The concept of beef quality: an introductory mini-review

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Abstract. The impact of food on health and well-being is a critical and ongoing global concern. Among all animal-derived products consumed by humans, meat holds a prominent position due to its high nutritional value. Beef, in particular, is one of the most appreciated and widely consumed animal-based foods, offering high-quality proteins, essential vitamins, and minerals. Ensuring beef quality involves multiple stages of processing, preservation, transportation, and distribution, all of which must adhere to strict hygiene standards. This article aims to analyze the concept of beef quality from an integrative perspective, exploring key factors that influence its quality, including sensory, nutritional, technological, hygienic, and toxicological attributes. Furthermore, it underscores the significance of implementing modern food safety management systems (e.g. HACCP) to safeguard consumer health and uphold high standards in the production and distribution of beef products.
Key Words: beef, food safety, meet quality, quality control.

Introduction. Beef is a significant source of animal-based protein and is regarded as a fundamental component of a healthy diet. Its consumption is influenced by cultural, psychological, medical, and sensory factors, as well as market considerations such as pricing (Tory & Kerry 2010). However, the risk of food spoilage remains a concern, arising from natural contaminants, atmospheric pollution, industrial and agricultural activities, or improper food handling (Wardencki et al 2009).

According to FAO (2023), beef ranks among the most widely consumed animal-based foods, with an annual production of approximately 72.2 million tons (Vidal et al 2022). In Europe, beef consumption shows a downward trend due to various factors, including environmental pollution, climate change, intensive farming practices affecting animal welfare, and variability in beef quality. Globally, meat consumption remains high, with the United States reporting an annual intake of 128.6 kg per person and Hong Kong exceeding this with 136.3 kg per person (FAO 2023).

Morphologically, meat comprises all tissues in direct natural adhesion, including striated muscle, connective, adipose, and bone tissues, as well as blood vessels and nerves (Shahidi 1998). The quality of beef is influenced by factors affecting the animal during its life, such as species, breed, gender, age, and nutritional status, as well as post-mortem biochemical processes in the muscle tissue (Druga 2004).

As Halagarda & Wojciak (2022) noted, meat is among the most essential foods for public consumption due to its unique organoleptic properties and high-quality nutritional profile. Consumers frequently prioritize these attributes when selecting meat products.

This article aims to explore the concept of beef quality from an integrative perspective, addressing key factors influencing quality, including sensory, nutritional, technological, hygienic, and toxicological aspects. It also emphasizes the critical role of modern food safety management systems, such as Hazard Analysis and Critical Control

Points (HACCP), in ensuring consumer health and maintaining high standards in the production and distribution of beef products.

Concepts of meat quality and safety. The evaluation of the quality of a product of animal origin is carried out by assessing the properties and characteristics of the product, which is focused on fulfilling the hygienic-sanitary requirements, specifying the protection of the final consumer against any possible existing risk (Mainz et al 1992; Mihaiu 2010).

The sensory quality of beef is considered one of the most essential quality parameters for the final consumer, and can be conditioned by several factors, among which we mention: breed, type of animal, sex, age and life management (Albechaalany et al 2024). The concept of beef quality requires knowledge of all sensory, nutritional, technological, hygienic and toxicological factors (Banu et al 2003; Smigic et al 2016).

The main quality biomarkers that are associated with meat production are: thyroglobulin, leptin, calpastatin (Sinclair et al 2001; Mihaiu 2010). Thyroglobulin (glycoprotein hormone) is associated with the degree of marbling of the meat and leptin is a protein hormone that is synthesized by adipose tissues and secreted into the bloodstream, with a role in regulating body weight, energy metabolism, osteogenesis and the immune system. The endogenous enzyme activity determines the tenderness of the meat, which is influenced by the calpain protease (m and μ calpain) that exists naturally in the muscles. The calpastatin gene has two genetic variants, the first which gives the meat tenderness and the second which is responsible for a meat with a tougher consistency. According to the studies, these alleles belonging to the calpastatin gene were found in all breeds but with certain differences (Stanescu & Apostu 2010). The correlation between the characteristics of carcass consistency and meat quality is not fully elucidated and can be determined by certain factors: breed, age, growth rate, body weight, food and living conditions of the animal (Bonny et al 2016).

Vestergaard et al (2000) specifies the fact that the influence of the breed on the qualitative muscular, sensory and nutritional characteristics is a difficult process to establish and explain.

Studies carried out over time in different countries of the world (USA, Australia, Great Britain, Japan, France, Poland) certify that most consumers have the same demands regarding beef. Consumers want affordable meat with an organoleptic, hygienic, nutritional quality of the highest standards, which is obtained following good animal husbandry practices and respect for the environment (Hocquette 2003; Dinnella et al 2023).

Food safety presents a concept that must be kept under constant supervision, by observing the specific legislation for each country, so that this notion has the role of maintaining the quality of food products throughout the officially declared validity period (Panisello & Quantick 2001; EFSA 2011, 2015).

The industry responsible for products of animal origin, in our case beef, is based on modern quality management systems to ensure the quality and safety of the products intended for the final consumer (Pop et al 2013). According to data from the literature, the main quality management systems used are:

1. Good Manufacturing Practices (GMP) impose the conditions and procedures for food processing. GMP has proven to ensure consistent quality and high safety of food intended for human consumption;

2. Hazard Analysis and Critical Control Points (HACCP) - this analysis focuses on the identification of potential risks and their control during the production process (Figure 1);

3. Quality Assurance Standards - established by the International Organization for Standardization - International Standards Organization (ISO).

The main objective of risk analysis is to protect public health (Mihaiu 2010). The correct application of the HACCP system involves obtaining and consuming food safely, by observing its principles, which address all stages of production, from the farm to the final consumer (Violaris et al 2008; Wallace et al 2018).

The biological hazards posing significant risks to human health include *Salmonella* spp., *Listeria monocytogenes*, *Escherichia coli*, *Campylobacter* spp., and *Clostridium* spp. (Mihaiu 2010; Panisello & Quantick 2001).

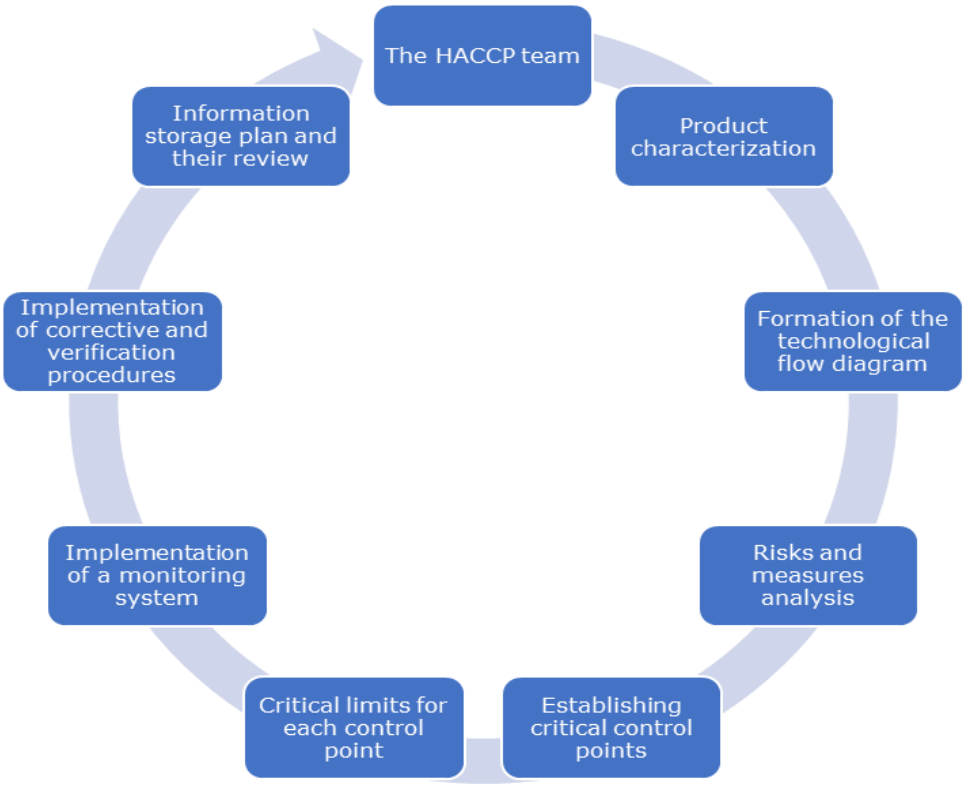

Figure 1. Logical steps for applying the Hazard Analysis and Critical Control Points method.

Currently, bacteria of the genus *Salmonella* are the most important Gram-negative food pathogens and belong to the Enterobacteriaceae family (Adams & Moss 2008). The genus *Salmonella* is composed of two species, *Salmonella enterica* and *Salmonella bongori*, each containing several serotypes, with *S. enterica* designated as the type species (Tindall et al 2005).

S. enterica is responsible for 99% of *Salmonella* infections in humans and warm-blooded animals and in most cases it is transmitted by ingestion of contaminated food or water. *S. bongori* is predominantly isolated from cold-blooded animals and environmental sources, and it is rarely associated with human infections (Velge et al 2005).

Salmonellosis is a disease that has been known for many years and yet it is the main cause of food infections in many parts of the world (EFSA 2011, 2015).

According to epidemiological data, *L. monocytogenes* is considered an important source of infection for the meat industry, especially as a post-processing contaminant of the products during their additional handling (slicing and repackaging) (Lianou & Sofos 2007). *L. monocytogenes* is considered ubiquitous and resistant to control measures, which are achieved with difficulty by the authorities responsible for food safety (EC No 2073, 2005). *E. coli* is a bacterial species belonging to the Enterobacteriaceae family. It is a Gram-negative, non-spore-forming rod that includes both pathogenic and non-pathogenic strains. Non-pathogenic strains are part of the facultative microflora of the gastrointestinal tract (Nataro & Kaper 1998).

Pathogenic *E. coli* comprises six pathotypes associated with foodborne diseases: (a) verocytotoxigenic *E. coli*, also known as Shiga toxin-producing *E. coli* (STEC), which includes enterohemorrhagic *E. coli* (EHEC); (b) enteropathogenic *E. coli* (EPEC); (c) enterotoxigenic *E. coli* (ETEC); (d) enteroaggregative *E. coli* (EAEC); (e) enteroinvasive *E. coli* (EIEC); and (f) diffusely adherent *E. coli* (DAEC) (Beauchamp & Sofos 2014).

The major reservoir responsible for non-O157 STEC is represented by cattle, including beef products that can lead to diseases caused by these organisms (Mathusa et al 2010).

The genus *Clostridium* is characterized by Gram-positive anaerobic bacteria, which are rod-shaped and form endospores (Dinev et al 2023). According to the data, most clostridia are saprophytic and only four species have been identified as human pathogens (*Clostridium perfringens*, *Clostridium botulinum*, *Clostridium difficile* and *Clostridium tetani*) (Carman et al 2008). Foodborne pathogens are *C. perfringens* and *C. botulinum*, while *C. difficile* has been identified as an emerging human pathogen with a potential for foodborne transmision (Shrestha et al 2024).

The pathogenic organism could be present in the muscle tissue, or be introduced into the food through the contamination with faecal matter of the carcasses at the stage of slaughtering the animals, and a last variant through the contamination of meat-based products during the processing stage (Thitaram et al 2011).

Regulation No. 1151/2012 of the European Parliament and of the Council of the European Union, issued in 2012, establishes precise quality schemes for agricultural and food products (Ghimpeteanu et al 2015). According to Biesalski (2005), meat and meat products are important sources of essential nutrients necessary for a healthy lifestyle, including proteins, fats, essential amino acids, minerals, and vitamins.

The quality of raw materials, technological processing conditions, and microbiota determine the final characteristics of products intended for human consumption (Živković et al 2012). Long-aged or dry-aged meat products typically contain significantly less water compared to fresh or smoked products that are not subjected to the drying process (Rason et al 2007).

Proteins from meat are nutritionally essential, providing maximum value by containing all essential amino acids. Muscle tissue generally contains 15-22 g of protein per 100 g, while lean meat can have protein concentrations as high as 24 g per 100 g. All technological processes, particularly thermal ones, influence the final amount and quality of protein (Jiménez-Colmenero et al 2010). Animal breed also impacts protein concentration and quality (Halagarda & Wojciak 2022).

Lipids are an essential energy source and play a critical role in the bioavailability of fat-soluble vitamins (A, D, E, and K). They also significantly influence the sensory characteristics of meat, particularly juiciness and aroma, due to the lipolysis process (Toldrá 2007).

The highest concentrations of fat can be noticed during the drying or long maturation process. Raw, smoked, baked or cooked meat products, due to their higher water content, have a lower fat content (Smagowska et al 2019). According to existing studies in the literature, the significant differences regarding the types of products, ingredients, processing techniques, processing time and including the origin of the meat or the breed of the animal can influence the amount of fat (Ikonić et al 2010).

Mineral substances are essential for the proper functioning of the human body, so they must be obtained from a correct and balanced diet (Halagarda & Wojciak 2022). Mineral substances play an important role in cellular development, regulation of cellular function, but also in establishing electrolyte balance. Mineral substances are part of the body's hormones and enzymes (Suman et al 2003).

The processing of meat does not increase the concentration of minerals, but the use of some spices can influence the concentration of mineral substances due to the fact that spices are mineral carriers, therefore the nutritional value is modified (Püssa 2013).

Food safety monitors the quality of the product intended for human consumption obtained from beef or other species, and the chemical compounds that can negatively influence the quality of the product are: polycyclic aromatic hydrocarbons, biogenic amines, mycotoxins, heavy metals, nitrates/nitrites and phenols (Prado et al 2019; Mastanjevic et al 2020).

The regular and continuous improvement of the quality of food products is achieved through the implementation of standards that assume important points to be reached (Oakland 2004; Pop et al 2013) (Figure 2).

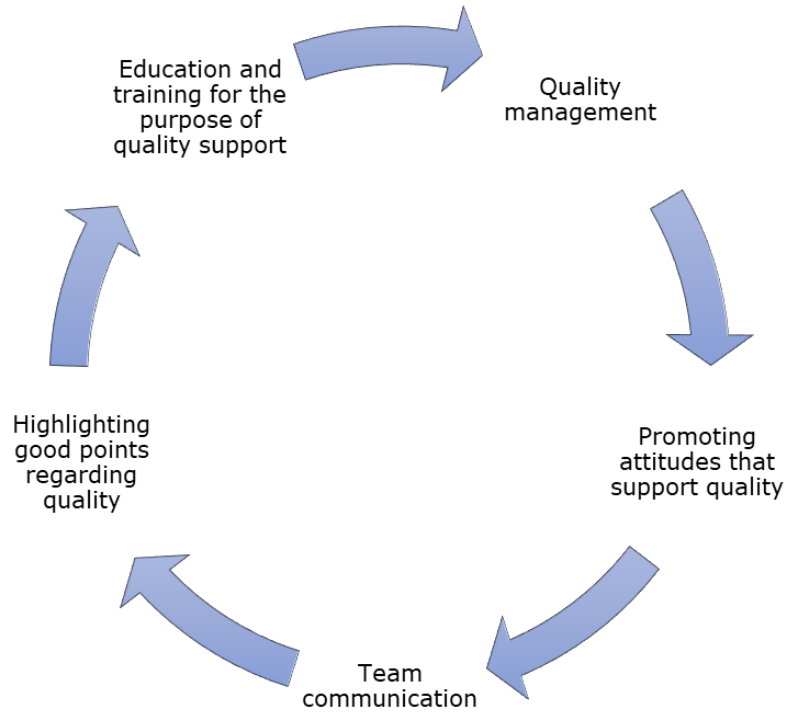

Figure 2. The important points of quality technology support.

Conclusions. The worldwide goal of maintaining the concept of quality and risk analysis is the protection of consumer health. In order to obtain safe food products for the final consumer, the food safety management system was developed, based on the principles of HACCP as a defining element to ensure safety and quality in the production and marketing of food. The system is characterized by the identification, evaluation and control of all physical, chemical and biological hazards that could disrupt the process of obtaining food, keeping and distributing food products.

Conflict of interest. The authors declare that there is no conflict of interest.

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