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Recent Developments in Sheep Meat Research Worldwide- a Review

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Abstract

The sheep meat production system contributes to the economy of sheep farmers to a greater extent. Considering the value of sheep meat, several researchers have attempted strategically to study various domains of sheep meat production and its marketing. The research on mutton production was mainly oriented to lean meat and fatty acid profile. Sheep meat marketing research has covered aspects of consumer demand and education. Studies reveal that the industrial meat production system in sheep contributes more water foot print. Researchers have also assessed the greenhouse gas emission of sheep meat production. Sheep carcass quality studies evaluated the effects of gender, production systems, body weight, age, hot and cold carcass. Sheep meat quality studies were majorly focused on the amino acid, fatty acid profiles, and sensory characteristics. Sheep meat flavor was thoroughly researched by a few investigators. The microbial profile of sheep carcass and meat indicated various microbial contaminants in the supply chain. Several antioxidants were used by researchers for improving the quality of meat and meat products. Antimicrobials such as metal oxides and essential oils were evaluated for effective sheep meat preservation. The heavy metal contaminants in sheep were also investigated by a few researchers. Different DNA and radioisotope methods have been explored for species and sex differentiation in sheep meat and meat products. The sheep meat products were assessed by researchers for various technological, nutritional, and sensory characteristics. The economic value of sheep meat by-products was calculated by researchers for their potential importance in the value chain. Parasitic meat borne diseases were found as the common zoonotic problem with sheep meat. The export potential of sheep meat and bottlenecks have also been studied by a few researchers. Overall, the broad dimensions of sheep meat research worldwide has a profound link with the economy of the nations.

KEYWORDS
Sheep, meat, mutton, research, production, quality

INTRODUCTION

Sheep meat popularly called mutton or lamb is a nutritious animal product available to mankind in countries rich in the sheep population. Sheep meat (the flesh of *Ovis aries*) is eaten by millions of people all over the world and is probably eaten in every country to some extent. There are no religious or cultural taboos on eating sheep meat, which contrasts sharply with the taboos that apply to beef (Hindu) and pork (Moslem, Jewish). Nevertheless, many people avoid sheep meat because they object to its odor (especially during cooking) and/or its flavor. The Chinese even have a special word for the disagreeable cooking odor of sheep meat,' soo', meaning sweaty, sour (Wong, 1975). Even in those Western countries that have a greater acceptance of sheep meat, many dislike it, particularly the meat from mature animals with its stronger odor and flavor. Also, the relatively high melting point of sheep fat contributes to a waxy mouthfeel that is unacceptable to many. On a cool plate, the fat tends to harden rapidly, which contrasts with the more oily character of, say, pork fat. Sheep meat consumption is also affected by historical agricultural practices that have led to current dietary traditions. As a domestic animal, sheep were historically suited to arid climates such as are found on either side of the equator. Many Middle Eastern countries, for example, Kuwait (35kg/person/year), Saudi Arabia (21kg), Libya (18kg), and Iran (9kg), have a history of sheep meat consumption and remain large per capita consumers. They import sheep meat, indicating a specific demand for it. Their populations like mutton odor and flavor, simply disregard it or use spices to modify it. All three factors may be important.
Sheep meat is the most expensive meat in developed countries. Consumption is dependent on cultural factors and will be increasing as populations and incomes grow. In the main exporting countries (New Zealand and Australia), sheep numbers are decreasing as the wool market is declining. Thus sheep meat production will develop in small and medium scale commercial systems, close to their markets (Boutonnet, 1999). Over the years,

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several researchers attempted research on various aspects of sheep meat starting from production, feeding, welfare, slaughter, carcass and meat quality, meat products, contaminants, meat borne diseases, and so on. This article will review different researches that have been carried out on sheep meat over the period to give comprehensive literature to work on future projects on sheep meat as desired by the consumers.

Various aspects of sheep meat research around the world

Sheep production for meat

The sheep industry is fragmented and served by a traditional supply chain. There needs to be a sense of direction and an alliance with each other. Quality, consistency, and cost-efficiency of lamb production must be improved. Farmers need to use existing livestock development initiatives. If they can't be joined directly, new stock can be the source from them. Best practices must be used on a farm. Farmers need to envelop quality assurance and traceability in systems of production (Anderson, 2001). Research at Scottish Agricultural College has shown that genetically leaner lambs produce a leaner carcass regardless of the way they are fed. High index lambs had more than a 20% advantage in lean to fat ratio compared to low index lambs (Lewis, 1999).

The effects of sheep age and diet on several odors and flavors are described by Rousset-Akrim *et al*. (1997). Ram lambs raised on ewe's milk then a corn-based diet were compared with lambs raised on milk and a pasture of grass/clover, six treatments in all. A seventh treatment comprised very old ewes maintained on pasture. Fat and lean from forequarters were minced and cooked together. Cooked lean was assessed for intensity by a sensory panel for 10 flavor attributes. Four showed significant ($P< 0.01$) treatment effects: 'sheep meat', 'animal', 'liver', and 'poultry'. Sheep meat flavor was strongest in the slow-grown pasture-fed lambs. The liver flavor was strongest in ewe meat. Eleven related odor attributes were assessed on the rendered fat with a novel olfactometer. Five attributes showed highly significant treatment effects for intensity ($P < 0.001$): animal and sheep meat odors showed a similar distribution to the equivalent flavors; cabbage and rancid likewise odors were associated with the two slow-grown pasture treatments. A comparison of the odor and flavor statistics showed that the sense of smell was the more discriminating in sheep meat assessment, and also confirmed that fat was the true source of sheep meat odor/flavor. In respect of sheep meat production for effective marketing, the data showed that at 90 days, a pastoral diet resulted in slightly enhanced odors when compared with a corn-based diet. By 215 days, however, many undesirable odors were exacerbated.

Volatile compounds were analyzed in subcutaneous fat from lambs raised and finished on grass (GG); raised and finished on concentrates (SS); raised on grass and finished on concentrates for a long (GS1) or a short (GS2) period (Priolo *et al*., 2004). Whereas 3-methylindole (skatole), a compound that has been described as a good discriminator of grass-feeding, was unaffected by the diet ($P>0.05$), 2,3- octanedione was lower ($P<0.01$) in the fat from animals that spent a period in the stall with a concentrate diet than in those finished on grass. Among the 20 monoterpenes detected, the only pcymene was affected by the treatment, being higher ($P<0.05$) in the fat from animals raised and finished on grass (GG) than in the other treatments. Eight among the 13 detected sesquiterpenes were affected by diet treatment. In particular, β-caryophyllene, not detected in the fat from animals raised and finished on concentrates (SS group), was at basal levels in the animals raised on pasture and finished for different durations on concentrates (GS1 and GS2 treatments) and was present at high levels in the animals raised and finished on grass ($P<0.0005$). From a factorial discriminant analysis, four of the 33 terpenes detected discriminated against perfectly those animals raised and finished on pasture (GG) from all the other groups (SS, GS1, GS2).

Small ruminants are the most efficient transformers of low-quality forage into high-quality animal products with distinguished chemical composition and organoleptic characteristics. There is a wide range of sheep and goat farming systems from highly extensive, based on natural grasslands or rangelands, to semi intensive ones, based on natural grazing and supplementary feeding. Usually, the systems which are under comparison are those based mainly on pasture vs. the indoor ones. The feeding system effects on meat quality are more difficult to be identified because lambs and kids of a different breed, weaned at different age and live weight or raised on different types of pastures have different growth rate and carcass characteristics like level of fatness, FA profile, flavor, tenderness, taste, etc (George Zervas and EleniTsiplakou, 2011). It has been demonstrated that lambs and kids raised under a grazing system without any supplementation, present an inferior fatness degree and a higher meat fat concentration of n−3 PUFA and CLA. Lamb meat has higher fat content, higher proportions of SFA, and lower MUFA compared to goats, under similar dietary treatment, which make goat meat especially valuable nutritionally and for consumer health. In conclusion, the existing unfavorable properties of small ruminant products can be improved by nutritional intervention to modify their FA profile for the consumer's health benefit.

Nevertheless, all the participants in the meat production chain must ensure quality to improve their competitiveness. The quality of the carcass and meat can be influenced by different factors such as breed and type of feed. The breed can influence weight, yields, and the conformation of the carcass, among other variables, as well as the pH level and the fatty acid composition of the meat, whereas the feed mainly affects carcass conformation and several physicochemical and organoleptic parameters of meat quality such as proximal composition, the fatty acid profile, tenderness and color. Consequently, the effects of breed and feed type should be considered to obtain a quality product that satisfies consumer demand (Jorge Ramírez-Retamal and Rodrigo Morales, 2014).

Dietary fatty acids (FA) consumed by sheep, like other ruminants, can undergo biohydrogenation resulting in high proportions of saturated FA (SFA) in meat. Biohydrogenation is typically less extensive in sheep than cattle, and consequently, sheep meat can contain higher proportions of omega (n)−3 polyunsaturated FA (PUFA), and PUFA biohydrogenation intermediates (PUFA-BHI) including conjugated linoleic acid (CLA) and trans-monounsaturated FAs (t-MUFA) (Chikwanha *et al*., 2018). Sheep meat is also noted for having characteristically higher contents of branched-chain FA (BCFA). From a human health and wellness perspective, some SFA and trans-MUFA have been found to negatively affect blood lipid profiles, and are associated with increased risk of cardiovascular disease (CVD). On the other hand, n−3 PUFA, BCFA, and some PUFA-BHI may have many potential beneficial effects on human health and wellbeing. In particular, vaccenic acid (VA), rumenic acid (RA), and BCFA may have the potential for protecting against cancer and inflammatory disorders among other human health benefits. Several innovative strategies have been evaluated for their potential to enrich sheep meat with FA which may have human health benefits. To this end, dietary manipulation is the most effective strategy of improving the FA profile of sheep meat. However, there is a missing link between the FA profile of sheep meat, human consumption patterns of sheep FA, and chronic diseases.

Sheep meat marketing

The industry has to be market-driven – responding to the consumer at all times. A constant review of the market conditions in each market (including niche) is necessary. The need for quality and consistent quality, convenience, and tenderness is vital to success as is presentation and packaging. The end product must exceed end-user expectations to include convenience, nutrition, health status, the system of production, and welfare. Adequate promotion is necessary, including service provided around the product, in the market, and education to the consumer (Anderson, 2001).

The meat consumption behavior by consumers will contribute to the development of the livestock sector in general and small ruminant in particular. Juma *et al*. (2010) specifically, explored the factors that influence demand for small ruminant meat. A structured questionnaire was used to elicit information on consumer demand. A transect line method was used to sample 103 households. Both descriptive and econometrics analyses were used to examine factors that influence the demand for small ruminant meat. The survey revealed that about 55% of the households preferred to consume small ruminants' meat over beef. The Tobit model revealed the small ruminant price, district location of household, household monthly income spent on food, purchase cost of small ruminant meat as a proportion of income, and perception of small ruminant meat as quality to be factors influencing the probability of consumer demand for the meat.

A national statistical study in India indicated that the price of live sheep was Rs. 170 per kg live weight and the price of bone-in mutton was Rs. 360 per kg. The proportion of boneless meat to the total value of the live animal ranged from 78.64 to 82.83% (Muthukumar *et al*., 2014).

Water footprint and sheep meat

The projected increase in the production and consumption of animal products is likely to put further pressure on the globe's freshwater resources (Mekonnen, 2012). The size and characteristics of the water footprint vary across animal types and production systems. The current study provides a comprehensive account of the global green, blue and grey water footprints of different sorts of farm animals and animal products, distinguishing between different production systems and considering the conditions in all countries of the world separately. The water footprint definitions and methodology is set out by Hoekstra *et al*. (2011). The blue water footprint refers to the consumption of blue water resources (surface and groundwater) along the supply chain of a product. 'Consumption' refers to the loss of water from the available ground-surface water body in a catchment area. Losses occur when water evaporates, returns to another catchment area, or the sea or is incorporated into a product. The green water footprint refers to the consumption of green water resources (rainwater in so far as it does not become runoff). The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards. The following animal categories were considered: beef cattle, dairy cattle, pig, sheep, goat, broiler chicken, layer chicken, and horses. The study shows that the water footprint of meat from beef cattle (15400 m^3/ton as a global average) is much larger than the footprints of meat from sheep (10400 m^3/ton), pig (6000 m3/ton), goat (5500 m3/ton) or chicken (4300 m^3/ton). The global average water footprint of a chicken egg is 3300 m^3/ton, while the water footprint of cow milk amounts to 1000 m^3/ton. Per ton of product, animal products generally have a larger water footprint than crop products. The same is true when we look at the water footprint per calorie. The average water footprint per calorie for beef is twenty times larger than for cereals and starchy roots. When we look at the water requirements for protein, we find that the water footprint per gram of protein for milk, eggs, and chicken meat is about 1.5 times larger than for pulses. For beef, the water footprint per gram of protein is 6 times larger than for pulses. In the case of fat, we find that butter has a relatively small water footprint per gram of fat, even lower than for oil crops. All other animal products, however, have larger water footprints per gram of fat when compared to oil crops. The study shows that from a freshwater resource perspective, it is more efficient to obtain calories, protein, and fat through crop products than animal products.

For beef cattle, pigs, sheep, goats and broiler chickens-animals that provide their products after they have been slaughtered-it is most useful to look at the water footprint of the animal at the end of its life because it is this total that will be allocated to the various products (for example, meat, leather). For sheep meat, they report a water footprint of 51,000 m /ton and for beef 43,000 m /ton, values that are very high when compared to the estimates (10,400 m /ton for sheep meat and 15,400 m /ton for beef) (Mekonnen and Hoekstra, 2011). They observed a larger blue water footprint per ton of product in industrial production systems for beef, milk, cheese, and pig, sheep, and goat meat.

Global warming and sheep meat production

The life cycle global warming potential of three of Australia's important agricultural production activities – the production of wheat, meat and wool in grazed subterranean clover (sub-clover) dominant pasture and mixed pasture (perennial ryegrass/phalaris/sub-clover/grass and capeweed) systems were compared in research by Biswas *et al*. (2010). Two major stages are presented in this life cycle assessment (LCA) analysis: pre-farm, and on-farm. The pre-farm stage includes greenhouse gas (GHG) emissions from agricultural machinery, fertilizer, and pesticide production and the emissions from the transportation of these inputs to the paddock. The on-farm stage includes GHG emissions due to diesel use in on-farm transport and processing (e.g. seeding, spraying, harvesting, topdressing, sheep shearing), and non-CO (nitrous oxide (NO), and methane (CH)) emissions from pastures and crop grazing of lambs. The functional unit of this life cycle analysis is the GHG emissions (carbon dioxide equivalents –CO-e) from 1 kg of wheat, sheep meat, and wool produced from sub-clover, wheat, and mixed pasture plots. GHG emissions (e.g. CO, NO, and CH emission) from the production, transportation, and use of inputs (e.g. fertilizer, pesticide, farm machinery operation) during pre-farm and on-farm stages are also included. The life cycle GHG emissions of 1 kg of wool are significantly higher than that of wheat and sheep meat. The LCA analysis identified that the on-farm stage contributed the most significant portion of total GHG emissions from the production of wheat, sheep meat, and wool. This LCA analysis also identified that CH emissions from enteric methane production and the decomposition of manure accounted for a significant portion of the total emissions from sub-clover and mixed pasture production, whilst NO emissions from the soil are the major source of GHG emissions from wheat production.

Dressing percentage

The dressing percentage in sheep differs with breed, age, sex, and feeding. Rahman *et al*. (2013) revealed that the Turki breed had better potentials for mutton production under Afghanistan conditions than Afghan Arabi (AA) and Baluchi. Dressing percentage of Turki (56.33%) was significantly higher than AA (54.11%) and Baluchi (51.90%). Cloete *et al*. (2004) found that Dormers had a 2.7% point higher dressing percentage and a 6.2% higher carcass weight than the South African Mutton Merinos (SAMM). Abd-Alla (2014) revealed that the dressing percentage of Barki carcasses (50.4%) was significantly higher than that of Zaraibi ones (47.7%). Mohammed *et al*. (2009) stated that the Naeemi x Border Leicester Merino (NaeemixBLM) crossbred had 5.5% higher dressing percentages and 14% higher carcass yields than the Naeemi lambs. Sharaby and Suleiman (1988) found that the dressing-out percentage ranged from 54.8 to 56.8% across different sheep breeds in Saudi Arabia. Hopkins (1991) revealed that the lambs weighing 35 kg and sired by Poll Dorset (PD) and Suffolk rams had dressing percentages of 44.7and 43.4%, respectively. For PD sired lambs weighing 35 kg and fat score 2 and 4, the dressing percentage increased from 44 to 49.7%, respectively. Carpet wool lambs had lower dressing percentages than second cross lambs. Greiner and Duckett (2006) found that the carcass characteristics of wethers sired by Dorper and Dorset rams differed with a dressing percentage of 58 and 57.3, backfat thickness of 0.25 and 0.22 inches, loin muscle area of 1.62 and 1.55 sq.inches respectively. Naveen Kumar *et al*. (2016) indicated that the pre-slaughter weight (PSW), hot carcass weight (HCW) and dressing percentage were 13.49 kg, 6.44 kg and 47.77 per cent, respectively in Bandur/Mandya rams. The results indicated that the mean primal cut weights for leg, loin, rack, chuck, and breast and fore shank were 2.09, 0.675, 0.646, 2.036 and 0.601kg, respectively. The highest proportion of meat was recorded in leg (25.06%) and chuck (23.23%). Fourie *et al*. (1970) showed that at maturity, the dressing percentage of Romney was 52.1% compared to 58.6% in Southdown and the dressing percentage in females (56.1%) were higher than the males (54.9%). Konig *et al*. (2017) found that the dressing percentage (DP) was significantly higher for ram lambs of Red Maasai (41.6%) compared with Dorper (39.1%). The cold carcass weight was found to be significantly higher (16.50kg) in cross bred of DorperXRed Maasai compared to Dorper (15.03kg) ram lambs. Traisov *et al*. (2017) reported that the Akzhik meat-wool breed showed 44.6kg preslaughter weight, 21.3 kg hot carcass weight, 47.7% hot carcass yield. Kirton *et al*. (1995) studied the effect of breeds on dressing percentage and found that Romney showed the lowest empty live weight of 26.1kg, while, Hampshire showed the highest empty live weight of 31.3kg. The lowest dressing percentage (45.8) was observed in Romney, while, the highest dressing percent (48.5) was observed in Southdown with an overall breed dressing out percent of 47.3. Johnson *et al* (2005) have found that at a set carcass weight, ewe lambs had higher dressing percentages (2%) than males. Omer *et al*. (2018) indicated that dressing out percentage in Elgash sheep were 49.4% and 47.3% for the male and the female respectively with overall average of 48%. Muir and Thomson (2008) reported that the pasture feeding resulted in difference in dressing percentage of 44.6 in ewes, 43.3 in rams and 44.2 in wether lambs. Adams *et al*. (1977) reported the carcass quality of rams and ewes with an average values of dressing percentage of 48.39 and 53.99 respectively. The dressing percentage was also affected by growth rates as mentioned as fast growth rate (7 months) resulted in fasted live weight of 40.1kg with a dressing percent of 43.1%, while, slow growth rate (14 months) resulted in fasted live weight of 43.2 kg with a dressing percent of 39.8%. The sex of lambs affected the dressing percentage as shown as 45.3 for ewes and 44.1 for rams.

Carcass fat content

The fat content of sheep carcass is affected by breed, age, sex, and feeding. Cloete *et al*. (2004) found that the Dormer had a higher fat content (kidney fat, back-fat depth) than the SAMM. Fourie *et al*. (1970) showed that the Romney is a larger (58.0kg starved live weight), leaner (11.32kg total fat weight in body) animal than the Southdown (52.8kg, 14.62kg) and that males are larger (49.8kg) and leaner (12.24kg) than females (61.7kg, 13.79kg). Traisov *et al*. (2017) reported that the Akzhik meat-wool breed showed 2.20% internal fat yield. Johnson *et al* (2005) have found that at the same leg weight, legs of ewe lambs were fatter than males (subcutaneous plus intermuscular fat; 11.2% vs 9.6%). Buttler-Hog *et al*. (1984) found that at the mean carcass weight of 16-8 kg, ram carcasses contained more lean (42 g/kg carcass weight) and bone (19 g/kg) and less fat (subcutaneous, 33 g/kg; intermuscular, 28 g/kg; perirenal-retroperitoneal, 14 g/kg) than ewe carcasses. Adams *et al*. (1977) reported the carcass quality of rams and ewes with an average values of 12th rib fat thickness as 0.17 and 0.32 inches, % kidney and pelvic fat of 2.92 and 4.44 respectively.

Muscle to bone ratio

The muscle to bone ratio in sheep carcass varies with breed, age, sex, and feeding. Abdullah and Qudsieh (2008) stated that the muscle to bone ratio increased while muscle to fat ratio decreased with increasing body weight in the four major cuts and the whole carcass of Awassi ram lambs. Fourie *et al*. (1970) showed that the muscle: bone ratio was estimated as 5.31 in Romney compared to 7.14 in Southdown and the females showed a higher (6.51) muscle to bone ratio than the males (5.85). Traisov *et al*. (2017) reported that the Akzhik meat-wool breed showed the meat to bone ratio of 3.78. Johnson *et al* (2005) have found that at the same leg weight, leg muscle to bone ratio (4.7 vs 4.4) and muscularity were higher for females than males.

Loin eye area

The loin eye area of sheep carcass differs with breed, age, sex and feeding. Rahman *et al*. (2013) revealed that the weight of loin area of Turki sheep (2.17kg) was significantly higher than AA and Baluchi sheep (1.71 and 1.94 kg) respectively. Naveen Kumar *et al*. (2016) indicated that the mean loin eye area was 15.43 ± 0.64 cm2 in Mandya lambs. Cloete *et al*. (2004) found that the eye-muscle area of the Dormers was 13% larger than that of the SAMM sheep. Rams were heavier than the ewes at slaughter. Adams *et al*. (1977) reported the carcass quality of rams and ewes with an average values of rib eye area of 2.12 and 2.15 sq.inches respectively.

Physico-chemical composition

The chemical composition of sheep meat differs with breed, age, sex, and feeding. Naveen Kumar *et al*. (2016) indicated that the meat quality traits viz., pH, water holding capacity, Warner-Bratzler Shear Force value, cooking loss and back fat thickness were 6.35, 49.74 per cent, 3.75, 26.01 per cent and 0.26 cm, respectively. The mean percentage values for proximate principles viz., moisture, crude protein, crude fibre, ether extract, and total ash were 72.10, 19.76, 0.24, 7.23 and 1.01 per cent, respectively. Traisov *et al*. (2017) reported that the Akzhik meat-wool breed showed the chemical composition of ram meat on fresh basis as 60% moisture, 40% dry matter, 16.1% protein, 23% fat, 0.9% ash.

Effect of feeding, handling and breed on carcass quality

Under similar levels of feeding, desert sheep grew faster and reached slaughter weight of 35 kg in a significantly (P<.001) shorter feeding period than desert goats (Khidir *et al*., 1998). Sheep consumed more feed and their gut fill was greater (P<0.0001) than that of goats. Desert goats had greater (P<0.001) carcass weight, higher killing-out proportion but more chilled shrinkage than desert sheep. Weights of wholesale cuts were similar in the two species. Carcass dissection revealed greater muscle proportion in desert goats than in sheep. Bone and fat proportions were significantly heavier in desert sheep, but the muscle: the bone ratio was greater in desert goats. Except for its slow growth rate, desert goats can yield heavier carcasses which are leaner than desert sheep.

Carcass composition and meat quality attributes were compared in yearling sheep and goats (Sen *et al*., 2004). After weaning at 3 months of age, the animals were maintained under stall-fed condition up to 1 year of age. Throughout the study, the animals were maintained on ad libitum complete feed (50:50 roughage and concentrate). The yearling sheep had higher (P<0.05) pre-slaughter weight, hot carcass weight, and dressing % than the goats. The muscular development as indicated by the loin eye area was significantly (P<0.01) greater in sheep than goats. In general, total non-carcass fat contents were more in sheep than goats. Similarly, the dissected total fat of half carcass was also more (P<0.01) in sheep than the goats. The neck and shoulder portions were heavier (P<0.01) in goats than the sheep. Shear force value was greater (P<0.01) in goats (7.42 kg/cm) than sheep (3.74 kg/cm). Goat meat had more (P<0.01) moisture and less fat than mutton. In sensory evaluation both the species were rated almost equal in overall palatability scores. The study showed that dressing yield was higher in sheep than goats. But goat yielded leaner carcass which is desirable for the calorie concern consumers. It was also revealed that meat from goat carcasses was tougher than mutton.

In most developing countries consumers purchase retail cuts from hot carcasses and prepare traditional meat products as per their convenience and requirements. In a study, the effects of different post mortem handling practices on the quality of meat curry from culled sheep meat have been studied (Mendiratta *et al*., 2008). After slaughter, leg cuts were subjected to nine commonly prevalent handling conditions in India with different deboning and cooking time at various storage conditions. From the results, it was concluded that to have the best quality product, meat should be cooked either immediately after slaughter or should be deboned just before cooking. Storage of deboned meat at refrigerated temperatures must be avoided.

In a study by Ilişiu *et al*. (2013) meat of fattened lambs, Tsigai breed, Romania was obtained from young males and females who were eliminated from breeding, they were usually14 to 15 kg at weaning and were fattened under semi-intensive or intensive systems (with high amounts of concentrates). They were slaughtered at a live weight of 35 to 40 kg, and the carcasses weighed on average 15 to 22 kg.

Among the 14 sheep breeds studied in a statistical survey in India, the Bikaneri breed showed lower live animal weight (15.9 kg) and dressed carcass weight (7.5 kg), whereas the Muzaffarnagri had higher live weight (28.9 kg), and dressed carcass weight (13.2 kg) (Muthukumar *et al*., 2014). In a nationwide study on sheep, the average live weight, carcass weight and dressing percentage were found as 20.79 kg, 9.56 kg and 45.98%, respectively The majority of the sheep slaughtered were in the weight group of >15 to <20kg (40.44%) which was followed by >25kg (23%), >20-<25kg (20%) and<15kg (16.23%) group.

Sheep meat quality

Coopworth and Merino lambs were slaughtered at 8 months after being grazed together on ryegrass/clover pasture from weaning. The flavor and odor intensities of the cooked lean (longissimus lumborum muscle) and odor intensity of subcutaneous fat were assessed by an analytical panel (Young *et al*., 1993). Sheep meat flavor in the lean was stronger (P < 0.01) in Coopworth and the foreign flavor was stronger in Merino (P < 0.001). However, the mean pH of the meats also differed significantly (P< 0.001) (Coopworth, 5.77; Merino, 6.16), thereby confounding the effects of pH and breed. Panelists' comments pointed to a breed effect in subcutaneous fat odor, but means for sheep meat and foreign odors in the fat were statistically identical. Meat toughness, assessed by the same panel, peaked around pH 6.0, irrespective of breed. In a parallel study of the Merino lambs and five Merino cross breeds, an in-house panel assessed acceptability rather than the intensity of meat attributes. All crosses and the pure Merino produced acceptable meat (5 or more on a 1–9 hedonic scale) for aroma, flavor, tenderness, texture, and juiciness. There was a breed effect for tenderness (P< 0.05) however, with Merino being the most tender and the Texel × Merino being the least. When the breed was disregarded, texture and tenderness were the best predictors of overall acceptability (r = 0.86, 0.80) and pH, which ranged between 5.41 and 7.12, was the poorest predictor (r = -0.14 to 0.12). The mean pH values of meat from the five cross breeds ranged between 5.93 and 6.08; i.e. lower than the mean pure-Merino pH and higher than the Coopworth pH. All animals were handled identically at slaughter. Thus, the Merino breed might be prone to the high pH condition which, in turn, would adversely affect bacteriological stability in chill storage. High pH meat might also affect meat odor and flavor. If Merino meat is intended for the chilled meat trade, particular care might be needed to ensure animals are not stressed.

Hopkin and Thompson (2002) examined the current theories of tenderization concerning sheep meat where tenderisation is defined as the reduction in toughness post-rigor. This examination is in the light of recent research on meat biochemistry, and from this, areas of research that may prove fruitful are highlighted. Based on available data, the major candidate to explain the tenderization post-rigor is the calpain protease system. Evidence that changes in the binding of actomyosin (the complex of contractile proteins formed at rigor) or cleavage of myofibrillar proteins due to Ca ions contribute to tenderization is far from compelling. Equally, it appears that the cathepsin proteases are unlikely to have a role in early postmortem cleavage of proteins (proteolysis) and thus tenderisation. The mode of action of the calpains is not yet fully defined and questions remain as to the role of m-calpain given the in vitro requirement for a Ca ion concentration exceeding that observed in post-mortem muscle. The existence of the calpains in living muscle and other tissues suggests a mode of action more subtle than currently thought. Additionally, the observation that the degradation of myofibrillar proteins occurs in the presence of effective synthetic and natural calpain inhibitors suggests that other enzymes may also have a role in tenderisation. Inevitably, the accumulated evidence points to a complex system likely to involve interacting proteases and ions, and only through an open-minded investigation with reliance on developments in the medical and biochemical fields will a more complete model of tenderisation be developed.

Mazzette *et al*. (2005) characterized Sarda sheep carcasses used in the processing of meat products. The mean slaughter weight value was 42.5 ± 5.7 kg (range 30–56.5 kg), carcass weight 1 h after slaughtering was 18.0 ± 3.1kg (range12–25.2 kg), while after 24h it was 17.6 ± 3.1 kg (range 11.7–24.9 kg), slaughter yield1 h after slaughtering was 42.3 ± 3.9%, while the slaughter yield 24h after slaughtering was 41.3 ± 3.6%, a mean value of pH1 was 6.7 ± 0.2 (range 5.5–7.5), while pH24 was 5.7 ± 0.1 (range 5.2–6.3).

Sheep meat intramuscular fat is a rich source of conjugated linoleic acid that has anticarcinogenic, antidiabetic, and antiatherogenic effects, as well as effects on the immune system, bone metabolism, and body composition (Schmid *et al*., 2006).

Crăciun *et al*. (2012) assessed the quality of meat from slaughtered sheep at different ages, through the protein content of different types of muscles. Biological material was represented by Longissimus dorsi muscles and Triceps brachii, collected from lambs and sheep slaughtered in the slaughterhouse. To determine the amino acid was used HPLC chromatographic method, meat color was analyzed using a spectrophotometer, meat acidity with pH meter, and meat tenderness by texturometer. Biological studies have highlighted the superior nutritional characteristics of sheep meat. The statistical interpretation of data for proteins in amino acid content reveals significant differences ($p<0.001$) according to the muscle; histidine, arginine, valine, and isoleucine presenting in Longissimus dorsi muscle superior value (23.82 mg/g, 55.76 mg/g, 38.92 mg/g and 35.23 mg/g) compared to amino acid values recorded for *Triceps brachii* (1.29 mg/g, 46.68 mg/g, 35.79 mg/g and 31.84 mg/g). *Brachial triceps* muscle analysis revealed significant differences by age (lambs showing lower values of histidine1.29 mg/g to 18.93 mg sheep/g).

Wang Zhen-yu *et al*. (2012) observed salient findings in Oula Tibetan sheep, a mutton sheep that live on the Qinghai-Tabet Plateau, and has excellent tolerance to high cold and anoxia. In this study, the *longissimus dorsi* muscles of Oula Tibetan sheep (1 to 1.5 years old) were analyzed for physicochemical properties and characterized by near-infrared(IR) spectroscopy. The contents of protein and intramuscular lipid were 24.18% and 2.05%, respectively, the shear force was 40.92 N, and the overall quality was considered as good. Original near-infrared spectra of *longissimus dorsi* muscles revealed two absorption peaks, at 1180 nm and 1450 nm, respectively. The first derivation allowed the effective processing of original spectral data. Processed near-infrared spectra displayed an obvious absorption peak at 1380 nm. The results demonstrated that Oula Tibetan sheep meat has excellent eating and cooking quality, which corresponds to its unique near-infrared spectroscopic characteristics.

Sheep meat flavor

Sheep meat has been found to contain several methyl-branched saturated fatty acids that have not been reported in other meats. These acids have been associated with the characteristic flavor of mutton which results in low consumer acceptance of sheep meat in many countries, and which the Chinese described as 'soo' flavor (Wong *et al*., 1975). Two acids, 4-methyl octanoic and 4-methyl nonanoic are considered to be primarily responsible for this flavor. The lipids of sheep contain significant quantities of methyl-branched fatty acids, unlike other species, and these are known to arise from the metabolic process occurring in the rumen of sheep. Branched acids with methyl substituents at even-numbered carbon atoms result from fatty acid synthesis utilizing methylmalonate (arising from propionate metabolism) instead of malonate in the chain lengthening. Fatty flavors, of course, originate from the lipid, and aldehydes (e.g. 2,4-decadienal), ketones and lactones will contribute to the fatty aromas associated with cooked meat.

Table 1. Concentrations of two branched-chain fatty acids present as the free acid in adipose tissue of lamb castrate and rams, at two ages. Data are means, µg per g tissue. Adapted from Sutherland and Ames (1996).

Fatty acid	Castrates		Rams	
	80 days	200 days	80 days	200 days
4-Methyloctanoic	2.9	3.9	3.8	50.3
4-Methylnonanoic	0.09	0.35	0.35	1.4

Schönfeldt *et al*. (1993) compared the quality characteristics of 27 Angora goats, Boer goats, and sheep carcasses. Significant differences between the quality characteristics of sheep meat and Angora or Boer goat meat is reported. Sheep meat has a more intense aroma, it is more tender, contains less fibrous tissue residue, and the species flavor is more pronounced (typical) than that of Angora and Boer goat meat. In general, goat meat was found to be significantly different from sheep meat, the Angora to a lesser extent, however, than the Boer goat. This study confirms the fact that the meat of younger animals is more tender, contains less fibrous tissue residue, and the species flavor is less typical than that of older animals. This was irrespective of whether it was obtained from sheep, Angoraor Boer goat. With increasing fatness of carcasses, the tenderness and species flavor of the cooked cuts increased significantly.

Sheep meat microbial quality

A study has been conducted on the microbiology of sheep carcasses processed in a modern abattoir (Narasimha Rao and Ramesh, 1992). The data revealed that careful handling at the different stages of processing of sheep reduced the level of microbial contamination of carcasses. Processing steps such as evisceration and washing did not increase the microbial counts on the carcass surface. Sources of microbial contamination in the abattoir were examined. It was observed that skin, floor washings, intestinal contents, and gambrels were the major sources of microbial contamination. Seasonality did not have any effect on the microbial contamination of carcasses. The study revealed that total plate counts in 86.6% of the carcasses ranged between 3.0–4.9log/cm. The counts of coliforms, *Staphylococci*, *enterococci*, and psychrotrophic were low. Pathogens such as *Salmonella* were not detected. The microbial counts were well within the generally acceptable levels. These findings demonstrated the hygienic handling of carcasses. Shoulder and neck are the critical points for microbiological sampling as these sites showed higher microbial counts. *Micrococcus* and *Staphylococcus* predominated among microorganisms associated with carcasses. It was noted that differences occurred in microbial types of carcasses processed in tropical and temperate climates. The data generated in a model facility provided useful information for improving meat handling practices.

Enterohemorrhagic *Escherichia coli* (EHEC) of the O157: H7 serotype is a worldwide zoonotic pathogen responsible for the majority of severe cases of human EHEC disease. Ebrahim Rahimi *et al*. (2012) investigated the prevalence of *E. coli* O157: H7/NM in raw meat samples from two provinces of Iran. During the period from March 2010 to March 2011. Two hundred and ninety five raw meat samples were collected from beef (n= 85), camel, (n=50), sheep (n=62), goat (n=60), and water buffalo (n=38). Fourteen (4.7%) of the 295 samples were positive for *E. coli* O157. The highest prevalence of *E. coli* O157 was found in beef samples (8.2%), followed by water buffalo (5.3%), sheep (4.8%), camel (2.0%), and goat (1.7%). Of fourteen *E. coli* O157 isolates, only one was determined to be serotype O157: H7 while 13 were determined as serotype O157: NM. Of the 14 *E. coli* O157: H7/NM isolates, one, four, two, and one strain were positive for *stx1, stx2, eaeA,* and *ehlyA* genes, respectively. The prevalence of this organism varied between seasons with the highest prevalence of *E. coli* O157 occurring in summer (9.3%). The data reported in this study provides some useful baseline information for future research such as molecular or epidemiologic works.

Sheep meat and antioxidants

Hongxia Luo *et al*. (2007) evaluated antioxidant and antimicrobial properties of 10 Chinese medicinal herb extracts by dipping raw sheep meat in extracts, packaging the samples in polyethylene, and refrigerating them at 4°C. The optimum concentrations of *Codonopsis pilosula, Platycodon grandiflorum, Artemisia capillaris, Cinnamomum cassia, Rheum palmatum, Ziziphus jujuba, Gardenia jasminoides, Santalum album, Angelica sinensis, and Bletilla striata* were 0.10, 0.10, 0.25, 0.10, 0.25, 0.25, 0.25, 0.10, 0.25,and 0.25%, respectively. The analysis revealed that test ingredients were more effective in reducing lipid oxidation and microbial counts in raw sheep meat. Correlation analysis revealed a significant negative linear relationship between the inhibition of hydroxyl and lipid oxidation, and inhibition of hydroxyl was the main factor affecting lipid oxidation. *A. capillaris* (0.25%), *C. pilosula* (0.10%), and *P. grandiflorum* (0.10%) were identified as the most effective antioxidants. S. album (0.10%), A. capillaries (0.10%), and *C. cassia* (0.10%) were the most effective antimicrobials. *A. capillaris* (0.25%), *C. pilosula* (0.10%), and *P. grandiflorum* (0.10%) increased meat redness significantly (P <0.05) when compared with the control samples on days 0, 3, 5,7, 9, 10, and 11. The pH values of sheep meat treated with *C. pilosula* (0.10%) and *A. capillaris* (0.10%) were lower than those of meat treated with other extracts.

Verma *et al*. (2013) explored the antioxidant potential and functional value of guava (*Psidiumguajava* L.) powder in muscle foods. Guava powder was used as a source of antioxidant dietary fiber in sheep meat nuggets at two different levels i.e., 0.5% (Treatment I) and 1.0% (Treatment II), and its effect was evaluated against control. Guava powder is rich in dietary fiber (43.21%), phenolics (44.04 mg GAE/g), and possesses good radical scavenging activity as well as reducing power. Incorporation of guava powder resulted in a significant decrease (p<0.05) in pH of emulsion and nuggets, emulsion stability, cooking yield and moisture content of nuggets while ash and moisture content of emulsion were increased. Total phenolics, total dietary fiber (TDF), and ash content significantly increased (p<0.05) in nuggets with added guava powder. Product redness value was significantly improved (p<0.05) due to guava powder. Textural properties did not differ significantly except, springiness and shear force values. Guava powder was found to retard lipid peroxidation of cooked sheep meat nuggets as measured by TBARS number during refrigerated storage. Guava powder did not affect the sensory characteristics of the products and can be used as a source of antioxidant dietary fiber in meat foods.

The efficacy of litchi fruit pericarp (LFP) extract (0.5%, 1.0%, and 1.5% concentration) in retarding lipid oxidation of cooked sheep meat nuggets was evaluated and compared to butylated hydroxyl toluene (BHT, 100 ppm) by Das *et al*. (2016). The total phenolic content and antioxidant potential of LFP extracts were determined. The thiobarbituric acid reactive substance (TBARS) values were evaluated to assess the potential of LFP extracts as natural antioxidants for oxidative stability of cooked nuggets during 12 days of refrigerated storage. Results show that total phenolics content in 10 mg LFP powder was comparable to 100 ppm BHT, but 15 mg LFP powder had significantly higher (p < 0.05) total phenolics content and reducing power than the synthetic antioxidant. LFP extract did not affect pH, cooking yield, and the sensory attributes of cooked nuggets. Non-treated control and nuggets with 1.0% LFP extract had significantly lower total phenolics than nuggets with 1.5% extract and BHT. TBARS values were significantly lower (p<0.05) throughout the storage period in cooked meat nuggets containing either LFP extract or BHT than in non-treated control. Results indicate that LFP extracts are promising sources of natural antioxidants and can potentially be used as functional food additives in meat products at 1.5% without affecting products' acceptability.

Oxidative damage is one of the main reasons for the loss of quality in sheep and goat meat and meat products (Cunha *et al*., 2018). Synthetic antioxidants are the current solution to stabilize the oxidative process and extend the shelf life of such products; however, the negative impact on health may impose a risk to consumers. Natural antioxidants, extracted from several vegetable sources, have been considered an attractive alternative for this conflicting situation. Phenolic compounds are minor components in herbs, spices, tea, and fruits that display potential application against the progression of lipid and protein oxidation and their consequences for meat quality, which can even overcome the protective effect of synthetic compounds.

Sheep meat and antimicrobials

The antimicrobial effect of oregano essential oil (EO) at 0.6 or 0.9%, nisin at 500 or 1000 IU/g, and their combination against *Salmonella enteritidis* was studied in minced sheep meat during storage at 4° or 10 °C for 12 days (Govaris *et al*., 2010). Sensory evaluation showed that the addition of oregano EO at 0.6 or 0.9% in minced sheep meat was organoleptically acceptable, and attribute scores were higher for the EO at 0.6 than 0.9%. According to the compositional analysis of the oregano EO, the phenols carvacrol (80.15%) and thymol (4.82%) were the predominant components. Treatment of minced sheep meat with nisin at 500 or 1000 IU/g, proved insufficient to act against *S. Enteritidis*. The combination of the oregano EO at 0.6% with nisin at 500 IU/g showed stronger antimicrobial activity against *S. Enteritidis* than the oregano EO at 0.6% but lower than the combination with nisin at 1000 IU/g, which in turn was lower than that of the oregano EO at 0.9%. In its turn, oregano EO at 0.9% showed lower antimicrobial activity than its combinations with nisin at 500 or 1000 IU/g, which showed a bactericidal effect against the pathogen. The inhibition percentages of all treatments against *S. Enteritidis* at 10°C were higher than those at 4°C.

Mahboubeh Mirhosseini and Vahid Arjmand (2014) investigated practical applications of different concentrations (0, 1, 2, 4, 6, and 8 mM) of zinc oxide (ZnO) suspensions containing 1%acetic acid against the pathogenic bacteria *Listeria monocytogenes, Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus.* ZnO suspensions (0, 1, 3, 6, and 8 mM) containing acetic acid had a significant inhibitory effect on the growth of *L. monocytogenes, E. coli*, and *S. aureus* during 12 h of incubation, and the 8 mM suspensions of ZnO were the most effective against all the strains. These data suggested that the antibacterial activity of ZnO was concentration-dependent. Thus, 6 and 8 mM ZnO were selected for further studies in sheep meat. ZnO nanoparticles reduced the initial growth of all inoculated strains in meat.

Sheep meat and heavy metals

Alturiqi and Albedair (2012) observed that the zinc contents of meat samples ranged between 16.74–147.82 and 30.34–73.94 µg/g. The lowest zinc concentrations were found in camel meat, while the highest value recorded in sheep meat at the southern district. The levels of cadmium in all analyzed samples ranged from 0.83 to 2.02 and 3.06 to 4.08 µg/g in meat and meat products respectively. This is above the guideline of 1.0 mg Cd/kg (EC, 2001) except for the concentration in camel's meat at northern and southern districts. Cd data showed high significance ($P<0.05$) in the veal, sheep, and meat products while there were noticeable insignificance ($P>0.05$) between Cd content in collected meats products. Cadmium concentrations in meat increase with the age of the animal and depend on the concentrations of Cd in the feed (Hecht, 1983). Vos *et al.* (1987) stated that cadmium may accumulate in the human body and may induce kidney dysfunction, skeletal damage, and reproductive deficiencies.

Sheep meat species and sex identification

A simple and reliable method has been developed for accurate identification of male and female raw meats in cattle, buffalo, sheep, and goat using the polymerase chain reaction (PCR) technique (Appa Rao *et al.*, 1995). The PCR assay was conducted on genomic DNA extracted from the raw muscle tissue of male and female animals. The method is accurate, reliable, and quick.

A simple assay suitable for the routine determination of species composition in admixtures of meat is described. A nonradioactive slot blot hybridization assay using species-specific oligonucleotide probes has been developed and applied to the species identification of rabbit, sheep, pork, beef, and goat meats (Hunt *et al.*, 1997). Clear species discrimination was demonstrated even between the closely related ruminants goat and sheep.

The probes were shown to identify species present in both raw and commercially cooked and canned products (e.g. pet food). The potential for semi quantitation of species in admixture was demonstrated to a detection limit of less than 2.5% adulteration. This DNA assay targets intracellular DNA and can, therefore, overcome the potential problem of blood and plasma drip contamination which has led to uncertainty when using soluble immunoassays directed towards soluble plasma protein.

RAPD fingerprinting was used on several meat products to identify the species used in their manufacture (Iciar Martinez and Ingrid Malmheden Yman, 1998). The tested species and products were: beef, horse (six breeds), mule, donkey, buffalo, elk, reindeer, pork, lamb, goat, kangaroo, ostrich, three identical packages of sliced, frozen red meat, labeled as `storfe' (cattle in Norwegian) and sold as beef, pork salami, boiled canned pork and `Lammerull'. RAPD analysis produced clear fingerprints from the products analyzed from which the species could be easily identified. All the products were correctly labeled except one of the packages containing sliced frozen red meat sold as beef. This product did not contain any of the above-mentioned species and it was very likely neither a hybrid nor a different race of them.

The effectiveness of the analysis of stable isotope ratios (C/C and N/ N) in fractions of lamb meat, measured by isotope ratio mass spectrometry, was evaluated as a method of feeding and geographical origin authentication (Piasentier *et al.*, 2003). Analyses were carried out on meat from 12 lamb types, produced in couples in six European countries (country of origin, CO) and divided into three groups according to the feeding regime during their finishing period: suckled milk only, pasture without any solid supplementation and supplementation containing maize grain (feeding regime, FR). These analyses were made on two samples of longissimus thoracis muscle, taken from the 13th rib section of the left side of two different lambs, randomly chosen between the 120 selected to represent each lamb type. δC values varied significantly in different meat fractions, the difference being higher in protein than in fat (average difference of 5.0%). However, the pairs δ C values of crude fat and protein were highly correlated ($r=0.976$) and similarly affected by lamb type, mainly reflecting animals' feeding regime. Even δ N values of meat protein fraction showed significant differences between lamb types, not dependent on the feeding regime. Lambs fed on similar diets, but in different countries, gave meat with different N relative abundances. These findings provide the possibility of discriminating lamb types within the same feeding regime. Canonical discriminant analysis was carried out to evaluate whether lamb meat from different CO or FR or CO×FR interaction could be mathematically distinguished by its stable isotope ratios. Based on CO, the corrected empirical allocation of 79.2% of the initial observations, and the corrected cross-validation of two-thirds of the individual meat samples was obtained. FR gave better results: 91.7% of the individual meat samples were both correctly allocated and cross-validated, indicating the high potential of stable isotope ratio analysis as a tool for lamb diet characterization. The most satisfactory classification attained, using the K-means clustering technique and canonical discriminant analysis, enabled a good resolution of six CO×FR groups of lamb types: Icelandic fed on pasture; British and French grazing; Italian; suckled and Karagouniko concentrates finished; French Lacaune; Ternasco de Aragon. It was concluded that multielement stable isotope analysis may be considered promising for the reliable evaluation of lamb meat authenticity, in the same way as for wine, fruit juice, honey, and dairy products.

Meat products are often composed of meat from several species. Due to fraud or incorrect manufacturing processes, different proportions of unexpected or undeclared meat may be incorporated. Pork, beef, chicken, turkey, horse meat, sheep (mutton), and goat are the most common types of meat in these products. To measure the fractional proportion of each of the seven meat types simultaneously, a quantitative multiplex PCR has been developed (René Köppel *et al.*, 2009). This system has proven its applicability in the examination of meat compounds with fractional proportions between 2 and 100%.

Septenary multiplex PCR method and protocol to identify DNAs of pig, cow, sheep, goat, chicken, horse, and yak were optimized and developed (Feng and Han, 2010). The sensitivity of the three species (cow, yak, and goat) in the septenary multiplex PCR system was analyzed. 10 products made of sheep and goat meat were detected. The results showed that routine agarose gel electrophoresis was sufficient to differentiate the multiplex PCR products ranging from 175 to 517 bp and differing by at least 41 bp each other, indicating that this septenary multiplex PCR method could be used for rapid and accurate identification of the seven species and three species (cow, yak, and goat) at the sensitivity of 2.5 ng DNA.

Detection of species fraud in meat products is important for consumer protection and food industries. A molecular technique such as PCR method for the detection of beef, sheep, pork, chicken, donkey, and horse meats in food products was established (Abbas Doosti *et al.*, 2011). The purpose of this study was to the identification of fraud and adulteration in industrial meat products by PCR-RFLP assay in Iran. These findings showed that molecular methods such as PCR and PCR-RFLP are potentially reliable techniques for the detection of meat-type in meat products for Halal authentication.

A highly precise, quantitative method based on the droplet digital polymerase chain reaction (ddPCR) technique was developed to identify and quantify the goat and sheep content in meat products (Qiang Wang *et al*., 2018). A formula for calculating raw meat weight based on DNA copy-number was established. Exclusive specificity was verified using samples from 24 different animal species, and inclusive specificity between goat and sheep was tested using five different breeds for each species. The limit of detection and the limit of
quantitation for both goat and sheep were 1 and 5 copies/µL, respectively, using a cloned plasmid containing goat- and sheep-specific target DNA fragments as calibrators. The accuracy and applicability of the method were verified using mixed powder samples with known proportions of goat and sheep meat, simulate meatball samples, and commercially available products, respectively. The results confirmed that the developed ddPCR methods are highly precise for identifying and quantifying the goat and sheep meat, indicating their potential applicability in future routine analyses.

Sheep meat product quality

Food exporters face difficulties in gaining acceptance for products that are unfamiliar to consumers in other cultures. One way of overcoming such resistance may be to make use of that culture's "flavor principles" as a way of making products more familiar. Product labeling may also be used to emphasize aspects of products that consumers within a culture will value. Prescott *et al*. (2004) evaluated liking for, and familiarity with, samples of a product made from lamb for a group of New Zealand and ethnic Chinese, Singaporean consumers. These two groups differ substantially in their consumption of sheep meat, with Singaporeans consuming it very infrequently. The samples were a relatively unflavoured control product, plus three other samples flavored with herb/spice combinations typical of Chinese, Indian or European cuisine. Each consumer received one of three different messages regarding the samples to be consumed, with the samples labeled as either: meat, lamb, or lamb, together with a message about the health properties of consuming lamb. Both groups completed a modified Food Choice Questionnaire (FCQ), which contained items related to the importance of health in meat consumption. Despite the relative infrequency of sheep meat consumption in Singapore, the control sample was rated as most liked for both sets of consumers. The main evidence for the action of culture-specific flavor principles was significantly lower liking and familiarity ratings by New Zealand than the Singaporean consumers for the Chinese flavored sample. There was no evidence of the action of the different label information conditions, even where groups were divided according to their ratings on the Health factor of the modified FCQ. Dutra *et al*., (2003) demonstrated that meat from adult sheep could be used to replace pork meat in ham-type pate as it did not affect chemical composition, pH, water activity or oxidation index, whilist ensuring similar preference value with the cunsumers.

A project between a research center, two breeder associations, and a meat manufacturing industry was developed to add value to animals with very low commercial acceptability, creating two new products, raw fresh meat sausage, and a processed meat product "mania"(Teixeira and Rodrigues Sandra, 2014). The ratio between MUFA+PUFA/SFA was 1.54 g/100 9 and 1.55 g/100 g of dry product and protein percentage 17.8%, and 18.8% for ewe and goat sausages, respectively. The most abundant unsaturated fatty acid was the C 18:1 and protein was 44.5 and 51% for ewe and goat mantas, respectively. Both are balanced products in protein and fat contents resulting in an interesting solution to give added value to animals with a very low commercial price.

The present study aimed to evaluate the influence of process parameters on consumer choice of two products from sheep meat under different evoked contexts, considering product concepts (Juliana Cunha de Andrade *et al*., 2017). A total of 375 Brazilian participants completed a choice-based conjoint task with three 2-level variables for each product: maturation time, smoking, and sodium reduction for dry-cured sheep ham, and natural antioxidant, smoking, and sodium reduction for sheep meat coppa. All the process parameters significantly influenced consumer choice.

Sheep by-products

Non-carcass parts of slaughtered animals can be used for a variety of purposes including edible use, pet food, or rendered to make tallow and meat meal. To determine the best use for a non-carcass part and the value of the part, the expected yield of potential products from the part must be known. The yield of non-carcass parts from three categories of sheep carcasses and six categories of cattle have been measured (Spooncer, 1992). Offals were analyzed for moisture, fat, protein, and ash content and from these analyses, the potential yields of tallow and meat meal from individual offals have been calculated. From the yield of offal and the amount of meat meal and tallow available from each offal, tables have been prepared to show how much offal, tallow, and meat meal is available from the non-carcass parts of the different categories of sheep and cattle. These tables can be used to determine the potential value of offals if they are rendered and to estimate the total amount of tallow and meat meal available from various classes of stock, depending on which offals are consigned to rendering.

Iciar Martinez and Ingrid MalmhedenYman (1998) and Kale *et al*. (2011) investigated the economic values of by-products obtained as a result of slaughter and to determine these values within the purchase of carcass for slaughtered cattle-buffalo and lamb-sheep. Cutting records for the years 2007 and 2008 of a slaughterhouse about the private sector and the weight and price data concerning the carcass and by-products obtained from the slaughtered cattle-buffalo and the lamb-sheep constitute the material of the study. The average by-product income obtained from a carcass for 2007 and 2008 has been calculated respectively as 117.91 TL and 141.23 TL for cows; 189.59 TL and 237.08 TL for calves-bullocks; 125.31 TL and 173.88 TL for heifers; 107.41 TL and 146.35 TL for buffalos; 14.00 TL and 17.00 TL for lambs; 14.00 and 16.00 TL for sheep. Additionally, the share of average incomes of by-products in the average purchase price per carcass has been determined for 2007 and 2008 respectively as 7.30% and 7.78% for cows, 7.86% and 8.24% for calves-bullocks, 7.93%, and 8.57% for heifers; 8.08% and 7.67% for buffalos; 11.71% and 13.02% for lambs; 10.15% and 9.56% for sheep. Besides, for the research period, the rate of the total monetary value of destroyed by-products within the total by-product income has been calculated as average 0.96% for lamb-sheep and 0.89% for cattle-buffalo. Finally, together with the increasing density of slaughter of the industrial meat enterprises in Turkey and as a result of their being operated with efficient and high-capacity utilization, for all species of slaughtered animals, also the possibility of collecting, processing and evaluating economically of all kinds of edible and inedible animal by-products shall be ensured. In the study, it has been determined that a substantial part of the amount the enterprises have paid for the carcass purchase has been obtained as the by-product income.

The national sample survey revealed that the yield of byproducts viz., blood, head, forefeet, skin, stomach, intestine, pluck, fat, hind feet, and trimmings were 4.20, 6.84, 1.83, 10.66, 14.40, 7.63, 3.78, 1.66, 1.47 and 1.61% of percentage of live sheep weight, respectively (Muthukumar *et al*., 2014).

Sheep meat borne diseases

Scala and Mazette (2009) analyzed the current epidemiological situation of sheep Cystic Echinococcosis (CE) in Sardinia, where the prevalence of ovine CE is still very high (70%) and this parasitosis is also frequently found in the human population. For this reason, Sardinia represents a peculiar model for CE study, because particular conditions allow Echinococcus granulosus to complete its life cycle. Some social and economical factors support the persistence of sheep CE: over 3 million Sarda breed heads are extensively bred; the presence, at farm level, of a strong relationship between dog, sheep, and human; the low commercial value of meat coming from adult sheep, which results in a large number of sheep being slaughtered at home or on the farm rather than in authorized slaughterhouses. Moreover, Sardinia is the only Italian region where partially successful echinococcosis control plans have been applied. The authors suggest some indirect and direct initiatives, including the use of a new vaccine against the development of this metacestode in sheep, to reduce the prevalence of CE.

Toxoplasma gondii is a protozoan parasite that is responsible for approximately 24% of all estimated deaths attributed to foodborne pathogens in the United States (Miao Guo *et al*., 2015). Human infection results from accidental ingestion of oocysts from the environment, in water, or on insufficiently washed produce or from consumption of raw or undercooked meat products that contain *T. gondii* tissue cysts. This study focused on *T. gondii* in meat because many human *T. gondii* infections are acquired through the consumption of raw or undercooked meat. Prevalence of *T. gondii* is higher in conventionally reared pigs, sheep, and poultry than in cattle and is greater in meat products from organic than from conventionally reared meat animals because of outdoor access, which poses substantially greater opportunities for exposure to infected rodents, wildlife, and oocyst contaminated feed, water, or environmental surfaces. Risk factors related to *T. gondii* exposure for livestock include farm type, feed source, presence of cats, methods of rodent and bird control, methods of carcass handling, and water quality. This study serves as a useful resource and information repository for informing quantitative risk assessment studies for *T. gondii* infection in humans through meat consumption.

Sheep meat export

McDermott *et al*. (2011) explored the nature and performance of the New Zealand sheep meat industry from 1980 to 2007. As almost 94 percent of sheep meat produced in New Zealand is exported the focus of this study is on the export sector of the sheep meat industry, and in particular, the lamb meat export industry. Deregulation of the New Zealand economy led to a fundamental change of philosophy within the sheep meat industry. Government support was reduced in the mid- to late-1980s, and financial deregulation was initially associated with rising interest rates and high exchange rates. After an initial adjustment period, interest rates fell, but variable exchange rates have remained. After having a high level of involvement in the processing and marketing sectors through ownership of both processing companies and products, the role of the New Zealand Meat Board reduced in the mid-1990s to that of an industry good role, managing quota and allocating research funding. In the sheep meat industry, markets and market destinations have not changed dramatically over the study period 1980-2007, but the product form has undergone some quite radical changes. The nature of the product now being sold has been transformed from a frozen carcass to a range of both chilled and frozen, and bone-in and boneless cuts of lamb. Over the period concerned, supermarkets have emerged as the dominant prescriber of specifications, and these specifications have become more demanding. This study has identified many factors that have been important in transforming the sheep meat industry from a heavily subsidized, production-driven sector to one that is more market-oriented operating in a market economy. The study has also identified factors that underpin the continued instability of the industry as a whole, and specifically, low profitability for process-exporting companies and variable returns for farmers.

CONCLUSION

Sheep meat research has always been into a multi-angled thought process over the period. The research results have greatly contributed to the development of potential meat breeds, altered the feeding strategies for early slaughter weight maturity, improved the carcass yield and meat quality, assured contaminant-free meat to the consumers besides substantially increasing foreign exchange for the exporting countries. Still, the changing scenario of the internet of things, big data analytics, and artificial intelligence demands the development of newer dimensions of research to drive the meat research in sheep to fulfill changing demands as per the time and location.

CONFLICT OF INTEREST

Author declare not to has a conflict of interest.

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