A Review of the Quality and Hygiene of Sheep and Goat Meat Produced in Greece

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Abstract. Meat quality and hygiene are perquisites for the marketing of meat and meat products. The characteristics that form the quality characterisation of meat are not always perceived but can affect several factors ensuring consumer satisfaction. Contemporary situations, such as food scandals and trends, can influence the perception of some of the quality attributes of meat. Such examples are the 2013 horse meat scandal and the increased perception of intensive meat production as cruel to animals. Sheep and goat farming is an animal production sector that is highly adapted to the Greek countryside, respecting animal welfare and an economic activity supporting a large number of families. Still, information about the characterization of Greek small ruminant's meat production is poor. In this review an effort is made to summarize the characteristics of sheep and goat meat that form the quality and hygiene of meat produced and marketed in Greece.

Keywords: meat quality; meat hygiene, lamb meat, mutton, goat, Greece.

1 Introduction

The quality of meat is characterized by measurable and non-measurable characteristics that shape the consumer preferences on raw or preserved meat (Elmasry *et al*., 2012). It is determined by the organoleptic characteristics, the nutritional value,

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the hygiene and the technological properties of meat. The organoleptic characteristics are appearance, colour, taste, aroma, juiciness, tenderness and texture. Nutritional value refers to the concentration of various macronutrients (moisture, saturated and unsaturated fat, proteins, and carbohydrates) and micronutrients (vitamins, minerals). The quality properties of meat (water retention capacity, pH, water activity, redox potential) are not perceived by the consumer, but describe meat quality in a measurable way and are required for its objective characterization (Elmasry *et al*., 2012). Consumer behaviour is determined by specific factors, mainly organoleptic characteristics, such as tenderness, juiciness and colour, with the most important being visual suitability (colour, freshness, marbling, cut), nutritional value (less fat, nutritional information, method of production, weight, vitamin and protein concentration), food safety (country of origin, absence of pathogenic microbes and dioxins), and lack of residues (hormones and antibiotics) (Krystallis *et al*., 2007). Meat hygiene is a perquisite for meat quality. Therefore, meat should be characterised by the absence of toxic residues and pathogenic microbes and their toxins, as evidenced by the influence of meat-related scandals to consumer behaviour. In the European Union, annual meat consumption per person decreased from 21.5 kg in 1990 to 18.6 kg in 1996 when the British government reported the possible correlation of the Bovine Spongiform Encephalopathy with the Creutzfeldt-Jakob syndrome (Krystallis & Arvanitoyannis, 2006; Verbekee *et al*., 2010). Hygiene risks mostly recognized by consumers as major threats are antibiotic residues, the meat fat and cholesterol concentration, and meat associated microbial risks like *Salmonella*, *Escherichia coli*, microbial toxins, and prions (Fearne *et al*., 2001; Vackier & Verbeke, 2003; Arvanitoyannis *et al*., 2004).

2 Goat and sheep meat production in Greece

Small ruminants are usually reared together. It is therefore quite common to refer to sheep and goat meat production. Comparing small ruminant's meat production among European countries, Greece was the fourth sheep meat producing country and first in goat meat production (European Union, 2020). Sheep farming in Greece is oriented towards dairy production (Skapetas *et al*., 2006). Meat production is an activity that can enhance the profitability of small ruminant farms. Sheep are mostly slaughtered as lambs (65-70%) according to the consumer preferences (Bernabeu *et al*., 2005), and possibly by breeders who prefer this practice, avoiding extra dietary costs and fat accumulation (Arsenos and Zygoyiannis, 2005). During the period 2011 to 2017 the animals slaughtered annually were 3,671,900 lambs with a total carcass weight of 35,836 tons, 496,657 hoggets and sheep weighing 9,891 tons, 1,856,613 kids weighing 17,325 tons and 258,295 goats weighing 5,067 tons. The weight of the carcass did not vary significantly, with the average weight of lambs ranging from 9.61 to 9.87 kg and kids from 9.13 to 9.49 kg, whereas the weight of sheep and goats ranged from 18.84 to 20.78 kg and from 18.84 to 20.17 kg respectively (Fig. 1).

Table 1. Number of small ruminants slaughtered during 2011 and 2015.

	LAMBS			HOGGETS AND SHEEP		
	Number	**Weight (t)**	**Average weight (kg)**	**Number**	**Weight (t)**	**Average weight (kg)**
2011	2,035,016	19,716	9.68	352,851	6,727	19.06
2012	1,997,941	19,474	9.75	341,403	6,433	18.84
2013	1,873,930	18,179	9.70	322,019	6,172	19.16
2014	5,307,247	52,344	9.87	735,446	15,001	20.40
2015	5,379,702	51,700	9.61	656,108	12,933	19.71
2016	4,710,183	46,217	9.81	554,014	11,275	20.35
2017	4,399,278	43,224	9.83	514,761	10,694	20.78

	KIDS			GOATS		
	Number	**Weight (t)**	**Average weight (kg)**	**Number**	**Weight (t)**	**Average weight (kg)**
2011	1,396,890	13,257	9.49	220,569	4,156	18.84
2012	1,346,843	12,433	9.23	222,069	4,263	19.19
2013	1,267,947	11,723	9.24	223,369	4,332	19.39
2014	2,573,065	23,491	9.13	325,138	6,394	19.67
2015	2,473,952	23,251	9.40	316,239	6,301	19.92
2016	2,122,906	20,044	9.44	255,938	5,163	20.17
2017	1,814,689	17,075	9.41	244,744	4,859	19.85

(Source: ELSTAT, 2020)

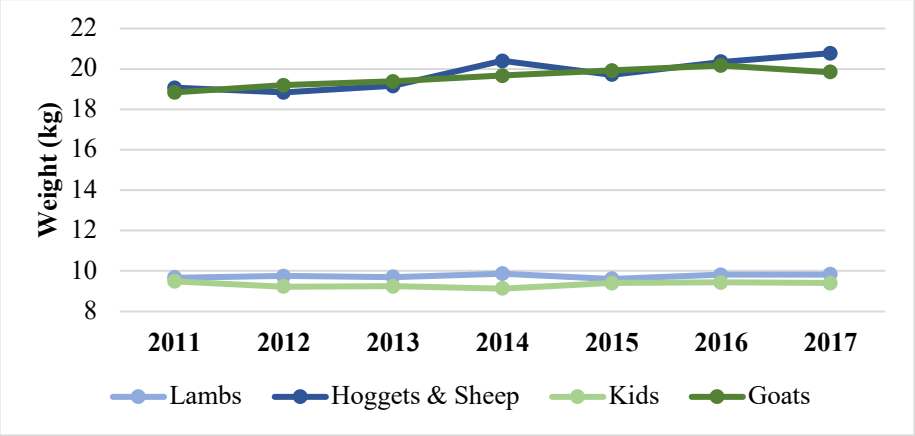

Fig. 1. Weight variation of carcasses of small ruminants in the period 2011-2017.

3 Quality characteristics of sheep meat

Katsaounis *et al*. (1996) report, among other, the average carcass performance of lambs of Karagouniko, Serres and Boutsko breeds slaughtered at different stages of development. They report significant variability due in part to the wide range of growth stages. In all breeds the carcass performance was high, being 49.65% (41.8-57.5%) in average. The muscle content was 50.55% (43.1-58%), whereas the fat content was 25.2% (9.4-41%), and bones consisted the 18.25% (12-24.5%) of the carcass. Concerning meat composition, the total proteins were 14.8% (12.1-17.5%), total fat was 30.3% (16.2-44.4%), and dry matter was 49.15% (38.5-59.8%). Meat water percentage was 50.85% (40.2-61.5%), ash 3.19% (2.38-4%) and energy was 3.74 kcal/g (2.57-4.91 kcal/g) in average. When the weight exceeded the 45% of the adult body weight, an increase in fat percentage and a decrease in muscle and bone percentage was observed. At this stage of development, the Boutsko lambs (small breed) still gave carcasses in the category of light carcasses (<13 kg). Skapetas *et al*. (2006) report similar characteristics in a study of 40 lamb carcasses of Greek mountain breeds at various stages of development, stating that it is possible to produce heavier carcasses with at least equal if not better characteristics, especially if the meat is sold in cuts and not as whole carcasses. Arsenos *et al*. (2006) studied the composition of mutton in polyunsaturated fatty acids at various stages of development, highlighting the possibility of increasing the polyunsaturated fatty acids content after a diet with Lucerne. In a similar study, Samouris *et al*. (2011) described the fatty acids profile of lamb meat, stating that no statistically significant oxidation was observed after refrigeration for up to 10 days. Tsolakidi (2007) has examined the meat-producing characteristics of the Chios breed and reports correlation between animal sex and colour, and chemical composition and tenderness of the meat, with female sheep producing carcasses of inferior quality due to slower growth rate and significantly higher fat values. The increase of carcass weight resulted to significant increase in fat, cooking loss and tenderness of the meat.

4 Quality characteristics of goat meat

Goat meat is regarded lean with nutritional properties that suit the modern nutritional requirements for lean and nutritious meat. It is generally acceptable by consumers, especially when it originates from animals about a year old. However, it tends to be harder and less juicy than other types of meat, while its special smell and taste differentiates it from mutton. In terms of colour, it has a slightly lower a* price than sheep, an attribute that is rarely perceived. The carcasses are usually smaller and leaner than those of sheep, which has an impact on the cuts that can be performed. In a study by Arsenos *et al*. (2009) the carcasses of domestic breeds weighed 9.56 kg when slaughtered at 85 days at a live weight of 16 kg. Their nutritional status ranged between 1.75 and 2, and the fat percentage was in average 2.13%. Fat accumulation occurs quite slowly in goats and is important when animals approach adult body weight. Most fat is deposited in the abdominal cavity, making the carcass appear lean with a small amount of subcutaneous fat (Kirton, 1988; Webb *et al*., 2005). In terms

of tenderness and juiciness, goat meat and its products are inferior to similar sheep meat and its products (Tshabalala *et al*., 2003; Sheradin *et al*., 2003).

The taste and aroma of goat meat are complex characteristics that are affected by breeds, age, fat percentage, tissue, sex, diet, and cooking. The characteristic odour and taste of sheep and goat meat is mainly formed by the branched chain fatty acids (Ha and Lindsay, 1990). Goat meat odour is attributed to 4-ethylchloanoic acid (Madruga *et al*., 2000), while other fatty acids such as 4-methylctanoic, 4-methylananoic and 4-ethylpetanoic acid are also involved (Webb *et al*., 2005). Regarding its chemical composition, water ranges from 59.5% to 69.8%, total proteins from 17.0 to 29.2%, fat content from 4.4 to 21.2% and ash from 0.95 to 3.4% (Webb *et al*., 2005). Arsenos *et al*. (2009) report that goat meat from domestic breeds had a water percentage of 74.2%, total protein 19.9%, fat percentage 4.9% and ash 1.1%. Goat meat is characterized as red meat and therefore has significant nutritional value, as it is an excellent source of iron, with bound iron having about 5-10% higher bioavailability than free iron (Webb *et al*., 2005). The goat meat iron concentration is reported to be 2.1 mg / g, which is comparable to that of lean beef (2.72 mg/g), mutton (1.74 mg/g) and calf beef meat (1.11 mg/g). Also, vitamin concentrations, such as those of thiamine, riboflavin and niacin, are comparable to those of beef and mutton.

5 Hygiene of goat and sheep meat

Goat and sheep meat are ranked as the type of meat least expected to be implicated in foodborne outbreaks in Europe (EFSA & ECDC, 2015; EFSA & ECDC, 2016; EFSA & ECDC, 2017). During 2015 it was responsible for only one foodborne outbreak (EFSA & ECDC, 2017). In a similar study on meat hygiene in the United States, there is no reference to goat / sheep meat (Painter *et al*., 2013). However, goat / sheep meat can be a carrier of several pathogens. EU epidemiological data for 2015 state that the samples most frequently tested positive for *Listeria monocytogenes* were small ruminant's meat samples (EFSA & ECDC, 2017). Also, in 2015, of the 354 sheep meat samples tested for STEC *Escherichia coli*, 15.5% were positive. In just 28 samples of goat meat officially examined, four (14.3%) were positive for STEC *Escherichia coli*. The main serotypes were O146, O6 and O113. Solomakos *et al*. (2009) report that 0.8% of goat meat samples and 1.3% of sheep meat samples were positive for *Escherichia coli* O157: H7, a serotype that is not the most common STEC.

The Hellenic Food Authority (EFET) has been publishing the results of food analyses since 2012. Among others, the concentration of dioxins is measured in small ruminant's meat. The annual reports indicate the detection of small concentrations of dioxins, well below the legislation limits (EFET, 2014; EFET, 2015; EFET 2016; EFET, 2017, EFET, 2018; EFET, 2019). Regarding monitored zoonoses, EFET reports that the *Brucella* spp. prevalence ranged between 0.049 and 0.0248 % in the eradication areas. Small ruminant meat can harbour pathogenic bacteria. Lazou *et al*. (2014) report that *Campylobacter* spp. was detected in 274 of the 343 carcasses of small ruminants examined (116 heifers, 110 lambs, 63 goats and 54 sheep) with infection rates of 78.4% for heifers, 94.5% for lambs, 63.5% for goats and 72.2% for sheep. Probably the adequate thermal processing of small ruminant meat before

consumption is reducing the possibility of *Campylobacter* infection, as evidenced by the limited number of foodborne cases attributed. Gousia *et al*. (2011) report that the 60% of small ruminant meat samples were positive for *Escherichia coli* and 66.7% for *Staphylococcus aureus*, with varying degrees of resistance to antibiotics. In addition, small ruminants can be infected by *Mycobacterium avium* subsp. *paratuberculosis*, a bacterium that has recently been implicated for Crohn's disease in humans (McNees *et al*.., 2015). Regarding parasites, the prevalence of echinococcosis in small ruminant's meat is quite high. Varcasia (2007) reported that among 210 sheep and 190 goats slaughtered in 2005, the infection rate was 30.4% and 14.7% respectively. Chaligiannis *et al*. (2015) report that 30.28% of the examined carcasses were found positive for echinococcal cysts, while the corresponding percentage for goats was 6.62%. The parasitic load of goats directly affects both yield and product quality, as reported by Arsenos *et al*. (2009) who have reported an increase in meat mono-unsaturated and poly-unsaturated fatty acids in goats free from gastrointestinal parasitic parasites.

6 Conclusions

Greek small ruminant's farms are mainly oriented towards dairy production. Still, small ruminant's meat production is of importance, since it can enhance the profitability of the rather widespread breeding of small ruminants. The quality of meat can play a significant role in the marketing of it. Sheep meat quality is rather variable, with several factors affecting its characteristics and the consumer acceptance. Goat meat is considered more compatible with modern nutritional requirements with its acceptance by consumers hindered only by the intensity of its distinct aroma. The hygiene of the small ruminant meat can be regarded as superior to other meat types. Consequently, the breeding of sheep and goats in Greece must take into account the standardization of meat production in order to produce meat of higher quality and ensure better marketing of its products.

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