Textural Images Analysis of Pasta Protein Networks to Determine Influence of Technological Processes

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ABSTRACT

The structure of pasta is largely governed by the presence of a structured protein network. This work analyzed the protein network textures of various cooked pasta products through textural image analysis. Six different pasta types were investigated: reference pasta made from durum semolina; pasta enriched with gluten proteins from soft wheat flour at 10 and 20%; autoclaved pasta; soft wheat flour pasta; and pasta made from reconstituted flour fractions. Pasta samples were sectioned, and each cross-section consisted of three distinct zones (central, intermediate, and external) based on the state of swelling of starch granules for each pasta product. Digital images of the protein network in each zone were acquired using confocal laser scanning microscopy. Textural image analysis was then performed. Similarities and differences in protein network texture were assessed by principal component, stepwise discriminant, and variance analyses. With the exception of autoclaved pasta, protein network structure differed greatly with the position in the pasta. Furthermore the effect of technological treatments was greatly influenced by the position in pasta. The most significant differences in protein network structure were obtained with the autoclaved and 20% protein-enriched samples.

Food products cannot only be characterized by chemical composition but also by three-dimensional organization at three distinct levels: molecular, microscopic, and macroscopic. The molecular level governs the steric hindrance and interactions of the food macromolecules. At the microscopic level, the structures and interactions of larger components such as protein, starch, matrices, and polymers play a critical role in food texture. At this level, microscopic methods (e.g., optical, scanning electron, and confocal laser microscopy) allow the description of the organization of the different components. Such description is facilitated by appropriate staining and by three-dimensional reconstruction. The macroscopic level is characterized by the shape of the isolated food particles and by the overall texture of foodstuffs, both of which largely depend on the three-dimensional arrangement of food components (e.g., three-dimensional polymeric networks). The recent development of confocal laser scanning microscopy (CLSM), with its ability to optically section samples, allows visualization of the three-dimensional organization of macromolecular food networks inside hydrated food matrices without impairing the physical structure. Such a technique is of particular interest for pasta in which partly swelled starch granules are encapsulated by a protein network. This network is responsible for the slow degradation of starch in pasta, due to its limiting effect on the accessibility of starch to α-amylases. Unlike other microscopic techniques, such as conventional optic and scanning electron microscopy, CLSM allows characterization of the geometry of the protein network both in single planes and in a three-dimensional space. The images resulting from CLSM may be digitized and stored. In this way, a great number of images can be rapidly acquired and processed.

In cereal-based products, a good understanding of the three levels of food organization is essential for the improvement of food product formulation. For example, the addition of surfactants to flour alters the textural appearance of the bread crumb (which is representative of the macroscopic level) (Pomeranz et al 1992). Such technological modifications can be characterized by certain rheological measurements (Keetels et al 1996), but may also be studied by artificial vision associated with image analysis (Bertrand et al 1992). Microscopic images often do not contain well-defined isolated objects, and it is easier to interpret them as a repetitive arrangement of basic patterns, called an image texture (Smolarz et al 1989). In the domain of artificial vision, many mathematical methods have been developed for the extraction of textural features from images (Haralick et al 1973, Galloway 1975). Such methods make it possible to emphasize the differences in the textural appearance of food products as a function of the applied technological treatments or of the origin of the raw materials (Fains et al 1997). In pasta particularly, it is possible to vary the choice of the ingredients and technological parameters involved in the manufacture to obtain a wide range of pasta products. However, currently it is difficult to rapidly characterize the subsequent modifications of the protein network texture. The present study aimed to apply image texture analysis for the characterization of the influence of various pasta processing parameters. Collections of images were acquired using CLSM. By analyzing the appearance of the protein network structure after cooking, the nature of the raw material (flour vs. semolina), the level of protein-enrichment, the fractionation-reconstruction procedure of flour, and the thermal treatments (normal cooking vs. autoclaving) were investigated. Fibers play an important role in the texture of cereal based products such as bread (Izydorczyk and Biliaderis 1995). It was therefore also interesting to study the influence of the insoluble fiber fraction on the structure of the protein network in pasta. In pasta, the degree of starch swelling increases from the center to the outer part of samples (Pagani et al 1986, Cunin et al 1995). Thus, the relationship between the texture of the protein network and the physical location in the pasta was also investigated.

MATERIALS AND METHODS

Sample Preparation

Wheat pastas were prepared from durum wheat semolina (3SE quality, 84.8% dry matter, 74.7% starch, 11.8% protein) (Semoulerie de Caen, France) and soft wheat flour (84.4% dry matter, 72.2% starch, 11.0% protein) (Minoterie du Feuillou, Boussay, France). Durum semolina and soft flour were extruded at 40°C as spaghetti (1.5 and 1.2 mm diameters, respectively). The spaghetti was then dried for 17 hr at 55°C. During drying, the relative humidity was decreased from 92 to 72% rh to obtain a final moisture content of 13%. The processed products were referred as SP_{ref} (for spaghetti made from durum wheat) and SP_{flr} (for spaghetti made from native soft wheat flour). SP_{ref} was considered the reference pasta for comparison with other samples.

All flours naturally contain a certain amount of insoluble fibers. A reconstructed flour was prepared to create a sample of insoluble

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