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Implementation of a novel tool to quantify dough microstructure

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Abstract

A method was developed to quantify the microstructure of wheat dough proteins assessed by a confocal laser scanning microscope (CLSM) in combination with an image processing and analyzing tool. A variation of the water addition especially showed high significant ($p<0.01$) linear correlations with the branching index ($r=-0.92$). This branching index exhibited high significant correlation coefficients with the rheological measures complex shear modulus ($r=0.88$), creep compliance ($r=-0.71$) and relative elastic part ($r=0.82$). In summary the results submit a novel view on the microstructure of dough. The obtained visual structure of the dough via CLSM in combination with image processing and analyzing has proven to be a reliable and powerful tool for the acquisition and validation of dough protein microstructure. The high dependency of rheology from structural elements could be verified.

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Keywords: wheat; CLSM; gluten; rheology; image analysis; branching index

1. Introduction

Wheat bread is an important part of the daily food-intake all over the world. Even though it is known since centuries it can be regarded as a ready-to-eat processed and therefore convenient food. Therefore it is necessary to understand the production and attributes of its pre-product dough. Wheat dough consists of the quantitatively major components starch, protein as the important gluten, and further valuable components as yeast, salt and water. Out of this dough is developed due to an addition of energy during mixing. First the flour components hydrate and secondly the gluten forms a widely distributed network within the dough matrix. Next to this protein network a second phase originates: the free water phase where starch granules and water-soluble components are located [1]. A third phase consists of dispersed

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gas, which is entrapped by mixing and the starting CO_2 production due to the yeast. The proteins are interconnected resulting in a continuous network. It is composed of glutenin (elastic) and gliadin (viscous) as the main water-insoluble proteins [2]. As a result of these viscoelastic properties wheat dough has attributes of a non-Newtonian viscous liquid and of an Hookean elastic solid. The characterization of the system is a challenging task. However, there exists a wide range of empirical methods as recording z-blades mixers (e.g. farinograph or mixograph) and load-extension tests. These methods are commonly used as quality control in bakery and milling industries [3]. However, fundamental rheological measurement systems, e.g. a rheometers are also recommendable because they do not largely affect nor destroy the structure of dough.

In general, this structure or microstructure determines next to other properties the rheology of foods. In cereal science a number of microscopic techniques were already applied to investigate the microstructure of dough. Different systems were used as scanning electron microscopy [4], light microscopy [5] and confocal laser scanning microscopy (CLSM) [6]. The advantage of the CLSM is a dynamic and nearly non-invasive observation of the microstructure of specific focal section of the sample, even in 3D. Components as starch granules or proteins can be dyed and separately detected. Further it is important to extract structural features out of these image data to distinguish between areas containing information to those containing background by image processing. Additionally an analysis of this data enables the acquisition of measures as area fraction or circularity of polymers or particles as protein.

The purpose of this study was to develop a method to quantify the microstructure of wheat dough proteins assessed by a confocal laser scanning microscope. The aim is to evaluate and characterize the often indicated relation between the microstructure and the process determining rheology of dough.

Nomenclature

BI	branching index
D_F	Feret’s diameter
G*	complex shear modulus
J_{el}	relative elastic part
J_{max}	creep compliance
J_r	creep recovery compliance
P	perimeter