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Expansion profiles of wheat doughs fermented by seven commercial baker's yeasts

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ABSTRACT

Commercial baker's yeast consists of *Saccharomyces cerevisae*, however the strain can vary in each baker's yeast, which might influence the dough fermentation time. The scope of this research was to investigate the dough expansion of wheat doughs fermented by seven commercial baker's yeasts at different yeast concentrations ($2.88 \cdot 10^{11}$, $5.76 \cdot 10^{11}$ and $8.64 \cdot 10^{11}$ colony forming units/kg flour) and fermentation temperatures (5 °C, 15 °C, 25 °C and 35 °C). Dough expansion was investigated by monitoring the dough height and it was found to be described well by a first order kinetic model. Doughs fermented with four of the seven yeasts generally had higher kinetic rate constants and hence shorter fermentation times compared to fermentation with the other three yeasts. The shortest fermentation times were found for doughs fermented at 25 °C and the highest yeast concentration, a trend found for all the yeasts tested. The differences in the kinetic rate constants indicate a differentiation in yeast strain among the commercial baker's yeasts emphasising the great importance of the choice of baker's yeast for the dough fermentation time.

1. Introduction

Baker's yeast used in bread makings is essential for dough fermentation. During dough fermentation, baker's yeast uses simple carbohydrates to produce ethanol and carbon dioxide as the most important primary products. The carbon dioxide diffuses into the air bubbles, which are incorporated and dispersed in the dough during mixing. The elastic and extensible gluten network formed during mixing retains the gas and enables the dough to rise (Poitrenaud, 2004; Romano et al., 2007). A wide range of secondary products are furthermore produced during dough fermentation and particularly aroma active compounds such as aldehydes, acids, esters and ketones produced from the fermentative activity of yeast are very important for the overall bread aroma (Birch et al., 2013b; Frasse et al., 1992; Schieberle and Grosch, 1991).

Several analytical methods have been used to study the expansion of dough volume during dough fermentation, particularly rheofermentometer measurements (Gujral and Singh, 1999; Ktenioudaki et al., 2010; Rollini et al., 2007) and image analyses (Bellido et al., 2009; Shehzad et al., 2010). The dough surface in a cylindrical solid container has a domed shape, which is dependent on dough rheology, however the volumetric expansion of dough has often been investigated by measuring dough heights (Gandikota and MacRitchie, 2005; Gujral and Singh, 1999; Ktenioudaki et al., 2010; Pérez-Nieto et al., 2010; Rollini et al., 2007; Therdthai et al., 2007) since the increase in dough height has been found to correlate well with the volume expansion of dough (Ktenioudaki et al., 2010). Dough expansion has been described previously as a first-order, non-Arrhenius kinetic model (Therdthai et al., 2007).

The dough expansion depends on several factors such as yeast concentration, type of wheat flour, additives (lactic acid, fat, sugar and sodium chloride) and process variables (relative humidity, fermentation temperature and mixing duration) (Birch et al., 2013b; Chiotellis and Campbell, 2003; Gujral and Singh, 1999; Ktenioudaki et al., 2010; Therdthai et al., 2007). Furthermore, the strain of baker's yeast might influence the dough expansion profile.

The production of commercial baker's yeast today is limited to relatively few companies and commercial baker's yeasts are typically highly selected strains of the species *Saccharomyces cerevisiae*. It is likely that different strains of *S. cerevisiae* are produced in each company and they might possess different dough leavening capacities during fermentation. Knowledge about the dough

Abbreviations: AACC, American Association of Cereal Chemists; ANOVA, analysis of variance; CFU, Colony Forming Units; HSD, Honest Significant Difference; ICC, International Association for Cereal Science and Technology; SPO, sporulation; YPG, yeast extract peptone glycerol.

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expansion profiles of the baker's yeast and hence the dough fermentation times are of great industrial interest, since strains with a high fermentative activity will result in a short dough fermentation time, which is an economical benefit for the bakers when focus is solely on bread volume.

The purpose of this work was to investigate the expansion profiles of doughs fermented by seven commercial compressed baker's yeasts by development of a theoretical kinetic model. Simultaneously, the effects of temperature and yeast concentration on dough expansion were investigated.

2. Materials and methods

2.1. Flour

Wheat flour (Reform) was supplied by Lantmännen Mills A/S (Vejle, Denmark). Water content of the flour was measured the day of baking (HOH-express, Pfeuffer) and varied from 12.6 to 13.2%. The gluten content was 30.0% (wet gluten) and the gluten index was 91 (Glutomatic 2100, Perten) according to the American Association of Cereal Chemists (AACC) international approved method no. 38-12 (AACC, 1995). The falling number was 300 s (Falling number 1500, Perten) according to the International Association for Cereal Science and Technology (ICC) standard method no. 107/1 (ICC, 1995).

2.2. Commercial baker's yeasts

The following types of compressed commercial baker's yeast were included in the study: MALTESERKORS from Lallemand, De Danske Gærfabrikker, Grenå, Denmark; SKÆRTOFTMØLLE, organically produced baker's yeast from Agrano, Riegel am Kaiserstuhl, Germany; RAPUNZEL, organically produced baker's yeast from Rapunzel Naturkost AG, Legau, Germany; SEMA from Lallemand, Panevezys, Lithuania; L'HIRONDELLE from Le Saffre, Marcq-en-Baroeul, France; BRUGGEMAN from Algist Bruggeman, Gent, Belgium; ZYMAROM from Algist Bruggeman, Gent, Belgium.

All baker's yeasts were used a few days after the purchase and therefore well before their expiration dates.

2.3. Count of yeast cells

1 g of baker's yeast was suspended in 9 mL sterile sporulation (SPO) medium (8.5 g NaCl, 1.0 g peptone, 0.3 g Na_2HPO_4, 1 L ion exchanged water, pH 5.5) to dilution 10^{-1}. The dilution was continued to 10^{-8}. 25 μL of the 10^{-6}, 10^{-7} and 10^{-8} dilutions were inoculated on sterile yeast extract peptone glycerol (YPG) agar plates (10 g glucose, 3 g yeast extract, 5 g peptone, 1 L ion exchanged water and 20 g agar, pH 5.5). The plates were incubated at 25 °C for 48 h before counting the yeast colony forming units (CFU) (Table 1). The dilution series and the inoculation on YPG plates were both performed in duplicate.

2.4. Monitoring dough height

300 g of flour (adjusted to 14% water content), 185 mL water (30 °C), 4 g saccharose, 4 g NaCl and an equal number of baker's yeast cells according to Table 1 (dough containing $2.88 \cdot 10^{11}$, $5.76 \cdot 10^{11}$ and $8.64 \cdot 10^{14}$ CFU/kg flour, respectively, corresponding to 20–40, 40–80 and 60–120 g/kg flour) were mixed in a baking machine (FAB-100, Funai) for 19 min. A dough sample of 235 g was transferred to a 1 L beaker glass. The beaker glass was covered with aluminium foil and the dough was left for fermentation at 5 °C, 15 °C, 25 °C and 35 °C respectively in an incubator (Cooling incubator series 6000, Termaks). The dough height was monitored by a web camera (Live! Cam Voice, Creative Technology Ltd.) taking pictures of the doughs at intervals of 1–15 min (depending on the expected fermentation rate of each dough). The dough heights were monitored as duplicates from the same dough that was divided in two samples of 235 g dough. The dough height was measured as the highest point of the dough, as the dough height has previously been found to correlate well with the volume expansions of the dough (Ktenioudaki et al., 2010). The height for optimally developed dough was 90 mm for fermentation at 5 °C and 100 mm for fermentation at 15 °C, 25 °C and 35 °C. The dough heights for optimally developed doughs were determined from pre-trials (results are not shown) where fermented doughs with different heights were baked and the crumb structures for each dough height were evaluated.

2.5. Data analysis

The data obtained for the 84 different conditions (seven baker's yeasts, four temperatures and three yeast concentrations) were fitted to first-order non-Arrhenius kinetic models using non-linear regression with the Levenberg–Marquardt fitting function. For each condition, the kinetic rate constant, b_0 and b_1 were estimated. Image editing, curve fitting and preparation of the box-and whisker plot were performed by the software Matlab (version 7.11/R2011b, Mathworks) using in-house routines. The Tukey Honest Significant Difference (HSD) test was used for comparison of means in the analysis of variance (ANOVA) computed by the software Jump (version 7.0, SAS Institute Inc.).

3. Results and discussion

3.1. First order kinetic model

The majority of the expanding dough profiles followed a first order kinetic model (Fig. 1A), which could be used to estimate the

Table 1
CFU[a] of yeast cells per g compressed baker's yeast and the amount of baker's yeast in the dough corresponding to $2.88 \cdot 10^{11}$, $5.76 \cdot 10^{11}$ and $8.64 \cdot 10^{11}$ CFU/kg flour.

Yeast	CFU of yeast pr. g yeast	Amount of baker's yeast in the dough (g baker's yeast/kg flour)		
		$2.88 \cdot 10^{11}$ CFU/kg flour	$5.76 \cdot 10^{11}$ CFU/kg flour	$8.64 \cdot 10^{11}$ CFU/kg flour
Malteserkors	$(1.44 \pm 0.17) \cdot 10^{10}$	20	40	60
Sema	$(1.33 \pm 0.42) \cdot 10^{10}$	22	44	66
Skærtoftmølle	$(0.92 \pm 0.14) \cdot 10^{10}$	31	62	93
Zymarom	$(0.77 \pm 0.14) \cdot 10^{10}$	37	74	111
Bruggeman	$(0.73 \pm 0.10) \cdot 10^{10}$	39	78	117
Rapunzel	$(0.72 \pm 0.19) \cdot 10^{10}$	40	80	120
l'Hirondelle	$(0.72 \pm 0.11) \cdot 10^{10}$	40	80	120

[a] CFU = Colony Forming Units.

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