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Predicting mechanical properties of fried chicken nuggets using image processing and neural network techniques

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Abstract

Typical approaches for measuring mechanical properties of fried food products are mostly destructive techniques. In this study, a non-destructive, image-based method was evaluated for predicting mechanical properties of fried, breaded chicken nuggets. The textural parameters of interest, namely maximum load, energy to break point, and toughness of fried chicken nuggets were measured. Values of the parameters changed over frying time. Images of the chicken nuggets were collected at different frying stages and five image texture indices were extracted using co-occurrence matrix. A multiple-layer feed-forward neural network was established to predict the three mechanical parameters. The correlation coefficients of the predicted results with those from mechanical tests were above 0.84.

Keywords: Image texture; Mechanical properties; Crispness; Co-occurrence matrix

1. Introduction

Quality of fried foods is defined in terms of texture, moisture and oil contents, porosity, color, taste and nutrition (Dogan, Sahain, & Sumun, 2005). Many studies (Baixauli, Sanz, Salvador, & Fiszman, 2003; Duizer, 2001; Fillion & Kilcast, 2002; Pedreschi & Moyano, 2005; Ross & Scanlon, 2004; Vincent, 2004) have focused on texture of fried foods since textural parameters such as crispness are of great interest to consumers. Roudaut, Dacremont, Pàmies, Colas, and Meste, 2002 reviewed scientific techniques for measurement of crispness. These techniques include sensory and instrumental methods. Although sensory analysis gives more complete description of product texture, there have been great interests in developing instrumental techniques due to their adaptability for quick, easy-to-use and industrial control protocols. Hence, mechanical measurements are achieved by parameters of force, power spectrum, the fractal dimensions and others. Also, acoustic and bio-rheology measurements are utilized. However, the parameters of instrumental measurement cannot give straight indication of crispness but are correlated to sensory attributes. During instrumental measurements, the samples are typically punched (or bitted) to obtained force or sound data. Most instrumental measurements also require contacts with the product and thus are destructive or require modification of the product. Surface texture provides important contributions to the texture of a food product. Visual method is an effective way to obtain surface texture features (Chen, Moschakis, & Nelson, 2004). Image processing has successfully been used in food quality inspections (Abdullah, Guan, Lim, & Karim, 2004; Du & Sun, 2004; Du & Sun, 2006; Qiao, Sasao, Shibusawa, Kondo, & Morimoto, 2004; Qiao, Sasao, Shibusawa, Kondo, & Morimoto, 2005). It is a rapid, non-destructive and low-cost means of assessing quality of food products. It is also very amenable to industrial online applications.

Fried chicken nuggets are widely consumed all over the world. They are usually coated with bread and batters. Rapid online technique of textural measurement is required

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for process control of nugget frying. However, prediction of textural attributes of chicken nuggets using the image processing approach has not been well developed. Although there is no clear definition of "texture", an image can be described in textural terms as fine, coarse, smooth or irregular, homogenous or inhomogeneous, etc. depending on its look (Theodoridis & Koutroumbas,, 2003). The texture of an image region is determined by the way the gray levels are distributed over the pixels in the region.

The objectives of this study were to characterize the changes in mechanical properties of fried chicken nuggets, obtain texture features by image processing and to develop a model to predict the mechanical textural properties of the fried breaded chicken nuggets by using image texture processing.

2. Experimental materials and methods

2.1. Samples preparation

Commercially ready to cook, frozen, breaded chicken nuggets made from white chicken breast meat were purchased from a local grocery store. The average weight of the chicken nuggets was 28 g. The size of the rectangular samples was 5 × 5 × 1 cm. The chicken nuggets were stored in a freezer at −18 °C until used.

Chicken nuggets were fried in a domestic electric fryer. The frying temperature was controlled at 175 °C using a programmable temperature controller (Eutech Instrument Pte Ltd., Singapore). Based on the size of the fryer, two samples were fried as a frying batch to reduce temperature fluctuations during frying. The samples were placed in a wire basket to keep them submerged for the required time 1, 3, 4.5, 6 and 8 min frying. After frying, samples were immediately withdrawn from oil, and blotted gently with dry tissue paper to remove excess oil on the surface. This procedure was necessary to reduce surface halation and to obtain high quality images of samples. The samples were cooled to room temperature before their images were acquired. Ten samples were analyzed at each frying time. A total of 50 fried samples were used for further measurement.

2.2. Image acquisition and preprocessing

The image acquisition system consisted of a digital camera (C-200 Zoom, Olympus Optical Co., Ltd. Japan) with a resolution of 0.09 mm/pixel. A DC regulated illuminator (Fiber-Lite PL900-A, Dolan-Jenner Industries Inc, MA, USA) with two fiber-optic line-light-guiding branches was utilized to provide uniform illumination. These light-guiding branches were mounted to illuminate the instantaneous field of view (FOV) at 5° forward and backward angles to minimize shadows and directional scattering caused by the rough surface of the chicken nuggets. The camera and the light-guiding branches were fixed on a supporting frame to obtain same conditions for the image acquisition. The samples were placed within the FOV as shown in Fig. 1. Two

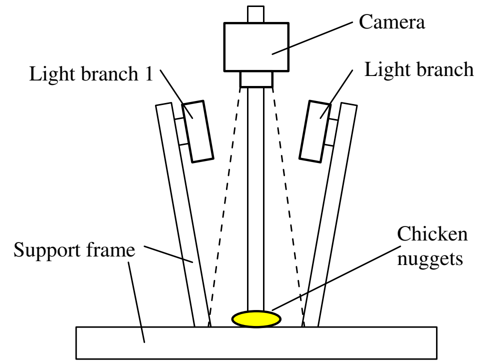

Fig. 1. Schematic diagram of the hyperspectral image acquisition system.

images were obtained from both sides of a sample. The images were saved on a flash memory of the camera as JEPG format for later analysis. A region of interest (ROI) on each acquired images was selected, which was the biggest internal rectangular inside the image of a chicken nugget. The ROI was converted to gray level image (255 levels) for texture analysis by a program developed using MATLAB v7.0 (Mathworks, Inc. Mass., USA). Mechanical tests were conducted immediately after acquiring sample images.

2.3. Mechanical test

An Instron Universal testing machine (Instron Corporation, Cantan, MA) equipped with a 500 N load cell was used for mechanical measurements. The textural features of a fried chicken nugget were measured by penetrating it with a 9-pin probe. Only 6 of the 9 pins actually penetrated the sample due to the size of the chicken nugget. The probe was allowed to penetrate up to a specified depth at a crosshead speed of 10 mm/min. The samples were punched twice, once on each side of the sample. The Instron Series IX software was used to acquire and record the mechanical textural parameters, namely maximum load, energy to break point (EBP) and toughness.

2.4. Co-occurrence matrix

The co-occurrence matrix has been successfully used to classify texture of image (Dulyakarn, Rangsanseri, & Thitimajshima, 2000; Gotlieb & Kreyszig, 1990; Lie, 1993). A co-occurrence matrix is generated from an image by estimating the pair wise statistics of pixel gray level. It is a square matrix with elements corresponding to the relative frequency of occurrence of pairs of pixels separated by a certain distance in a given orientation. The elements of a $N \times N$ gray level co-occurrence matrix $C_{(d,\alpha)}(i,j)$ count the co-occurrence of pixels with gray values i and j at a given distance d and an orientation angle α. Therefore, the co-occurrence matrix $C_{(d,\alpha)}(i,j)$ is defined as in Eq. (1).

$$C_{(d,\alpha)}(i,j) = P(I(p_1) = i,\ I(p_2) = j) \tag{1}$$

where P is the probability of occurrence of gray levels with respect to relative spatial pixel position, and p_1 and p_2 are