Goat Meat Production: Present Status and Future Possibilities

J. S. Dhanda*[2], D. G. Taylor[1], P. J. Murray[2], R. B. Pegg and P. J. Shand

Department of Applied Microbiology and Food Science, University of Saskatchewan, 51 Campus Drive, Saskatoon SK S7N 5A8, Canada

ABSTRACT : The bulk of the world's goat population is found in South-East Asia and Africa, where goats are the major source of meat production. Unfortunately, lack of an organized goat meat industry and marketing structure in developing countries is primarily responsible for their poor export earnings compared to those in developed countries such as Australia and New Zealand. Goat meat is leaner than meat from other domestic red meat species as well as being comparable in terms of its nutritional constituents. Furthermore, there are few, if any, religious or cultural taboos limiting the consumption of goat meat. Development of a carcass grading system and a suitable infrastructure in developing countries are some of the key requirements needed to establish a sustainable goat meat industry in the world. With an increase in demand by consumers for low-fat red meat alternatives, the future of the goat meat industry looks promising. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 12 : 1842-1852)***

Key Words : Goat Meat Industry, Meat Production Potential, Nutritive Value, Future Needs

INTRODUCTION

Meat production traits of goats have received relatively little scientific attention, as compared to domesticated species used for meat production; that is, cattle, pigs and sheep. This is probably due to the traditionally low economic significance of goats in the developed world and preference for other red meats such as beef, pork and mutton. In developed countries, goats are considered as specialty or exotic livestock, whereas in developing countries- mainly those in South-East Asia and Africa- goats are the major source of meat production.

Goat is the most prolific ruminant of all domesticated ruminants under tropical and sub-tropical conditions and most goat breeds have average litter sizes of 1.5 or higher (Naude and Hofmeyr, 1981). Two reasons for the goats' ability to survive in some of the most inhospitable regions of the world are their exceptional tolerance to heat stress (Norman, 1991) and ability to grow on poor quality feed. Therefore, goat production is equally suited to marginal farming areas, small farms or large-scale production in the tropics and sub-tropics. When not properly managed, goats can cause extensive damage to vegetation and forests. However when carefully controlled, these animals can be used to improve the quality of rangelands, to control weeds (Norman, 1991) and to be a source of meat, milk and fibre. Goat meat is acceptable to those who, for religious or cultural reasons, do not eat pork (Muslims) or beef (Hindus). For this reason, goat has been designated as the national meat animal in India (Pal and Agnihotiri, 1996).

The adult male goat is traditionally known as a buck, the female as a doe and a young goat as a kid. As with other young animals, a goat that has been weaned from its mother is known as a weaner. The goat population has been described as comprising three main types; namely, fibre goats (e.g., Angora, Cashmere), dairy goats (e.g., Saanen, Toggenburg, Nubian) and meat goats (e.g., Boer, Spanish). In Australia and New Zealand, there are also wild goats called Feral goats and they exhibit characteristics similar to a range of dairy and fibre breeds (Murray et al., 1997). For marketing purposes however, goat meat has been divided into two distinct classes; these being Capretto, which is obtained from milk-fed, suckling kids with a carcass weight of 6 to 12 kg and pink flesh, and Chevon, which is from older goats with a carcass weight of 16 to 22 kg.

The purpose of this review is to compile current data and to report on the status of the goat meat industry throughout the world. The distribution of goats worldwide, the breeds of goats available and the types of production systems in use will be examined. The later sections will discuss in detail the suitability of goat as a meat animal and current consumer trends. The final section will postulate future needs and strategies for goat meat research.

CURRENT STATUS OF THE GOAT MEAT INDUSTRY

The world's goat population was approximately 715 million in 2000 (Table 1), with over 60 percent of that found in Asia and more than 95 percent in developing countries (FAO, 2001). India has the largest goat population at 123 million, which represents slightly more than 17 percent of the world's population (FAO, 2001). Since 1985,

* Corresponding Author: Jagvinder S. Dhanda. Tel: +1-306-966-5030, Fax: +1-306-966-8898, E-mail: dhanda@sask.usask.ca

[1] Baroona Park, Mail Service 1497, Toowoomba, Qld. 4352, Australia.

[2] School of Animal Studies, University of Queensland, Gatton, Qld. 4343, Australia.

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Table 1. Global goat population figures

Region	Year			
	1985	1990	1995	2000
Goat population (1,000 head)				
World	484,594	583,358	664,726	720,007
Africa	147,234	172,576	197,368	209,346
Asia	282,488	349,714	408,844	455,246
Europe	12,877	15,481	19,667	18,069
North America	1,575	1,927	1,878	1,380
South and Central America	32,948	35,227	36,199	35,287
Oceania	1,146	1,870	769	677
Developed countries	27,622	31,848	32,002	29,456
Developing countries	456,972	551,510	632,723	690,551
Goat population (head) per 1,000 capita				
World	100	111	117	119
Africa	274	281	283	269
Asia	99	112	120	124
Europe	26	31	27	25
North America	5	5	3	2
South and Central America	82	80	75	68
Oceania	47	71	27	22
Developed countries	23	25	25	23
Developing countries	126	137	144	145

FAO, 2001.

Table 2. Number of goats slaughtered and meat production figures throughout the world

Region	Year			
	1985	1990	1995	2000
Goat slaughtered (1,000 head)				
World	180,322	226,953	268,652	308,893
Africa	44,703	54,631	62,358	68,449
Asia	113,624	147,670	182,883	218,452
Europe	10,372	11,463	12,679	11,841
North America	<1	<1	<1	<1
South and Central America	9,348	10,043	10,093	9,601
Oceania	575	769	636	548
Developed countries	14,510	16,706	16,103	15,236
Developing countries	165,811	210,247	252,549	293,657
Goat meat production (1,000 metric tonnes)				
World	2,050	2,654	3,331	3,713
Africa	513	645	747	826
Asia	1,293	1,738	2,266	2,601
Europe	95	100	130	121
North America	<1	<1	<1	<1
South and Central America	104	116	122	131
Oceania	13	16	12	11
Developed countries	166	189	188	179
Developing countries	1,879	2,464	3,089	3,512

FAO, 2001.

there has been a significant increase (48%) in goat numbers throughout the world. Global data on goat populations, numbers slaughtered and trade are presented in Tables 1 to 4.

Around 3.7 million metric tonnes of goat meat was produced worldwide in 2000 (Table 2); this represents only 1.6 percent of the total world meat production, which is at 233 million metric tonnes (FAO, 2001). Yet, this amount of goat meat production does not clearly reflect the actual level of production: a high proportion is either sold to consumers directly at the farm gate and consequently does not follow proper marketing channels, or is consumed in the home and therefore not marketed at all. Lack of an organized meat industry and marketing structure in developing countries is clearly reflected in the export figures for goat meat. In 1999, developed countries exported more than double the amount of goat meat and earned around 4.5 times more compared to those of developing countries (Table 4). This scenario takes on more significance when we consider that goat populations and goat meat production figures in developed countries are negligible compared to those of developing countries (Tables 1 and 2). For example, Australia has a very small goat population (2.2 million) compared to India (123 million), but it is the world's largest exporter (worth $15 million) of goat meat with over 90% of its goat meat production being exported. On the other hand, India's export earnings from goat meat are a meagre $0.6 million. The contribution of goat meat to total meat exported from India (mainly to Middle Eastern countries) accounts for less than 7%, compared to 70 to 80% for buffalo and 20% for mutton (Pal and Agnihotiri, 1996). One could argue that in the developing world most of the goat meat produced is consumed locally, thereby leaving little for export, but is this the only explanation for the poor state of the goat meat industry in developing countries? The disease status in developing countries is not helping the situation either, as it is not uncommon that the exportation of live goats and goat meat from these countries to developed markets is prohibited. The inability of developing countries in the Western hemisphere to gear their production systems to worldwide market demands for goat meat has been exploited in recent years by countries like Australia and New Zealand. Goat meat exports from Australia and New Zealand are derived from harvesting Feral goats (Norman, 1991). Australia exports bone-in whole carcasses with a carcass weight range of 12 to 20 kg to Singapore, Malaysia, Japan, Mauritius and the Caribbean, and boneless meat to the United States of America and Canada. There is a rapidly

Table 3. Trade of live goats throughout the world

Region	Goat numbers (1,000 head)				Value (1,000 $)			
	Year				Year			
	1985	1990	1995	1999	1985	1990	1995	1999
Live goats imports								
World	1,181	2,163	3,031	2,376	51,255	91,654	122,698	96,939
Africa	471	535	643	649	19,688	29,820	39,975	41,723
Asia	590	1,529	2,315	1,562	23,272	55,730	77,607	48,831
Europe	17	43	55	91	1,030	2,837	3,020	3,002
North America	<1	6	2	5	55	437	1,164	509
South and Central America	98	50	15	68	4,366	2,814	542	2,856
Oceania	4	<1	<1	<1	2,843	16	390	18
Developed countries	22	49	57	96	3,927	3,355	4,574	3,573
Developing countries	1,159	2,114	2,974	2,280	47,328	88,299	118,124	93,366
Live goats exports								
World	2,276	2,014	2,702	2,853	104,416	99,981	103,263	93,355
Africa	1,337	934	1,488	1,562	58,332	40,434	52,629	51,155
Asia	875	812	1,109	1,005	39,879	49,200	37,469	31,864
Europe	59	68	68	158	3,756	3,696	4,013	4,319
North America	0	92	16	74	0	3,440	1,765	3,524
South and Central America	<1	13	<1	<1	33	333	121	23
Oceania	5	93	20	54	2,417	2,878	7,266	2,470
Developed countries	65	254	104	287	6,563	10,023	13,080	10,506
Developing countries	2,211	1,760	2,598	2,566	97,854	89,958	90,183	82,849

FAO, 2001.

Table 4. Goat meat trade throughout the world

Region	Goat meat (metric tonnes)				Value (1000 $)			
	Year				Year			
	1985	1990	1995	1999	1985	1990	1995	1999
Goat meat imports								
World	2,783	16,376	21,606	31,834	4,950	52,862	57,829	70,828
Africa	119	899	1,149	139	130	2,131	3,238	248
Asia	631	7,076	11,040	22,100	873	13,434	22,408	36,791
Europe	0	3,828	3,255	0	0	28,709	18,432	21,287
North America	71	1,809	3,630	3,906	91	3,173	8,104	9,904
South and Central America	1,918	2,638	2,450	1,229	3,793	5,187	5,373	2,366
Oceania	44	126	78	195	63	228	274	232
Developed countries	198	5,833	7,205	8,380	370	32,342	27,231	31,772
Developing countries	2,585	10,543	14,401	23,454	4,580	20,520	30,598	39,056
Goat meat exports								
World	1,100	18,308	15,841	17,463	1,543	47,724	42,482	43,397
Africa	85	237	302	244	113	382	612	535
Asia	230	2,425	2,024	5,064	369	3,754	4,369	7,658
Europe	0	3,613	2,442	2,511	0	27,218	18,295	0
North America	0	1,606	58	162	0	3,659	118	197
South and Central America	274	247	0	6	268	377	1	5
Oceania	511	10,180	11,015	9,476	793	12,334	19,087	18,333
Developed countries	511	15,414	13,532	12,150	793	43,240	37,522	35,200
Developing countries	589	2,894	2,309	5,313	750	4,484	4,960	8,197

FAO, 2001.

growing export market of Australian Capretto carcasses to Europe. Much of New Zealand's goat export, which has an average carcass weight of 10 kg. is destined for markets in southern Europe. the Caribbean and South-East Asia (Murray, 2000).

GOAT BREEDS AND PRODUCTION SYSTEMS

Goats have been bred for various purposes: that is. as a source of meat, milk or fibre. There are 102 recognized breeds of goats throughout the world, ranging in mature

Table 5. Mature size of some selected goat breeds around the world

Breed	Country	Sex	Body weight (kg)	Withers height (cm)
Saanen	Switzerland,	M	80-120	80-95
	France	F	50-90	74-85
Toggenberg	Switzerland	M	65	75-85
		F	45	70-80
Alpine	France	M	80-100	90-100
		F	60-90	70-80
Criollo	Mexico	M	40-50	75
		F	30-35	65
West African Dwarf	Guinea, Angola, Namibia	M/F	20-25	40-50
Feral	Australia	M	50	75
		F	30-40	65
Feral	New Zealand	M	27-36	
		F	19-26	
Angora	U.S.A.	M	46	65-70
		F	40	55-60
Barbari	India, Pakistan	M	35-45	66-76
		F	27-36	61-71
Jamnapari	India	M	70-90	90-102
		F	45-65	76-86
Beetal	India	M	65-85	91-99
		F	45-60	76-83
Black Bengal	India	M	14-15	45-50
		F	8-13	40-45
Zhongwei	China	M	39	61
		F	24	57
Kambing Kachang	Indonesia	M/F	30	50-60
Improved Boer	South Africa	M	115	75
		F	50-70	65

Adapted from Devendra and McLeroy (1982); Mason (1981); Warmington and Kirton (1990).

weight from 9 to 13 kg for small tropical breeds to over 100 kg for the large dairy breeds and improved Boer goats (Warmington and Kirton, 1990). Mature weights and wither heights of selected goat breeds found around the world are presented in Table 5. Without actually seeing the animals, it is difficult to appreciate the striking differences in form between the long-legged Jamnapari to the stocky improved Boer to the dachshund-like West African Dwarf goats (Warmington and Kirton, 1990). In the broadest sense, all goats are meat goats. Irrespective of the breed, every goat put up for sale is eventually slaughtered for human consumption. Yet, certain breeds such as the Boer, Spanish and Anglo-Nubian are better suited for meat production than others.

In most developing countries, the average flock size is between 3 and 10 goats with little provision for special forage or housing. Goats serve as the material, cultural and recreational needs of the farmer by providing income, employment, security, power, food and by-products. Recommendations aimed at increasing the complexity and cost of the production system are not likely to be adopted, as they take away one of the major reasons for maintaining the goats in the first place: goats require no capital input and their sale represents a large profit with virtually no investment risk (Norman, 1991). In India, the most common system for managing goats is extensive grazing of flocks on natural rangelands with or without nutritional supplements. Nevertheless, there is a small but growing number of organised farms that follow intensive or semi-intensive management systems (Pal and Agnihotiri, 1996). In South Africa, processing of goat meat is similar to that of lamb; meat from young Boer goats competes with lamb (Murray et al., 1997).

In developed countries, goats are managed under a number of systems. In Australia, the management of dairy breeds has traditionally been intensive, whereas fibre-producing breeds are managed through mixed farming systems. The main source of goats for slaughter comes from the opportunistic harvesting of Feral populations. Estimates of the number of Feral goats in Australia vary between 1 and 3 million (Bajhau and Kennedy, 1990). These Feral goats show characteristics of dairy and fibre breeds (e.g., some have well developed udders while others produce reasonable amounts of good quality cashmere). Until the 1980s there were no true goat meat breeds in Australia. Besides Feral goats, the only other sources of goat meat were males from dairy goat breeds and cull animals, these being mostly older goats from the fibre-producing breeds. Because these breeds were bred for traits other than carcass characteristics, the quality of meat from the animals would have done nothing to enhance a consumer's desire to eat more goat meat. With the importation of Boer goats from South Africa in the early 1990s there has been a growing interest by investors, hobby farmers and farmers involved in traditional animal industries, in the development of an Australian goat meat industry. This goat meat industry is developing on a crossbred goat, which is basically Boer bucks mated with domesticated Feral does or does from the fibre or milking breeds (Murray et al., 1997). In the USA, the rising demand for goat meat, loss of government support for mohair production, and the introduction of the Boer goat are the factors contributing to an increasing interest in raising goats for meat (Cameron et al., 2001). A major portion of goat meat is derived from goats kept for fibre and milk such as the Spanish, Angora and Anglo-Nubian, although the number of Boer crossbred meat goats has been increasing rapidly. Goats are usually managed as part of multi-species grazing systems, with the addition of one to three goats per cow to increase forage production by reducing shrub competition (Glimp, 1995). Due to the large ethnic populations within the Eastern USA and their consumer preference for goat meat, there is a great potential for farmers to market goat meat in this region (Lechner et

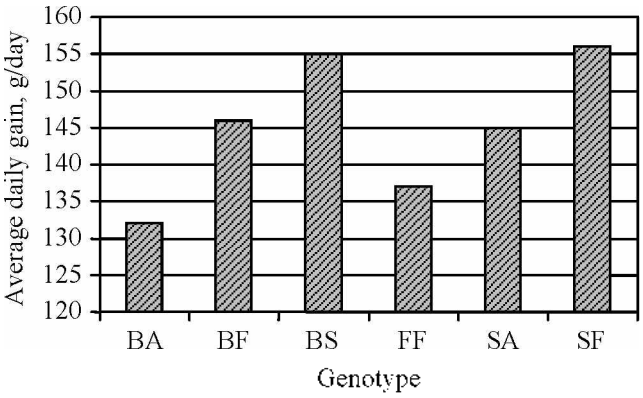

Figure 1. Growth (average daily gains, g/day) of male kids from six different genotypes (BA, Boer×Angora; BF, Boer×Feral; BS, Boer×Saanen; FF, Feral×Feral; SA, Saanenl×Angora and SF, Saanen×Feral) (Dhanda, 2001).

al., 2001).

GOAT AS A MEAT ANIMAL

Growth and nutrition

Inherently slow growth rates (especially in fibre and dairy goats) and poor management conditions are two major factors responsible for low meat production from goats. There are also nutritional influences, which affect the growth of goats; these include pasture type and its availability, grazing competition and the amount and type of supplements provided. Improved nutrition of lactating goats can increase milk yield (Norton et al., 1984), which is translated into improved kid growth and ultimately a better potential for meat production.

As aforementioned, there are over 100 goat breeds throughout the world ranging in weight from 10 to 100 kg. This diverse and vast genetic pool offers a rapid method for improving traits of economic importance in goats. For example, crossbreeding is a good tool to improve growth; this has been demonstrated by Dhanda (2001) on growth performance and some carcass traits in goats. Heterosis and genetic effects on the growth of kids were studied by Anous and Mourad (1993). These authors found an increase in body weight of female and male crossbreds over straightbreds. Furthermore, estimates of heterosis were significant ($p<0.01$) and positive for some carcass traits, namely carcass yield, width, shape and internal fatness. Growth rate in goats is dependant on mature size of a particular breed. Generally, progeny of larger breeds grow faster than those of smaller breeds. This fact has been supported in a study by Dhanda et al. (1999a) where male kids from larger breeds (Boer and Saanen) grew faster than kids born to smaller breeds (Feral and Angora). The rate of growth in goats can vary from around 50 g/day for the small tropical breeds (e.g., Indian Barbari, Indonesian Kambing) to over 200 g/day for large European dairy breeds (e.g., Saanen, Alpine) and the South African Boer breed (McGregor, 1985). The amount of variation in growth rates between different goat genotypes is depicted in Figure 1. As heritability estimates for mature size and growth are high, an easy way of achieving faster growth rates is to breed larger goats either by selective breeding within breeds or by crossbreeding with larger breeds (McGregor, 1985). Importation of Boer goats has provided an impetus for expansion of the goat meat industry in Australia, where the genetic potential of Boer goats is being utilised to improve the domesticated Feral, fibre and milking breeds (Murray, 2000).

As an environmental factor, nutrition is the most important influence on growth and development of an animal. The growth of suckling kids is highly dependent on milk intake (Warmington and Kirton, 1990). Beischer (1986) proposed that low milk production of Australian Feral does is responsible for the lower growth rates of kids. Whereas in a study conducted on Thai native goat kids, it was observed that there was no significant correlation between milk availability (ml/day) and the growth rate of the kids from one to six weeks of age, although the growth rates of single kids were significantly better than twins (Pralomkarn et al., 1991). In a separate study, kid weight was significantly ($p<0.01$) affected by breed, maternal nutrition and sex at each weighing between 2 and 13 weeks of age; however, litter size had no significant ($p>0.01$) effect on the weight of Feral and Feral×Anglo-Nubian crossbred goats (Bajhau and Kennedy, 1990). Age of the doe has been reported to have little influence on birth weights and subsequent growth of kids (Warmington and Kirton, 1990). Birth weight had a significant ($p<0.05$) effect on the growth rate of male kids from six goat genotypes with the heaviest ones at birth growing fastest (Dhanda et al., 1999a).

Pre-weaning growth of kids is invariably faster than post-weaning growth, even when adequate high-quality feed is available after weaning and weaning is gradual (Mavrogenis, 1983). In Australian Feral goat kids, high growth rates were observed in the pre-weaning period followed by post-weaning depression (Allan and Holst, 1989). Dhanda et al. (1999a) also observed a significant ($p<0.05$) decrease in average daily gains of kids with advancement in age. Replacement of milk feeding by solid feeding results in a reduction in weight and sometimes retardation of the weight gain. The earlier the weaning, the more marked the reaction (Widdowson and Lister, 1991); although when weaning was done at a satisfactory live weight, the age at weaning did not affect the subsequent growth rate to any significant extent. This was depicted in a study by Morand-Fehr (1981) with French Alpine female kids. Kids weaned at 7 and 8.5 kg exhibited a delay in

Table 6. Dissectible carcass composition from selected goat breeds

Breed /genotype	Carcass weight (kg)	Carcass composition (%)			L:B ratio	Source
		Lean	Fat	Bone		
Nubian×Florida native	10.9	69.0	9.3	21.7	3.22	(Johnson et al., 1995b)
Spanish×Florida native	9.6	38.3	10.5	21.2	3.36	
Florida native	9.5	68.0	11.6	20.4	3.37	
Batina	6.0	68.0	10.6	16.4	4.15	(Mahgoub and Lu, 1998)
	8.9	65.8	13.5	16.1	4.09	
Dhofari	6.9	68.8	11.9	15.2	4.53	
	9.2	70.0	12.9	13.2	5.30	
British Saanen	12.8	63.5	14.8	17.7	3.59	(Gibb et al., 1993)
Boer×British Saanen	13.3	61.0	16.8	18.0	3.39	
Anglo-Nubian	13.6	62.3	13.4	19.5	3.19	
Thai native	10.4	63.5	12.7	16.2	3.95	(Pralomkarn et al., 1995)
New Zealand Saanen	10.0	59.8	11.8	23.6	2.53	(Colomer-Rocher et al., 1992)
	20.0	59.6	14.0	21.5	2.77	
Saanen×Angora	15.8	66.7	11.2	20.0	3.34	(Hogg et al., 1992)
Egyptian Baladi	12.3	57.5	10.9	31.6	1.82	(Latif et al., 1987)
Angora	11.0	57.4	11.3	31.3	1.83	
Black Bengal	10.0	63.4	13.3	21.9	2.89	(Sharma et al., 1988)
Boer	4.0	70.0	9.2	20.7	3.38	(Van Niekerk and Casey, 1988)
	12.0	68.1	17.8	13.8	4.93	
	17.0	64.5	21.8	12.6	5.12	
	22.0	63.4	24.1	12.0	5.28	
Boer×Spanish	15.0	57.7	16.2	26.1	2.21	(Cameron et al., 2001)
	11.9	57.6	13.5	28.9	1.99	
	14.1	55.7	16.3	28.0	1.99	
Boer×Angora	10.7	65.1	12.4	21.0	3.10	(Dhanda, 2001)
Boer×Feral	11.9	64.8	11.2	22.3	2.91	
Boer×Saanen	11.6	64.9	10.9	23.7	2.74	
Australian Feral	11.5	65.6	12.4	20.9	3.14	
Saanen×Angora	11.4	63.0	12.7	22.9	2.75	
Saanen×Feral	12.1	65.1	11.0	22.5	2.89	

growth, whereas weaning at 10 kg resulted in almost no growth retardation. Male kids are more susceptible to adverse effects of early weaning compared to female kids (Morand-Fehr, 1981). Kids consuming more milk and a small amount of solid feeds before weaning exhibited the highest post-weaning growth rate, which is probably due to larger rumen development (Morand-Fehr, 1981). McGregor (1984) observed that nutritionally deprived Angora goats could catch up lost liveweight gain if provided suitable conditions. Compensatory growth is dependent on the age or weight of the animal when under-nutrition is imposed; the younger the animal the less the compensatory growth (Morgan, 1972).

Goats reared under intensive and semi-extensive systems showed better dressing percentages and muscle-to-bone ratios as compared to those kept under extensive systems of feeding management (Saini et al., 1988). Similar results have been reported for intensively reared Florida native goats by Johnson and McGowan (1998). Feeding of grain supplements to Feral goat kids resulted in heavier carcasses with more subcutaneous fat cover (McGregor et al., 1988). Goats had a lower dressing percentage and leaner carcasses compared to sheep raised under identical feeding and management practices (Wildeus et al., 2001). The fact that Boer goats have a higher visceral fat content than sheep could be related to poorer feed conversion efficiency in goats than sheep (Naude and Hofmeyr, 1981).

Carcass and meat quality characteristics

Stage of maturity attained at a particular live weight governs the body composition of an individual animal (Widdowson and Lister, 1991). Late maturing animals will be leaner compared to early maturing ones. Immature animals have a more leggy shape. With maturity, the muscle-to-bone ratio improves and this is a desirable feature in animals (Kirton and Morris, 1989); this has been demonstrated by Simela et al. (1999) in Matbele goats from Zimbabwe. Owen and Norman (1977) reported that the total edible and saleable proportions of goat carcasses decreased steadily with age. On the other hand, dressing percentage increased as the animal increases in age and live weight (Dhanda, 2001). The dressing percentage of goats normally varies between 44 and 55% (Naude and Hofmeyr, 1981). The weight of the gastrointestinal contents can have a

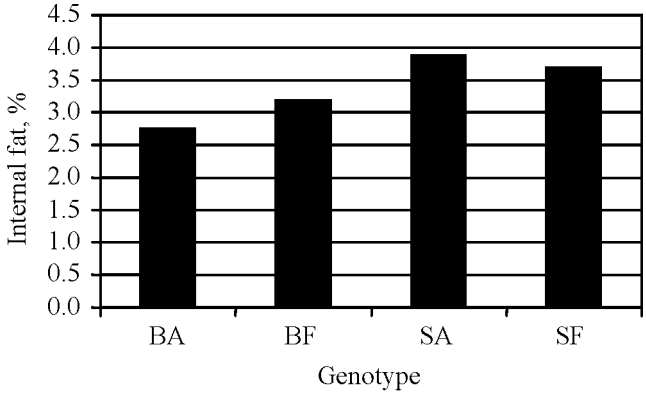

Figure 2. Deposition of internal fat (as percentage of empty body weight) by male kids from different goat genotypes (BA, Boer×Angora; BF, Boer×Feral; SA, Saanenl×Angora and SF, Saanen×Feral) (Dhanda, 2001).

dramatic effect on the dressing percentage of meat animals; therefore, all comparisons involving this parameter should be made on the basis of empty body weight (i.e., liveweight minus the weight of the gastrointestinal tract) (Gall, 1982). Generally, does contain less bone in their carcass than bucks, and yield more edible tissue at the same carcass weight (Kirton, 1970). Due to a greater tendency to deposit fat, does have less muscle than bucks. Furthermore, females exhibit lower carcass yields than male goats when compared at similar liveweights (Norman, 1991).

Studies of carcass tissue growth rates have demonstrated the late maturing nature of the goat (Norman, 1991). It is, therefore, possible to have carcasses with dissectible levels of lean meat as high as 66% to 68% (Fehr et al., 1976). Carcass tissue distribution of male kids from six goat genotypes was estimated as follows: muscle, 64 to 66%; fat, 10 to 14% and bone, 19 to 21% (Dhanda et al., 1999b). Dissectible lean, fat and bone contents of goat carcasses from various studies have been compiled in Table 6. A typical feature of goat carcasses is their thin subcutaneous fat cover (Colomer-Rocher et al., 1992). Dhanda (2001) reported a subcutaneous fat cover of 1.3 to 2.4 mm in crossbred male kids and similar results have been obtained by other researchers (Naude and Hofmeyr, 1981). The subcutaneous fat cover is a reliable predictor of yield especially in lambs and mutton carcasses and is currently used in classification and grading of carcasses; however, it is not suitable for classifying and grading goat carcasses (Van Niekerk and Casey, 1988). Goat meat is leaner than meat from other red meat species, as goats tend to deposit most of their body fat around the omentum, mesentery and kidneys; this is especially true for dairy breeds (Gibb et al., 1993; Hogg et al., 1992). Dhanda (2001) found that male kids from dairy genotypes (Saanen×Angora and Saanen× Feral) deposited more internal fat compared to kids from other genotypes investigated (Figure 2).

Meat quality is known to be influenced by a number of pre- and post-slaughter factors. Similar to that observed in other meat animals, the meat from goats becomes progressively darker and less tender with increasing age (Dhanda et al., 1999c). For this reason, the bulk of goats that are slaughtered for marketing in most Mediterranean, Caribbean and Latin American countries are young; that is, Caprettos between 8 to 12 weeks of age (Norman, 1991). Tenderness of meat depends on, among other factors, the amount and nature of connective tissue (i.e., collagen) in the muscles. Young animals have more connective tissue per unit weight in their muscles, but it is fairly soluble. With age, the solubility of collagen decreases when the meat is cooked, and intra- and inter-molecular cross-linking of collagen molecules increase resulting in tougher meat (Lawrie, 1998). In a study by Babiker et al. (1990), it was reported that goat meat was leaner, darker in colour and had lower acceptance compared to lamb. Dhanda et al. (1999c) found that meat obtained from six goat genotypes was well accepted by the panellists; however, there were only subtle differences in the sensory scores between varying goat genotypes. Although there is some evidence that goat meat is tougher than sheep meat, it was proposed that pre- and post-slaughter treatments might be responsible for tenderness differences between sheep and goats. Unless chilling rates are strictly controlled after slaughter, thin subcutaneous fat covers in goats will always pose a risk of cold shortening (i.e., muscles when rapidly chilled tend to contract extensively) leading to reduced tenderness (Naude and Hofmeyr, 1981).

Flavour, tenderness, aroma and juiciness influenced goat meat acceptability in decreasing order, while pH and colour of the meat, had very little organoleptic influence (Naude and Hofmeyr, 1981). Age has a marked influence on palatability, as meat from older goats is considered to be juicier (Smith et al., 1978). Babiker et al. (1990) reported that *longissimus* muscle from goat was less juicy than that from lamb; these differences may be due to variation in fat contents. Juiciness increased with higher marbling scores, but only up to a moderate amount of marbling (Shorthose and Harris, 1991). Consistent, but low correlations, have been reported between juiciness and marbling. In combination with water, the melted lipids constitute a broth, and this is released upon chewing and acts as a means of lubrication thereby ensuring sustained juiciness (Cross et al., 1986). In spite of the influence of fat, the major contributor to the sensation of juiciness is the water remaining in the cooked product. As the moisture content of lean muscle tissue is relatively uniform, differences in juiciness relate primarily to the ability of muscles to hold water during cooking (Aberle et al., 2001). The juiciness of meat is also influenced by the method of cooking and the end-point temperature attained. For example, steaks/roasts from bison *semimembranosus* muscle cooked by moist-heat cooking

were more tender and juicy compared to those cooked by dry-heat (Dhanda et al., 2002).

There is a general perception that meat from adult bucks has a strong unpleasant flavour and odour, but the scientific evidence to support this postulate is inconclusive. Intarapichet et al. (1995) reported that the consumption of goat meat is limited to certain ethnic groups and that discrimination against goat meat is associated with the so-called "goaty" odour. This chevon flavour is reported to be associated with C_8 to C_{10} branched chain fatty acids in the meat, principally 4-methyloctanoic and 4-methylnonanoic acid (Wong et al., 1975). Louca et al. (1977) reported a taint of varying intensity from intact males from 7.5 months of age upwards, but not in castrates of similar age. Carlucci et al. (1998) also reported better acceptance by consumers for meat from castrated compared to intact goats. Therefore, the problem of off-flavour, if there is any, may be overcome by castrating male kids.

Nutritive value of goat meat

The importance of meat and other animal proteins to the human diet is well established and has been recognised by nutritionists. Meat is a very good source of protein, B vitamins, certain minerals and essential fatty acids. Furthermore, it contains only a limited amount of carbohydrates. Meat also provides a high quality protein; skeletal muscle is a good source of essential amino acids, namely leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine (Aberle et al., 2001). Goat meat on average consists of 72.3% moisture, 21.0% protein, 4.7% fat and 1.1% ash per 100 g of fresh meat (Dhanda, 2001). Studies comparing sheep and goat meat based on their protein contents have revealed that goat meat is not inferior to sheep (Hoffman et al., 2002; Schonfeldt et al., 1993) nor is it from other red meat species (Johnson et al., 1995a). In fact, goat meat contains more arginine, leucine and isoleucine compared to mutton and beef, thereby indicating that goat meat is comparable to other types of red meats in terms of the quality of protein (i.e., the amino acid composition) (Srinivasan and Moorjani, 1974).

The caloric value of lipids in muscle tissue is derived from the fatty acids in triacylglycerols (TAGs) and phospholipids, of which TAGs constitute the bulk (Aberle et al., 2001). Similar to other meat animals, the most common fatty acids found in the TAGs of goat meat are saturated palmitic (16:0) and stearic acids (18:0), monounsaturated oleic acid (18:1, ω9) and polyunsaturated linoleic (18:2, ω6) and α-linolenic acids (18:3, ω3) (Dhanda et al., 1999d; Hoffman et al., 2002). Comparisons of the fatty acid composition of goat muscle and fat depots with those of beef and lamb indicated that the ratio of polyunsaturated to saturated fatty acids (P:S) was higher in goats. The P:S ratio reported for beef and lamb was 0.11 and 0.15, respectively (Enser et al., 1996), whereas it was 0.33 for goat meat (Rhee et al., 2000). Plasma cholesterol concentration is influenced by the fatty acid composition of dietary fat; high dietary levels of saturated fatty acids increase plasma cholesterol levels (Grundy and Denke, 1990). Higher values for the P:S ratio indicate that meat is healthy especially in relation to cardiovascular disease (Harrington, 1994); this can be a positive marketing asset for goat meat. Meat from ruminants contains a range of polyunsaturated fatty acids including those from the ω6 and ω3 series, which have potential significance in human nutrition. Polyunsaturated fatty acids may have beneficial effects on blood cholesterol but a diet rich in polyunsaturated fatty acids with a high ω6:ω3 ratio can lead to an imbalance in the levels of these polyunsaturated fatty acids in the tissue membrane (Banskalieva et al., 2000). However, information pertaining to the amounts of these fatty acids in muscles of goats is limited. Data from a study by Matsuoka et al. (1997) suggested that the ratio of ω6:ω3 polyunsaturated fatty acids for male goats is similar to that for bulls as reported by Enser et al. (1998).

On comparing the nutritive value of cooked goat meat to that of beef goat meat has lower fat, similar protein, higher calcium, magnesium, potassium and sodium, similar iron and lower vitamin B_{12} and folate contents (Johnson et al., 1995a); this further lends support to the view that goat meat offers an attractive alternative to other types of red meat.

CONSUMER TRENDS AND GOAT MEAT

Changing demographics and consumer demands are having a significant impact on what people eat. There is a trend towards more global products and flavours. With an increase in demand for low-fat red meat alternatives by consumers, the future of the goat industry looks promising. Chevon, being lean, can be an excellent source of lean in the preparation of low-fat meat products (James and Berry, 1997). Several workers have successfully used chevon to make various types of value-added meat products (Dawkins et al., 1999; Dzudie et al., 2000; Karthikeyan et al., 2000; Swan et al., 1998). There exists a potentially large market for goat meat in Europe and North America, which is mainly comprised of immigrant populations. For example, South-east Asians, Jamaicans, Arabs and Mexicans use goat meat for curries, shish kabobs and tacos. It is no surprise that the amount of goat imported into the USA has more than quadrupled in the past decade. According to the United States Department of Agriculture (USDA), goat meat import figures increased from 1.4 million kg in 1990 to 5.7 million kg in the year 2001. All in all, this translates to a solid market demand for goat meat in the developed world.

There has been no reported problem in marketing high-priced cuts such as the loin, but improvement in the quality

of lesser-value cuts like the chuck and round as well as utilization of carcass trim is needed to increase the overall value of the goat carcass. One of the major limiting factors in acceptance of meat products from specialty livestock like goat, is that they tend to be very lean and are often over cooked. Resultant products are dry and give the consumer an unpleasant eating experience. This can be overcome through the inclusion of marinades or non-meat ingredients at levels sufficient to compensate for most of the cooking losses. The final product is more succulent and offers the consumer a satisfying eating experience without losing the characteristic flavour of the meat in question. Injection of marinades containing various salt and phosphate formulations into primal meat cuts is routinely practiced to enhance the tenderness and juiciness of fresh meat products (Vote et al., 2000). Several studies demonstrating the potential of marination technology to improve the palatability of red meats have been reported (Smith et al., 1984; Scanga et al., 2000). Tenderness of goat leg and loin improved significantly ($p<0.01$) by injecting marinades containing various salt solutions (i.e., sodium tripolyphosphate) (Hively et al., 2002). Dhanda et al. (2002) successfully employed this technique to improve the tenderness and consumer acceptance of lean bison top round steaks. Using combinations of different herbs, spices and flavours in the marinade can further add to the variety and the value of the final meat product. Based on the results from previous studies of other species, processors could successfully employ this technology to produce value-added meat products from lesser-value cuts and to make goat meat more acceptable, or at least an attractive red meat alternative, to consumers.

FUTURE NEEDS AND STRATEGIES IN GOAT MEAT RESEARCH

In order to compete with and complement other domestic food-animal industries, there is a lot of scope and need for improvement in the goat meat industry. Some suggestions for future needs and research strategies are given below:

There is a need to determine suitable production systems using different goat breeds suited to the different environments which produce carcasses that cater to the needs for domestic and export markets; i.e., to improve the progeny from smaller breeds (e.g., Angora, Feral, Barabari, Kambing) by crossbreeding them with larger breeds (e.g., Boer, Saanen, Anglo-Nubian, Spanish, Jamnapari) and to study their performance in tropical and subtropical environments.

A complete management programme detailing the breeding, nutrition, management, health care and economics of goats for different production systems is required through comprehensive and collaborative research; i.e., package of practices for the producers to raise goats in different environmental conditions.

A normal practice in other species reared for meat production is to use of intensive production systems to achieve target market weights faster. Keeping in view that goats are mostly reared extensively, it will be interesting to know how they perform in a feedlot situation; i.e., to study the growth, carcass and meat quality of feedlot goats and to quantify the optimum time needed for goats in a feedlot to achieve desirable growth and carcass quality.

There is an urgent need to develop an international live goat and goat carcass grading system for international trade. To promote domestic and international trade there is a need to develop an organised meat goat industry especially in Asian and African countries, where the bulk of the goat population of the world is found; i.e., to evolve universal live animal and carcass classification systems by compiling the information available from all the goat rearing countries.

To launch goat meat into the international market, further processing of meat is desirable to improve its sensory characteristics. Further processing will also help increase the overall carcass value, especially when lesser-value cuts are used.

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