Food Research International 42 (2009) 353–362

Contents lists available at ScienceDirect

Food Research International

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

Texture appearance characterization of pre-sliced pork ham images using fractal metrics: Fourier analysis dimension and lacunarity

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ARTICLE INFO

Article history:
Received 29 October 2008
Accepted 21 December 2008

Keywords:
Computer vision
Fourier analysis fractal dimension
Gliding box lacunarity
Pork ham slice
Surface characterization
Texture appearance

ABSTRACT

An important goal for characterization of texture appearance is the quantification of spatial patterns. The objective was to investigate the potential usefulness of two fractal metrics based on fast Fourier transform and gliding box lacunarity as descriptors of visual texture in ham slices. Images were acquired from three qualities of sliced pork ham, typically consumed in Ireland (200 slices/quality). Unexpected characteristics in textural pattern were revealed; the values of fractal dimension were larger for the smoothest surface. Alternatively, the decreasing trend of the power spectrum intercept towards the smoother premium quality ham showed that it correlates well with the overall magnitude of visual roughness. The results of lacunarity suggest that it has a discriminating power among the three ham qualities and its behaviour resembles the one of an exponential decay function. Results showed that Fourier analysis dimension, power spectrum intercept and lacunarity are important fractal parameters and useful quantitative descriptors that capture information embedded in the spatial structure of the underlying image texture of hams.

1. Introduction

A fractal describes a rough or fragmented geometric shape that can be subdivided into parts, each of which is, at least approximately, a reduced-size copy of the whole. Contrary to classical geometry, fractals are not regular and may have an integer or non-integer dimension. Also, they are generally self-similar and independent of scale (Mandelbrot, 1983).

An important goal for the characterization of visual texture in biological materials, using computer vision technology, is the quantification of spatial patterns. These patterns are often complex, exhibit scale-dependent changes in structure, and are difficult to identify and describe (Plotnick, Gardner, Hargrove, Prestegaard, & Perlmutter, 1996). Consequently, the use of fractal metrics like Fourier analysis fractal dimension and lacunarity, have been increasingly applied to tackle this problem. More specifically, Fourier spectrum quantifies the periodicity of surface objects in the frequency domain in terms of frequencies and peak amplitudes, and lacunarity quantifies the degree of translational invariance of the analyzed objects, with low values of lacunarity indicating high levels of such invariance (Rodrigues, Barbosa, & Costa, 2005). Fractal dimension is a measure of how complicated a self-similar object is. Natural objects do not show exactly the same shape, but look quite similar when they are scaled down. Self similarity is not visually obvious but there may be numerical or statistical measures that are preserved across scales. Due to their statistical scaling invariance, natural objects may exhibit statistical fractality (Klonowski, 2000). It should be noted that the meaning of the term "visual texture" is completely different from the usual meaning of texture in foods. Visual texture can be defined as the spatial organization of intensity variations in an image at various wavelengths.

Computer vision has been implemented for quality assessment in meats and meat products, overcoming most of the drawbacks of traditional methods, e.g. human inspectors and instrumental techniques (Du & Sun, 2005; Kumar & Mittal, 2009; Quevedo & Aguilera, 2009; Quevedo, Aguilera, & Pedreschi, 2009; Zheng, Sun, & Tan, 2008; Zheng, Sun, & Zheng, 2006). Ham slices in general have complex and inhomogeneous colour surfaces and their textures do not contain any detectable periodic or quasiperiodic structure (Mendoza et al., 2009). Instead, they exhibit random but persistent patterns that result in a cloudlike texture appearance. These inhomogeneities can be attributed mainly to formulation, presence of pores/defects and fat-connective tissue, and colour variations (Valous, Mendoza, Sun, & Allen, 2009). Thus, for objective characterization, image analysis techniques need to take into account the high variability in colour and texture appearance. Consequently, suitable descriptors to characterize sliced ham images

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doi:10.1016/j.foodres.2008.12.012