Journal of Food Engineering 132 (2014) 1–13

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Review

Recent developments of hyperspectral imaging systems and their applications in detecting quality attributes of red meats: A review

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ARTICLE INFO

Article history:
Received 29 September 2013
Received in revised form 3 February 2014
Accepted 5 February 2014
Available online 12 February 2014

Keywords:
Pork
Beef
Lamb
Quality attributes
Hardware
Software
Hyperspectral imaging

ABSTRACT

Red meats, such as pork, beef, and lamb meats, play an important role in people's daily diet as they can provide good protein, vitamins, and minerals to promote human health. Either the meat processing industry or consumers usually evaluate meat quality with some common quality characteristics, which generally encompass microbiological attributes (freshness, spoilage), chemical attributes (fat, protein, moisture), sensory attributes (color, tenderness, flavor) as well as technological attributes (pH, water-holding capability). Manual inspection and chemical detection methods are tedious, time-consuming, and destructive. Consequently, fast and nondestructive methods are required for detecting these attributes in the modern meat industry. Hyperspectral imaging is one of the promising methods, which integrates the merits of imaging and spectroscopy techniques. This paper provides a comprehensive review on the recent development of hyperspectral imaging systems and their applications in detecting some important quality attributes of pork (color, drip loss, pH, marbling, tenderness, chemical compositions), beef (color, pH, tenderness, water-holding capacity, microbial spoilage), as well as lamb (color, drip loss, pH, tenderness, chemical composition). Finally, the future potential of hyperspectral imaging is also discussed.

Contents

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http://dx.doi.org/10.1016/j.jfoodeng.2014.02.004
0260-8774/

1. Introduction

Red meats are a significant part of people's daily diet as they can provide good protein, vitamins, and minerals to promote human health (McAfee et al., 2010). Among a variety of red meats, pork, beef and lamb are commonly served as people's first-choice sources of animal protein. With the improvement in living standards, people currently pay more attention to the quality of food products. Therefore in the modern agri-food industry, quality is one of the most important concerns and the industry is always looking for new technologies such as novel cooling (Sun and Brosnan, 1999; Sun and Zheng, 2006; Sun and Hu, 2003; Wang and Sun, 2001), freezing (Delgado et al., 2009; Zheng and Sun, 2006), drying (Sun, 1999; Sun and Byrne, 1998; Sun and Woods, 1993, 1994a, 1994b, 1997; Cui et al., 2004) and edible coating (Xu et al., 2001) to enhance product qualities. For meat products, how to keep them in high quality is critical as high quality products are the basis for success in today's highly competitive market. Therefore, the meat industry should manufacture superior red meats to fulfill consumers' expectation so that they can dominate the market better. Meat quality is usually defined as a measurement of attributes or characters that determine the suitability of meat to be eaten as fresh or stored for reasonable period without deterioration (ElMasry et al., 2012a). Furthermore, meat quality attributes could encompass chemical attributes, microbiological attributes, sensory attributes and technological attributes (Mancini and Hunt, 2005; Chen and Qin, 2008; Rosenvold and Andersen, 2003; Otto et al., 2004; Andrés et al., 2008; Warner et al., 1997; Agullo et al., 1990; Pathare et al., 2013), as illustrated in Fig. 1. These attributes highly affect the quality of red meats because of the great variability in these attributes, which results from a direct integration of conditions such as pre-slaughter, stunning method, and electrical stimulation. Particularly, this issue will be aggravated if the industry is unable to characterize this level of quality satisfactorily. Traditionally, sensory attributes (color, flavor, firmness, marbling, tenderness, etc.) of many foods (Chen and Qin, 2008; Rosenvold and Andersen, 2003; Otto et al., 2004; Andrés et al., 2008; Hernández et al., 2008a, 2008b), including red meats, are inspected by some well trained assessors. In some abattoirs, tenderness is evaluated using a "finger method", and for meat color and marbling, the evaluation methods are similar and are usually carried out by comparing the color of the rib eye muscle (*Musculus longissimus dorsi*) or the proportion of intramuscular fat within the *M. longissimus dorsi* and scored against the reference standards specific for each of the meat species. However, manual inspection is subjective, tedious, time-consuming and inconsistent. In addition, some important internal quality attributes such as acidity and nutritional constituents cannot be detected by manual inspection.

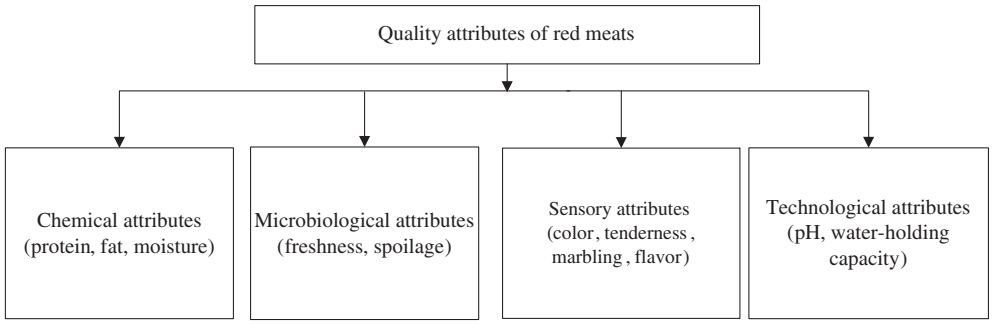

Fig. 1. Common quality attributes of red meats.

Table 1
Comparison of computer vision, spectroscopy, hyperspectral imaging, ultrasound and CT scanning.

Methods	Advantages	Disadvantages
Ultrasound technique	Rapid Non-polluting High sensitivity	Easily affected by operators, measurement sites as well as the ultrasonic frequency Only detecting chemical compositions for some specific parts
CT scanning	Non-invasive Providing detailed images	Expensive Longer evaluation time Limited range of application
Computer vision	Providing spatial information Higher accuracy than manual inspection Able to detect external attributes	Limited multi-constituent information Unable to detect internal attributes
Spectroscopy technique	Simple Providing spectral information Able to detect internal attributes	Limited sensitivity to minor components and complicated analysis
Hyperspectral imaging	Providing spatial and spectral information Sensitive to minor components Building chemical images	High cost Problems of data processing