Journal of Food Engineering 124 (2014) 64–71

Contents lists available at ScienceDirect

Journal of Food Engineering

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

X-ray microtomography and statistical analysis: Tools to quantitatively classify bread microstructure

Barbara Cafarelli [b], Alessia Spada [b], Janine Laverse [a], Vincenzo Lampignano [a], M.A. Del Nobile [a,*]

[a] Department of Food Science, University of Foggia, Via Napoli, 25, 71100 Foggia, Italy
[b] Department of Economics, University of Foggia, Largo Papa Giovanni Paolo II, 1, 71100 Foggia, Italy

ARTICLE INFO

Article history:
Received 3 April 2013
Received in revised form 30 September 2013
Accepted 1 October 2013
Available online 11 October 2013

Keywords:
X-ray microtomography
Characterization
Bread microstructure
Bread classification

ABSTRACT

In this study, five different types of Italian bread samples chosen for their visible differences in physical structure were analysed by X-ray microtomographical analysis. The average and individual object microstructural parameters of the bread samples were obtained from data analysis. Following data analysis, the application of advanced statistic analysis to the obtained microtomographical data was used to quantitatively classify the different bread types in this study. The results of this work show that X-ray microtomography combined with an integrated statistical approach does not only provide important microstructural information of the product under investigation but is also able to classify these products into specific group types based on the average or individual microstructural properties of the objects present in the sample.

1. Introduction

Bread relies on its cellular foam structure for value and functionality. Breadcrumb is usually defined as a spongy porous material characterized by both closed and open pores. Each bread sample can differ in porosity and the pores/air spaces can have different dimensions, shapes, orientation and connectivity. The knowledge about the microstructure of foods can be used to identify the important processing parameters that affect the quality of a product and as Pyler (1988) stated, the crumb texture is greatly influenced by the cell structure of the crumb therefore the microstructural parameters obtained can be used to provide a quantitative description of a breadcrumbs' microstructure. Many factors affect the variability of breadcrumb structure, including varietal differences of the ingredients used and the bakery process. These variability sources and their interactions influence the breadcrumb microstructure, which in turn influences to a large extent the physical, textural and sensory properties of the product. Developing a proper understanding of the microstructure, particularly the distribution and interaction of food components, is a key tool in developing products with desired mechanical and organoleptic properties. Information about the 3-D microstructure of food products and ingredients can be obtained using various imaging techniques. Although, these wide varieties of imaging techniques exist, they are mostly invasive, as they require sample preparation hence, formation of artefacts or are restricted to certain types of food products.

X-ray microtomography (μCT), on the other hand, has been proved to constitute a non-invasive but reliable tool for food quality analysis (Laverse et al., 2012), it has several advantages over other imaging methods, including the ability to image low moisture materials. μCT uses the differences in X-ray attenuation arising, principally, from differences in density within the specimen. A series of 2D X-ray images are obtained as a sample is rotated. The series of slices, covering the entire sample, can be rendered into a 3-D image that can either be presented as a whole or as virtual slices of the sample at different depths and in different directions. Manipulation and analyses of μCT data using special software also allows reconstruction of cross-sections at depth increments as low as 15 μm, and along any desired orientation of the plane of cut. A series of non-invasive μCT slices of the same sample in any direction can provide much more information than just one Scanning Electron Microscopy (SEM) or optical imaging picture for example. μCT has been successfully used to observe the stability of gas bubbles in dough during the bread making process (Whitworth and Alava, 1999), the microstructure of foams (Lim and Barigou, 2004), three-dimensional quantitative analysis of breadcrumb (Falcone et al., 2005), the study of bread porous structure (Falcone et al., 2004) and ice crystals within frozen foods (Mousavi et al., 2005). Recently this technique has also been used to study the bubble size distribution in wheat flour dough (Bellido et al., 2006), the effect of far-infrared radiation assisted drying on microstructure of banana slices (Léonard et al., 2007), three-dimensional pore space

* Corresponding author. Tel./fax: +39 881 589 242.
E-mail address: ma.delnobile@unifg.it (M.A. Del Nobile).

0260-8774/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jfoodeng.2013.10.002

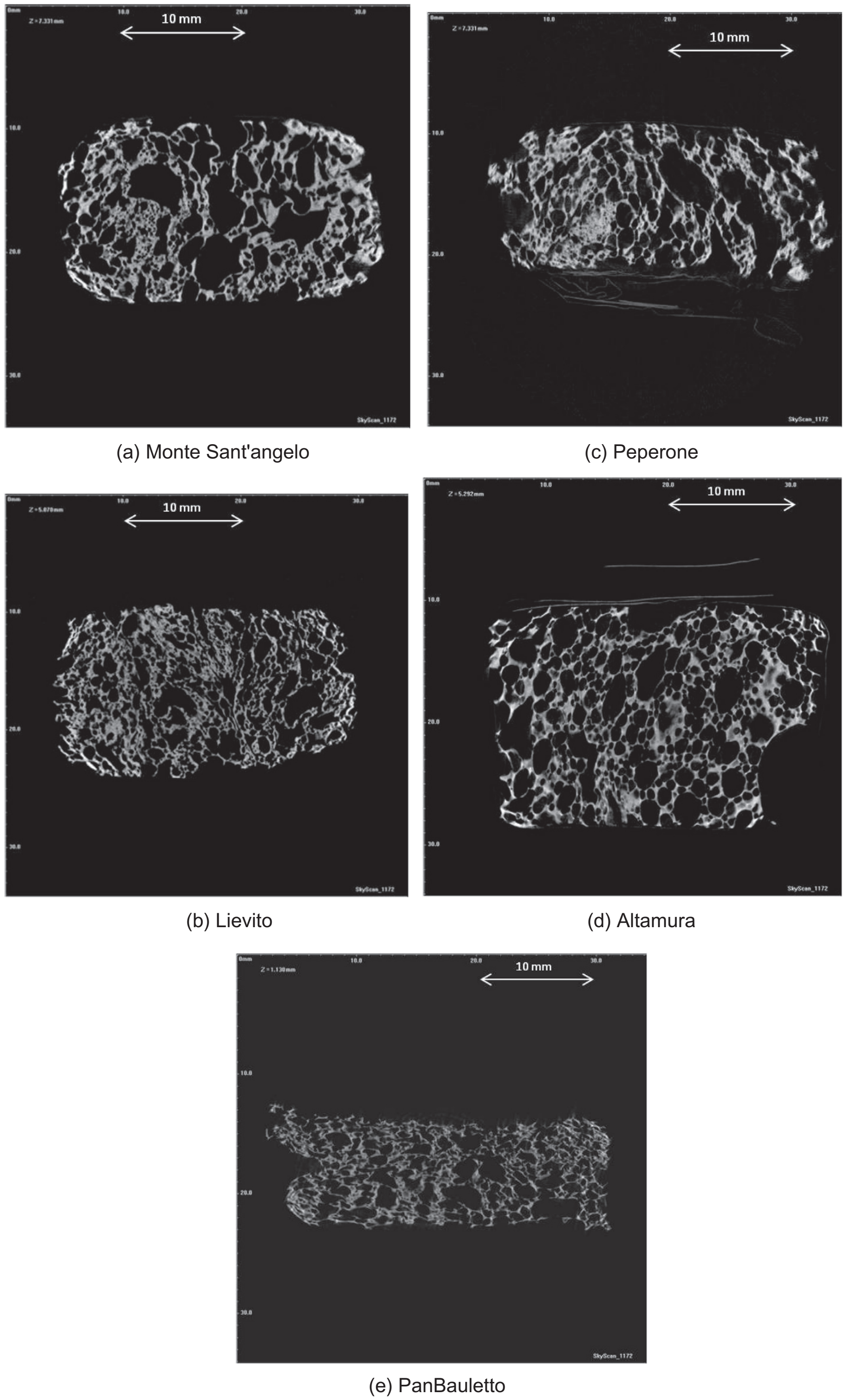

Fig. 1. (a–e) Show the grey level reconstructed cross section images of the samples acquired by microtomographical analysis.

quantification of apple tissue (Mendoza et al., 2007) and to study the microstructure, textural and sensorial properties of drum wheat bread as affected by yeast content (Lampignano et al., 2012).

Through μCT image analysis, it is possible to obtain the average and/or individual quantitative microstructural properties for the objects present in a breadcrumb sample, i.e. pore/air spaces (e.g., percentage object volume (POV), object surface/volume ratio (OSVR), Structure Separation (St.Sp), structure or cell wall thickness (ST), fragmentation index (Fr.I), Object Volume (OV) and Object Surface (OS)). Previous studies by Laverse et al. (2012) have shown that the average quantitative microstructural data obtain can indeed be used to characterise and classify samples under investigation. The classification process is useful in quality measurements of real samples and also in the validation of synthetic representations of them. The previous problems faced was how to analyse of the dataset generated by individual