JAP&T
TPA-Timişoara

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Journal of Agroalimentary Processes and Technologies 2021, *27* (1), 9-14

Journal of Agroalimentary Processes and Technologies

Effect of dry sourdough addition in wheat flour on dynamic rheological properties and bread quality

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Abstract

The aim of this study was to analyse the effect of dry sourdough addition (0 %, 1 %, 2 %, 3 %, 4%) in a refined wheat flour on dough rheological properties by analysing the dynamic rheological parameters (G', G") at a constant stress and during heating between 20-90^{0}C. The G', G" moduli increased when high levels of dry sourdough were incorporated in dough recipe. From the bread making quality point of view the physical (loaf volume, porosity, and elasticity), textural and sensory characteristics were determined. According to the data obtained the bread with the highest level of dry sourdough addition presented the lowest values for loaf volume and porosity. The elasticity presented the lowest value for the control sample. For the samples with dry sourdough addition the bread springiness value presented highest levels than for the control one. From the sensory point of view, in general, the bread with a level up to 4% dry sourdough addition was well appreciated by the panellists in especially from the taste and flavour point of view.

Keywords: dry sourdough, wheat flour, fundamental rheological properties, bread quality

1. Introduction

Sourdough is a mixture of flour and water, fermented by yeast and lactic acid bacteria which lead to the acidification of the wheat flour dough [1]. The use of sourdough in bread recipe as a leavening agent is one of the oldest process in bread making [2]. The role of using sourdough in the bread making process is to ferment the wheat flour dough in order to obtain bread with an aerated crumb, good sensory characteristics and a higher freshness. With the increasing demand for natural, tasty and healthy foods, in the last years has been increasing the consumers demand for traditional bread production with sourdough addition [3].

The fermentation of the wheat flour dough with sourdough addition changes in a significant way it functional and rheological characteristics by decreasing dough elasticity and viscosity, leading to a soft dough and increasing it content in lactic acid bacteria which leads to a lactic fermentation along with an alcoholic one [4-6]. The use of sourdough in bread making improves bread quality by increasing it shelf life due to its high acidity but also to its antimicrobial and antifungal activity. In addition to these positive effects on the finished products, there are studies that show a number of improvements in loaf volume, crumb structure and aromatic profile of the bakery products [7].

By using sourdough in bread making it improves bread quality and from the nutritional point of view due to the fact that it reduces phytic acid, a natural antinutrient found in wheat flour in especially if it is of a high extraction rate [5, 8-11]. In the industrial production of sourdough, as an ingredient for bread making two main parameters are representative ones such as the amount of lactic acid from wheat flour and the pH value which is a low one. Measurement of pH under defined conditions such as dough yield, temperature and flour extraction rate is used to analyze the fermentation stage of the flour dough used to obtain sourdough. Free amino acids and sugars are the main components for the flavors development and sourdough production for which may be selected strains with a high capacity to produce metabolites [12, 13].

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In addition to decrease the pH level, the amount of acetic acid from the sourdough system is a very important factor that can be influenced by the addition of fructose or a higher yield of dough. The leavening of the final dough for bread can be influenced by the production of CO_2 from bacteria that produce in a heterofermentative way the lactic acid. A negative aspect in the use of sourdough in a traditional way in bread making is the fact that it production presents some difficulties in controlling the fermentation process and also to the fact that the time for bread making is a longer one. A successful attempt to overcome all these negative aspects is the use of dry sourdough, easy to use, with shorter bread making process period and finished product quality similar to those obtained through a traditional bakery process [3].

The aim of this study was to investigate the effect of dry sourdough (DS) addition in wheat flour and to analyze the dynamic rheological properties and bread quality through it loaf volume, porosity, elasticity, textural and sensorial characteristics.

2. Materials and methods

2.1. Materials

Wheat flour (harvest 2019) of a refined type was provided by S.C. MOPAN S.A. (Suceava, Romania) and dry sourdough from wheat flour by Enzymes & Derivates S.A. Company (Romania, Neamt). The wheat flour analyzed through Romanian and international methods presented the following values: 0.65 g/100 g ash content (ICC 104/1), 12.67 g/100 g protein content (ICC 105/2), 30 g/100 g wet gluten content (ICC 106/1), 6 mm gluten deformation index, 14 g/100 g moisture content (ICC 110/1), and 322 s Falling Number value (ICC 107/1).

2.2. Methods

The dough fundamental rheological properties were obtained by using a Haake Mars 40 rheometer (Termo-HAAKE, Karlsruhe, Germany) with 2 mm gap and parallel plate geometry. Frequency sweep tests were carried in the linear viscoelastic region from 1 to 20 Hz in the linear. The storage modulus (G') and loss modulus (G'') were determined at a constant stress at 25^0C and during heating (20-90^0C) at the rate of 4^oC per min.

The ingredients were mixed at 200 rpm in a laboratory mixer (Kitchen Aid, Whirlpool Corporation, Benton Harbor, Michigan, USA) for 15 minutes, then divided, molded and fermented in a fermentation chamber (PL2008, Piron, Cadoneghe, Padova, Italy) at 35°C for 40 minutes at 85% relative humidity and baked in a bakery convection oven (Caboto PF8004D, Cadoneghe, Padova, Italy) at 180°C for 50 minutes. After cooling, the samples were analyzed.

The bread quality characteristics loaf volume (using a Fornet device, China), porosity, elasticity were determined according to SR 91:2007. The bread textural characteristics were determined by using a textural Analyzer (Perten TVT 6700, Sweden) equipped with a cylinder of 35 mm and the two cycle's method under the action of the cylinder was used to determine bread samples texture.

The bread sensory characteristics were determined by a hedonic method (9-point scale) as following: appearance, color, taste, smell, texture, flavor, overall acceptability. The sensory analysis was made in a sensory laboratory of Stefan cel Mare University, Faculty of Food Engineering. For the sensory analysis, the numbered samples were analyzed by 24 semi-experienced evaluators, with the age between 21 and 23 years.

2.3. Statistical analysis

All of the data were made in duplicate and were expressed as the means of the measurements ± standard deviation. The significance of the variations observed among the samples ($p < 0.05$) was tested using the XLSTAT statistical package (free trial version, Addinsoft, Inc. Brooklyn, NY, USA).

3. Results and discussion

3.1. Effect of dry sourdough addition on fundamental dough rheological properties

From a rheological point of view, the fundamental characteristics of the wheat flour dough were studied using the dynamic oscillating method in the linear viscoelastic region. The storage (G') and loss modulus (G'') variations with frequency are shown in Figure 1. As it may see, all the dough samples, as expected, presented $G' > G''$ at all frequency ranges, which indicated a solid elastic-like behavior of wheat flour dough. Similar observations have also been reported by [19, 20]. The G' and G'' values increased slightly with the increase in frequency from 1 to 20 Hz. Low levels of SD addition

presented lower values for *G'* and *G"* compared to the control sample meaning that it decreases it elasticity and viscosity, these data being in agreement with other studies when SD are incorporated in dough recipe [4-6]. This fact may be due to the SD enzymatic activity which acts on gluten system weakening it [21]. However, when high levels of dry sourdough are incorporated in wheat flour the *G'* and *G"* values increased compared to the control sample probably due to the fact that SD decreases in a significant way the pH of the dough system. SD contains organic acids such as lactic, acetic ones which causes gluten dehydration due to the fact that increases the osmotic pressure outside of the protein globules [22].

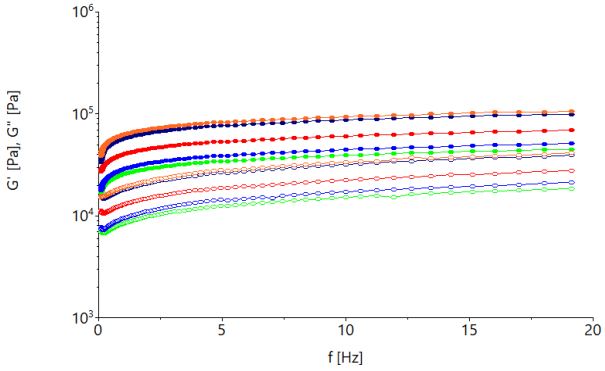

Figure 1. Frequency dependent evolution of *G'* (represented by solid symbols) and *G"* (open symbols) for dough samples with different SD addition levels (-●-M%; -●-1%; -●-2%; -●-3%; -●-4%)

The changes of the viscoelastic moduli with temperature are showed in Figure 2. At the beginning, the decrease of *G'*, *G"* moduli to a minimum up to a certain temperature occur, then the *G'*, *G"* moduli significantly increases until achieves the maximum level, then it decreases again. Compared to the control samples, the *G'*, *G"* moduli are lower for the samples when 1% and 2% SD were incorporated in wheat flour and higher when 3 and 4% SD were added in dough recipe. This behavior may be also due to the pH and enzymatic activity of wheat flour in which SD was incorporated. At low levels of SD addition it is possible that the pH value of dough sample not to be so high. However, the enzymatic activity from the dough system increases due to the SD which is a fermented flour which may also presents a slightly enzymatic activity (including amylolitic one). At high levels the dough pH may decrease to a more high levels fact that may lead to a decrease of amylolitic activity which is no longer in the optimal pH range [21, 22].

3.2. Effect of dry sourdough addition on bread quality characteristics

The bread quality characteristics such as loaf volume, elasticity and porosity are shown in Table 1, Figure 1.

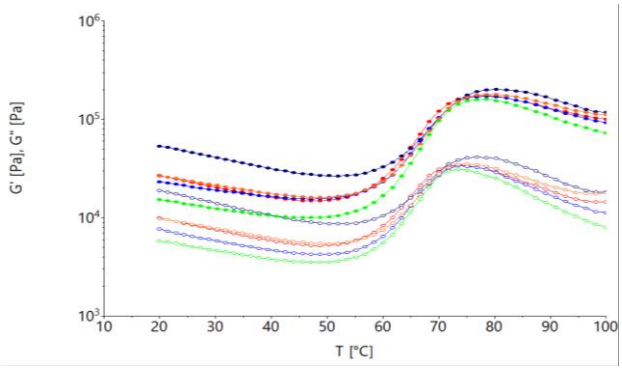

Figure 2. Temperature dependent evolution of *G'* (represented by solid symbols) and *G"* (open symbols) for dough samples with different SD addition levels (-●-M; -●-1%; -●-2%; -●-3%; -●-4%)

As it may be seen from the table 1, with the increase level of SD addition in wheat flour, the loaf volume of the bread samples gradually decreased. However, for P1-P3 samples the loaf volume is higher than the control one. An increase in the level of dry sourdough added to wheat flour type 650 will lead to a decrease in bread volume probably due to a lower pH conditions caused by sourdough addition which may inhibit the amylolitic activity causing decrease of the CO_2 production during proofing, resulting in lower volume and harder crumb of the bread [16]. This fact indicates that dough becomes softer when SD was added in wheat flour. However, in general, the loaf volume is higher for the samples in which SD is added compared to the control one probably to the higher amylolitic activity from the dough system.

Table 2 shows the bread textural properties values. It may be seen that springiness value do not change in a significant way for the samples in which SD were added in wheat flour. Also, the springiness value is higher for the samples with SD addition, these data being in agreement with those obtained by [17], which concluded that an increase of the fermentation time will allow a higher expansion of

the gluten network because of it softer nature induced by SD addition. SD increases the springiness up to 1.70% for P1 compared to the P3 sample and increases to 2.7% for P4 compared to the control sample. It may be seen that cohesiveness do not change in a significant way and it may be noticed a slightly increase of this value for P3 sample.

Table 1. Physical characteristics of bread samples

Sample	Loaf volume (cm^3/110g)	Elasticity (%)	Porosity (%)
M	304.37±0.6[a]	89.66±0.3[a]	86.39±0.4[a]
P1	318.19±0.5[a]	93.13±0.4[a]	92.34±0.5[a]
P2	316.08±0.6[a]	92.33±0.3[a]	91.21±0.3[a]
P3	310.11±0.7[a]	91.37±0.5[a]	87.44±0.5[a]
P4	302.64±0.4[a]	91.66±0.2[a]	85.18±0.2[b]

Means followed by the same letter within a column are not significantly different ($p < 0.05$).
M - control sample; P1- sample with 1% SD addition, P2 - sample with 2% SD addition, P3 - sample with 3% SD addition, P4 - sample with 4% SD addition.

Table 2. Textural characteristics of bread samples

Sample	Springiness [%]	Cohesiveness	Gumminess [g]	Chewiness [g]
M	88.66±0.1[a]	0.8880±0.001[a]	7686±2.1[a]	7693±1.4[a]
P1	93.13±0.5[a]	0.8445±0.005[a]	4758±0.7[a]	4763±2.1[a]
P2	91.66±0.2[a]	0.7912±0.004[a]	2089±0.8[a]	2303±1.4[a]
P3	91.37±0.4[a]	0.8537±0.001[a]	4758±0.7[a]	4758±2.1[a]
P4	91.33±0.3[a]	0.8345±0.005[a]	6435±0.7[a]	6581±1.6[a]

Means followed by the same letter within a column are not significantly different ($p < 0.05$).
M - control sample; P1- sample with 1% SD addition, P2 - sample with 2% SD addition, P3 - sample with 3% SD addition, P4 - sample with 4% SD addition

Figure 3. Bread samples with different levels of SD addition

The sensory data obtained are shown in Figure 4 which indicates the fact that bread samples with high levels of SD addition was well appreciated from the taste, smell and flavor point of view. This fact are explainable due to the positive effects of SD addition in bread making which leads to an improved crumb structure [18] and a better sensory and aromatic profile [15].

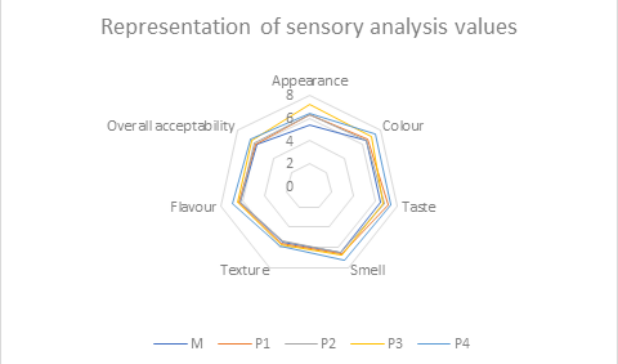

Figure 4. Representation of sensory analysis values

4. Conclusions

The addition of high levels of dry sourdough addition conducted to an increase of dough elasticity and viscosity as it can be seen from the increase of the *G′* and *G″* values for the samples with 3% and 4% dry sourdough incorporated in dough recipe. The storage modulus *G′* presented a higher values than the loss modulus G" in the whole range of set frequencies indicating a solid elastic-like behavior of all dough samples. Also, both modules *G′* and *G″* values increased with the increase value of frequency. As the temperature increases, the sample with 1% dry sourdough addition presented lower values for the *G′* and *G″* than for the dough samples with 4% addition. From the bread quality point of view, the loaf volume of the bread samples gradually increased when low levels of SD was incorporated in bread recipe and decreased when high levels were added. With the increase level of SD addition in wheat flour, the loaf volume of the bread samples gradually decreased. The textural properties shown an increase of the springiness value for the samples with SD addition compared to the control one and from the sensory point of view the bread samples with high levels of SD addition were the most appreciated by the panelists.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

Acknowledgement. This paper has been financially supported within the project entitled „DECIDE-Development.through entrepreneurial education and innovative doctoral and postdoctoral research, project code POCU / 380/6/13/125031, project co-financed from the European Social Fund through the 2014 – 2020 Operational Program Human Capital".

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