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Review

Meat quality assessment using biophysical methods related to meat structure

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A R T I C L E I N F O

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A B S T R A C T

This paper overviews the biophysical methods developed to gain access to meat structure information. The meat industry needs reliable meat quality information throughout the production process in order to guarantee high-quality meat products for consumers. Fast and non-invasive sensors will shortly be deployed, based on the development of biophysical methods for assessing meat structure. Reliable meat quality information (tenderness, flavour, juiciness, colour) can be provided by a number of different meat structure assessment either by means of mechanical (i.e., Warner–Bratzler shear force), optical (colour measurements, fluorescence) electrical probing or using ultrasonic measurements, electromagnetic waves, NMR, NIR, and so on. These measurements are often used to construct meat structure images that are fusioned and then processed via multi-image analysis, which needs appropriate processing methods. Quality traits related to mechanical properties are often better assessed by methods that take into account the natural anisotropy of meat due to its relatively linear myofibrillar structure. Biophysical methods of assessment can either measure meat component properties directly, or calculate them indirectly by using obvious correlations between one or several biophysical measurements and meat component properties. Taking these calculations and modelling the main relevant biophysical properties involved can help to improve our understanding of meat properties and thus of eating quality.

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1. Introduction

One challenge facing the meat industry is to obtain reliable information on meat quality throughout the production process, which would ultimately provide a guaranteed quality of meat products for consumers. To meet this challenge requires fast, accurate and non-invasive techniques for predicting technological and sensory qualities. Over the last few years, a number of methods have been developed to objectively measure meat quality traits. The majority of these methods are invasive, meaning that a sample has to be taken or that they are difficult to implement on-line. In muscle food, the pivotal qualitative characteristics that need to be determined are texture, nutritional value, and appearance. Several very promising measurement techniques are currently being studied and used in laboratories, some of which will shortly be ready for industrial deployment.

The great variability in raw meat leads to highly variable products being marketed without a controlled level of quality. This problem is aggravated when the industry is unable to satisfactorily characterize this level of quality and cannot therefore market products with a certified quality level, which is an otherwise essential condition for the survival and development of any modern industry. Meat quality depends on the same criteria generally attached to other food. The basic traits relate to nutritional content such as proteins, fat, fibers, vitamins and minerals, mainly iron. Another key criterion is safety. The food must be clean in terms of agrochemical residue, heavy metals, pathogenic micro-organisms, and any other substance representing a potential health hazard. The other aspect of quality deals with "functional" characteristics, i.e., related to the sensory properties of taste and appearance (Grunert, 1997). The variability in functional traits is in part related to the biological diversity of the animals from which meat is obtained. Numerous studies have shown the important influence of zootechnical characteristics on meat tenderness, other studies have focused on collagen and myofibrillar structure. Factors influencing meat properties are partly related to breed, age and sex (Judge & Aberle, 1982; Huff-Lonergan, Parrish, & Robson, 1995; Horcada, Beriain, Purroy, Lizaso, & Chasco, 1998). These factors are either known or can be contained and controlled. However, the variability in myofibrillar and conjunctive components remains uncontrolled. In fact, meat toughness depends mainly on these two structures: the myofibrillar structure, and conjunctive tissue. Myofibrillar structure is strongly influenced by the animal rearing conditions. For instance, (Greenwood, Harden, & Hopkins, 2007), found that single- or multiple-reared lambs present significant differences in myofiber types and so in myofibrils, whereas (Gondret, Combes, Lefaucheur, & Lebret, 2005), found changes in myofiber types according to indoor or outdoor rearing systems. On the other hand, conjunctive tissue is directly related to the zootechnical characteristics of the animal at slaughter. These components need to be assessed not only in terms of quantity but also in terms of intramuscular distribution. The spatial organization of the conjunctive network of fat and meat fibers bundles, which defines the "meat grain" and marbling, is one of the meat structure traits strongly connected to meat tenderness. The assessment of this trait is of prime interest, not only for the development of a diagnostic system making it possible to determine the muscular origin of a meat sample and therefore optimize production processes, but also as a non-invasive method of sorting muscle meat in terms of potential tenderness, since consumer demand is for consistency in meat tenderness.

Beyond tenderness, meat structure, as considered in this paper, groups together sensory properties associated with meat eating like texture, pastiness, crusting, palatability, chewiness, juiciness and of course tenderness. These sensory properties are associated with several objective physical properties of the product: fat content, fat spatial organization, collagen content, collagen spatial organization, myofibers spatial organization, myofibers type, size, shape and density, sarcomere length, Z lines and I bands integrity, membranes integrity and sarcolemma attachment to myofibrils. Water content also takes part in these physical properties because it is connected with juiciness and with pale, soft and exsudative (PSE) and dark firm dry (DFD) defects. These defects are more precisely related to water holding capacity (WHC), a water property correlated with water activity (Kuo & Chu, 2003). PSE and DFD defects can also be accessed thanks to the measurement of myofibers metabolism. Another indirect marker of structure is salt diffusion which depends on structure integrity. This review gives a non-exhaustive overview of biophysical methods which can measure one or another of all these sensory and direct or indirect physical parameters. These methods are summarized in Table 1 with the type of information they give and with their main advantages and drawbacks.

Biophysical methods of assessment can either measure meat component properties directly or calculate them indirectly (Monin, 1998) by using obvious correlations between one or several biophysical measurements and meat component properties (Brunton, Lyng, Zhang, & Jacquier, 2006; Swatland, 1997b). This paper pinpoints five groups of biophysical assessment: mechanical methods, optical methods, dielectrical methods, X-ray measurements, and