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Surface texture characterization of an Italian pasta by means of univariate and multivariate feature extraction from their texture images

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ABSTRACT

Surface texture is an important characteristic of foods, as well as color, shape, consistency and taste. It plays an important role in consumers' decision and it can affect the properties of a product during its preparation. This work shows the ability of three different image analysis techniques to characterize the surface texture of three Italian pasta samples. The first method is based on the evaluation of *Heterogeneity* (*HTG*); the second on the *gray level co-occurrence matrix* (*GLCM*) and Haralic statistics; the third, the *angle measure technique* (*AMT*), is based on image multivariate feature extraction. The results obtained showed that it is possible to highlight differences in the surface aspect of pasta samples both before and after cooking, and that it is also possible to correlate them to some of their chemical–physical characteristics (e.g., total starch and protein contents, solids lost in the cooking water, pasta adhesiveness; $r>0.6$, $p<0.05$). A partial least square discriminant analysis (PLS-DA) applied on *GLCM* and *AMT* results allowed the classification of the different pasta samples only on the basis of their surface texture features (sensitivity > 0.963; specificity > 0.648).

1. Introduction

Food products are increasingly being studied from many points of view, not only for their nutritional and healthy properties but also for technology and engineering aspects. Indeed with the increasing development of new foods (Siró, Kápolna, Kápolna, & Lugasi, 2008; Stewart-Knox & Mitchell, 2003), characterization studies are focused on obtaining finished products with specific technological and sensory characteristics able to produce a well-defined sensation in the final consumer. Obviously these characterizations regard not only the chemical and qualitative aspects (Faller & Fialho, 2009; Huang, Yu, Xu, & Ying, 2008; Muller & Steinhart, 2007; Rodriguez-Amaya, 2010) but also the physical and rheological properties of foods (Borwankar, 1992; Lucisano, Mariotti, Pagani, Bottega, & Fongaro, 2009; Lucisano, Cappa, Fongaro, & Mariotti, 2010). Aspects such as color, size, shape and consistency in fact are immediately perceived by the consumer, primarily through the eyes and then by touching (Fongaro, Lucisano, & Mariotti, 2012). The external surface of a food is the place where the consumer takes contact the first time through sight, and it is the site where the chemical and physical changes occur early on. The possibility to understand and also to predict how these properties could be influenced by raw materials, chemical composition, process technology and how they may change during the shelf life (Acevedo, Briones, Buera, & Aguilera, 2008; Bruneel, Pareyt, Brijs, & Delcour, 2010; Mariotti, Alamprese, Pagani, & Lucisano, 2006; Oey, Vanderplancken, Vanloey, & Hendrickx, 2008; Olivera & Salvadori, 2009) is thus essential.

Among the physical properties of foods, surface texture is an important aspect towards which the scientists are showing an increasing interest. It can be used, for instance, to describe and predict different properties of foodstuffs (Chandraratne, Samarasinghe, Kulasiri, & Bickerstaffe, 2006). Generally, the term "surface texture" is used to describe the appearance of the surface of non-organic materials. It can be referred to the sensations received through the sense of touch when touching the outer surface of an object, and it can be described as composed of many points of different heights and with a different distribution (Beyer, 2010, The GLCM Tutorial http://www.fp.ucalgary.ca/mhallbey/). These features can be perceived and evaluated, as stated before, through sight looking directly at the objects or at their images: surfaces can appear smooth or rough, depending on how light is reflected by the surface material, and the differences detected can be related to differences in color, due to a specific chemical composition and a different surface topography of the material under observation (Chen, 2007).

Abbreviations: ADH, adhesiveness; AC, after cooking; AMT, angle measure technique; BC, before cooking; CON_{UC}, contrast of uncooked sample; CON_C, contrast of cooked sample; COR_{UC}, correlation of uncooked sample; COR_{UC}, correlation of cooked sample; ENR_{UC}, energy of uncooked sample; ENR_C, energy of cooked sample; ENT_{UC}, entropy of uncooked sample; ENT_C, entropy of cooked sample; GLCM, gray level co-occurrence matrix; *HTG*, heterogeneity; MA, mean angle; PC, protein content; PCA, principal component analysis; PLS-DA, partial least square discriminant analysis; SLCW, solid losses in cooking water; TS, total starch content; C and UC, as subscript cooked and uncooked.

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In recent times computer vision employing image processing techniques has been developed rapidly in order to quantitatively characterize complex size, shape, color and texture properties of foods (Du & Sun, 2004; Mariotti, Fongaro, & Catenacci, 2010; Sun, 2008). In particular, texture properties of foods can be determined by means of image analysis in the evaluation of their image texture. This is possible because the image texture, despite its many different definitions (Russ, 1999), depends on the spatial distribution, frequency and gray level value of each pixel composing the image, and all these properties are linked to the surface structure of the object (Amadasun & King, 1989; Bharati, Liu, & MacGregor, 2004). Surface texture is currently being studied and correlated with the chemical and physical properties of foods (Basset, Buquet, Aboielkaram, Delachartre, & Culioli, 2000; Chandraratne et al., 2006). In general, it is evaluated by means of computer visual inspection, by using different image texture analysis methods applied directly to food images (Johansen, Laugesen, Janhoj, Ipsen, & Frost, 2008; Kvaal, Wold, Indahl, Baardseth, & Næs, 1998; Quevedo, Lopez-G, Aguilera, & Caduche, 2002; Zheng, Sun, & Zheng, 2006).

The aim of this work was the evaluation of the ability of three different image texture analysis methods to objectively describe the surface aspect of an Italian peculiar pasta (*Pizzoccheri*), as well as its changes associated with cooking. At this purpose, the *Heterogeneity* parameter (*HTG*), the gray level co-occurrence matrix (GLCM) and the angle measure technique (AMT) were applied, as different image texture analysis methods, to three different *Pizzoccheri* brands, both before and after cooking. The surface texture of pasta, in fact, depends on many factors, such as the quality of the raw materials used, the operative conditions (e.g., drying process) adopted, the die used in the forming process (Lucisano, Pagani, Mariotti, & Locatelli, 2008; Zardetto & Dalla Rosa, 2008) and so on. The results obtained were also correlated with some chemical–physical parameters, in order to test the potential ability of these image analysis techniques in predicting some important features of pasta quality.

2. Experimental

2.1. Pasta samples

Pizzoccheri is a kind of Italian pasta traditionally made in the Valtellina valley (north of Italy). An aliquot of buckwheat flour (generally from 20% to 30%) is added to fine and coarse semolina, and the dough (about 35% moisture) is formed into a tagliatella-shaped pasta form (Pagani, Lucisano, & Mariotti, 2007): the final product is very porous and rough, about 2 mm thick, 0.8 cm wide and 7 cm long.

In particular, three different *Pizzoccheri* brands (coded A, B, and C), and three different batches for each brand, were analyzed. Sample A was formed into short-strands pasta (about 6.7 cm long, 0.75 cm wide, 0.15 cm thick), mixing buckwheat flour (25%) with coarse semolina, durum wheat semolina and water, extruding the resulting mass. Sample B was produced as nest-shaped pasta (coils weighing about 35 g each, formed by strands 0.74 cm wide and 0.14 cm thick), mixing buckwheat flour (24%) with durum wheat semolina and water, sheeting the resulting mass. Before the analysis, sample B was cut into pieces 6 cm long. Sample C was formed into short-strand pasta (about 5 cm long, 0.78 cm wide, 0.15 cm thick), mixing buckwheat flour (25%) with coarse semolina, durum wheat semolina and water, combining extrusion and sheeting to form the mass. Samples B and C were produced in the Valtellina valley; sample A was produced in Lombardy as well, but outside of the Valtellina area.

2.2. Pasta cooking conditions

An aliquot of 50 g of pasta was cooked in 500 mL of boiling natural spring water (pasta: water ratio = 1:10) with no salt added at the optimum cooking time (OCT) as defined by each producer: 12 min for sample A, 10 min for sample B and 15 min for sample C. After cooking pasta was drained for 1.5 min and was buffered lightly with a paper towel to absorb the excess of water present on the surface before being characterized by Image Analysis.

2.3. Image acquisition

Three sub samples of six pasta strands were selected for each *Pizzoccheri* brand (A, B, C) and their corresponding images were acquired both before (54 images) and after (54 images) cooking. Each sample was thus described by means of 108 images of pasta strands, and 324 images were totally analyzed. During the acquisition process performed with a flatbed scanner (Epson Perfection 3170 Photo, Seiko Epson Corporation, Nagano, JP), samples were covered with a black box to prevent loss of light and images were acquired at a resolution of 600 dpi (dots per inch) and a color depth of 24 bits. The captured image was saved in uncompressed TIFF format. To create the final data set of images shown in Fig. 1, a region of interest (ROI) of $800*125$ pixels was extracted from each single image of the pasta strand. The ROI was selected on the basis of the maximum area that could be extracted from the smallest sample (B) and it represents at least the 40% of the total area of each strand analyzed. After converting the color images in 8-bit gray-scale images, the surface texture of each image of the pasta strand was evaluated.

2.4. Surface texture analysis

The assessment of pasta surface texture was carried out by means of three different image analysis methods, as reported below.

2.4.1. Heterogeneity (HTG)

The *Heterogeneity* (*HTG*) parameter is frequently used to characterize the surface of different materials (Mahavir, Bijay, & Ambikanandan, 2007; Marti, Fongaro, Rossi, Lucisano, & Pagani, 2011; Padhi, Mahavir, & Ambikanandan, 2009; Sabo et al., 2006) and it is a texture feature obtained from first order statistical measure. It is defined as the fraction of pixels whose intensity value deviates more than 10% compared to the average intensity of the entire image. The *HTG* value is thus calculated by the ratio between the number of pixels that exhibit a intensity value 10% higher or lower than the mean intensity value and the total number of pixels composing the image. The value of each pixel in an image depends on how the light is reflected by the surface; for a smooth surface the reflection and incidence light angles are equal and denote an homogeneous reflection; on the contrary, for a rough surface the reflection and incidence light angles are different and denote a diffusion phenomenon (Chen, 2007). An *HTG* value equal to 0 corresponds to an homogeneous surface (smooth surface); an *HTG* value equal to 1 corresponds to a heterogeneous surface (rough surface). In this research, images were processed by Image-Pro Plus v. 7.0 (MediaCybernetics, Inc. MD, USA) and the *HTG* index was automatically calculated by the software for the whole ROI selected.

2.4.2. Gray level co-occurrence matrix (GLCM)

This approach is based on statistical calculations on the second-order histograms of the gray scale images. The gray level co-occurrence matrix (GLCM) calculates how often two pixels, in the matrix element $P_\delta(i,j)$, with intensity values i and j at a particular displacement distance δ from along a given direction θ (horizontally, vertically, or diagonally) occurs in the image (Bharati et al., 2004). Haralick, Shanmugam, and Dinstein (1973) proposed a quantitative analysis of GLCM with 14 descriptors for the surface texture, although generally only few of these are widely used. In this work the following descriptors were used (Zheng et al., 2006):