

ENHANCING THE VALUE OF CULLED SHEEP: MEAT QUALITY, AGING POTENTIAL, AND SUSTAINABLE PRODUCTION STRATEGIES

Ivan Vnučec¹ – Ivica Kos¹ – Ivan Širić¹

¹ University of Zagreb Faculty of Agriculture, Svetošimunska cesta 25, 10 000 Zagreb, Croatia

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ABSTRACT

Culled sheep contribute significantly to sheep meat supply in several production systems, yet their meat is often undervalued and poorly utilised due to unfavourable quality traits. Compared with lamb, meat from adult sheep is characterised by increased toughness, darker colour, higher fat content, and more intense age-related flavour, which negatively affect consumer acceptance. This review examines the main factors influencing the quality of meat from culled sheep, with particular emphasis on post-mortem aging as a strategy to improve eating quality. Current evidence indicates that aging can enhance tenderness and modify sensory attributes, with dry aging showing potential for developing distinctive flavour profiles suitable for premium product concepts. The outcomes of aging are influenced by animal characteristics, processing conditions, and aging duration. Beyond technological improvements, successful utilisation of culled sheep meat depends on appropriate product differentiation and market positioning. Improved valorisation of this resource may reduce waste, increase production efficiency, and contribute to the sustainability of sheep production systems.

Keywords: mutton, matured meat, consumer acceptance, sustainability, sheep farming

INTRODUCTION

Sheep and lamb meat, as complex and nutritionally rich foods, form an integral part of culinary traditions worldwide (Bouton et al., 1999). Lamb meat is characterized by a light red colour, a fine muscle structure, minimal intramuscular fat, and white subcutaneous and internal fat deposits, resulting in a mild and distinctive flavour profile (Carrasco et al., 2009). In contrast, meat from adult sheep exhibits a darker red colour, a higher proportion of adipose tissue, thicker muscle fibres, and increased toughness (Fruet et al., 2016). Due to these characteristics, meat from older, predominantly culled animals often faces market challenges, which are reflected in relatively low prices and limited consumer acceptance in many regions (Bhatt et al., 2012). Nevertheless, in some production systems, such as in India, culled animals account for more than 40% of total meat production, highlighting their substantial contribution to meat supply (Mendiratta et al., 2008). Breed characteristics may further constrain the effective valorisation of meat from culled sheep. For example, in Mediterranean European countries, sheep meat production is largely based on local, autochthonous breeds of small to medium body size (Sañudo et al., 1998), which are associated with low carcass yields and meat that is not highly valued on the market (Sargentini et al., 2016). Consequently, a substantial proportion of meat from culled ewes is downgraded for use in pet food, or carcasses are simply left on pastures as a food source for local wildlife and scavengers (Gigante et al., 2021). In contrast, sheep breeds with a larger body frame may exhibit a better body condition score at culling, particularly if they have previously undergone a fattening period to increase slaughter weight and, consequently, meat yield (Maggiolino et al., 2024).

Aging is a well-established post-mortem process that improves meat tenderness, flavour, and overall palatability through endogenous proteolytic activity (Koohmaraie and Geesink, 2006). Both wet and dry aging have been shown to enhance sensory attributes of red meat, although dry aging additionally contributes to flavour development through moisture loss and concentration of flavour precursors (Dashdorj et al., 2016). Recent studies suggest that, despite its higher toughness and stronger flavour profile, meat from culled sheep

may be particularly suitable for extended aging, offering an opportunity to transform a low-value raw material into premium products (Hastie et al., 2021; Maggiolino et al., 2024). The aim of this review is to provide an overview of current research on the quality attributes of meat from culled sheep and to assess its suitability for aging processes as a means of increasing its value, thereby contributing to the sustainability of sheep production systems.

Meat quality characteristics of culled sheep

Meat quality is a key determinant of consumer choice and purchasing decisions and is defined by physicochemical traits such as pH, colour, water-holding capacity, intramuscular fat content, fatty acid composition, and sensory properties (Wood et al., 1999; Carrasco et al., 2009). It represents a complex, multidimensional attribute shaped by the combined effects of pre-slaughter production factors and technological processes occurring immediately before and after slaughter (Andersen et al., 2005). In culled sheep, these attributes are strongly influenced by age, physiological status, nutrition, and genotype. Increased age is associated with a higher degree of collagen cross-linking, resulting in reduced solubility of connective tissue and increased meat toughness (Purslow, 2005). Additionally, muscle fibre hypertrophy and a higher proportion of oxidative fibres contribute to darker meat colour and firmer texture. Increased meat toughness represents a major constraint to the utilisation of meat from culled sheep, largely because slaughtered animals are predominantly ewes with low body condition score, typically following lamb rearing or at the end of the lactation period (Fruet et al., 2016).

Fat composition also differs markedly between lamb and adult sheep. Culled sheep meat typically contains higher total fat levels, along with elevated proportion of short-chain and branched-chain fatty acids that are responsible for a pronounced “mutton” odour and flavour (Watkins et al., 2013). While this flavour profile is often perceived negatively in conventional markets, it may be advantageous in niche or gourmet contexts when properly managed through processing and culinary techniques. From a technological perspective, meat from culled sheep often exhibits higher ultimate pH values due to reduced glycogen reserves at slaughter, especially in animals in poor body condition. Elevated pH can negatively affect shelf life and colour stability but may also improve water-holding capacity, which is beneficial for certain processed products (Lawrie and Ledward, 2006).

Aging processes and their effects on sheep meat

Post-mortem aging is a key intervention for improving the eating quality of meat. The primary mechanism underlying tenderization during aging is the degradation of myofibrillar proteins by endogenous proteolytic enzymes, particularly the calpain system (Koohmaraie and Geesink, 2006). In older animals, the rate and extent of proteolysis may be reduced; however, extended aging periods can partially compensate for this limitation.

Wet aging, conducted under vacuum packaging at refrigerated temperatures, is widely used due to its simplicity and minimal weight loss. Studies have shown that wet aging can significantly improve tenderness of mutton, although flavour development is generally less pronounced compared with dry aging. Dry aging, on the other hand, involves controlled exposure of unpackaged meat to air under specific temperature, humidity, and airflow conditions. This process leads to moisture evaporation, concentration of flavour compounds, and the development of characteristic aged aromas (Dashdorj et al., 2016).

Emerging evidence indicates that meat from culled sheep may respond particularly well to dry aging, as its higher fat content and stronger intrinsic flavour can contribute to a more complex sensory profile after aging (Hastie et al., 2021). Nevertheless, dry aging is associated with greater weight loss and trimming requirements, which must be considered when evaluating economic feasibility.

Value-adding strategies and consumer acceptance

Enhancing the value of meat from culled sheep requires an integrated approach that combines appropriate processing technologies, product design, and targeted marketing strategies. Variability in meat quality among culled animals is not determined solely by breed, but is also strongly influenced by production system, physiological status, and management and slaughter practices prior to processing. For example, Sargentini et al. (2016) reported significant differences in carcass and meat quality characteristics between ewes destined for traditional and Halal markets, despite originating from the same breeds, clearly demonstrating the influence of market destination and production conditions on meat quality outcomes. In addition to technological factors, sensory attributes are critical determinants of the utilisation and consumer acceptance of meat from culled sheep. As animals age, sheep meat is more likely to present a stronger flavour intensity and a higher incidence of unpleasant taste/off-flavour notes, which can reduce consumer liking (Gravador et al., 2018). In the sheep meat literature, two recurring sensory constructs are often distinguished: “mutton” flavour, which is primarily associated with animal age, and “pastoral” flavour, which is more closely linked to pasture-based diets (Watkins and Warner, 2011). Importantly, recent evidence indicates that post-mortem aging can modulate these sensory outcomes and improve the acceptability of meat from culled ewes, although the direction and magnitude of changes depend on aging method and duration (Maggiolino et al., 2024).

Within this framework, aging represents a central technological strategy for improving eating quality; however, its effectiveness largely depends on alignment with consumer expectations and market positioning. Recent studies indicate that consumer acceptance of mutton can be significantly enhanced when products are marketed as premium, aged, or gastronomic items, rather than as direct substitutes for lamb, which is often associated with milder flavour and greater tenderness (Hastie et al., 2021). This highlights the importance of differentiation and value-based communication in overcoming traditional consumer resistance toward meat from older animals.

In addition to aging, further value can be created through tailored portioning strategies, innovative culinary preparation methods, and the promotion of traditional or region-specific product concepts. Such approaches are particularly relevant in Mediterranean regions, where strong culinary heritage, established consumption of sheep meat, and growing interest in sustainable, local food systems can support the development of niche markets for premium products derived from culled sheep. By integrating technological interventions with cultural and market-oriented strategies, the valorisation of culled sheep meat can contribute both to increased economic returns and to the overall sustainability of sheep production systems (Bhatt et al., 2013; Gigante et al., 2021).

Sustainability implications

From a sustainability perspective, improved utilization of meat from culled sheep aligns closely with the principles of the circular economy and resource efficiency by maximizing the value extracted from animals at the end of their productive life. Redirecting this meat from low-value uses, such as pet food, or from disposal in the environment, toward human consumption reduces food waste and improves the overall efficiency of sheep production systems (Gigante et al., 2021). Such practices also contribute to lowering the environmental footprint per unit of edible protein by better exploiting existing biological resources rather than increasing primary production.

Moreover, the development of value-added products derived from culled sheep meat, including aged or differentiated premium products, can generate additional income streams for farmers and processors, thereby enhancing the economic resilience of sheep production chains (Esteves et al., 2018; Hastie et al., 2021). This is particularly relevant for extensive sheep farming systems in marginal and less-favoured areas, where alternative agricultural opportunities are limited and where improved valorisation of culled animals can

support farm viability, rural livelihoods, and the long-term sustainability of traditional production systems (Bernués et al., 2011).

CONCLUSION

Meat from culled sheep remains an underutilised resource within sheep production systems, mainly due to increased toughness, intense age-related flavour, and limited consumer acceptance compared with lamb meat. As a result, a considerable proportion of this meat is diverted to low-value uses, despite its potential nutritional and economic value. Available evidence indicates that post-mortem aging can significantly improve the eating quality of meat from culled sheep. Both wet and dry aging enhance tenderness, while dry aging may further contribute to flavour complexity and premium sensory characteristics, particularly in meat with higher fat content. Nevertheless, the success of aging strategies depends on appropriate processing conditions and market positioning. Overall, improved valorisation of culled sheep meat supports circular economy principles by reducing waste, increasing resource efficiency, and enhancing the sustainability and economic viability of sheep production systems.

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Contact Information: Invited speaker: Prof. Ivan Vnučec, Ph.D., Division of Animal Science, University of Zagreb Faculty of Agriculture, Svetošimunska cesta 25, 10 000 Zagreb, Croatia, e-mail: ivnucec@agr.hr