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Review

Control of fresh meat quality through manipulation of muscle fiber characteristics

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ABSTRACT

Variations of fresh meat quality exist because the quality traits are affected by various intrinsic and extrinsic factors. Because the meat quality is basically dependent on muscle fiber characteristics, numerous studies have reported the relationship between quality traits and fiber characteristics. Despite intensive research, the relationship is yet to be fully established, however, the present knowledge suggests several potential ways to manipulate muscle fiber characteristics to improve meat quality. The present paper reviews the definition of fresh meat quality, meat quality traits and variations of meat quality. Also, this review presents recent knowledge underlying the relationship between fresh meat quality traits and muscle fiber characteristics. Finally, the present work proposes several potential factors including breed, genotype, sex, hormone, growth performance, diet, muscle location, exercise and ambient temperature that can be used to manipulate muscle fiber characteristics and subsequently meat quality in animals.

1. Introduction

Meat quality has always been important to the consumer, and it is an especially critical issue for the meat industry in the 21st century. As consumer demand for high quality meat is increasing in most countries, the meat industry should consistently produce and supply quality meat that is tasty, safe and healthy for the consumer to ensure continued consumption of meat products. In order to produce high quality meat, it is necessary to understand the characteristics of meat quality traits and factors to control them.

Fresh meat quality is difficult to define because it is a complex concept determined by consumer preferences. Because fresh meat is animal tissue that is suitable for use as food, the quality characteristics are influenced by various factors such as muscle structure, chemical composition, chemical environment, interaction of chemical constituents, postmortem (p.m.) changes in muscle tissues, stress and pre-slaughter effects, product handling, processing and storage, microbiological numbers and populations, etc. In particular, fresh meat quality is directly related to muscle fiber characteristics because skeletal muscles mainly consist of muscle fibers. The muscle fibers are characterized by their morphological traits, and contractile and metabolic properties (Lee, Joo, & Ryu, 2010). Morphology traits such as total number of fibers (TNF) and cross-sectional area of fibers (CSAF) are major determinant factors of muscle mass as well as meat quality. Also, contractile and metabolic properties of muscle are differentiated by muscle fiber types, and thus fresh meat quality is strongly related to fiber type composition (FTC) in muscle.

In general, there are four different muscle fiber types in adult skeletal muscle, which are slow-oxidative or type I, fast oxido-glycolytic or type IIA, and fast glycolytic IIX and IIB (Schiaffino & Reggiani, 1996). All of these fiber types are observed in most muscles of meat animals, and their relative composition in the different muscles can determine the predominance of muscle's metabolic properties (Ozawa et al., 2000; Ryu & Kim, 2005). Consequently, p.m. muscle metabolism which is a crucial factor to determine fresh meat quality is affected by TNF, CSAF and FTC (Kim, Jeong, et al., 2013; Ryu, Lee, Lee, & Kim, 2006). These muscle fiber characteristics vary by various factors including breed (Ryu et al., 2008), selection (Larzul et al., 1999), gender (Ozawa et al., 2000), hormone (Rehfeldt, Fiedler, & Stickland, 2004), growth performance (Gondret, Lefaucheur, Juin, Louveau, & Lebret, 2006; Kim, Kim, et al., 2013), diet (Jeong et al., 2012) and muscle location (Beermann et al., 1990; Hwang, Kim, Jeong, Hur, & Joo, 2010). Therefore, understanding the relationship between muscle fiber characteristics and meat quality traits will improve the production of quality meat, and manipulation of muscle fiber characteristics would have profound impacts on the profitability of the meat industry. The present paper reviews the scientific literature in meat quality traits, muscle fiber characteristics and potential factors to manipulate muscle fiber characteristics.

2. Fresh meat quality

The term 'fresh meat quality' is very ambiguous because its definition varies depending on the background of consumers in different

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regions of the world. Accordingly, first of all, meat quality should be defined by most consumer preferences. Consumer preferences are related directly to the human senses such as appearance, smell, taste and mouthfeel. Also, fresh meat quality can be defined by scientific factors including composition, nutrients, colorants, water-holding capacity (WHC), tenderness, functionality, flavors, spoilage, contamination, etc.

The quality of fresh meat indicates its usefulness to the consumer and its acceptability for cooking. The important quality traits for fresh meat are color, WHC, texture and amount of fat (intramuscular fat/intermuscular fat/subcutaneous fat), while the important traits for eating quality of cooked meat are tenderness, flavor and juiciness. In general, consumers rate color as the most important quality trait for fresh meat, while tenderness is rated as the most important palatability trait for cooked meat followed by flavor and juiciness (Glitsh, 2000). However, this can vary among consumers depending upon past experiences and cultural background. Therefore, the order of importance of meat quality traits can vary by country (Warner, Greenwood, Pethick, & Ferguson, 2010).

The appearance of meat is determined by meat color, packaged meat color, amount and distribution of fat, fat color, amount of drip on the surface of the meat, purge in the tray, and texture of the meat (Becker, 2000). These appearance quality traits (AQT) strongly influence the consumer's decision to select good quality meat at the point of purchase. However, the consumer determines the actual meat quality at the point of consumption with eating quality traits (EQT) such as tenderness, flavor, juiciness and succulence (Acebron & Dopico, 2000). Additionally, consumers assess meat quality by reliance quality traits (RQT) such as safety, nutrition, animal welfare, ethics, price, product presentation, origin, and brand of meat products (Troy & Kerry, 2010). Therefore, it is appropriate to define the term 'fresh meat quality' by consumer preferences that are determined by RQT as well as AQT and EQT of meat (Joo & Kim, 2011).

3. Meat quality traits

Quality traits of fresh meat are categorized based on major intrinsic and extrinsic factors. Generally, intrinsic factors are the physiological characteristics of meat such as AQT and EQT, whereas extrinsic factors are the RQT of meat products (Joo & Kim, 2011). All these traits contribute to the consumer's expectation of high quality meat. Consumers determine quality meat as one with desirable color, firm texture, less drip, high marbling, and moderate visible fat and fresh meat odor, while discoloration, soft texture, large amount of drip, less marbling, excessive visible fat and abnormal meat odor are considered as poor quality traits for fresh meat. Also, the consumer expects quality meat that is reliable in relation to safety, nutrition, sustainability and ethics (Troy & Kerry, 2010).

3.1. Appearance quality traits (AQT)

Meat color is the most important AQT because it is the first factor seen by the consumer and is used as an indication of freshness and wholesomeness. Basically, meat color is dependent on species, age and muscle type, and the color differences are due to the different content of myoglobin (Mb) in muscle. The higher Mb content in type I muscle fiber is due to Mb's function of storing and delivering oxygen in the muscle. The Mb content in muscle is affected by factors such as exercise and diet of the animal as well as genetic and environmental factors. Many factors contribute to the discoloration of meat during processing, storage and display. The predominant determinant of meat color stability is the rate of OxyMb oxidation (Faustman, Sun, Mancini, & Suman, 2010), and the rate of discoloration in meat is muscle-specific. Rapid discoloration occurs in muscles that contain greater relative proportions of type I muscle fibers because of higher oxygen consumption rate (Jeong et al., 2009).

Two other important AQT for fresh meat are the amount of drip on the surface of meat and purge in the tray. Drip and purge loss depend on the WHC of meat, and WHC is closely related to the color of meat due both to its role in the loss of Mb and reflectance at the surface of the meat (Joo, Kauffman, Kim, & Kim, 1995). Additionally, WHC influences other physical properties including texture and firmness of raw meat, and eating properties of cooked meat. Drip loss originates from the spaces between muscle fiber bundles and the perimysial network, and the spaces between muscle fibers and the endomysial network (Offer & Cousins, 1992). These spaces appear during rigor development when muscle converts to meat. It is well known that excessive drip exudation and soft texture result from the combination of rapid pH decline, and high temperature in p.m. muscle (Joo, Kauffman, Kim, & Park, 1999; Warner, Kauffman, & Greaser, 1997). This is an especially prevalent problem for pork which contains greater relative proportions of type II muscle fibers compared to beef or lamb.

Meat texture is directly related to the size of muscle fiber and the amount of connective tissue, and is partially affected by the quantity of intramuscular fat (IMF). Relatively large muscle bundles are responsible for the coarse, undesirable texture on the transversely cut surface of meat. The diversity of muscle is attributed to the heterogeneous characteristics of the individual muscle fibers and the mosaic composition (Taber, 1998). Muscle fiber diameter varies with species, chronological age, state of nutrition of the animal, genetic background and composition of muscle fiber types (Karlsson et al., 1993). The coarseness of the meat surface is increased with thickened connective-tissue strands as well as increased size of muscle bundles. The connective tissue content of meat varies with species, chronological age, state of nutrition of the animal and muscle fiber characteristics (Klont, Brocks, & Eikelenboom, 1998). Meat firmness is also influenced by the status and quantity of the subcutaneous fat surrounding muscles and IMF. Because IMF deposits mainly in the perimysium between muscle bundles, meat firmness is partially influenced by the IMF firmness which is affected by composition of fatty acids and temperature.

It is known that IMF produces effects on flavor, juiciness, tenderness and visual characteristics of meat with increased marbling in meat, although there has been extensive debate about the contribution of IMF to the tenderness of meat. The quantity of IMF is affected by many factors including animal breed, slaughter weight (Park et al., 2002), feeding strategy (Du, Yin, & Zhu, 2010), and growth rate (Smith et al., 2009). In animals, adipogenesis occurs the earliest in the visceral fat deposit, closely followed by subcutaneous and intermuscular deposits, and adipogenesis in intramuscular fat occurs last (Hausman et al., 2009). This adipogenesis can be affected by genetic, nutritional and environmental factors that are the key signaling pathways regulating adipogenesis in skeletal muscle (Du & Dodson, 2011). Although there are variations among species, IMF tends to increase with advancing age when the major stages of muscle growth have been completed. IMF deposition is highly heritable and is positively correlated with general body fatness in the animal. Moreover, IMF is positively correlated with percentage of red muscle fiber, but negatively correlated with white muscle fiber in muscle (Hwang et al., 2010).

3.2. Eating quality traits (EQT)

Tenderness is the most important EQT because it strongly influences consumer's perceptions of acceptability. Meat tenderness is mainly affected by the amount and solubility of connective tissue, the composition and contractile state of muscle fibers, and the extent of proteolysis in rigor muscle. Also, IMF content indirectly affects meat tenderness. Tenderness is more important for red meat such as beef and lamb because of a high composition of red muscle fibers and connective tissue compared to pork or chicken. The content of connective tissue is related to muscle fiber characteristics because