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RHEOLOGICAL BEHAVIOUR OF TYPE I SOURDOUGH DURING REFRESHMENT PROCEDURE

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Abstract

Sourdough technology is one of the oldest biotechnological processes to produce healthier and long shelf life bread. Type I sourdough is a kind of traditional sourdough containing a certain amount of wheat or rye flour and water. Refreshment procedure is used to produce mature Type I sourdough, which can be used as a leavening agent. This procedure continues until obtaining mature sourdough. Mature sourdough is characterized to reach constant technological properties in terms of acidification and the ratio between lactic acid bacteria and yeasts (100:1). Rheological behaviour can also be considered as a new criterion. Frequency sweep test was carried out during refreshment procedure in order to determine the maturity of sourdough in this study. Frequency sweeps from 0.1 to 100 rad/s were performed with a target strain of 1% at 25 °C. Seven days' refreshment procedures were applied to monitor the maturity of sourdough. The pH values decreased from 6.18 to 3.93 after 7 refreshments. A significant reduction was observed for both elastic (G') and viscous (G") modulus after first fermentation period (25 °C, 24 h). The damping factor (tan δ) of the doughs produced by subsequent refreshments (3th, 5th and 7th) was higher than the dough obtained after first refreshment procedure. Damping factor was also higher than 1 for the doughs (3rd, 5th and 7th refreshment), indicating an increase in viscous characteristics. These results extended the knowledge of rheological changes during refreshment procedure and might contribute to the better understanding of producing mature Type I sourdough.

Keywords: Rheology, Type I sourdough, refreshment.

1. Introduction

Sourdough was the only bread leavening method before the discovery of yeast in beer production. It was discovered by chance as most things in science. The oldest recorded use of sourdough is from the ancient Egyptian civilizations (Röcken and Voysey, 1995). Sourdough is defined as spontaneous fermentation of a mixture of wheat and/or rye flour and water for a bit of time. Addition of salt is also possible (Hammes and Gänzle, 1998). Lactic acid bacteria (LAB) and yeast are present dominantly in a mature sourdough and determine its acidifying and leavening capability (Corsetti and Settanni, 2007). In recent years, sourdough is considered as a good alternative to the use of baker's yeast since offering many advantages to the bakery products such as shelf life extension, improved dough quality, enrichment of flavour and nutritional value (Minervini et al., 2014).

Sourdough making, which is an oldest biotechnological process, depends on cultural habits and may be grouped into four distinct types (Type I, II, III, and IV) from a technological point of view (Böcker et al., 1995). Type I sourdough is a traditional sourdough characterized by daily refreshment procedure. The terms of refreshment, backslopping, re-buildings are used to emphasises the multi-step fermentation process. It is the process which is repeated daily with the addition of a certain amount of flour and water to obtain mature sourdough with a constant acidifying and leavening capacity (Böcker et al., 1995; Hammes and Gänzle, 1998). Type I sourdough distracts the researchers' attention mainly its large microbial diversity although liquid and dried sourdough are widespread among bakers.

The sourdough Type II is a kind of liquid sourdough for industrial production. Single-step fermentation for 15-24 h is carried out with starter culture including only LAB or the combination of LAB and yeast. Autochthonous microbiota of the dough is inhibited and the dough acidifies rapidly by using starter culture addition. Type III sourdough is another industrial type of sourdough which is produced by dehydrating the stabilized form of Type II sourdough. The drying process is used Starter culture selection which is a critical step in this sourdough, is based on their specific flavour production and rapidly acidifying capacity (De Vuyst et al., 2014). Type IV sourdough is a kind of mixed sourdough produced generally for laboratory studies and some artisanal bakeries. In this sourdough process, traditional refreshment procedure is applied after the addition of starter culture (De Vuyst et al., 2014; Paramithiotis et al., 2005). Baker's yeast is added into the flour-water mixture to start the fermentation in sponge dough process. It is also known as Type 0 sourdough (Corsetti, 2013).

The use of spontaneous multistep fermentation is required for obtaining mature sourdough with a constant and leaving acidifying capacity. Therefore, some criteria are used to evaluate the performance of the sourdough. Both microbiological and physicochemical parameters are considered. In the microbiological aspect, LAB and yeast should be dominant in good quality of sourdough and generally present at the ratio (LAB: yeast) approximately 100:1 (Gobbetti, 1998).

Dough yield (DY), dough acidity and fermentation quotient (FQ) are the physicochemical parameters of the sourdough. DY deals with dough consistency. It is the ratio between water and flour in the dough (Equation 1). The consitency of dough is liquid if DY is 200. The firm dough is obtained if DY is 160.

$$DY = \frac{amount\ of\ flour + amount\ of\ water}{amount\ of\ flour} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Equ. 1$$

Total titrable acidity (TTA) and pH are considered as dough acidity. Final pH ranges from 3.90 to 4.3 for well-developed sourdough. The optimal value of TTA depends on the type of bread. FQ is the molar ratio between acetic acid and lactic acid during sourdough fermentation. It is strictly related to type of LAB and factors such as temperature, time, and moisture during fermentation.

Maturity of Type I sourdough is a big challenge to understand. Monitoring LAB and yeast count, pH, FQ and TTA are used for determining the maturity during refreshment procedure. Measuring the pH is not sufficient alone. LAB and yeast count is important to understand the maturity, but it is labour intensive and sometimes hard to obtain consistent results. Practical, consistent and easy criteria independent from human-related mistakes are required. The aim of this study is to monitor the rheological behaviour of Type I sourdough during refreshment procedure and to find alternative criteria to for understanding the maturity of sourdough.

2. Materials and Methods

2.1 Materials

The wheat flour with a 12. 45 % moisture content was used in this study. Yeast and LAB were counted by using SDA (Oxoid) and MRS agar (Merck), respectively. The pH of the sourdough was measured by using a pH meter (HANNA instrument, Germany).

2.2 Methods

2.2.1 The procedure of Type I Sourdough Preparation

Type I Sourdough was prepared with the mixing of 62.5% flour and 37.5% water (DY=160) and fermented at 25 °C for 24 h. Fermented dough (FD) was subsequently added as an inoculum to start the fermentation of

a new mixture of flour and water. It is repeated seven times and sampling was performed after each refreshment. The details of the experimental procedure were shown in Figureure1.

2.2.2 Technological characterization of Type I sourdough

Measurement of pH, enumeration of yeasts and lactic acid bacteria (LAB) of sourdough were carried out to determine the technological characteristic of sourdough. For the enumeration of yeast and lactic acid bacteria (LAB), 10 g sourdough were homogenized with 90 mL of sterile peptone water (1 g/L). Yeast and LAB were counted by using SDA (Oxoid) and MRS agar (Merck), respectively. The pH of the sourdough was measured by using a pH meter (HANNA instrument, Germany).

2.2.3 Dynamic rheological measurements

Dynamic rheological measurements the dough samples were carried out by stress and temperature-controlled rotational rheometer (Antonpaar MCR 302, Austria). Firstly, the amplitude sweep test was carried out to determine the linear viscoelastic region and found to be 0.1%. Frequency sweep test was conducted at between 0.628 and 62.8 rad/s at 25°C using a 2 mm gap. Elastic modulus (G′), viscous modulus (G″), tan δ value (G″/ G′) were determined.

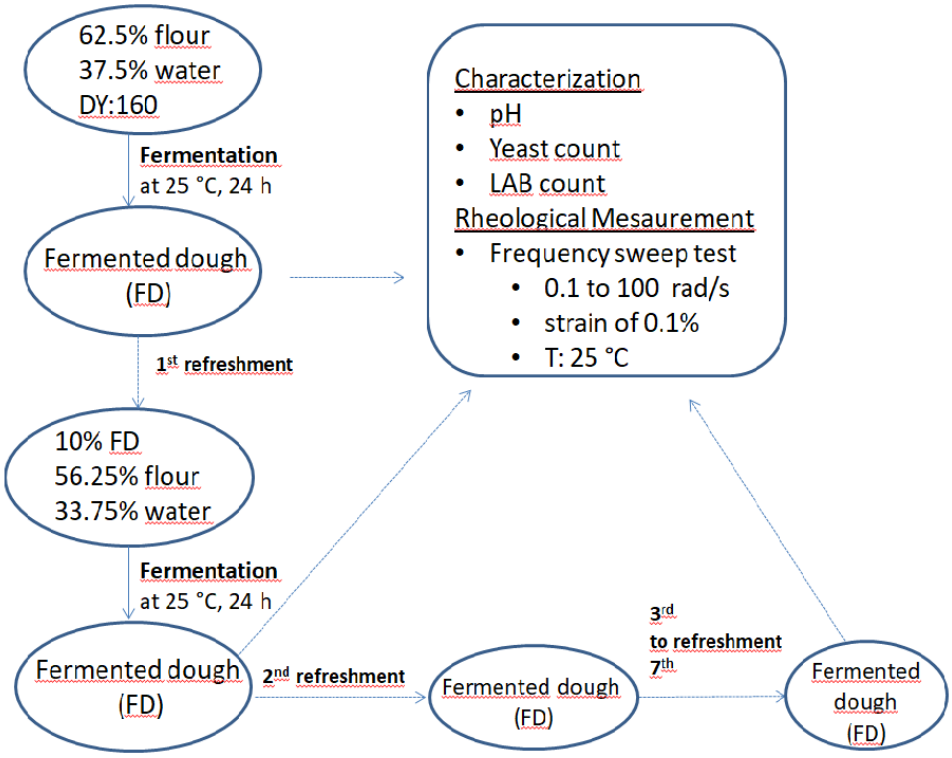

Figure 1. Experimental procedure of the study

3. Results and Discussions

3.1 Technological characteristics of Type I sourdough

During refreshment procedure, the values of pH ranged from 6.18 ± 0.04 (day 0) to 3.93 ± 0.01 (day 8). Dramatic decreases were observed after 1st refreshments referring day 2. The value of pH of the dough became constant after 3 refreshment procedure (Figure 2). Sourdough on the 4th day can be mature in terms of pH value since the pH of well-developed sourdough was determined as 3.5 to 4.3 according to Collar et al. (1994). The final pH of the sourdough at around 3.93 ± 0.01 at 25°C with 7 refreshments every 24 h. The end pH of Type I wheat flour sourdoughs fermented at different temperature were reported as 3.3 for 30°C, 3.4 for 37 °C and 3.7 for 23°C with backslopping every 24 h (Vrancken et al., 2011).

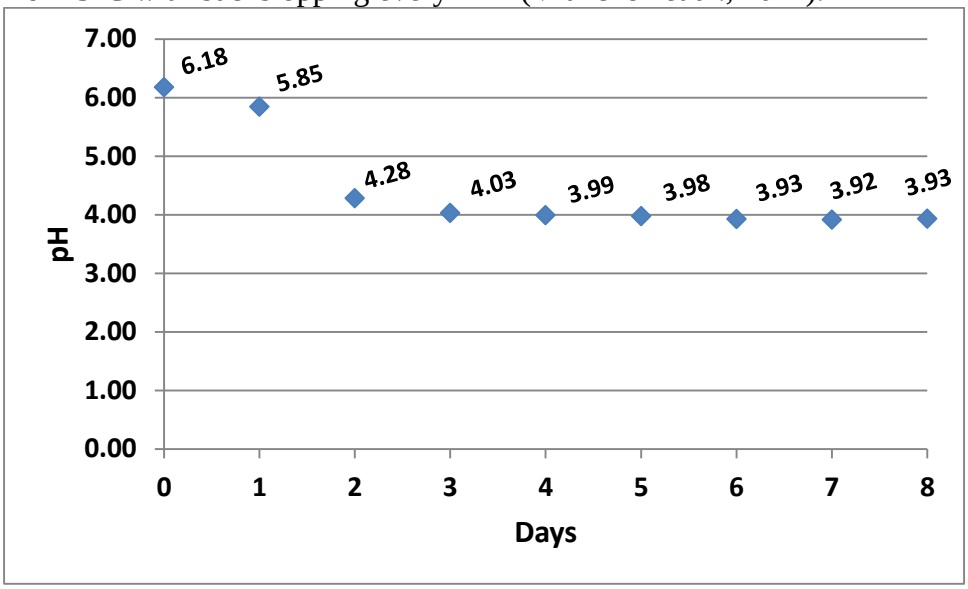

Figure 2. The pH of the sourdough during refreshment procedure

After first fermentation at 25°C (day 1), LAB and yeast counts were 7.85 ± 0.06 and 7.12 ± 0.07 log cfu/g, respectively. LAB and yeast count balanced on the 4th day of sourdough. The cell densities of LAB and yeast stayed almost constant value during subsequent propagation after the 4th day of refreshment referring day 5. The cell densities of LAB reached values ranging from ca.8.93 ± 0.15 to 9.12 ± 0.09 log cfu/g and yeast counts stabilized between 7.41 ± 0.09 and 7.59 ± 0.07 log cfu/g (Figure 3). These results are in line with the study previously carried out by Vrancken et al. (2011), in which the final cell densities for LAB were determined generally between log 8 and log 9 cfu/g, with the highest counts (just above log 9 log cfu/g) reached in the fermentation at 23°C with a backslopping time of 24 h. As for the yeast cell densities, log 8 cfu/g was reported for 23 °C with a 24 h backslopping (Vrancken et al., 2011).

Ercoloni et al. (2013) reported in a study which was monitored microbial ecology during rye and wheat sourdough preparation that sourdoughs achieved maturity during 5 to 7 days of propagation. The results of this study were in agreement with the study of Ercoloni et al. (2013) since the five days were required the maturity of wheat flour sourdough in terms of pH value, LAB and yeast count. Mature sourdough is defined as a sourdough that has reached constant cell densities of LAB and yeasts, acidification and leavening capacities that depending type of flours (Ercolini et al., 2013; Van der Meulen et al., 2007). A stable microbiota during sourdough propagation is required to achieve the standard and repeatable final products. Minervini et al. (2012) showed that different endogenous (e.g. type of flour, the quantity of water) and exogenous (e.g. temperature/time of fermentation) parameters determined the microbial stability and thesefactors also affected the technological characteristics of sourdough.

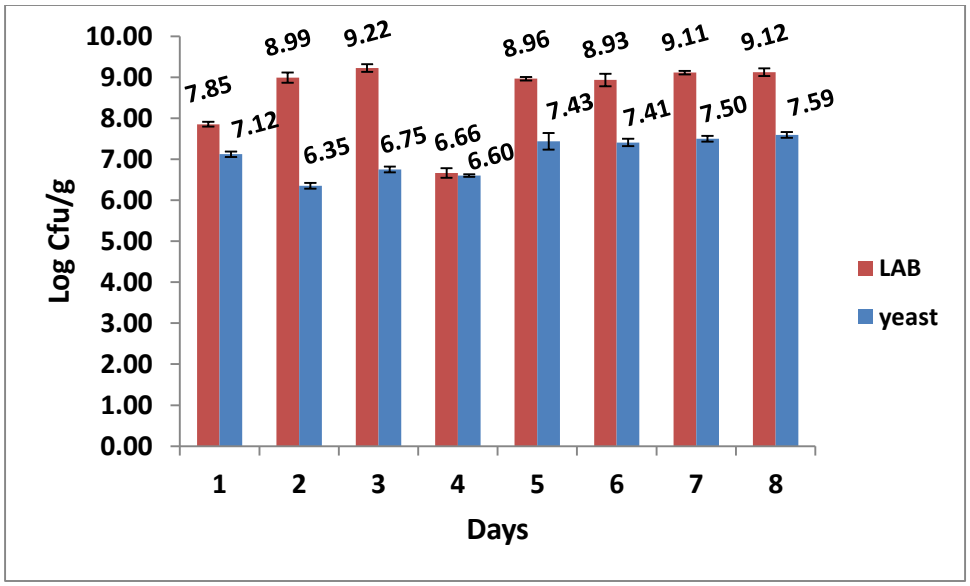

Figure 3. LAB and yeast cell densities of the sourdough during refreshment procedure

3.2 Dynamic rheological behaviour of Type I sourdough

Elastic modulus (G′), viscous modulus (G″) and damping factor, known as Tan δ (G″/G′), were as the parameters for expressing the dynamic rheologic measurements. Elastic modulus (G′) describes solid/elastic character of the samples while viscous modulus (G″) describes viscous/liquid state of the sample (Meziani et al., 2011). Table 1 shows the dynamic rheological parameters of Type I sourdough during refreshment procedure. The Power Law model was used to calculate the consistency coefficient (K) and n values of the doughs. The R2 value was between 0.97 and 0.99 showing the suitability of the model for the rheological parameters (K′, K″, n', n"). A drastic reduction was observed after 1st refreshment for consistency coefficient (K′, K″) belonging to storage (G′) and viscous modulus (G″). K′ and K″ values increased on 7th day of sourdough ($P<0.05$). There was no significant effect of the refreshment procedure on the K′ and K″ values for the sourdoughs between on the 2nd and 6th days ($P>0.05$). As for the n″ value for viscous modulus (G″), three refreshments decreased the n″ value significantly and four refreshment referring the day 5 was required to reach the constant value.

Table 1. Dynamic rheological parameters of Type I sourdough during refreshment procedure

	$G'=K'(\omega)^{n'}$			$G''=K''(\omega)^{n''}$		
Days	**K′ (Pa.s^n)**	**n′**	**R^2**	**K″ (Pa.s^n)**	**n″**	**R^2**
1	483,66±17,59^{a}	0,2983±0,0045^{a}	0,99	410,43±15,61^{a}	0,3232±0,0035^{ab}	0,99
2	251,17±34,81^{d}	0,2955±0,0052^{a}	0,98	203,90±29,92^{bc}	0,3469±0,0070^{a}	0,99
3	232,69±3,84^{d}	0,2514±0,0156^{bc}	0,99	179,15±1,06^{bc}	0,3427±0,0018^{a}	0,98
4	258,14±60,18^{cd}	0,21785±0,0333^{c}	0,98	230,16±95,90^{bc}	0,2824±0,0668^{b}	0,97
5	209,18±9,72^{d}	0,2721±0,0148^{ab}	0,99	177,16±9,65^{bc}	0,3285±0,0073^{ab}	0,99
6	236,45±22,30^{d}	0,2325±0,0134^{c}	0,98	174,01±15,94^{c}	0,3083±0,0014^{ab}	0,97
7	345,43±35,06^{b}	0,2439±0,0001^{bc}	0,99	262,99±28,52^{b}	0,3118±0,0003^{ab}	0,98
8	325,08±10,18^{bc}	0,2408±0,0156^{bc}	0,99	243,16±10,98^{bc}	0,3257±0,0078^{ab}	0,99

Columns having different letters are significantly different ($P < 0.05$)

Tan δ describes which character of the material is dominant. Phase angle (δ) ranges from 0° to 90° for all viscoelastic material. The lower the values means that the more elastic the material. For ideally viscous material, the phase angle (δ) is 90° (Clarke et al., 2002). Tan δ is significantly higher at 10 Hz after 2nd refreshments referring day 3 and were also higher than 1 for the doughs (3rd, 5th and 7th refreshment), indicating an increase in viscous characteristics (Figure 4). Tan δ development is closely related to gas (CO2) production by heterofermentative LAB in sourdough (Wehrle and Arendt ,1998). Gas production after 2nd refreshments referring day 3 may increase correspondingly the increase in Tan δ markedly which was occurred on the same day ($P<0.05$). There were no major changes in terms of Tan δ between the 3rd and 8th day of sourdough. It can be due to no differences in CO2 development.

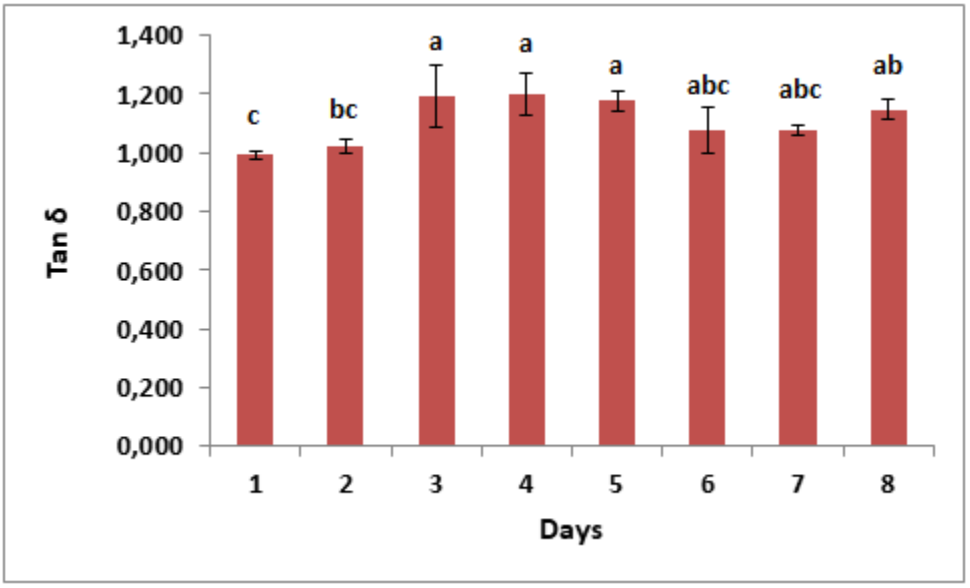

Figure 4. Tan δ value at 10 Hz during refreshments procedure

4. Conclusions

Monitoring the rheological study of Type I sourdough during refreshment procedure is aimed in this study since the most of the studies focused on the microbial ecology of Type I sourdough. Sourdough Type I can be standardized by using fundamental rheology. Rheological behavior of the sourdough Type I should be incorporated into the criteria of mature sourdough besides LAB: yeast ratio and acidification. This can offer an easy, practical and consistent method and reduce the human-related mistakes.

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