GOAT MEAT IN HUMAN NUTRITION

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ABSTRACT

Goat meat in human nutrition as a primary and supplementary nutrient source is presented in terms of the distribution of goats, production characteristics, composition and nutrient value of goat meat, muscle fat and processed goat meat.

Man is a complex being living in a complex environment, under varying degrees of psychological and physical strain. The most severe and most common physical stressor is nutritional stress. Although it is estimated that only 1-2% of the world population suffers severe malnutrition, nutritional stress occurs to a greater or lesser extent in all societies, social and economic status groups, and is expressed in different pathological conditions.

Nutritional stress may result from (a) inadequate availability of foods; (b) deficiencies of specific nutrients essential for maintaining normal physiological function according to a person's physiological requirements and within a specified environment; (c) interactions between food components and a person's physiological conditions; (d) interactions between specific food components; and (e) interactions between nutrients and food contaminants.

The value of nutrition in maintaining health and happiness would be emphasized if dietary guidelines were published, and reviewed regularly, in every region of the world, similarly to those of the United States of America (Dietary Guidelines Advisory Committee). Regional dietary guidelines would incorporate local foods and take local customs into account.

The ultimate aim of studying human nutrient requirements according to age, physiological state and physical activity, and nutrient sources, is to provide balanced, formulated diets to prevent nutrients deficiency diseases and excessive energy intake leading to obesity.

Trends in lifestyles, gadgets and refined, 'stylish' processed foods of the technologically and economically developed world are rapidly invading the developing world, often to the detrement of time-tested local custom. In terms of nutrition, the adopted ways should not lead to an increase in dietary and lifestyle related diseases. The challenges facing the developing regions are to overcome political, economic and ecological (animal-environment interactions, using natural resources optimally) constraints in basic animal production, to apply appropriate technology in food production, to improve and maintain the nutritive status of food. These developments should centre around local customs in order to avoid the pitfalls and deterimental effects of foreign influences.

DISTRIBUTION

Goats are an important nutrient source, particularly for people in the technologically developing regions, situated mainly in the tropics. These regions account for more than 90% of the estimated world goat population of 504 million, with approximately *56%* in Asia, 33% in Africa and 7% in South and Central America and the Caribbean (FAO, 1988). The FAO statistics indicate the world goat population increased between 1965 and 1987 by *35.5%;* the growth in Africa was 60% and in Asia 40%. However, in view of the poor ability to conduct an accurate census of livestock in many of the developing countries these statistics must be interpreted with caution. The distribution of goats varies within regions. Norman (1991) noted from several references that goats are concentrated in the drier regions of Brazil and Nigeria. This is true also in southern Africa. Norman (1991) also noted high population densities in the Caribbean, being 76 km^2 in Barbados and 40 km^2 in Jamaica and Haiti.

CONSUMPTION

The dependence of humans on goats was illustrated by French (1970) and Norman (1991). They calculated ratios of humans to goats for various world regions from FAO statistics. The ratio was 3:1 in Africa as a whole and southern Africa *4.05;* Asia 10:1; Latin America 12:1. On a global scale goats provide the least meat per caput, being *0.5* kg per caput, compared with beef at 10.1 kg, pork at 12.7 kg, sheep at 1.3 kg and poultry at 7.2 kg. In terms of world regions the provision by goats is the highest in Africa, 1.04 kg per Ca put, followed by Asia, 0.47 kg per caput (Norman, 1991).

Meat is the primary reason for goat keeping, resulting in meat goats constituting the major proportion of the world goat population. Goat meat is also derived from male much goat kids and culls from angora and milch goat herds. Where other goat products such as cheese, hair, mohair and cashmere are either primary or secondary products, the culling of goats is influenced by the economic value of these.

Specific consumption patterns and preferences for goat meat are dictated by cultural and traditional backgrounds and the socio-economic status of the community. There are virtually no religious or cultural taboos on the eating of goat meat, with the result that goat is readily available to societies in which eating beef, pork or other meat types is prohibited. In many parts of the world goat is preferred to mutton and commands a better price. Interestingly, in southern Africa, mutton commands the higher price and goat meat, both kid and mature goats, is regarded as a cheaper substitute. This is illustrated by the average prices attained on auction markets in metropolitan areas during 1990: Lamb - average carcass mass 16.5 kg @US$ (equivalent) 2.15 kg^{t} mutton - 20.6 kg @US$ 1.82 kg'; kid - 11.5 kg @US$ *1.58;* goat-13.5 kg @US$ 1.48 (Meat Board Statistics, 1991).

Chevon has become an established term for goat meat, originally applied to Angora goat meat and

emanates from the united States. Cabrito, a term derived from Spanish refers to goat kid, and is a delicacy in Central and South Americas.

Prepa ration and method ofeatingvaries widely between cultures. Carcasses may be dressed down completely and the pluck (head, heart, lungs, spleen, kidneys and caul) sold separately, or included with the carcass. In West Africa the custom is to slaughter by severing the jugularvein and then either to flay the carcass and remove the organs, or to leave the carcass intact and roast it overa bed ofcoals. In the latter, the skin protects the meat and organs which are then consumed. The tradition in southern Africa is to slaughter by severing the jugular, collect the blood, and dress down the carcass. The pluck, digestive tract and genitals are kept. In traditional.preparation blood and lungs are cooked together. The cleaned digestive organs may be added or prepared separately. The carcass is cut up (there is no standard cutting method adding to the dilemma expressed by Colonier-Rocheretal. 1987), and the flesh boiled in water with only table salt being added and eaten. The organs are usually prepared separately.

Meat goats also contribute to human nutrition through their milk. Meat goats are poor milk producers, not having been selected for this trait. However, Boer goat does (2-6 teeth in age) produce *1.5-2.5* kg milk/day under extensive, semi-hardy veld conditions, with a protein content of *3.9-4.5%,* fat 6.4-9.4% and total solids of 15.8-19.2% (Raats *et al.*, 1983).

PRODUCTION CHARACTERISTICS OF MEAT GOATS

The value of goat meat in human nutrition cannot be considered without reference to the production characteristics of goat keeping. Traditionally goats in the developing regions are free-ranged or are herded communally with little management care.

General characteristics of goat favouring meat production are: (1) Females are early maturing, highly prolific, have good fecundity and mothering ability; (2) an extended breeding season, (3) foraging preferences of goats cause them to graze a wider spectrum of plants than other small stock which accounts for their ability to thrive in adverse conditions; (4) foraging may account for relatively low parasite infestation; *(5)* goats exploit available feed resources selectively, consuming material with sufficient digestible organic matter at or exceeding their maintenance needs; selectivity and small size enable them to utilize tropical shrub and scrub pastures more efficiently than cattle; (6) goats are generally well adapted to hot environments, tolerating the extremes of desert conditions and high temperature-humidity conditions of the tropics, because of small size, large surface area to body weight ratio, an ability to conserve water, limited subcutaneous fat cover and the particular nature of their coats.

NUTRIENT VALUE OF GOAT MEAT

The nutrient value of meat, as also other food items, is becoming increasingly important in the health management of people. Research in this respect is concentrated in the developed world where research funding and advanced technology are more available, general education is at a higher level, communications are more efficient and health care of the individual is well developed. The association between meat and health has been reviewed extensively under the

editorialship of Pearson and Dutson (1990). The general low profile of goat meat and the dirth of information on goat is reflected in the absence of goat from the index.

Meat is generally defined as the skeletal muscle from animals, including the connective tissue and fat naturally associated with the muscle (Jeremiah, 1978), but may also include all the edible parts.

The nutrient value of a food item should not be assessed in isolation from other nutrient sources. It is quite incorrect to determine the nutrient value of meat through proximate analyses, digestibility and bioavailability studies and then to apply these as a norm for human nutrition without considering the role of meat as a supplementary nutrient source in most human diets. Human eating preferences and the many influences on these preferences, including the constituents of palatability, flavour, taste and texture, tend to dictate dietary composition. In view of the absence of a complete dietary analyses, goat meat is discussed from the basis of proximate analyses.

Meat protein has a digestibility coefficient of 97% giving ingested meat a heat combusion of 17.87 kg' (Gopalan *et al.*, 1971). The average biological value of goat meat reported by Mitra and Mitra *(1945)*, based on feeding trials with rats fed a 10% level of protein, was 60.4% which was slightly lower than the 68.6% of beef.

Nutrient value of muscle

The nutrient value of muscle lies in the extent to which the protein and specifically the indisposable amino acid requirements of humans are satisfied. Pellett and Young (1990) proposed that dietary protein quality should be determined in terms of 2 standards: that which is needed for infants, and for persons older than 2 years. The analyses of goat muscle are presented in terms of the latter group.

The nutrient value of muscle is influenced by its composition and the extent to which nutrients are lost in processing or rendered inaccessible.

The often quoted standard composition of normal adult mammalian muscle is *75%* water, 19% protein, *2.5%* lipid, 1.2% carbohydrate and soluble non-protein, being 1.6% nitrogenous compounds, *0.65%* minerals and <0.1% vitamins (Lawrie, 1985). The composition of muscle varies between muscles owing to greater or lessera mounts ofconnec~ive tissue and inter,nuscular fat. Composition also changes with age. As sarcoplasiuic proteins accumulate and muscle hypertrophy occurs, the water:protein (W:P) ratio changes. Castrated Boergoat kids at 9.1% total body fat (TBF) (slaughter mass 11.02kg), had a W:P ratio in the buttock of 4.28. This decreased to 3.7 at a TBF of 21.4%. Similarly, castrated SS Mutton Merino lambs at *4.5%* TBF (slaughter mass 11.62 kg) had a W:P ratio in the buttock of 4.42, which reduced to 3.95 at 14.2% TBF (Casey, 1982). A greater interniuscular fat content which occurs at heavier masses and in older animals, would decrease the relative content of other nutrients. In Boer goat castrates subcutaneous fat and intermuscular fat increased over the 10.41 kg growth range at the exponential rates of 1.6840 and 1.6406 against empty body mass respectively (Casey and Naude, 1984).

Amino acids

The amino acid profile is most important in terms of the indespensible amino acids provided. Revised estimates of daily amino acid requirements for average young adults are shown in Table 1. The amino acid profile of goat muscle shows a close resemblence with the analyses of beef, pork and lamb (Table 2). The usual limiting amino acids in various diets in various areas of the world are lysine, total sulphuramino acids, thereonine and tryptophan. Young and Pellett (1990) noted that by expressing amino acids in mg bOg’ meat, the supply of amino acids is determined largely by the amount of protein in a particular cut of meat. It was noted further that meat is an important source of Iysine, since 100 glean meat would provide 30-50% of the total protein needs of an adult and 60-100% of the estimated lysine needs.

Table 1. Revised amino acid requirements in adults and a proposed amino acid scoring pattern for adults

Amino acid	FAO/WHO/UNU	Revised estimates~	
	requirement mg kg’d’	requirement mg kg’d’	pattern mg prot.g’
Isoleuci ne	10	23	38
Leuci ne	14	39	65
Lysine	12	30	50
Met+Cys(SAA)	13	15	25
Phe + Tyr	14	39	65
Threoni ne	7	15	25
Tryptophan	3.5	6	10
Valine	10	20	35

Young and Pellet (1990) with estimates from FAO/WHO/UNU~ (1988) and based on Pellett and Young (1988).

On a lean meat (muscle tissue) basis the amino acid profile between species varies little. However on a whole meat basis (bone, fat and connective tissue included), the amount ofatnino acids could be affected considerably. Cuts of meat within species differ in composition according to degree of fatness, age and sex. The cookout due to moisture and fat loss from a cut serves to increase the protein fraction which would have the effect of increasing the amino acid content of the joint (Schonfeldt, 1989; Webb, 1991). Both subcutaneous and interniuscular fat would increase the cookout. Compositions of cooked Angora and Boer goat meat and lamb are shown in Table 3.

The amount of connective tissue in a cut would provide a different spectrum of amino acids due to the collagen and actin. Although no analysis on the amino acids in goat connective tissue could be traced, an analysis of bovine tissue (Table 2) shows a distinctly greater amount of proline and glycine, slightly more arginine and alanine and no cysteine and tryptophan. The implications are the altered nutrient value in terms ofaniino acids of meats high in connective tissue. Furthermore, species and breed differences in collagen content and solubility may increase the variation in nutrient value, as is illustrated in Table 4. This characteristic of goat meat may be responsible for the marginally lower biological value reported by Mitra and Mitra (1945).

Minerals

Lean meat is an excellent source of minerals required for normal growth and good health. The

mean mineral content of muscle and organs from male crossbred goats, as adapted from Wan Zahari and Wahid (1985), are shown in Table 5.

Table 2. Amino acid composition of muscle proteins of goat beef, pork and lamb and beef collagen (mg prot. g’)

Amino acid	Ooat	Beef	Pork	Lamb	Beef collagen
Aspartic acid	–	88	89	85	43
Threonine	48	40	51	49	18
Serine	–	38	40	39	35
Glutamic acid	–	144	145	144	99
Proline	–	54	46	48	114
Glycine	–	71	61	67	187
Alanine	–	64	63	63	74

Valine	54	*57*	50	52	23
Methionine	27	23	25	23	8
Cystine	–	14	13	13	0
lsoleucine	51	51	49	48	15
Leucine	84	84	75	74	28
Tyrosine	–	32	30	32	67
Phenylalanine	35	40	41	39	21
Histidine	21	29	32	27	8
Lysine	74	84	78	76	30
Arginine	75	66	64	69	75
Tryptophan	15	11	13	13	0

Extracted from Srinivasan *et aI.*, (1974).

Pellet and Young (1990).

Table 3. Mean composition (%) of cooked muscle of lamb, Angora and Bocr goats

Component	Mm longissimus thoracis et lumborum			M semimembranosus		
	Lamb	Angora	Boer	Lamb	Angora	Boer
Moisture	64.6	64.7	65.4	63.9	64.2	64.4
Protein	26.6	26.8	27.2	29.4	29.2	29.1
Fat	7.1	7.0	6.2	4.7	4.7	4.4
Ash	1.06	1.07	1.08	0.99	0.97	1.00
DM	35.3	35.3	34.4	36.0	35.8	35.8

Schonfeldt, 1989.

Red meat muscle has a high myoglobin content and provides a high level of bioavailable iron (Worthington-Roberts and Monsen, 1990), the haem iron being *5-10%* more available than nonhaem iorn and appears to enhance the absorption of non-haem iron from other foods. A value ofaround 2.1 mg 100g~’ reported for lean goat meat from Malaysia (Abdon *et aI.*, 1980) compares favourably with value for separable lean beef (2.72) (USDA Composition of Foods, 1986), lamb (1.74) (Ono *eta!.*, 1984) and veal (1.11) (Ono *et a!.*, 1986). In crossbred goats values ranged from 3.11 to 6.49mg (Wan Zahari *et a!.*, 1985). Worthington-Roberts and Monsen (1990) conclude the merits of lean meat as a source of iron particularly important in women of reproductive age.

Table 4. Mean collagen content and solubility of seven muscles of three sheep breeds and the Boer goat

	Nguni sheep	Merino sheep	Dorper sheep	SAMM sheep	Boer goat
Content	*5.5’*	5.5’	3.8”	4.0”	5.0’
Solubility	35.6wd	32.0”	*35.5’*	37.2w	32.9’

““Row values with different superscripts differ (P<0.01).
dc differ (P<0.05).

Table 5. Mean mineral concentrations (mg lOOg’) in muscle and selected organs of crossbred goats

Mineral	Muscle	Liver	Kidney	Heart	Spleen	Brain
Ca	11	10.06	13.58	7.7	11.47	46.99
P	*155.5*	253.9	168.1	111.71	214.03	245.64
Mg	19.7	15.08	10.19	9.63	15.28	12.82
K	350	188.55	122.26	100.15	194.9	277.68
Na	64.48	58.18	148.68	38.52	59.38	136.92
Cu	0.30	8.28	0.52	0.53	0.41	0.40
Zn	3.51	2.99	2.61	1.41	2.19	1.40
Fe	4.37	7.82	9.78	4.40	34.79	3.07
Mn	0.087	0.66	0.19	0.098	0.159	0.122
Dry matter %	21.90	25.14	16.98	19.26	19.11	21.36

Adapted from Wan Zahari *eta!.* (1985).

Calcium is an important element in the body required for bone development, neuro-muscular activity, secretory functions, buffers, certain co-enzymes and nutrients for the nursed young. Calcium intake has been linked to hypertension with the critical daily intake required to reduce high blood pressure between 400 and 600mg. Below this levels the risk of elevated blood pressure increases sharply while above these levels the antihypertensive effect is modest (Karanja *et a!.*, 1990). Although an e3sential dietary component, lean meat has a low Ca content which is insufficient to provide the recommended daily allowance (RDA). Values reported are raw mutton 12.6 mg lOt7Y' and beefsteak 5.4mg 100.1 (McCance and Widdowson, 1960) and lean goat 11-12 mg 100 g[1] (Abdon *et a!.*, 1980; Wan Zahari *eta!.*, 1985). The latter differed from that of beef (96 mg 100 g[1]) in the same report (Abdon *eta!.*, 1980). Mechanically deboned meat tends to have higher Ca content, in the range of 0.05-0.75% (Kolbye and Nelson, 1977).

Phosphorus is essential for bone formation, enzymes and energy metabolism. The RDA for P, based on the need to provide a dietary Ca:P ratio of 1, is 800 rng &k According to Lee, Brautbar and Kleeman (1980) the P intake in western cultures is insufficient yielding a ratio of as low as 0.3. Protein foods are good sources of P, with beef, mutton and goat muscle containing 334,246 (McCance *et a!.* (1960) and 156.5 mg 100 g~' (Wan Zahari *et a!.*, 1985). Goat liver (258.9 nlg) and brain *(245.64* mg) had about 100 n~g more P than muscle.

Fresh meat is also a good source of K contributing to total K intake. Beefsteak contains 334 mg

100 g~', mutton 240 nig 100 g' (McCance *eta!.*, 1960)and goat lean 350mg 100g' (Wan Zahari *ci a!.*, 1985). Beefand mutton have Na contents of 69 and 75mg 100 g[t], respectively, according to McCance *et a!.* (1960), while goat muscle has *55-77* mg 100 g[1] (Wan Zahari *et a!., 1985).*

The RDA of Mg is 300-400 mg for adolescents, adult men and non-pregnant and non-lactating women, increasing to 1,000 mg in highly active men (reviewed by Johnson and Nielsen, 1990). Meat is a supplementary source to leafy yegetables, nuts and grains. The Mg level in goat muscle is 19.7 mg 100 g'. Of the organs the spleen had the highest content (15.28 mg), followed by the liver (15.08 mg) and brain (12.82 mg).

The trace minerals Cu, Mn and Zn in meat are highly bioavailable since meat does not contain inhibitors present in some vegetables. The estimated safe and adequate daily dietary intake presented byKies (1989) of Cu is 0.7-3.0 mgd' and of Mn 0.7-5.0 mgd[t] the RDA of Zn is *5.0*-15.0 over all age groups. A 100 g portion of goat muscle would provide 0.28-0.35 mg Cu, 0.059-0.145 mg Mn and 2.79-4.2 1 mg Zn (Wan Zahari *eta!.*, 1985). This compares favourably with the contents in beef steak and mutton published by McCance *et a!.* (1960).

Minerals in meat are not affected by normal cooking procedures, but salting and curing can increase Na levels dramatically.

Vitamins

The vitamins thiamine, riboflavin and niacin in lean goat meat (Abdon *et a!.*, 1980) alsi~ compared well with that of lean beef (USDA Composition of Foods, 1986), lamb (Ono *et a!.*, 1984) and *yea!* (Ono et al., 1986) (Table 6). Gopalan *eta!.* (1971) reported 4.5 mg total folic acid and 2.8 mgvitamin B_{12} per 100g. A comparison of the vitamin content of mutton, liver and kidney indicates the richer source these organs are than muscle (Table 7). These differences could be expected in goats also.

Table 6. Thiamine, riboflavin and niacin contents of goat meat, lean beef, veal and lamb

Species	Thiamine	Riboflavin	Niacin
Goat'	0.1	0.56	3.6
BeeP	0.082	0.218	3.6
Lamb'	0.088	0.234	5.33
Veal[4]	0.06	0.3	7.6

Abdon eta!. (1980); [2]USDA Composition of Foods;' Ono *eta!.* (1984); 'Ono *eta!.* (1986).

Quality parameters of muscle

Muscle not only provides nutrients but contains the most important quality parameters. Quality parameters have an indirect effect on consumption where the mere availability of food is not a factor. These parameters become more important when meat is merchandised and the customer has a free choice between meat types. Quality parameters are also important if meat is to be processed. Through processing poor quality meat can be upgraded, shelf-life extended or stabilized and the product can be distributed and merchandized more effectively.

Table 7. Vitamin content of mutton, sheep liver and kidney

Vitamin	Mutton	Liver	Kidney
A (IU)	Trace	20000	100
B, (thiamin) (mg)	*0.15*	0.27	0.49
B_2 (riboflavin) (mg)	0.25	3.3	1.8
Nicotinic acid (mg)	5	14.2	8.3
Pantothenic acid (mg)	0.5	–	
Biotin (jig)	3	41	37
Folic acid (ug)	3	220	31
B_6 (mg)	0.4	0.42	0.30
B,$_2$ (mg)	2	84	55
C (ascorbic acid) (mg)	0	10	7
D (IU)	trace	***0.5***	0

Adapted from Lawrie (1985) quoting McCance *et* a?. (1960), Kiernat et ***aL*** (1964) and Paul ***et a!.*** (1978).

pH

Goat muscle has a high myoglobin content, contains both aerobic (red) and anaerobic (white) muscle fibres and undergoes the same postmortem biochemical changes as beef and mutton (Heffron and Dreyer, 1975; Lawrie, 1985). The decline of muscle pH followed a pattern typical of red meat carcasses, to stabilize at around pH *5.4* (Owen *et a!.,* 1978; Breukink and Casey, *1985).*

Variations occur due to differences between muscles, sexes and pre-mortem stress. Exhaustive pre-mortem stress yields dark, firm and dry meat with a high ultimate pH (pH >6.0). Postmortem biochemical changes are associated with the loss of water binding capacity as the pH reaches the isoelectric point of the muscle proteins, the onset of rigor mortis and the release and activation of proteolytic enzymes, notably cathepsins, responsible for the ripening of meat.

Tenderness and flavour

Several studies have indicated that goat meat is inherently less tender than sheep. As already referred to, muscles of male Boer goat kids had a higher collagen content with a lower collagen solubility than male lambs of 4 sheep breeds (Heinze *eta!.,* 1986). Schonfeldt (1989) found lamb and mutton to be more tender with less fibrous tissue residue and a more intense aroma than Angora and Boergoat meat. The species flavour was also more pronounced. Goat breeds may also differ in their meat quality. Meat of Angora goats has a more acceptable flavour and is more tender with less residue than meat of Boer goats. This could be explained by the lower collagen content and slightly better collagen solubility. Evaluation of collagen alone, however, would be insufficient for conclusions on differences in tenderness. Other factors may be involved, especially muscle fibre size, the type of matrix formed by collagen and the state of muscle contra ction.

The attributed toughness of goat has been ascribed to the marketing of mature animals, in which the collagen in the connective tissue has a decreased ability to gelatinise under the influence of heat and moisture. The meat of kid is as in the case of cabrito, a tender delicacy. Goat muscle

fibres are however thicker and the fibre bundles larger than sheep giving goat meat a characteristic courser grain (Gaili and Au, 1985).

The effect of cooking on muscle is method, time and temperature dependent. The response of muscles to heat treatment varies between muscles and according to pre- and postmortem influences. Generally, temperatures below 100^0C affect palatability, but do not reduce the nutritive ~‘alue of meat severely (Lawrie, 1985).

Electrical stimulation

Goat carcasses, having a poor insulating subcutaneous fat cover, are susceptable to muscle toughening through the effects of cold shortening. This can be countered by electrically stimulating the carcasses imtnediatelyafterslaughter. Electrical stimulation increases the rate of postmortem glycolysis, depleting the ATh energy source for muscle contraction due to the anaerobic state. The residual contractile properties of muscle are reduced, rigor mortis is advanced and the enzymes associated with the conditioning of meat are activated. Electrical stimulation of goat carcasses, as with beef, can improve meat tenderness (Savell *et a!.,* 1977). Low voltage stimulation (21 V rectangular wave, 60Hz, 110 volts 0, 25A, 65W) has been applied to prevent cold shortening and to improve meat quality of matures does (Breukink *eta!.,* 1989). Electrical stimulation facilitates accelerated processing of carcasses by hot boning, preferably after a 2 hr conditioning period, with no detrimental effect on total bacterial count, tenderness or cooking loss (Casey and Paterson, 1990). Advantages of hot boning are a reduced mass loss in chillers, less carcass chiller space required and faster throughput and packaging of the meat.

The principle of elevated temperature conditioning of meat may be exploited without electrical stimulation. It has been proposed that in countries with ambient temperatures above 30^0C, goat sides and carcasses can be cut hot after a 3-hour banging period at ambient temperature and subsequently frozen without deterioration in the quality or processing properties of the meat (Babiker and Bellow, 1986).

Muscle:bone ratio

Goat carcasses have a higher muscle to bone ratio than is deceptively reflected in their conformation. A greater carcass and leg length results in a less compact carcass which may be interpreted erroneously as signifying poor muscling (Naude and Hofmeyer, 1981). In addition, the muscle mass distribution is unattractive when compared with sheep (Table 8) (Casey, 1982). The mean muscle to bone ratio of male Boer goat kids slaughtered between 10 and 41 kg alive mass was 4.7:1 compared with 4.4:1 of SA Mutton Merino, 4.3:1 of Merino and 4.8:1 of Dorper sheep (Naude *et a!.,* 1981; Casey, 1982). The ratio of these goats was considerably higher however than those values obtained in milk-, 2-, 4- and 6-tooth indigenous male castrates from Botswana, which ranged from 2.6:1 to 3.0:1 (Owen *eta!.,* 1978). Fully mature goats had a ratio of 3.1:1. Differences may be ascribed to better nutrition.

Characteristics of fat

Fat is a healthy essential dietary component providing both easily metabolisable energy and essential fatty acids. Fat also imparts pleasant palatability attributes to food hence the partiality

to deep fried foods, spreads (butter, margarine), oil-based salad dressings and many other uses in foods. Owing to circumstantial and intervention evidence on coronary heart disease (CHD) in mainly westernized societies, people are advised to limit their fat intake to about 30% of total energy intake and to increase carbohydrates to *50-60%.* The apparent risk in this is that changes in plasma glucose, insulin, triglycerides and lipoproteins that could accompany high carbohydrate intake could increase CHD (Reiser and Shorland, 1990). As in the case of amino acids, the emphasis is shifting to component fatty acids and the *trans* or *cis* configurations.

Table S. Muscle mass distribution (%)

Breed	Fore limb	Neck	Ventral trunk	Dorsal trunk	Hind limb
Goat					
Boer	17.3	9.3	25.8	19.3	28.4
Sheep					

SAMM'	16.1	8.3	20.9	20.6	34.1
Merino	16.0	8.8	22.9	20.7	31.6
Dorper	15.4	7.9	*23.5*	20.4	32.8
Nguni[2]	15.0	8.0	24.9	20.1	32.0

South African Mutton Merino; [2] indigenous fat-tailed breed of southern Africa (Casey. 1982).

Carcass and meat quality

Fat remains an important quality determinant of carcasses and meat. The chemical and physical properties of fat may have no direct effect on the commercial value of carcasses, as does fatness, but do influence the organoleptic properties, keeping quality and nutrient value of meat. The degree of saturation of fat, determined by the number of double bonds in the components fatty acids, is one of the most important characteristics affecting these quality parameters. Saturated fats containing long chain fatty acids with no or very few double bonds, solidify easily upon cooling thus affecting the palatability of the meat. The less saturated fats containing a greater number of fatty acids with double bonds, are easily oxidized, either by direct chemical action or through intermediary activity of lipolytic enzymes. Direct chemical oxidation is less important in meat than the action of lipases that split fatty acids from triglycerides. The rate ofautoxidation increases with the numberofdouble bonds, increasing the probability ofaffecting the flavour and odour of the meat. Chemical oxidation releases peroxides with free radicals (ROO-, RO- OH-) which may react to damage proteins, enzymes, other lipids and vitamins. In goat meat as with other red meat with low lipid:haeme ratios, haem compounds can stabilize peroxides or free radicals and exert an anti-oxidant effect.

Carcass fat increases carcass yield (dressing percentage) and total meat yield. Being able to predict carcass yield and other quality characteristics is important when carcasses are merchandized. Subcutaneous fat thickness is used successfully to predict meat yield in beef (Klingbiel, 19.84), lamb and mutton (Bruwer, 1984) and pork carcasses (Bruwer, 1991). The poor subcutaneous fat cover on goat carcasses, a positive attribute in other respects, has limited value as a predictor of carcass yield (Casey, 1982). Differences between sheep and Boer goat carcasses in this respect appear in the review of Boer goats by van Niekerk and Casey (1988).

Fatty acids

The profile of the long chain fatty acids of goat meat show oleic acid (C18:1) to be the most abundant, with palmitic (C16:0) and stearic acid (C18:0) being relatively high (Table 9) (Casey and van Niekerk, *1985;* Kuhne *eta!.,* 1986; Casey *et aL,* 1988). Nutritional influences on the fatty acid profile of ruminants is less than monogastric animals. It would appear however that nutrition could cause subtle changes in ruminants, including goats (Casey *et aL, 1985).* The high variance of each fatty acid of the goat kids shown in Table 4, could be ascribed to the monogastric characteristic of suckling animals which would be sensitive to nutritional influences. In adult Boer goat castrates, stearic acid and oleic acid in subcutaneous and kidney fat responded to *5* different energy levels *(7.5,* 8.4, 9.3, 10.3, 11.2 MJ ME kg-' DM) fed for 90 days; stearic acid decreased from 19.48 to 11.52% ($P<0.05$) and oleic acid increased from 36.98 to 46.78% ($P<0.01$) (Casey *eta!.,* 1985). Similarly, type of pasture influenced the levels of myristic (14:0), heptadecanoic (17:1) and linoleic (18:2) ($P<0.01$) and stearic acid *($P<0.05$)* of subcutaneous fat of groups of SA Mutton Memo wbethers having grazed 8 different pastures for 84 days (Casey *et a!.,* 1988). In both the goats and sheep oleic acid made up the greatest proportion (42.9 and 32.7%) of the subcutaneous fat. In the goats palmiticacid (16:0) was 23.9% and stearic acid (18:0)
15.3%, while in sheep the proportions were 22.9% and *25.9%* respectively. Clearly, a range occurs in the fatty acid profile of goat meat, for example, levels ofstearic acid range between 11.5 and 26.4% and oleic acid 21.2 to 46%.

Table 9. Fatty acids in goat and sheep fat depots

Fatty acid	14:0	16:0	16:1	17:0	17:1	18:0	18:1	18:2
Boer goats'								
S ubcutaneo us:								
Mean	3.0	23.9	3.2	1.7	1.5	15.3	42.9	0.95
±	0.6	1.6	0.8	0.3	0.4	4.2	4.5	0.1

Kidney								
Mean	3.4	27.0	1.2	2.1	0.5	32.1	25.2	0.99
+	0.4	1.8	0.2	0.4	0.1	3.1	4.3	0.2
Goat kids[2]								
Mean	5.2	21.5	2.7	-	-	18.1	34.4	6.0
+	3.6	5.0	1.0	-	-	5.4	7.3	3.7
Sheep[3]								
Mean	5.0	22.9	2.1	1.7	0.8	25.9	32.3	1.6
+	0.9	0.8	0.2	0.1	0.1	2.0	0.9	0.4

'Casey *et aL* (1985); [2]Kuhne *eta!.* (1986); [3]Casey *et a!.* (1988).

Goat meat has a low Q-6 and Q-9 polyunsaturated fat content (Gimenez *eta!.*, 1985), which may have health related nutritional implications for humans, particularly in terms of the effect these fats may have on the immune system (Wan *et a!.*, 1989). The mean levels of 18:2Q 6, 20: 1Q9 and 20: 4Q6 in the subcutaneous fat of goats on 4 different diets were 3.12-0.89 and 1.18% respectively.

Visceral fats are more saturated than subcutaneous fats, as is illustrated in the differences between

the fatty acids of the subcutaneous and kidney depots. The unsaturated: saturated ratio in the subcutaneous fat of goats was 1.11 and of sheep 0.67. Fat from the triceps brachii, biceps femoris and obligues internus abdominus muscles of Korean goats contained *55.2* to 59.6% C18:1 and 24.5 to 25.6% C16:0. Unsaturated fatty acids predominated (68.5 to 72.3%, Ha *eta!.*, 1986). Oleic acid levels were slightly higher in the subcutaneous, intermuscular and kidney fats of Sudanese goats than of sheep (Gaili *eta!.*, 1985). Comparing iodine numbers within and between species could be misleading owing to the range of fatty acids occurring in the fat and the exogenous and endogenous influences on the fatty acid profiles. Fatty acids, particularly C18 and C18:3, influence the flavour of lamb and 4-methyloctanoic acids appears to contribute mutton and goat meat odour (Wong *et aL*, 1975).

Processing

Processing is important in the context of human nutrition since it refers to applying technology to improve or maintain quality, extend shelf life (preserving), produce a convenient item for use later and elsewhere, and prepare meat for consumption. Meat processing is an extensive subject and only some aspects relating to goat meat are discussed.

Goat meat has been preserved by eitherdrying, curingwith salts orsmoking, or manufactured into a reconstituted product, in various regions of the world. In modern times, meat is processed not only as a means of preserving, but also for producing consumer acceptable products, compatible with lifestyles and the philosophy of a health-related quality of life. To achieve this the processor has to define clearly the image and saleability of the envisaged product. The decision making process of the consumer needs to be defined in terms of real and perceived value, the convenience the product offers and its palatability.

Cooking

Normal cooking changes the composition of meat and increases the concentration of fat as an energy source. Mass reduction can be 20 to 35% of which 70 to 80% is lipid cookout (Breidenstein and Williams, 1987). The cooking loss of cuts from the Mm longissimus thoracis et lumborum of Angora and Boer goats were, respectively, 18.61 and 15.54% (NS), and of the M semimembranosus 20.04 and 22.20 ($P<0.05$) (Scbonfeldt, 1989). Increasing age had no significant effect on cookout whereas increasing fatness had a significant effect. Fatty tissue of cooked meat is typically about 3 times as concentrated a source of energy as is cooked lean tissue, with variances between cuts. Prolonged cooking leads to rendering in which a very high percentage of fat cookout is obtained.

Freezing

The rate of freezing and subsequent thaw drip loss may reduce the nutrient content of meat. Drip losses of cuts of sheep, Angora and Boer goat Iongissinlus muscles frozen at -20~'C and thawed at 10^0C for 24 hr were 5.24, 3.68 and 3.19%, respectively, the sheep being highly significantly different from the goats which did not differ. Drip losses of the semimembraneosus muscles of the sheep and Angora and Boer goats were about 3.5 times greater at 14.59 14.41 and 15.51% (NS) (Schonfeldt, 1989). Although the sheep and goat differed, a treatment effect on sheep would

probably affect goat in the same way. The method and related rate of freezing (~2o, 2^0C at 10 mm depth) had a significant effect on percentage thaw drip but not on the protein content of the drip of cuts of Mm longissimum thoracis et lumborum, following equalisation at -20^0C and thawing at 4oC for 24 hr:-90^0C (cryogenic), 0.82% and 0.358 g mV^1 ~65oC (cryogenic), 1.16% and 0.341 g m['; -21^0C (walk-in freezer) 1.61% and 0.362 g $m[^1$ - 21^0C (blast freezer) 2.81% and 0.363 $m1^1$
-25^0C (domestic freezer) 2.38% and 0.363 g nff^1 (Sacks *et* at., 1991).

Electrical stimulation

The envisaged advantages of electrical stimulation and hot cutting following early postmortem high temperature aging of goat carcasses have been noted under the discussion of muscle quality attributes.

Comminuted products

Although goat meat has a less desirable flavour, aroma, tenderness and juiciness than beef or pork to Western taste panelists, a panel found up to 40% substitution of beef by Angora goat meat, to be quite acceptable in frankfurters (Table 10) (Marshall *et a!.,* 1977). The goat frankfurters had good physical attributes, being firm, resilient and springy under forefinger pressure and a finn bite, a desirable textural attribute in quality emulsified sausages. Such frankfurters would maintain their form and shape during peeling, indexing and packaging operations. Vienna sausages manufactured from meat of mature does (6 teeth) had detectably different palatability characteristics compared with viennas manufactured from beef (Breaukink *eta!.,* 1989). The goat viennas also recorded higher shear force values (P.cO.0002). Differences in both physical and textural attributes could be related back to the characteristics of the raw meat. Cured and smoked buttocks of low voltage electrically stimulated carcasses of mature does (6 teeth), compared with curd and smoked beef silverside (2 teeth), received higher ratings (P<0.01) in terms of aroma, tenderness, juiciness and tastiness (Table 6; Breukink *eta!.,* 1989). No difference in residue could be detected. Overall, the goat was rated 3.54 with a standard deviation of 0.6 on the scale 0-5, as opposed to the 2.96 $\pm$ 0.97 rating of beef. The results suggested that smoked and cured goat buttock or leg of goat has the potential ofbeinga delicacy and could compete comfortably with other products such as smoked beef and pork gammon.

Processing hot muscle holds decided advantages. Pre-rigor muscle has a higher water-holding capacity, better fat emulsifying properties and produces sausages with less moisture loss and rendering out when cooked. Patties manufactured from hot goat meat (3-4 hpm), not electrically stimulated, had lower cooking yields (P<0.05) than patties prepared from chilled meat (24 hpm) (Padda *et a!.,* 1988). However, reducing the postmortem time lapse to processing to 1-2 hr improved the yield. The organoleptic scores of patties broiled in an oven at 190^0C for 15 mm to an internal temperature of $720+2^0$C were similar for hot and chilled meat. Reheating pre-cooked, forzen patties reduced sensory scores significantly (P<0.05). The fat content of patties has a significant influence on cooking loss and flavour, texture and overall acceptability (Padda *eta!.,* 1985). According to sensory scores a 20% fat content would be the optimal. The quality of warm minced goat meat (3 hpm) could be improved by addition of 2.5% NaCl and 1% t.etrasodium pyropbosphate (Kondaiah *et a!.,* 1985). These salts resulted in a significantly increased pH, water-holdingcapacity and water-soluble proteins, decreased cooking loss and improved redness

and overall appearance. The effects on the emulsifying capacity and salt-soluble protein concentration were also significant. Indications are that bacterial growth can be inhibited by treatment with ~ added at a concentration of 0.402-0.67M (Gupta *eta!.,* 1988). The effect was more pronounced on gram-positive bacteria.

Table 10. Cooking losses and sensory panel rating for frankfurters in which beef is substituted by 40% goat, mutton and pork

Formulation	Cooking loss (%)	flavour	Juiciness	Texture	Overall
Control	7.1	4.4	*5.0*	4.6	4.5
Old goat	1.7	5.3	5.8	5.3	5.4
Young goat	4.4	5.1	5.3	5.1	5.2
Mutton	1.6	5.1	*5.5*	4.8	5.1
Pork	14.4	3.1	3.2	1.8	2.4

Marshall *et aL* (1977).

Table 11. Sensory parameters of cued and smoked goat buttock and beef silverside

Parameter	Mean	Standard deviation	P>F
Aroma			
Goat	4.05	0.27	0.0062**
Beef	3.89	0.29	
Tenderness			
Goat	2.95	0.50	0.0001~
Beef	2.37	0.49	
Juiciness			
Goat	3.16	0.32	0.00O1~
Beef	1.88	0.64	
Tastiness			
Goat	4.02	0.24	0.0OO1~
Beef	3.71	0.24	
Residue			
Goat	0.14	0.17	0.8419
Beef	0.15	0.23	
Pooled aroma, tenderness, juiciness and tastiness			
Goat	3.54	0.60	0.0001~
Beef	2.96	0.97	

Breukink *et aI.* (1989).

CONCLUSION

The future of goat meat as an important nutrient source to a large part of the world population is indisputable. Goats have good meat characteristics, but unfortunately have not been researched as extensively as beef, pork and mutton, due to many factors includingavailable research funding, technology and the poor image of goat. Goats are small hardy ruminants, easily managed and able to utilise a wide range of plant material that has no food value to humans. Continued and increased

research is required in production efficiency (reproduction, growth, nutrition, performance testing) and in meat quality characteristics.

Goat meat is a nutrient dense food, as defined by Hansen and Wyse (1979), but the complimentary role of goat meat in local diets, taking lifestyles and customs into consideration, should be quantified. Dietary recommendations could then be drafted.

Through the appropriate technology, the quality of goat meat as a fresh meat consumer item can be maintained or improved.Processing is a means of extending the product, improving the shelf-life and producing an upgraded, value added product. The value of goat meat in human nutrition in the developing regions, however, cannot be over emphasised.

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