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## Review

## Strategies for the aeration of gluten-free bread – A review



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## ABSTRACT

**Background:** Deficient gas retention properties and consequent low loaf volume are major issues in the production of gluten-free bread. Owing to fundamental differences in medium properties of gluten-free and wheat dough, a strict adherence to traditional techniques is counter productive.

**Scope and approach:** The present study reviews analysis tools that enable the monitoring of single bubbles as well as the aeration state with regard to spatial and temporal resolution. Various methods used for the aeration of conventional dough and batter are evaluated and compared with those used for gluten-free dough production. Promising strategies and processing parameters that might improve the incorporation and stabilization of gas in gluten-free dough are presented.

**Key findings and conclusions:** The substrate availability of gluten-free raw materials plays an important role for biological gas production through microorganisms, which can additionally improve the gas retention capacity by synthesizing hydrocolloids. Moreover, the deficient volume of gluten-free dough might be substantially improved by optimizing mechanical aeration via beating. High-speed mixing can provide a homogeneous distribution of small gas bubbles. Computed tomography is the method of choice to monitor gas bubbles if structure-conserving preparations and sufficient resolution are provided. To replace the traditional kneading stage, processing adaptations should provide maximum gas entrapment by mixing.

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## 1. Introduction

Aerated foods such as cake and bread owe their distinctive texture and appearance to the presence of bubbles (Campbell & Mougeot, 1999). The incorporation of gas into dough is a central challenge for the bakery industry because volume and cell structure are particularly relevant quality attributes that can vary depending on the type of product. In the case of traditional bread production, initial gas cell nuclei are incorporated by kneading. The bubbles grow initially by chemical or biological carbon dioxide formation and subsequently through evaporation and gas expansion caused by baking heat. To achieve a low crumb density, both the incorporation and the stabilization of gas bubbles are crucial. Thus, the evolution of bubbles during kneading, proofing, and baking in traditional wheat-based systems has been investigated (Chiotellis & Campbell, 2003; Shah, Campbell, McKee, & Rielly, 1998). However, owing to differences in composition and structure, such results are only partly transferable to the mechanisms in

gluten-free formulations. Because the absence of gluten makes it challenging to stabilize and retain gas, improvements of current aeration methods are required to fulfill steadily rising demands and expectations regarding these products.

Various approaches for bread dough aeration are possible. After the incorporation of gas and throughout all further processing steps, destabilizing mechanisms must be suppressed as far as possible to maintain the foam structure. While for traditional dough rheological properties such as strain hardening, high viscosity, and extensibility aid in gas retention (Bloksma, 1990; Mills, Wilde, Salt, & Skeggs, 2003; Stauffer, 2007), dough made from gluten-free flour and water typically lacks all these qualities. Therefore, new strategies for gluten-free products must include ingredients and production methods other than those used in conventional bread making. Merely modifying the recipe composition is insufficient because of the fundamental differences in the dough structure. The entire bread-making process comprising preconditioning steps, mixing, resting, proofing, and baking must be adapted to the gluten-free medium.

Previous reviews have mainly focused on ingredient interactions; in contrast, this study summarizes recent strategies for the aeration of gluten-free bread. Methods for assessing the gas

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volume fraction and the bubble size distribution in dough are critically compared, and the impact of the aeration method on bubble growth and stabilization is assessed. Finally, chemical, biological and physical aeration methods are presented with a stress on those suitable for gluten-free dough. This may encourage the development and improvement of new approaches for the production of gluten-free products.

## 2. Bread as food foam: how gas adds value to bread

The controlled and steady production of aerated food is challenging and requires the interaction of industrial experience and scientific research. Although most cereal-based products such as breakfast cereals, popcorn, croissants and bread attain most of their value and functionality from aeration, comparatively little research has been conducted on this process. Since the macrostructure of bread can be described as cellular, the entrapment and stabilization of gas bubbles play a crucial role. Cellular solids comprise a cluster of enclosed spaces that can differ in size, shape, orientation, and connectivity (Cafarelli, Spada, Laverse, Lampignano, & Del Nobile, 2014). Such structures are present in natural and man-made sponges, corks, etc., the uses of which have increased in popularity because of superior thermal insulation and cushioning properties (Gibson & Ashby, 1999). Cell-like structures in food facilitate biting, chewing, and digestion. For example, the crisp and crunchy textures that are desired in snack products result from the cellular honeycomb structure formed by extrusion (Barrett & Peleg, 1992). Moreover, the heat transfer during baking strongly depends on the gas volume fraction in the product such that increasing the porosity by 20% results in a 7 min reduction in baking time (Mack, Hussein, & Becker, 2011). Thus, by considering the spongy, porous crumb as a cellular solid new perspectives and insights can be gained.

The number and size distribution of gas pores substantially differ among bread types. While the quality of ciabatta and baguettes is strongly related to the presence of large pores, consumers expect white pan-baked bread to feature small, homogeneously distributed pores. The mechanical behavior and overall quality of cellular foods are mainly influenced by the degree of aeration and bubble size distribution. In addition, the geometry of the cells as well as the thickness and strength of their wall material are essential factors (Dogan & Kokini, 2007).

## 3. Evaluation of gas volume fraction and gas-free density

To evaluate the various aeration methods, the level of gas entrapment must be defined. However, several challenges need to be overcome to obtain this value. In this section, the different methods and formulas employed to determine the amount of air in cake and wheat dough will be discussed with regard to their applicability for gluten-free dough.

### 3.1. Determination of the gas-free density

A problem often neglected is the determination of the gas-free density, often termed “true density”, representing the continuous phase of the foam structure of a dough or bread sample. Particularly in the case of gluten-free dough, extensive recipe variations presuppose the awareness of the gas-free density to enable a comparison of the aeration level. Applied methods and their results for various dough and cake formulations are summarized in Table 1. A theoretical approach is the estimation of the gas-free density by summing the densities of single ingredients in their corresponding ratios, also referred to as the rule of mixtures. However, it is not understood how the density of a powder such as flour can be used to estimate the density of hydrated particles in dough without

considering volume changes. Moreover, interactions among salt, polymers, and water are neglected. Further factors reported to influence the gas-free density of dough independently from its formulation include oxygen availability during mixing, mixer design, mixing speed, and shear history (Campbell, Rielly, Fryer, & Sadd, 1993; Chin & Campbell, 2005).

In previous experiments, the gas-free density of dough or batter has been measured by carefully stirring the ingredients to obtain a homogeneous mixture without air inclusion (Massey, Khare, & Niranjani, 2001), by mixing the dough under vacuum (Baker & Mize, 1937), or by degassing the samples (Richardson, Langton, Fäldt, & Hermansson, 2002). Campbell et al. (1993) obtained a gas-free wheat dough density of 1.28 g/cm<sup>3</sup> by mixing samples at various pressures and extrapolating the graph of dough density versus mixing pressure back to zero pressure. This labor intensive method is based on the assumption that mixing at zero pressure (vacuum) results in dough without gas, featuring the same chemical properties as the continuous phase of aerated dough.

Alternatively, the density with and without gas as well as the gas volume fraction can be evaluated with the aid of computed tomography or other imaging techniques. These methods are discussed in Chapter 4. Lassoued, Babin, Della Valle, Devaux, and Réguerre (2007) reported a correlation of  $r^2 = 0.91$  between the gas-free density as determined by calculation and X-ray analysis for bread. Similarly, Bellido, Scanlon, Page, and Hallgrímsson (2006) presented a difference less than 1% when comparing both methods, although they noted that this led to a larger error for the respective gas volume fractions. No degassing step is required if the density of the continuous phase derives from image analysis, but the validity of the result strongly depends on the resolution of this method. If gas bubbles are smaller than the detection limit, they will falsely decrease the corresponding gas-free density. Richardson et al. (2002) used centrifugation for the purpose of degassing cake batter; however, they did not give the centrifugation parameters. For gluten-free dough, probably all of the methods are applicable, although no data have been reported thus far. Due to the large number of recipes, a time-efficient technique would be convenient. Degassing by (ultra-) centrifugation might be a suitable technique because it is rapid and lacks the aforementioned disadvantages.

### 3.2. Methods used to evaluate the dough density

In 1993, Campbell et al. devoted an entire study to the measurement and interpretation of dough density. Their labor-intensive method included freezing the dough and adding water to a high density calcium chloride solution until buoyancy was reached. In 2001, a more convenient double-cup buoyancy technique was developed, allowing calculation of the density by comparing the sample weight in air with that in xylene (Campbell, Herrero-Sanchez, Payo-Rodriguez, & Merchan, 2001). However, because gluten-free dough is usually more sticky and fluid than wheat dough, which can easily be formed into a ball, this method might not be applicable.

During fermentation, aeration through a microorganism such as *Saccharomyces cerevisiae* can be monitored in a Rheofermentometer. With this method, however, the initial aeration through kneading and fermentation prior to the measurement is neglected. Gómez, Talegón, and De La Hera (2013) reported that the lack of consistency causes an overflowing of the gap between the rheofermentometer basket and the probe when measuring gluten-free dough, even without the addition of resistance weights. As a consequence, the interpretation of the obtained curves may be challenging. Verheyen, Jekle, and Becker (2014) compared the density of wheat dough in different analysis devices and

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