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Investigation of scale reduction in a laboratory bread-making procedure: Comparative analysis and method development

Renáta Németh, Ágnes Bánfalvi, András Csendes, Sándor Kemény, Sándor Tömösközi*

Department of Applied Biotechnology and Food Science, Budapest University of Technology and Economics, Műegyetem rkp. 3, 1111 Budapest, Hungary

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Baking trials of eleven Hungarian wheat varieties were performed on macro- and micro-scale. The aim of this work was to investigate the applicability of a micro-scale bread making method using 10 g flour/loaf compared to a standard method requiring 250 g flour/loaf. Volume, height and sensory properties of loaves were evaluated. Chemical and physicochemical properties, like crude protein content, wet gluten content, Zeleny sedimentation index, damaged starch, Falling number, RVA, Mixolab, Alveograph and Farinograph parameters were determined.

According to the results, the micro-scale method can be a valuable tool for laboratory research, even the crumb quality showed comparable results with the conventional method. Specific volume of micro loaves had significant positive correlation with the results of the standard baking method and related mainly to the parameters characterizing starch properties. Specific volume of standard loaves correlated positively to falling number, wet gluten content, water absorption and setback.

However, the micro-scale method was not able to differentiate significantly the investigated wheat varieties, which can be caused by the increased level of variance and error of the method and the volume measurement. These results are indicating the necessity of further method development, standardization and the investigation of the boundaries of sample size reduction.

1. Introduction

So far several standards and accepted methods were developed to evaluate the characteristics of wheat flour and to predict baking performance enabling the partial replacement of the time-consuming baking trials. The role of these methods in the evaluation of baking quality has been extensively reviewed (Dap et al., 2011; Zaidel et al., 2010).

Flour testing methods consist of determination of chemical composition and physicochemical properties, including various rheological parameters. Considering chemical composition, proteins and starch affect end-product quality the most. Both protein (gluten) quantity and quality have an important effect on loaf volume: an increase in protein content and in glutenin-to-gliadin ratio can lead to an increase in both loaf volume and loaf height (Uthayakumaran et al., 1999). Other important quality parameters of wheat proteins are the Zeleny sedimentation index and wet gluten content, which had been associated with baking volume (Zeleny, 1947). Methods related to characterization of protein properties in water-flour systems mainly consist of large deformation rheological tests, which enable the investigation of dough behavior against mixing (e.g. Farinograph, Valorigraph, Mixograph) or extension (e.g. Extensograph, Alveograph), while Rheofermentometer analysis allows the simulation of the leavening process of dough containing yeast. Pasting properties of starch granules and amylase activity can be investigated by e.g. Amylograph or RVA (Rapid Visco Analyser) techniques and with the Falling Number method. Influences of the milling process can be examined through the determination of damaged starch content of the flour, which causes higher water absorption capacity and its increased level can lead to a deterioration of the end product (Barrera et al., 2007). A recent technique, the Mixolab (introduced in 2004 by Chopin Technologies) makes simultaneous determination of mixing and heating properties of dough possible in a single test (Collar and Rosell, 2013).

Although chemical and physicochemical properties of flour can be indicative of baking performance, most of the above mentioned methods are specified primarily for (white) wheat flour. In cases of special meals of wheat or other cereals and pseudocereals, the

* Corresponding author.
E-mail address: tomoskozi@mail.bme.hu (S. Tömösközi).

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relationship among these properties and end-product quality is mostly uncertain, and end-product tests are necessary for the evaluation of baking quality. The most common end-product is bread, which occurs in a large assortment considering the raw materials, preparation processes, shape, texture, etc. Recently the number of special breads (gluten-free products, products with reduced starch and/or enhanced fiber content, etc.) has strongly increased on the market, therefore the development of this product range has been in the focus of intensive research activity (Masure et al., 2015). Direct analysis of baking quality can be performed only by baking trials, which enables the determination of quite important parameters, e.g. volume, crumb structure and porosity, crumb to crust ratio, sensory properties, etc. The most important disadvantages of baking trials are that they are time-consuming, labor-intensive and they require a relatively large sample size. To improve reproducibility, baking tests were standardized internationally. There are standards available for both basic bread making processes, namely the straight-dough (AACC 10-09, AACC 10-10B, ICC Nr. 131, ISO 6820:1985) and the sponge-and-dough (AACC 10–11) methods. At the early stages of breeding and in research and development, where sample size (e.g. raw material, additives, isolated or expressed proteins) is limited, micro-scale baking trials integrated with micro-scale sample preparation equipment and rheological instruments may allow a complex analysis and classification of cereals.

The development of small-scale methods is a rather challenging task, especially for end-product tests like baking tests. Since the development of the 2 g-Mixograph (Gras and O'Brien, 1992), different micro-scale apparatuses as well as the effects of the reduction of sample quantities on the measured parameters were thoroughly investigated and a family of micro-scale instruments has been developed. Reduced sized milling and sample preparation of grains can be performed by using a micro-scale laboratory mill (FQC-2000, Inter-Labor, Hungary) with a minimum sample size of 5 g grain and then the fractions can be separated with a micro-sieve (Metefém, Hungary) (Varga et al., 2000a). Some examples for sample size reduction of rheological methods can also be mentioned such as the micro Z-arm mixer (Tömösközi et al., 2003), the combined micro and macro Zeleny sedimentation instrument (Tömösközi et al., 2009), the GluStar system (Tömösközi et al., 2012), the micro Kieffer rig (Kieffer et al., 1981) or the Dobraszczyk-Roberts dough inflation system (Dobraszczyk, 1997).

A survey of the publications of the last 80 years shows that several baking tests with reduced sample amounts were also developed and used in baking trials. There are small-scale tests requiring 25–50 g of flour (MacRitchie, F., Gras, 1973; Mandala, 2005) and micro-scale baking tests using only 10 g (AACC, 1999; Kieffer et al., 1993; Pflaum et al., 2013; Shogren and Finney, 1984; Thanhaeuser et al., 2014) or even less, e.g. 2 g of flour (Beasley et al., 2002; Uthayakumaran et al., 1999). Typically pin type mixers (AACC, 1999; Shogren and Finney, 1984) and Mixograph (Uthayakumaran et al., 1999) were used for kneading dough to optimal consistency but there are examples of using z-arm mixers, e.g. 10 g-Farinograph (Kieffer et al., 1998; Pflaum et al., 2013) too. Furthermore, usage of commercial mixers for dough making were also published (Kieffer et al., 1993; Mandala, 2005). Sheeting and moulding of dough usually were carried out using a pastry sheeter (Campbell et al., 2008; Kieffer et al., 1993) and some kind of a pressure board (Campbell et al., 2008; Shogren and Finney, 1984) or dough was simply moulded manually (Mandala, 2005). Evaluated parameters of micro loaves include loaf volume (specific volume) measured mainly by the seed displacement method (AACCI Method 10–05.01) or glass beads (Campbell et al., 2008)) or by water displacement of coated loaves (Pflaum et al., 2013). Generally, the small-scale baking methods showed a positive correlation with (standard) methods requiring more sample. However textural analysis of micro breads was not carried out, indicating that the prepared loaves might not be suitable for this kind of analysis. In some cases the method of volume measurement was not clarified, however it can be crucial in case of micro-scale breads.

The aim of this study was to investigate the applicability of micro-scale baking tests for the reliable evaluation of baking performance compared to conventional baking trials on macro-scale using 11 Hungarian wheat varieties. Chemical and physicochemical properties of flour samples were determined and correlated with baking parameters to investigate their ability to predict baking performance. Our main questions were what extent sample amount can be reduced while retaining the possibility of textural and sensory evaluation and if the observed phenomena will be the same as in trials with larger sample sizes. To answer these questions, components of variance and sources of error were determined by statistical methods.

2. Materials and methods

2.1. Wheat samples

Eleven Hungarian winter wheat samples (Bánkuti-1201, MV-Karéj, MV-Karizma, MV-Kokárda, MV-Lepény, MV-Magdaléna, MV-Nádor, MV-Nemere, MV-Pántlika, MV-Suba, MV-Tallér) were selected representing different breadmaking quality. The grains were provided by the Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences (Martonvásár, Hungary). The wheat samples were milled using a CD1 laboratory mill (Chopin, Villeneuve-la-Garenne, France) according to the NF EN ISO 27971 standard.

2.2. Chemical composition

Moisture and ash content were determined by the oven drying method and the muffle furnace technique according to the standards ICC Nr. 110/1 and ISO 2171:2007, respectively. Crude protein content of the flours was determined by the Dumas method (ISO/TC34/WG 19) using a FP-528 instrument (Leco, Saint Joseph, USA) and wet gluten content was measured according to ISO 21415-2:2006 by a Glutomatic 2200 gluten washer (Perten, Stockholm, Sweden). For the determination of damaged starch content the Amperometric Method (ICC Nr. 172) was carried out using SDmatic (Chopin, Villeneuve-la-Garenne, France).

2.3. Rheological measurements

The Zeleny sedimentation test was performed by the automated version of ISO 5529:2007 standard method using SediCom System (Labintern & Budapest University of Technology and Economics, Budapest, Hungary). Falling number determination was carried out according to the Hagberg-Perten method (ICC Nr. 107/1) by a Falling Number FN 1700 instrument (Perten, Stockholm, Sweden). Pasting properties of flour slurries were investigated by a RVA-4SA (Newport Scientific Pty. Ltd., Warriewood NSW, Australia) type Rapid Visco Analyser (RVA) according to the ICC Standard Method Nr. 162. Dough rheological properties were examined by the Farinograph method (ICC standard Nr. 115/1) using a Farinograph-E instrument equipped with a 50 g mixing bowl (Brabender, Duisburg, Germany). Rheological behavior of flours was also examined by Mixolab (Chopin, Villeneuve-la-Garenne, France) and Alveograph (Chopin Alveolink, Villeneuve-la-Garenne, France) according to ISO 17718:2013 and ICC Nr. 121 standards, respectively.