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Noninvasive discrimination and textural properties of E-beam irradiated shrimp

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ABSTRACT

Discrimination of irradiated foods is critical for facilitation of international trade, consumer choice, and enhancement of consumer confidence. The performance of discriminating the irradiated shrimp samples at various irradiation doses using Multispectral Imaging (MSI) system (405–970 nm) and the effects on the textural properties were investigated in this study. Principal component analysis (PCA), least squares-support vector machines (LS-SVM), and back propagation neural network (BPNN) methods were all applied to discriminate the irradiated shrimps at different irradiation doses. The classification accuracies from 76% to 100% were achieved by using LS-SVM and BPNN models. Comparatively, the LS-SVM model was proved to demonstrate the better performance with 100% prediction accuracy when using 10 kGy doses or above. All results of this study reveal MSI in combination with different chemometrics methods has been proved to be a very powerful tool for the discrimination of the irradiated shrimps from non-irradiated ones.

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1. Introduction

Shrimp, an important source of protein, is consumed for its unique flavor and texture properties by global consumer (Heu et al., 2003). Textural property is also considered as the critical indicator to guarantee the quality and freshness of seafood products (Dai et al., 2014). Textural property determines the taste feeling and the acceptability of consumers, while the soft flesh brings a poor eating quality with an unpleasant mushy feel (Nunak and Schleining, 2011; Moreno et al., 2012). Therefore, inspection of changes in textural property is an important and key step for providing shrimp products with the consistent premium quality.

Besides, shrimps are also susceptible to be decomposed due to the existence of contaminations of spoilage and pathogenic microorganisms (Gram and Huss, 1996). Recently, irradiation has been proven to be one of the most successful techniques for the preservation of food with minimum interruption to the functional, nutritional, and sensory properties of food products (Diehl, 2002; Mahapatra et al., 2005; Akram and Kwon, 2010). Practically, the adopted doses vary according to the type of foods and the final desired effect. A dose of 4 kGy has been proved to be adequate enough for elimination of non-spore-forming pathogens in different frozen seafood (Venugopal et al., 1999). Several toxicological reviews and publications of regulatory and health organizations have extensively studied and reported that the irradiation below 10 kGy is safe (Smith and Pillai, 2004). High dose (higher than 10 kGy) irradiation has been used for sterilization and long-term storage of meat, poultry, seafood, and other special purposed foods for safe (Arvanitoyannis et al., 2009). However, high-dose irradiation might also lead to the physicochemical changes and sensory properties deterioration of foods, including taste, flavor, texture, and color (Yun et al., 2012).

Although the safety of irradiated foods has already endorsed by

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international organizations (IAEA, Codex, and WHO), there is still no accepted consensus for the applied regulations of this technology (Marchesani et al., 2012). Almost 40 countries, including China have approved the usage of irradiation for over 100 food items. At the same time, this irradiation technology is still prohibited for food preservation in many other countries (Chauhan et al., 2009). Therefore, extensive research has been carried out for discrimination of irradiated samples from non-irradiated samples with easy-operated analytical methods (Chauhan et al., 2009).

The spectroscopic based techniques developed with improved computer capacity and powerful chemometrics tools have been extended into various fields, allowing efficient management of spectra and chemical data obtained from the samples. Multispectral imaging (MSI) is developed by integrating the imaging and spectroscopy techniques together, which makes it possible to be acquired with both spatial and spectral information from a target object simultaneously. As a rapid and noninvasive analytical protocol, MSI has recently been adopted to assess food safety and quality including contaminants detection (Kim et al., 2002), defect identification (Xing et al., 2006; Dissing et al., 2013), constituent analysis (Lu, 2004; Peng and Lu, 2006, 2007; Lleó et al., 2009), quality evaluation (Lunadei et al., 2011, 2012; Sun et al., 2012; Løkke et al., 2013; Panagoua et al., 2014), and also identification of transgenic rice (Liu et al., 2014a). To the best of our knowledge, there is no published study about discrimination of irradiated shrimp using the MSI protocol.

Therefore, the development of rapid and noninvasive methods for irradiated shrimp discrimination with MSI is highly desired. In this study, the three basic and specific objectives were to: (1) investigate the changes of textural property in the irradiated shrimp with different irradiation doses; (2) study the feasibility of MSI technique to distinguish irradiated shrimps from the non-irradiated ones; (3) compare the discrimination performance of different chemometrics methods, mainly including the LS-SVM and BPNN models.

2. Material and methods

2.1. Samples and electron-beam irradiation

Solenocera crassicornis is an important shrimp species in fishery resource and is widely distributed in the adjacent waters of the South Yellow Sea and the East Sea of China (Song et al., 2003; Liu et al., 2012; Ye et al., 2012). In this study, packed frozen shrimp (*S. crassicornis*) samples were obtained from Zhejiang province (East of China) with same batch in June 2014, and stored at −18 °C. Subsequently, the samples were divided into five groups: Sample 0 (non-irradiated, 0 kGy), sample 1 (1 kGy), sample 2 (4 kGy), sample 3 (10 kGy) and sample 4 (20 kGy). As a result, there are 150–200 shrimp in each group with the total weight of 1000 g. The samples surrounded with cooling cartridges were placed in a polystyrene box and transported immediately to Hefei USTSC Aike Science and Technology Co., Ltd. (Hefei, Anhui, China), the transportation and irradiation process duration was controlled within 4 h and temperature inside the box was maintained below −10 °C. The irradiation treatments were conducted by an electron beam irradiator of 10 MeV with pulse duration of 13 μs, average beam of 1.0 mA; the scan width was 30–90 cm, the conveyer speed was settled to the range 20–100 cm/min, and the scan frequency was 25–50 Hz. The actual absorbed dose was measured by using Radiochomic dosimeters (Far West Technology Inc., USA) and dosimeters were calibrated with Fricke Reference standard dosimeter. During irradiation process, a single layer of shrimps was packed in polyethylene bags without any stacking between each other. Four dosimeters were positioned, respectively, on the exterior at the top and bottom surfaces of each package (two on each side). Samples were treated with target absorbed doses of 0, 1, 4, 10 and 20 kGy. Results indicated that dose was uniformly distributed over the samples. The absorbed dose was within ±10% of the targeted dose.

Prior to the analysis of the samples and model development, all samples were divided into two subsets, namely, calibration set consisting of 410 samples (90 samples from non-irradiation, 80 samples × 4 irradiation doses) and validation set consisting of 110 samples (30 samples from non-irradiation, 20 samples × 4 irradiation doses). Samples in the calibration set were used to establish the model, while samples in prediction set as external validation were applied to verify the robustness of the established model.

2.2. Measurement of textural properties

After wiping the surface water with paper towel, each shrimp was firstly captured by a laboratory MSI system and then textural properties were measured by using a TA.XT2i texture analyzer (Stable Micro Systems, Guildford, UK). Each measurement location was compressed twice to 40% of their original thickness with the speed of 1 mm/s using a compression platen (100 mm in diameter) (Cheng et al., 2014; Dai et al., 2014). Cheng et al. (2014) reported the compression degree was 40% of the depth, showing the maximum force (N) obtained for representing the hardness. The platen re-compressed the sample 5 s after the first compression cycle. The most common parameters obtained from the curve of the texture profile analysis (TPA) were hardness, springiness, cohesiveness, gumminess, chewiness and resilience.

2.3. Multispectral imaging system

2.3.1. Image acquisition

Images of shrimp samples were acquired with VideometerLab equipment (Videometer A/S, Hørsholm, Denmark) that illuminates a given sample under an integrating sphere in 19 different wavelengths from the visual to near infrared region and the detailed wavelengths were 405, 435, 450, 470, 505, 525, 570, 590, 630, 645, 660, 700, 780, 850, 870, 890, 910, 940 and 970 nm (Liu et al., 2014b; Xiong et al., 2015). The image system records surface reflections with a standard monochrome charge coupled device chip, nested in a Point Grey Scorpion camera. The object of interest is placed inside an integrating sphere with a matte white coating to ensure that the light is scattered evenly with a uniform, diffuse light at illumination. At the rim of the sphere light emitting diodes (LEDs) are positioned in the pattern of side by side distributing the LEDs at the specific wavelength uniformly around the entire rim. When an image is obtained, the LEDs are turned on successively, and the reflection from that specific wavelength is recorded by top-mounted camera. The result is a monochrome image with spatial resolution of 2056 × 2056 pixels. The system is first calibrated using a uniform white and dark disc. Then the system is geometrically calibrated with a geometric target to ensure pixel correspondence for all spectral bands (Dissing et al., 2013; Gomez et al., 2007; Liu et al., 2014a). In this study Fig. 1 shows the flow chart of main steps in data acquisition and analysis (a) multispectral imaging system; (b) picture captured by MSI of raw, RGB and different wavelength, color bar shows the visual reflectance value in each wavelength picture.

2.3.2. Image pre-processing

To obtain the relative reflectance from each image by MSI, it is necessary to segment the mass images into distinct regions. The image segmentation process was considered as an essential and fundamental step because the precision of its operation directly affect the selection of region of interest from an input image and

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