Electrolyzed water and ultrasound treatments to improve beef shelf life

Effects of different packaging methods on quality and microbial stability

By Süleyman Gökmen, Şeyda Işik, Nuran Erdem, and Aytaç Kocabaş

This study investigated the effects of electrolyzed water and ultrasound treatments, both individually and in combination, alongside vacuum and aerobic packaging, on the shelf life and quality attributes of beef. The research aims to assess their combined impact on the physicochemical, microbiological, and sensory properties of beef. Various analyses, including pH, TBA, color stability, cooking and drip loss, texture profile, microbial growth, and sensory evaluation, were conducted to determine the efficacy of these preservation methods. The results suggest that vacuum packaging, electrolyzed water, and ultrasound treatments effectively extend the shelf life of beef while maintaining its quality. Among these treatments, the combined application of electrolyzed water and ultrasound with vacuum packaging showed the most promising outcomes in terms of microbial inhibition, oxidative stability, and texture preservation. These findings highlight the potential of non-thermal preservation technologies in the meat industry to enhance product quality and safety.

KEYWORDS

- Electrolyzed water
- Shelf life
- Different packaging conditions

Food safety is at risk due to emerging threats. Without proper measures, access to safe and sufficient food will decline, increasing disease and hunger. Key issues include nutritional disorders, food insecurity, and safety deficiencies. Food safety ensures that food remains risk-free from production to consumption by following hygiene and sanitation rules. Foodborne illnesses occur due to pathogenic microorganisms or microbial toxins, causing gastrointestinal symptoms as infections or intoxications (Vergis et al., 2025).

Food preservation technologies aim to protect food from spoilage while maintaining its quality. Cold storage is commonly used for meat, but it can lead to quality losses due to microbial activity and oxidation. Cold-stored meats are primarily affected by bacteria like *Pseudomonas* and *Psychrobacter* species, as well as oxidative reactions that impact color, taste, and texture. While synthetic additives are used to control bacterial growth and oxidation, concerns about their carcinogenic effects have led consumers to seek natural preservation methods. Research is increasingly focused on developing chemical-free alternatives to preserve meat products (Vergis et al., 2025).

Electrolyzed water is an emerging non-thermal decontamination technology in the food industry, produced by electrolysis of a diluted sodium chloride solution. It comes in two forms: acidic (low pH) for its strong disinfectant properties, and alkaline (high pH) for its detergent-like effects and bacterial inactivation. Electrolyzed water is eco-friendly, using only NaCl and water, and is effective against a wide range of microorganisms, including bacteria, molds, and viruses. It has been applied to decontaminate poultry, seafood, meat, fish, vegetables, and fruits, offering a promising alternative to traditional pasteurization methods due to its high antimicrobial activity and environmental safety (Du et al., 2025; Xu et al., 2025).

Ultrasound is a non-thermal food processing method that enhances meat tenderness and is used in various applications in the meat industry, such as tenderization, emulsification, marination, freezing, homogenization, and microbial inactivation. It works by converting electrical energy into vibrational energy, improving meat's physicochemical properties, processing techniques, safety, and sensory attributes. When combined with sterilizing agents, ultrasound can also enhance microbial reduction, making it a valuable tool for improving both the quality and safety of fresh and processed meats (Rathnayake et al., 2025).

Ultrasonically treated meats have improved cooking performance and easier protein extraction. Ultrasound technology is particularly effective for tenderizing meat from older animals, making it more appealing to consumers. With benefits like short processing times, low cost, and microbial reduction at lower temperatures, ultrasound is a promising technology for enhancing meat quality (Pang et al., 2025).

Cold storage and packaging are key to preserving meat quality. Vacuum packaging, in particular, is widely used to extend shelf life by removing air, reducing oxygen, and minimizing microbial growth and oxidation. This method helps prevent discoloration, flavor loss, and weight loss, maintaining the quality and consumer appeal of meat products (Park et al., 2025).

Tenderness is a key factor in meat quality, and research into meat tenderization is growing. Recent studies highlight the effectiveness of ultrasound in improving the tenderness of beef, particularly in beef round cuts, which is beneficial for both producers and consumers. This study focuses on examining the quality characteristics of beef during its shelf life, specifically investigating the effects of electrolyzed water and ultrasonic sound waves – applied individually and together – along with vacuum and aerobic packaging. The research aims to assess their combined impact on the shelf life and various quality attributes of beef, including physical, chemical, microbiological, and sensory properties (Xie and Grossmann, 2025).

This study aimed to investigate the effects of electrolyzed water and ultrasound treatments, both individually and in combination, alongside vacuum and aerobic packaging, on the shelf life and quality attributes of beef.

Materials and methods

Materials

In this study, beef thigh meat cuts from 1.5-year-old cattle slaughtered in Karaman Province were used and packaged in 1 kg batches. The meat was stored under refrigerated conditions both before and after processing, ensuring that the cold chain remained intact. The beef samples were obtained from animals slaughtered in a commercial facility, and the time from slaughtering to the beginning of laboratory analyses was approximately 24 hours. During this period, the carcasses were stored under standard cold-chain conditions (4 ± 1 °C).

Received: 20 October 2025 | reviewed: 16 November 2025 | revised: 19 November 2025 | accepted: 20 November 2025