BIOSYSTEMS ENGINEERING 144 (2016) 85–93

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Digital image analyses as an alternative tool for chicken quality assessment

Douglas F. Barbin [a,d,*], *Saulo M. Mastelini* [b], *Sylvio Barbon Jr.* [b], *Gabriel F.C. Campos* [b], *Ana Paula A.C. Barbon* [c], *Massami Shimokomaki* [c]

[a] *Department of Food Science, Federal University of Technology – Paraná (UTFPR), Brazil*
[b] *Department of Computer Science, State University of Londrina (UEL), Brazil*
[c] *Department of Animal Science, State University of Londrina (UEL), Brazil*
[d] *Department of Food Engineering, University of Campinas (Unicamp), Brazil*

ARTICLE INFO

Article history:
Received 25 June 2015
Received in revised form
5 January 2016
Accepted 30 January 2016
Published online 26 February 2016

Keywords:
Pale poultry muscle
PSE
Computer vision
Classification
Multivariate statistical analyses

Poultry meat colour is an important quality attribute for the rapid detection of "pale poultry syndrome", as it is affected by conditions of animal welfare during pre-mortem period. The meat processing industry demands a fast and non-contact method for accurate meat colour assessment. In the present study, computer vision was tested as a potential tool to predict colour measurements compared to CIELab attributes of chicken breast (*pectoralis major*) obtained by analytical reference measurements. The proposed approach using computer vision was successful in avoiding pixels with little information (specular reflection) and based on an illumination normalisation step it was obtained an acceptable correlation between colorimeter measurements and the proposed framework (Delta E = 5.2). High correlation coefficients obtained between computer vision and colorimeter validate the approach for measuring L^* colour component. Results for determination coefficient was $R^2 = 0.99$ for L^*. In addition, our framework reach $R^2 = 0.74$ for a^*, and $R^2 = 0.88$ for b^* component. Results suggest that computer vision methods base on an RGB device can become useful tool for fast quality assessment of chicken meat in large-scale processing plants.

1. Introduction

Poultry meat is considered an important element in healthy diets, reaching high levels of consumption worldwide (Alexandrakis, Downey, & Scannell, 2012). Poultry meat producers and consumers demand thorough quality assessment and control. Chicken meat quality is related to physical and chemical attributes usually evaluated in the breast (pectoralis major) muscle. One of the most important and frequently found quality deviations of chicken meat is PSE (pale, soft and exudative) defect (Smith & Northcutt, 2009). PSE condition was previously reported in poultry, with biochemical factors

* *Corresponding author*. Department of Food Engineering, University of Campinas (Unicamp), Rua Monteiro Lobato, 80. Barão Geraldo, Campinas, SP, CEP:13083-862, Brazil

E-mail addresses: dfbarbin@unicamp.br (D.F. Barbin), saulomastelini@gmail.com (S.M. Mastelini), barbon@uel.br (S. Barbon), camposg@uel.br (G.F.C. Campos), apbarbon@gmail.com (A.P.A.C. Barbon), mshimo@uel.br (M. Shimokomaki).

http://dx.doi.org/10.1016/j.biosystemseng.2016.01.015

affecting the colour, water-holding capacity and tenderness of poultry meat, in addition to being a sign of meat quality that also indicates conditions of animal welfare during pre-mortem period (Barbut, Zhang, & Marcone, 2005; Carvalho et al., 2015). Breast meat with low ultimate pH value is commonly related to lower tenderness scores when compared with meat with higher values of ultimate pH (Barbin et al., 2015; Droval et al., 2012).

Several investigations have reported chicken breast meat that appears lighter than normal with lower ultimate pH and water-holding capacity, assigning the term PSE for this particular poultry muscle defect (Smith & Northcutt, 2009; Van Laack, Liu, Smith, & Loveday, 2000; Wilhelm, Maganhini, Hernandez-Blazquez, Ida, & Shimokomaki, 2010; Zhang & Barbut, 2005). Occasionally, broiler chickens may not exhibit a true PSE condition, leading to the proposition of the term pale poultry muscle syndrome (Smith & Northcutt, 2009). Hence, colour is a highly significant feature in the fast assessment of "pale poultry syndrome" in poultry meat, as well as the occurrence of PSE condition (Barbut et al., 2005). In reality, the primary feature used to differentiate broiler muscle for the PSE defect is pale colour. Considering the issue of chicken samples that are pale with normal pH values (pale poultry muscle), it is important to establish an application for image analyses in order to predict colour attributes in chicken samples.

Meat has a heterogeneous surface because of its complex composition of muscle fibres, connective tissue and intramuscular fat. In addition, a single muscle may have colour variations among its regions. Currently, poultry meat colour is measured by a colorimeter in terms of CIELab colour space, hue angle and chroma (Commission Internationale de l'Eclairage – CIE, 1978). The colorimeter often evaluates a single spot (with a surface of about 10–30 mm^2), thus being unable to measure the colour of the whole sample surface in a single measurement (Kang, East, & Trujillo, 2008). Broadening the area where colour is measured could provide a wider range of values, thus reducing the error in colour determination. On the other hand, widening the measured area would possibly include fat and connective tissue, thus yielding unreliable measurements (Girolami, Napolitano, Faraone, & Braghieri, 2013). Hence, this method requires a substantial set of measurements to provide a reliable value for meat quality characterisation, and therefore is not applicable to the highly increasing fast-paced industrial meat sector.

Visual inspection is routinely used to assign grades or quality labels to chicken carcasses. Recently, novel techniques have been investigated for fast, reliable and reagent-less meat quality assessment. The application of image analyses has gained increased interest due to its simplicity, low-cost and speed of analysis, providing a whole image of the product, instead of the colour measurement of a single point or of a reduced area such as the area spotted by the colorimeter.

Rapid advances in hardware and software for digital image processing impelled several studies on the development of different types of acquisition equipment (digital cameras, webcams and scanners) for computer vision systems (CVS) as a process analytical technology (PAT) to evaluate the quality of meat (Lu, Tan, Shatadal, & Gerrard, 2000; dos Santos & Pereira Filho, 2013). In particular, CVS technique allows estimating the overall colour of the sample along with other features in the entire surface of the sample (Brosnan & Sun, 2004; Du & Sun, 2004; O'Sullivan et al., 2003; Wu & Sun, 2013; Zheng, Sun, & Zheng, 2006).

Several applications of image analyses have been reported for food quality assessment and safety control: quality control, inspection for foreign objects, and general processing-line applications (Acevedo et al., 2009; Borah & Bhuyan, 2005; Medina, Quevedo, & Aguilera, 2013; Torrence, Wright, & Conway, 2004). Images obtained by combination of computer monitors and webcams were used for detection and quantification of total anthocyanins and polyphenols in red wine, with results comparable with those obtained by standard methods (Alimelli et al., 2007; dos Santos & Pereira Filho, 2013). Digital images were used to investigate quality and compositional attributes of pork ham (Valous, Mendoza, Sun, & Allen, 2009b).

The poultry processing industry could benefit from a system that can predict variations in single colour attributes or even classify samples according to visual features. Therefore, the main objective of the present study was to investigate the potential application of image colour identification framework as a fast and robust method to predict chicken colour attributes and classify chicken breasts accordingly. Specific objectives were to (1) establish an adequate procedure of sample preparation for image acquisition, (2) to study whether image features can improve robustness of the prediction models for this particular application, (3) to investigate the influence of samples from different qualities in the dataset acquired, (4) to build robust normalisation models to quantitatively relate digital image information and colour features measured by colorimeter.

2. Materials and methods

2.1. Sample preparation

Slaughtered poultry breast fillets (pectoralis major muscle) were acquired from a local retailer (ntotal = 52 samples) and transported under refrigeration to the Laboratory of Food Science at UEL, Londrina-PR, Brazil, for further analysis. Samples were selected by an experienced grader in order to encompass as large variation in quality features as possible, including normal and PSE samples. After acquiring RGB images from the samples, the colour of samples was measured using a reference method (as described in Section 2.2) and each sample was divided into three different analysable regions. This approach was adopted because it was observed a wide variation in colour features within the same sample, leading to unrealistic lack of precision to the regression method. By splitting the sample into three regions, there was less variance between colorimeter measurements for each region.

2.2. Analytical measurements

After a 30 min blooming period, colour was obtained as the average of 3 consecutive measurements at random locations of breast samples using a Minolta colorimeter (CR 400, D65