Journal of Food Engineering 118 (2013) 426–433

Contents lists available at SciVerse ScienceDirect

Journal of Food Engineering

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

Prediction of texture characteristics from extrusion food surface images using a computer vision system and artificial neural networks

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ARTICLE INFO

Article history:
Received 1 November 2012
Received in revised form 17 April 2013
Accepted 18 April 2013
Available online 7 May 2013

Keywords:
Color
Texture
Extrusion food
Computer vision system
Artificial neural networks

ABSTRACT

Surface images and the texture characteristics of 17 samples and the 25 different parts within one sample were detected using a computer vision system and texture profile analysis in extruded food. According to the linear fitting model, the hardness and gumminess score can be reflected directly by the a^* and *Intensity* based on correlation coefficient of 0.9558, 0.9741 and 0.9429, 0.9619, respectively. The springiness could be reflected from color values through calculating from hardness and gumminess scores, indirectly. Neither of cohesiveness and chewiness presented relationship with two different color spaces. A desirable and accurate two hidden layers of back-propagation artificial neural network was trained for simulating and predicting the hardness and gumminess scores from a^* and *Intensity* based on the data in 17 samples, respectively. The simulation processing in ANN showed higher correlation coefficient of 0.9671 and 0.9856 than linear fitting model.

1. Introduction

Food extrusion is a well established food processing technique that has developed rapidly during the last decade (Harper, 1981; Dziezak, 1989; Antonio et al., 2006). Secondary-puffed processing involves the blending of raw materials (prior to the use of dies), then shaping the preliminary products and frying or puffing them again to achieve a unique shape, taste or give specific physicochemical properties. The quality of the preliminary product will directly affect the quality of the final product, and texture value is one of the main factors used to determine secondary-puffed processing quality control. Texture profile analyzer (TPA) is traditionally used to measure food texture characteristics (Rahman and Al-Farsi, 2005; Wu and Jiang, 2005). However, it may be difficult to measure texture following secondary-puffed processing, since the traditional TPA method has certain limitations in that its disrupts the entire processing line and destroys the product during the test procedure.

Color is an important visual characteristic of food, and it also affects consumer preference and purchase decisions. As well, color correlates well with other physical, chemical and sensory quality indicators in food (Esteve et al., 2005; Tiwari et al., 2008). In fact, color plays a major role in the assessment of internal quality in the food industry and in food engineering (Cornforth, 1994; Segnini et al., 1999; Abdullah et al., 2001; Mancini and Hunt, 2005; Alcicek and Balaban, 2012). Commercial colorimeters, are available to analyze for food external color. However, the major disadvantage of these devices is that the area that can be measured is quite small, and its accuracy is limited when the food surface is curved or uneven. Image analysis techniques can be used to extract color information from curved and uneven food surfaces (Kumar and Mittal, 2010; Pallottino et al., 2010; Fathi et al., 2011), and these techniques have been widely used in food processing and quality control (Gokmen and Sugut, 2007; Valadez-Blanco et al., 2007). The most commonly used image analysis equipment is known as a computer vision system (CVS). CVS is a simple and powerful machine that can detect uneven coloration or curve surfaces and acquire whole color information from the surface image of food products (Kang et al., 2008). In particular, food surfaces are curved, with non-homogeneous coloration. In addition, calibrated average color measurements and other features apparent through the use of CVS correlate highly with some inner physical properties (Mendoza and Aguilera, 2004).

Artificial neural networks (ANNs) is an analytical tool based on the structure of biological neurons, and it has been widely used in several fields, including food industry. Unlike other analytical methods, where prior knowledge of relationships among process parameters is required, ANN draws on previously gathered information and utilizes this when analyzing new data input (Bishop, 1995; Jain, 2010). It is particularly useful in managing uncertainties and non-linear data relationships. In the area of food quality control, ANN has been successfully applied to predict the quality of agricultural raw material (Ni and Gunasekaran, 1998; Xie and

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0260-8774/$ - see front matter
http://dx.doi.org/10.1016/j.jfoodeng.2013.04.015

Xiong, 1999; Singh et al., 2009), beef sensory quality (Park et al., 1994), the shelf life of pasteurized milk (Vallejo-Cordoba et al., 1995), the sensory attributes of noodles (Tulbek et al., 2003) and the shelf life of soya milk (Ko et al., 2000), but there have been few published reports on the application of ANN in food extrusion processing.

In this study, six color values were measured ($h, s, i, L^*a^*b^*$) from CVS and five texture characteristics were measured based on the TPA, in two independent experiments. A linear fitting model and ANN were used to determine the relationship between the external color and the internal textures. We attempt to develop a simple and accurate method for on-line quality control in extrusion processing using a multilayer, feed-forward ANN to predict the internal texture characteristics from the external color values.

2. Materials and Methods

2.1. Materials

Long-grain, high-amylose commercially milled rice was purchased from a local Guangzhou, China supermarket. The milled rice was ground into flour using a hammer mill and then passed through a 100-mesh sieve (British standard, 150 μm). Cheese (Original Illertaler, Kaserei Champignon, Germany), edible colza oil (Golden Dargon Fish, China), noli powder and rice bran were also used as raw material. The noli powder was added to enhance the color of the extrusion products and to insure a more readily apparent color change for subsequent detection.

In order to realize the color change among different formulations and the distribution of color in the same food, this study was divided into two experiments. In experiment 1, the rate (w/w) of each ingredient was: rice flour mixture (include rice bran): cheese: edible oil = 2:1:1, the weight proportion of rice bran in rice flour mixture varied from 0% to 50% with interval 3%. In experiment 2, the formulation was same as experiment 1 except the rice bran proportion in rice flour mixture was fixed in 25% (w/w). The raw materials were mixed with 60% (w/w) water in preparation before the extrusion process in both two experiments.

Blended materials were processed in a corotating twin-screw experimental extruder (DS32-II, Jinan Saixin Food Machinery, Shandong, China), which consisted of three independent zones with controlled temperature in the barrel without the die. The length to diameter (L/D) ratio for the extruder was 18.9:1, feed rate was: 60 kg/h, screw speed was: 480 r/min. The temperature profiles in the feed and compression metering zones was kept constant as 80 °C and 100 °C, respectively, and the third zone temperature was 110 °C.

After extrusion processing, the seventeen samples with the amount of rice bran added varying were cut into 5 cm (length) × 5 cm (width) × 0.5 cm (thickness) proportions and the entire surface color values and texture characteristics on each one were analyzed in experiment 1. In experiment 2, however, the extrudate was separated into 25 parts with 1 cm (length) × 1 cm (width) × 0.5 cm (thickness), and the CVS and TPA for each one was determined. After placed samples in two experiments in an air oven at 25 °C for 15 min, the water balance in each sample was established, then the samples were stored at 4 °C in sterile polyethylene bags under a vacuum for subsequent analysis.

2.2. Methods

2.2.1. Computer vision system (CVS)

The illumination condition affects the color values in samples' surface significantly. In different illumination condition, the surface color values reflected in color image vary at the same time and the results of experiment change as well. So, in order to avoid the occurrence of this phenomenon, the colorful surface images of samples in two experiments were captured by computer vision system (CVS), as described by Alcicek and Balaban (2012). This system, which can create a stable illumination condition, was a box type enclosure with two fluorescence tube lamps (TL-D Delux, 18W/965, 6500 K, Phillips) attached at the top corner of the box, in parallel, at a 45° angle to the product location. The internal size of the box was 900 mm (width) × 900 mm (length) × 900 mm (height). A color digital camera (DSC-WX5C Sony Cyber-Shot, Japan) captured images on surface. The CCD-camera settings for the two experiment were ISO: 200, shutter speed: 1/25, aperture: 3.5, view area: 640 × 480, format: JPEG; and zone ISO: 200, shutter speed: 1/25, aperture: 3.5, view area: 4000 × 2248, format: JPEG, respectively. The camera was connected to the USB port of a PC provided with a Picture Motion Browser (Version 5.3, Sony, Japan) to visualize and acquire the digitalized images directly from the computer.

In food research, the color is frequently represented in the L^*a^*-b^* color space. This color model is considered approximately uniform, i.e. the distance between two colors in a linear color space corresponds to the perceived differences between them. Therefore, it permits an objective color representation, and its use is essential for applications where the results must match those of the human perception (Sangwine, 2000). Another widely used color space in foods is the HSI. It is a user oriented color system based on the human vision system (Du and Sun, 2005). The average value of the pixels for each color scale in the image is registered as the color of the samples. The background image was removed from the image using a toolbox in ACDsee 5.0 (ACD system, British Columbia, Canada), and the regions of interest (ROI) were then selected. In both two experiments, the ROI should contain the whole surface of the samples and the extracted color information in the ROI. After the MATLAB R2011b (The Math-Works, Inc., USA) acquired the ROI image and extracted the R, G and B values from it, the simple color information was converted to $L^*a^*b^*$ and HSI color spaces.

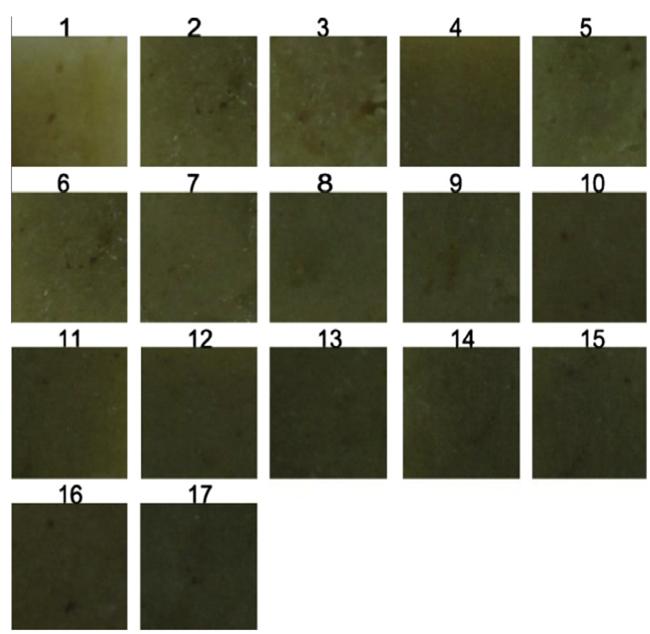

Plate 1. Photos of the whole surface of second-puffed products, with rice bran added in rice flour mixture at levels of 0% (1), 3% (2), 6% (3), 9% (4), 12% (5), 15% (6), 18% (7), 21% (8), 24% (9), 27% (10), 30% (11), 33% (12), 36% (13), 39% (14), 42% (15), 45% (16), and 48% (17) for second-puffed food.