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Comparison of the effects of different heat treatment processes on rheological properties of cake and bread wheat flours

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ABSTRACT

Dry and hydrothermal heat treatments are efficient for modifying the technological-functional and shelf-life properties of wheat milling products. Dry heat treatment process is commonly used to enhance the volume of cakes. Hydrothermal heat treatment makes wheat flours suitable as thickener agents. In this study, cake and bread wheat flours that differed in baking properties were exposed to dry (100 °C, 12 min) and hydrothermal (95 °C, 5 min, 5–20 l/h water) heat treatments. Rheological differences caused by the treatments were investigated in a diluted slurry and in a dough matrix. Dry heat treatment resulted in enhanced dough stability. This effect was significantly higher in the cake flour than the bread flour. Altered viscosity properties of the bread flour in the slurry matrix were also observed. The characteristics of hydrothermally treated samples showed matrix dependency: their viscosity increases in the slurry and decreases in the dough matrix. These results can support us to produce flour products with specific techno-functional properties.

1. Introduction

Heat treatment processes are applied to achieve modifications in physical, rheological or shelf-life properties of wheat flour and other milling products. Two basic methods, dry and hydrothermal processes can be distinguished based on the presence or absence of moisture (Lehtinen, Kiiliäinen, Lehtomäki, & Laakso, 2003).

Thermal treatment has numerous applications, it is a valuable tool for extending shelf-life of the flours by reducing the enzyme activity and moisture content of the lipid-rich fractions (Lehtinen et al., 2003; Purhagen, Sjöö, & Eliasson, 2011, 2012). Beside the biological effects, dry heat process has a significant impact on the techno-functional properties of flours. These properties are mainly determined by the gluten proteins and starch molecules. At high temperatures – above 50 °C – unfolding of gluten proteins occurs. The hydrophobic parts of the protein molecules are getting more exposed, which allows the rearrangement of disulfide bonds (Jeanjean, Damidaux, & Feillet, 1980). As a result, gluten aggregates are forming, with decreased extractability and modified molecular weight distribution (Guerrieri & Cerletti, 1996). Therefore, a stronger dough or more stable foam can be produced that can tolerate a higher sugar content. Hence, it is suitable for cake butter or biscuit production (Chesterton, Wilson, Sadd, & Moggridge, 2015; Li, Cui, & Kakuda, 2006; Nakamura, Koshikawa, & Seguchi, 2008). It has also been reported that dry heat has an impact on the viscosity properties of flours due to structural changes of gluten molecules. During dry heat treatment, starch structure does not change significantly (Ozawa, Kato, & Seguchi, 2009).

In contrast to dry thermal heat treatment, only limited information is available about the hydrothermal treatment of cereals. The application of steam on wheat flour causes a more significant modification in the structure of wheat components. Starch pre-gelatinization occurs and the gluten proteins suffer a nearly total loss of functional properties due to denaturation. Thus, the gluten network in the dough cannot be formed and flours with higher viscosity are produced that are suitable as thickeners in sauces, soups, baby food and coatings (Prakash & Haridas, 1999). Moreover, noodle end-product quality can also be improved with the usage of hydrothermally treated rice flour. The rice flour has originally low gel forming properties and is not resistant to shear forces (Cham & Suwannaporn, 2010). The available scientific data are limited on the effects of different parameters (such as applied temperature and steam moisture content) in heat treatment processes. Additionally, comparative studies on the effects of dry and hydrothermal treatment on the quality of wheat flour are not available. Therefore, the aim of this study was to compare the effects of the two different kinds of heat treatment processes on the rheological properties of two different types of wheat flours.

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The rheological behaviors were examined by standard methods routinely applied by the cereal industry. The standard Farinograph, Z-arm mixers and pin mixers (Mixograph) are proper tools for determine the mainly protein dependent mixing properties (AACC, 1999; Békés, Lukow, Uthayakumaran, & Mann, 2002; ICC, 1992a). In the practice the viscosity characteristics are monitored in stirred diluted suspensions during heating, tempering and cooling (RVA, Amylograph) (AACC, 1999; ICC, 1992b). Mixolab is a recently developed powerful tool in cereal technology (Chopin Applications Laboratory 2009). The method connects the mixing and viscosity (RVA) methods in one technique. Thus, the dough properties and the gelling ability can be investigated in one process in the dough matrix which saves time and allows a more complex evaluation of these parameters.

In the recent study changes of protein characteristics during the different thermal treatments were studied with the Zeleny sedimentation test and with the Mixolab instrument. Viscosity properties of the processed flours were monitored by determining the falling number values of the samples and by the application of the RVA and Mixolab methods.

2. Materials and methods

2.1. Materials

Two wheat flours were examined this study: a Hungarian cake flour (CF) with low baking quality and a commercially available Hungarian bread wheat flour (BF). Both flour types were produced by the Gyermelyi Zrt, Hungary in industrial scale from *Triticum aestivum* wheat.

2.2. Heat treatment processes

The dry thermal and hydrothermal procedures were carried out in the pilot plant laboratory of Bühler AG (Uzwil, Switzerland) in a continuous process. The experimental design including the coding of the flour products are tabulated in Table 1. During the dry heat treatment the samples were first heated up with the thermo pneumatics and then were fed into the conditioner and the retention screws where they were hold at 100 °C for 12 min. The throughput capacity of the procedure was 150 kg product/h.

During the hydrothermal process, the flours were heated up with steam in the conditioner and then they were dried with the thermo pneumatics after the retention screws. The production capacity was 150 kg/h.

At the end of the processes the moisture content of the products were adjusted to 5% at dry treatment and 10% at hydrothermal treatment. Afterwards, the samples were sieved to homogenize the material and to remove aggregates. 25 kg flour product was prepared for each setting.

The sample codes of the treated samples was indicated by the raw material (BF: bread flour or CF: cake flour) with the type of the treatment (th: thermal or hyd: hydrothermal) and in case of the hydrothermally treated samples with the moisture content of the applied steam (i.e. 5 l/h steam: 5).

2.3. Determination of chemical composition of flour samples

Ash, moisture, crude protein, crude fiber, crude fat and wet gluten content of the untreated flours were measured according to international standard methods (ICC, 1996b). The digestible carbohydrate content was calculated from the crude chemical composition and expressed in dry matter basis [digestible carbohydrate (%) = 100 − (ash (%) + crude protein (%) + crude fat (%) + crude fiber (%))] (FAO, 2003).

2.4. Zeleny sedimentation test

The flour samples were suspended in 50% (v/v) lactic acid and the degree of their sedimentation was detected after a standard time. The Zeleny sedimentation values were determined according to the standard method (ICC, 1994) with four replicates.

2.5. Evaluation of mixing and pasting properties by Mixolab

The water absorption capacity and the dough properties such as dough development time (DDT), dough stability (C1), protein weakening (C2), starch gelatinization (C3), amylase activity (C4) and starch gelling (C5) were determined by Mixolab (Chopin, Tripette et Renaud, Paris, France). The measurements were carried out according to the Mixolab manual. The Chopin+ protocol was applied for studying both the mixing and the pasting behavior (CHOPIN, 2009). The Chopin+ protocol determines the water absorption of the flour by the dosage of water until the dough is able to reach the maximum consistency. This maximal consistency is equal to 1.1 Nm (+/− 0.05 Nm is equivalent to 500 Farinograph units). Three replicate measurements were performed for each sample.

2.6. Viscosity properties by RVA and falling number

The viscosity properties were also studied in flour–water slurries by using the rapid visco analyzer (RVA, Newport Scientific, Sydney, Australia) and by measuring the falling number. In the RVA system the suspension was prepared by suspending 3.5 g flour in 25 ml water. The RVA peak, through final breakdown and the setback viscosity values, the pasting temperature and peak time were determined according to a standard method (ICC, 1996a). The RVA measurements were carried out three times for each sample. The falling numbers were measured according to a standard method (AACC, 2003). These measurements were also carried out in three replicates.

Table 1
Parameters of the applied thermal treatments and the mode of sample identification.

Type of flour	Type of treatment	Temperature (°C)	Retention time (min)	Steam moisture (l/h)	Sample code
Cake flour (CF)	Dry thermal (th)	100	12	0	CFth
Bread flour (BF)		100	12	0	BFth
Cake flour (CF)	Hydrothermal (hyd)	96	5	5	CFhyd5
Bread flour (BF)		96	5	5	BFhyd5
Cake flour (CF)		96	5	10	CFhyd10
Bread flour (BF)		96	5	10	BFhyd10
Cake flour (CF)		96	5	20	CFhyd20
Bread flour (BF)		96	5	20	BFhyd20