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Colour and image texture analysis in classification of commercial potato chips

Fernando Mendoza [a,*], Petr Dejmek [b], José M. Aguilera [a]

[a] Department of Chemical Engineering and Bioprocess, Pontificia Universidad Católica de Chile, P.O. Box 306, Santiago, Chile
[b] Department of Food Technology, Engineering and Nutrition, LTH, Chemical Center, Lund University, P.O. Box 124, 221 00 Lund, Sweden

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Abstract

The images of commercial potato chips were evaluated for various colour and textural features to characterize and classify the appearance and to model the quality preferences of a group of consumers. Features derived from the image texture contained better information than colour features to discriminate both the quality categories of chips and consumers' preferences. Entropy of a^* and V and energy of b^* from images of the total chip surface, average and variance of H and correlation of V from the images of spots and/or defects (if they are present), and average of L^* from clean images (chips free of spots and/or defects) showed the best correspondence with the four proposed appearance quality groups (A: 'pale chips', B: 'slightly dark chips', C: 'chips with brown spots', and D: 'chips with natural defects'), giving classification rates of 95.8% for training data and 90% for validation data when linear discriminant analysis (LDA) was used as a selection criterion. The inclusion of independent colour and textural features from images of brown spots and/or defects and their clean regions of chips improved the resolution of the classification model and in particular to predict 'chips with natural defects'. Consumers' preferences showed that in spite of the 'moderate' agreement among raters (*Kappa-value* = 0.51), textural features have potential to model consumer behaviour in the respect of visual preferences of potato chips. A stepwise logistic regression model was able to explain 86.2% of the preferences variability when classified into *acceptable* and *non-acceptable* chips.

Keywords: Potato chips; Quality; Colour; Image texture; Classification; Preference

1. Introduction

One of the most important quality parameters of fried potato products strictly related to consumer perception, is the colour (Segnini, Dejmek, & Öste, 1999). Colour is critically appraised by consumers and often is the basis for their selection or rejection of chips. Potato chip colour is the result of the Maillard reaction, which depends on the content of reducing sugars and proteins, temperature and time of frying (Mackay, Brown, & Torrence, 1990; Márquez & Añón, 1986).

In potato chip manufacture the most important quality parameters to be controlled are the intensity of darkening during frying, texture and crispness (Smith, 1975; Scanlon, Roller, Mazza, & Pritchard, 1994). However, there are other important factors that must be controlled to avoid diminishing the sensorial properties and healthful quality of potato chips. They are the amount of oil absorbed during frying and post-frying process, which can produce a slightly dark appearance of the chips and sometimes the presence of oily or transparent regions on the surfaces. Numerous studies have shown that most of the oil is confined to the surface region of the fried product (Bouchon, Aguilera, & Pyle, 2003; Bouchon & Pyle, 2004; Rimac-Brnčić, Lelas, Rade, & Šimundić, 2004). Likewise, the presence of dark and brown spots due to natural defects or injuries in raw potatoes, which we believe that could be immediately detected and rejected by the consumers. Consequently, an integral characterization of the surface of

* Corresponding author. Tel.: +56 2 354 4254; fax: +56 2 354 5803.
E-mail address: fmendoza@ing.puc.cl (F. Mendoza).

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potato chips that identifies and quantifies those traits that are desirable by consumers as well as defects, could provide a useful tool in the quality control of the frying process.

An interesting alternative for analyzing the surface of the actual chips and quantifying appearance characteristics is to use computerized image analysis techniques. Computer vision analysis is a non-destructive method to objectively measure colour patterns in non-uniformly coloured surfaces, and also determine other physical features such as image texture, morphological elements, and defects (Chen, Chao, & Kim, 2002; Mendoza & Aguilera, 2004). Moreover, with the advantage of superior speed, accuracy, and recent advances in hardware and software, computer vision has attracted a significant amount of research aimed at replacing human inspection (Brosnan & Sun, 2002, 2003). Colour sorting is a commercial reality, but quantitative analysis for quality control is not common.

In food research, colour is frequently represented using $L^*a^*b^*$ colour space, which is an international standard for colour measurements adopted by the Commission Internationale de I'Eclairage (CIE) in 1976. L^* is the luminance or lightness component that goes from 0 (black) to 100 (white), and parameters a^* (from green to red) and b^* (from blue to yellow) are the two chromatic components, varying from -120 to $+120$. The system is based on the spectral sensitivity of human sight and its adaptation to prevailing lighting conditions. One of its disadvantages is that it is not intuitive. Another colour space less used in foods is HSV. It is a user-oriented colour system based on the artist's idea of tint, shade and tone. HSV separates colour into three components varying from 0 to 1 (when it is calculated using the function *rgb2hsv* available in Matlab®); H (hue) distinguishes among the perceived colours, such as red, yellow, green and blue; S (saturation) refers to how much of the light is concentrated at the hue's specific wavelengths, respectively is made up of white light of all wavelengths; and V (value) represents the total brightness similar to L^* (Du & Sun, 2005).

The meaning of the term texture in image processing is completely different from the usual meaning of texture in foods. Image texture can be defined as the spatial organization of intensity variations in an image at various wavelengths, such as the visible and infrared portions of the spectrum (Haralick, Shanmugam, & Dinstein, 1973). Image texture is an important aspect of images and textural features play a major role in image analysis (Li, Tan, Martz, & Heymann, 1999). These features provide summary information defined from intensity maps of the scene which may be related to visual characteristics (coarseness of the texture, regularity, presence of a privileged direction, etc.), and also to characteristics that cannot be visually differentiated (Basset, Buquet, Abouelkaram, Delachartre, & Culioli, 2000).

Numerous researches on the colour appearance of potato chips have employed colour measurements and classification methods by image analysis techniques. A first study by Scanlon et al. (1994) used computerized video image analysis to measure lightness of potato chips, expressed on a gray level scale. Segnini et al. (1999) developed a procedure based on a video technique and image analysis to quantify the colour of potato chips in the $L^*a^*b^*$ colour space and the presence of undesirable brown spots from gray scale images. They showed that the sensitivity of this technique to separate colours correlated well with the perception of the human eye. Marique, Kharoubi, Bauffe, and Ducattillon (2003) modelled colour classification of fried potato chips by image analysis and artificial neural networks, but using gray scale images. Their results showed a good agreement with human estimations, obtaining correlation coefficients of 0.972 for training data and of 0.899 for validation data. Pedreschi, Mery, Mendoza, and Aguilera (2004) used a pattern recognition approach for classification of potato chips obtained under six different processing conditions (e.g. blanching and frying temperature). More than 1500 geometric and colour features (in gray level scale and $L^*a^*b^*$ colour space) were extracted from the colour digital images. Using 11 features and a simple classifier, they obtained a good classification performance in the confidence interval of 78% and 89%. However, there are no studies that correlate features from images of commercial potato chips with colour appearances, defects, and preferences of consumers.

The objectives of this study were: (i) to evaluate the potential of $L^*a^*b^*$, HSV and gray scale intensities and their image texture information (energy, entropy, contrast, and homogeneity from each colour scale) to characterize and to classify four quality categories of commercial potato chips, and (ii) to evaluate the capability of these extracted features to characterize and to model the potato chip preferences of a group of consumers.

2. Materials and methods

2.1. Samples of potato chips

Potato chips (Lättsaltade, OLW, AB Sweden) were taken randomly from four commercial packages and sorted subjectively into four quality categories (18 samples per category): (i) 'pale chips', having a clean surface, and no apparent spots; (ii) 'slightly dark chips', or chips with acceptable colour, but sometimes characterized by the presence of oily or transparent regions; (iii) 'chips with brown spots', which also have an acceptable colour, but present brown spots due to the Maillard reaction; (iv) 'chips with natural defects', which are chips with darker and browner spots due to natural defects or injuries in raw potatoes.

2.2. Image acquisition

Images were captured using an image acquisition system for colour digital camera similar to that developed by Mendoza and Aguilera (2004). This system consists of the following elements: