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Comparison of crumb microstructure from pound cakes baked in a microwave or conventional oven

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Abstract

Imaging, light microscopy and scanning electron microscopy were used to compare the microstructure of crumbs from pound cakes baked in a microwave or conventional oven. The microwave baking conditions for pound cake (240 W, 5 min) were established in previous research, conventional baked pound cakes were obtained using a swing oven at 180 °C for 40 min. Statistical differences in total cell, cell/cm^2 and mean cell area ($P \leqslant 0.05$) were observed in the image analysis. Cells from microwaved pound cake crumbs were 20% larger. However, factor shape was 0.81 for both microwave and conventionally baked crumbs, and crumbs from both oven types were similar in appearance. Light microscopy revealed birefringence in crumbs from both types of pound cakes. Scanning electron microscopy revealed that the conventionally baked product had a greater amount of protein matrix however; the matrix structure of the crumb was comparable between microwave-baked and conventionally baked pound cakes. In conclusion, our results suggest that the unique aspects of pound cake dough, including its high content of fat, sugar and moisture, make it well suited to microwave baking.

Keywords: Crumb; Starch; Gelatinization; Microstructure; Microwaves

1. Introduction

During conventional baking, dough is heated from the outer surface inward by conductive, radiant heat and undergoes structural transformations, including starch gelatinization, protein denaturation, volume increase, liberation of carbon dioxide from leavening agents, water evaporation, crust formation and non-enzymatic browning (Therdthai & Zhou, 2003). In contrast, under ambient oven conditions, microwave radiation interacts with molecules that are coupled, such as water (including its dissolved solutes and ions), to produce heat that results in structural changes and water movement (Umbach, Davis, & Gordon, 1990).

Microwave baking saves time, energy and space and preserves nutrients compared with conventional baking (Sumnu & Sahin, 2005). However, microwave-baked products have not been fully accepted by consumers due to quality issues. A firm, tough texture as well as rapid staling and a lack of color, flavor and crust formation are some of the common quality problems of microwave-baked products. The interaction of microwaves with dough is highly dependent on the dielectric properties of the ingredients. Water is the most important dipolar component, but salt, fat and protein also act as dielectric components (Sumnu & Sahin, 2005).

Microwave baking has limited applications in the food industry (Schiffmann, 2001). However, investigating the interaction of different ingredients with microwave energy should provide insight that will help to improve the quality of microwave-baked products. A better understanding of

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the microstructural changes that occur during microwave baking may also help to reduce quality defects.

Understanding the internal microstructure of bakery products is also essential for comprehending the enormous influence of appearance—for example the appearance of a breadcrumb—on the perceived product quality. Examining food microstructure is always difficult because of the complexity of the material involved. The three-dimensional structure of cereals and their products has been studied using image analysis (IA). To date, the major applications of image analysis in the area of cereal research include differentiation of bread brands (Zayas, 1993), direct quantification of breadcrumb grain features (Sarpirstein, Roller, & Bushuk, 1994), and description of the crumb grain structure of baked goods (Noll & Kuhn, 1997).

Another useful approach for differentiating structural features from artifacts is correlative microscopy, or the use of a combination of microscopy techniques. This approach reduces problems associated with image interpretation as well as the attendant strengths and weaknesses of each instrument.

The magnification range of the light microscope is modest in comparison with the electron microscope, but it spans the range most useful for many processed foods and allows for staining of different chemical components, such as proteins and starch granules like amylose and amylopectin. Light microscopy (LM) permits visualization of textural differences in cereal material and the structural changes that take place during processing (Autio & Salmenkallio-Marttila, 2001). A major advantage of light microscopy is its versatility. Because biological tissues are most often colorless and therefore lack contrast, staining can be useful. If the specimen is not highly colored, contrast must be introduced to make it visible (Kaláb, Allan-Wojtas, & Shea Miller, 1995). Polarizing light microscopy (PLM) is a contrast-inducing technique with many applications in the study of food structure. In this form of light microscopy, plane polarized light (light that vibrates in a single direction only) is allowed to impinge upon the sample. If the materials contain birefringent structures (i.e., capable of rotating the light plane) the emerging polarized light will be twisted and partially extinguished (Aguilera & Stanley, 1999).

Scanning electron microscopy (SEM) is an important tool for examining food characteristics. Sample preparation is easier than in light microscopy and introduces fewer artifacts because no sectioning is required, and a wide spectrum of food structures can be viewed. When the electron beam strikes an ultra-fine sample section (100 nm), some of the incident electrons are transmitted to form an image with the impression of three dimensions (Aguilera & Stanley, 1999; Bozzola & Russell, 1991). SEM has been widely used to study changes that occur during baking (Thomas & Atwell, 1999).

Previous studies have examined differences between conventional- and microwave oven-baked products, including cakes (Brand, 1987; Evans, 1982), starch (Zylema, Grider, Gordon, & Davis, 1985), gluten (Le Page, Gordon, & Davis, 1989), bagels (Umbach et al., 1990) and bread from direct dough (Içöz, Sumnu, & Sahin, 2004) heated in a conventional or microwave oven. However, few studies have addressed microwave baking of leavened breads from batted dough. Many of the quality problems associated with microwave baking may be reduced in pound cake, which is a high-fat batted dough product (Shurkla, 1993; Yaylayan & Roberts, 2001).

In 2003, the value of the bread industry in Mexico, which includes small bakeries and industrially produced bread, was estimated at 4.7 billion dollars (Grupo Bimbo, 2003). Pound cake called "panqué" is one of six sweet breads ("pan dulce") produced on an industrial scale and represents 7% of total bread production, including salty and sweet breads (Grupo Economistas Asociados, 2003).

In the present study, image analysis, bright field microscopy (BFM), PLM and SEM were used to compare the microstructure of crumbs from pound cakes baked in a microwave oven or conventional oven.

2. Materials and methods

The steps used to prepare, evaluate and analyze pound cakes baked in a microwave or conventional oven are described in Table 1.

2.1. Ingredients

Pound cake was prepared using commercial wheat flour containing 12.0 g of protein and 0.22 g of ash per 100 g of flour (A.A.C.C., 2001). Further, 80 g of butter, 80 g of

Table 1
Steps for preparing, evaluating and analyzing pound cake samples

Steps	Information or product that resulted
I. Pound cakes baked in a microwave or conventional oven	Samples from pound cakes microwave baked at 240 W for 5 min and conventionally baked at 180 °C for 40 min.
(a) Image analysis	Compare the structure of crumbs from pound cakes baked in a microwave or conventional oven.
(b) Light microscopy	
• Bright field microscopy (BFM)	Compare the starch/protein ratios in matrix of crumbs from microwaved and conventionally baked pound cakes.
• Polarized light microscopy (PLM)	Determine the degree of starch gelatinization in pound cake crumbs by identifying the Maltese cross pattern produced by the crystalline nature of starch granules.
(c) Scanning electron microscopy (SEM)	Three-dimensional comparison of starch granules and protein matrix in pound cake crumbs from both processes.