	25.8
Dorsal trunk, %	19.3
Hind limb, %	28.4

approximately 60.4 and digestibility coefficient of 97% based on trials with rats fed a 10% protein level from goat meat (Casey et al., 2003).

Goat meat provides an acceptable source of protein and essential amino acids to meet the dietary requirements of the average adult consumers. The amino acid composition varies little between species on a lean meat basis, while the differences are more significant on a whole-meat basis. Goat meat also provides an excellent source of iron because the haeme iron is about 5 to 10% more available than non-haem iron (Casey et al., 2003).

In terms of fat, both the chemical and physical properties of fat influence the sensory and keeping properties of meat (Webb et al., 2005; Webb and O'Neill, 2008). The degree of saturation of fat [ratio between saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids] influences the consistency, chemical composition, and sensory characteristics of carcass fats and the shelf life of meat products. Desirable fatty acids are also important and include C18:0 and all unsaturated fatty acids (Banskalieva et al., 2000) because they have no adverse implications on consumer health. The PUFA/SFA ratio should be high and be at least 0.45 (Enser et al., 1998). Within PUFA, a high proportion of n-3 fatty acids is beneficial while the ratio of n-6/n-3 of less than 5 is acceptable (Raes et al., 2004).

Chevon has an advantageous fatty acid profile, and the meat is ideal for health-conscious consumers (Hogg et al., 1992; Mahgoub et al., 2002). Desirable fatty acids in chevon ranged between 61 and 80% (Banskalieva et al., 2000), while figures were 67.45% for Omani goats (Mahgoub et al., 2002) and 65.37 and 66.4% for Boer and South African indigenous goats, respectively (Tshabalala et al., 2003). The PUFA/SFA ratios of chevon are often greater than similar values for lamb/mutton, beef, and pork. Although grain feeding improves the ratio of PUFA/SFA, it also increases the n-6/n-3 ratio to an unfavorable level (Enser et al., 1998). The cholesterol content of goat meat generally varies between 30 and 60 mg/100 g (Werdi Pratiwi et al., 2006).

Cooking and Preparation of Goat Meat

The effect of cooking on muscle is method-, time-, and temperature-dependent, and the response to heat treatment varies between muscles and according to pre- and post-mortem influences. Cooking could be either direct (in a pan or over an open fire or heated coals) or indirect (in a pot with or without moisture). Prolonged indirect cooking appears to be the standard method of preparation in African countries while the cooking methods in other countries are comparable with that employed for mutton or lamb (including both direct and indirect cooking methods). Prolonged cooking leads to rendering in which a very high percentage of fat cookout is obtained.

Table 3. Summary of proximate composition of goat meat from meat type (Boer goat), unimproved indigenous goats (Savanna goat), and hair-type goats (Angora goat; adapted from Webb et al., 2005).

Nutrient	Moisture	Protein	Fat	Ash
	%			
Boer goat	69.4	22.8	10.5	0.95
Savanna goat	69.8	24.3	7.9	0.97
Angora goat	64.2	29.1	4.4	1.0

Generally, temperatures below 100°C affect palatability, without severely reducing the nutritive value of the meat (Casey et al., 2003). Cooking losses from goat meat tend to be high (35%), and this detracts from the sensation of juiciness. Cooking losses contributed at least in part to the perception of consumers that goat meat is less juicy than lamb or mutton (Schönfeldt et al., 1993b; Tshabalala et al., 2003). Goat meat from different breeds can be used to manufacture processed products of acceptable sensory quality (Breukink and Casey, 1989; Tshabalala et al., 2003).

Conclusions and Future Prospects for Goat Meat Production and Quality

Goats are adaptable and resilient ruminants that provide an invaluable resource to ensure sustainable livestock production and contribute to the mounting protein needs of a rapidly growing human population. Goat meat is widely regarded as lean meat, and indications are that the demand for this healthy meat will increase. Goat producers will have to employ new technologies and feeding methods to improve the productivity and yields of goats, especially the improved or indigenous breeds of goats. Better management and feeding of goats are essential to improve carcass composition and reduce the risk of cold shortening and moisture losses post-mortem. The use of electrical stimulation of carcasses appears to be essential to manage the effects of transportation and peri-mortem stress in goats. Marketing goat meat as a lean and healthy product should be a major future initiative to improve the acceptance of goat meat as alternative source of good quality protein from animal origin.

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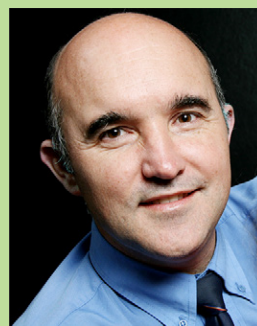
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