

Effects of Spray-Dried Sourdough on Flour Characteristics and Rheological Properties of Dough

ABOLFAZL GOLSHAN TAFTI¹, SEYED HADI PEIGHAMBARDoust², FLORA BEHNAM²,
AKBAR BAHRAMI², ROYA AGHAGHOLIZADEH³, MAHDIEH GHAMARI⁴
and SEYED ABBAS RAFAT⁵

¹Department of Agricultural Engineering Research, Agricultural Research Centre, Kerman, I.R. Iran; ²Department of Food Science, College of Agriculture, University of Tabriz, Tabriz, I.R. Iran; ³Iran Cereals Research Institute, Tehran, I.R. Iran; ⁴Young Researchers Club, Hamedan Branch, Islamic Azad University, Hamedan, I.R. Iran; ⁵Department of Animal Science, College of Agriculture, University of Tabriz, Tabriz, I.R. Iran

Abstract

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The effect of incorporating different levels of spray-dried sourdough (3, 6, 9, and 15% w/w) on flour characteristics and dough properties of two wheat flours was studied. As the spray-dried sourdough level in the blends increased, the pH values significantly ($P < 0.05$) decreased. Wet gluten content and sedimentation values were decreased in the flours containing spray-dried sourdough compared to those of the control. Water absorption significantly increased compared to that of the control. However, the dough development time was not affected by sourdough powder addition. Degree of softening significantly increased with an increase in the sourdough level and dough stability was significantly reduced. Doughs incorporating sourdough powder showed higher resistance to extension and lower dough extensibility than the control doughs.

Keywords: spray-dried; sourdough; dough; rheology; flour

Sourdough has been reported to have a major effect on dough properties and bread quality. In wheat breads, sourdough is used to improve bread flavour, volume, crumb structure and shelf-life and to reduce phytic acid content as a natural anti-nutrient compound in the flour (HANSEN & HANSEN 1994; CLARKE *et al.* 2002; CROWLEY *et al.* 2002; LAVERMICOCCA *et al.* 2003; DAL BELLO *et al.* 2007). Sourdough is a mixture of flour and water, in which lactic acid bacteria are dominant microorganisms leading to dough acidification (IACUMIN *et al.* 2009). This will lead to a reduction of dough elasticity and firmness (ARENDRT *et al.* 2007). Yeasts are also associated with lactic acid bacteria in sourdoughs. They are mainly

responsible for dough leavening (CORSETTI & SETTANNI 2007). Sourdough lactic acid bacteria have proteolytic activity and can release amino acids and small peptides from wheat proteins, thereby enhancing flavour development. In addition to lactic acid bacteria, cereal flour and yeasts contain proteolytic enzymes (GOCMEN *et al.* 2007) which degrade prolamines under acidic conditions and therefore provide negative effects on the rheological properties of dough (LOPONEN *et al.* 2004). A screening of several strains of *Lactobacillus plantarum*, *Lactobacillus curvatus*, and *Leuconostoc mesenteroides* for enzymatic activity showed a combination of protease, peptidase, β -glucosidase and phytase activities (ZOTTA *et*

al. 2007). Proteolysis by lactic acid bacteria during sourdough fermentation has been reported to influence the rheological properties of dough and consequently, the texture of bread (ANGIOLONI *et al.* 2006; GOCMEN *et al.* 2007). A number of studies have examined the influence of sourdough on dough properties by empirical and fundamental rheological tests (WEHRLE *et al.* 1997; CLARKE *et al.* 2002; ANGIOLONI *et al.* 2006). Fundamental rheological tests have shown that the addition of sourdough causes higher phase angle and lower storage modulus (G') (ANGIOLONI *et al.* 2006). According to CLARKE *et al.* (2002), the addition of sourdough prepared from single-strain or mixed-strain cultures led to significant changes in the behaviour of the dough system. It is shown that a drop in pH value during the sourdough fermentation process changes the rheological behaviour of dough (WEHRLE *et al.* 1997).

Based on the technology used for sourdough production, sourdoughs have been grouped into three types. Dried sourdoughs are considered as type III (CLARKE & ARENDT 2005). They are prepared from a mature sourdough under controlled conditions after which they are submitted to a drying process. Dried sourdoughs are added to the formula to enhance taste and flavour. There are several techniques for the production of dried sourdoughs. Spray drying is considered as a suitable method for the continuous production of dried powders (PEIGHAMBARDUST *et al.* 2011). The drying technique strongly affects the acidity of dried sourdoughs. Dried sourdoughs usually have lower acidity compared to the corresponding fresh sourdoughs (BRANDT 2007). It is reported that dried sourdoughs increased the water absorption of the flour, however, dough stability was decreased (KULP & LORENZ 2003). To our best knowledge, information about the effect of spray-dried sourdoughs on dough rheological properties is scarce. In this study, we investigated the impact of type III sourdough prepared from *Lactobacillus paralimentarius* on flour characteristics and dough rheological properties.

MATERIAL AND METHODS

Sourdough preparation and spray drying. *Lactobacillus paralimentarius*, isolated from Iranian traditional sourdoughs, was used as a starter culture for sourdough fermentation. Overnight cultures

of the strain were inoculated at 1% (v/v) into MRS (DE MAN *et al.* 1960) broth and incubated at 30°C for 24 hours. Microbial cells were harvested by centrifugation (3000 g, 15 min, 4°C; Universal 320R; Andreas Hettich, Tuttlingen, Germany) and washed twice in sterile distilled water. The dough was inoculated with initial viable cell counts of about 10^8 CFU/g. The dough (dough yield = 350) was placed in an incubator at 30°C for 20 h (CROWLEY *et al.* 2002; KATINA *et al.* 2006a). The dough yield was obtained as: $DY = (\text{amount of flour} + \text{amount of water}) \times 100 / \text{amount of flour}$. The sourdough was prepared from whole wheat flour (98% extraction rate). The sourdough was spray-dried in a pilot-scale spray drier (Maham Sanat, Neishaboor, Iran) with a centrifugal atomiser at a constant inlet air temperature of $180 \pm 5^\circ\text{C}$. The moisture was evaporated in a vertical, co-current drying chamber. The spray-dried (SD) sourdough was sealed in plastic bags and stored at 4°C before further analysis.

Preparation of flour blends. Commercial bread-making wheat flour with 10% protein (db), 0.68% ash (db), and 12.66% moisture was obtained from Tabriz-Kar flour mill (Tabriz, Iran). To increase the flour ash content to 1.8% (db) (an extraction rate of 98%), wheat bran was added. Therefore, two flours with different ash contents were obtained. SD sourdough at different concentrations (3, 6, 9, and 15% w/w flour basis) was added to the flours with different ash contents.

Flour analysis. Sedimentation test and falling number (Falling Number 1500, Perten Instruments, Huddinge, Sweden) were determined following AACC methods 56-61A and 56-81B, respectively (AACC 2000). Wet gluten content was measured by hand-washing according to AACC 38-11 method (AACC 2000). The pH and total titratable acidity (TTA) were measured in a suspension of 10 g of the flour and 90 ml distilled water (HAGGMAN & SALOVAARA 2008). The mixture was titrated with 1N NaOH using phenolphthalein as indicator. The pH values were determined with a pH meter (pH 209; Hanna Instruments, Amorim-Povoa de Varzim, Portugal).

Rheological measurements. Rheological characteristics of flour samples including water absorption, dough stability, dough development time and degree of softening after 20 min were determined using Farinograph-E (Brabender, Duisburg, Germany) (AACC 54-21 2000). Maximum resistance (R_{max}), extensibility (E) and extension energy were determined using Brabender Extensograph-E.

Statistical analysis. All determinations were carried out in triplicates. Mean values and standard deviation were calculated. Data were analysed using SAS software, Version 9.1 (SAS Institute, Inc., Cary, USA). Analysis of variance was performed to determine significant differences ($P \leq 0.05$) between means.

RESULTS AND DISCUSSION

Effect of spray-dried sourdough on flour physico-chemical characteristics

The results of pH determination are shown in Figure 1. As expected, the control flours showed the highest pH. Addition of sourdough powder to the flours resulted in a significant ($P < 0.05$) decrease in pH. The pH value of the white flour was 6.07, which decreased as the SD sourdough level increased from 3% (5.34) to 15% (4.17). The highest pH value (6.34) was found in the control wholemeal flour, which decreased with an increase in the SD sourdough level from 3% (6.02) to 15% (5.1). Incorporating the sourdough powder to the flours increased TTA values of the flours (data are not shown).

There was a significant ($P < 0.05$) decrease in wet gluten content of the flours upon the addition of different levels of SD sourdough as shown in Figure 2. The wet gluten content of the wholemeal flour was lower than that of the white flour. This is due to the mechanical disruption effect of hard bran particles on the gluten network as well as to the dilution of gluten in these flours (KATINA *et al.* 2006b). The wet gluten content of both flours decreased as the SD sourdough level increased from 3% to 15%. It was about the same for the flours at the level of 15% SD sourdough addition.

This may be due to a remarkable pH drop in the white flour containing 15% SD sourdough which leads to an increase in the solubility of gluten proteins and consequently to a decrease in wet gluten content. The highest (25.83%) and lowest (16.33%) amounts of wet gluten were attributed to the white flour containing 3 and 15% SD sourdough, respectively. A similar trend was observed for the wholemeal flour. It ranged from 16.73% to 19.3% in blend wholemeal flours with the highest wet gluten content (19.3%) in the wholemeal flour containing 3% SD sourdough (Figure 2).

The swelling of gluten proteins in dilute acids has long been used as a test (sedimentation test) for evaluation of flour quality. Figure 3 shows sedimentation values of both white and wholemeal flours incorporating SD sourdoughs. The wholemeal flours showed significantly ($P < 0.05$) lower sedimentation values (10–13.5 cc) compared to those of the white flours (19–29.33 cc).

Wheat gluten proteins consist of two groups of proteins, the glutenins, and the gliadins. The glutenin fraction has the main role in the elastic properties of dough and consists of low molecular weight glutenin (LMW) and high molecular weight glutenin (HMW) subunits (GOCMEN *et al.* 2007). It is reported that low pH conditions have a direct effect on flour components like gluten, starch, and arabinoxylans and it increases the solubility of glutenins (CLARKE & ARENDT 2005) leading to a reduced amount of polymeric glutenins. This could explain the reduction of wet gluten content and sedimentation value in sourdough added flours. Acidic conditions also create an ideal environment for the activation of cereal aspartic proteinases and degradation of gluten proteins (LOPONEN *et al.* 2004).

Figure 4 shows the results of falling numbers for the white and wholemeal flours incorporating

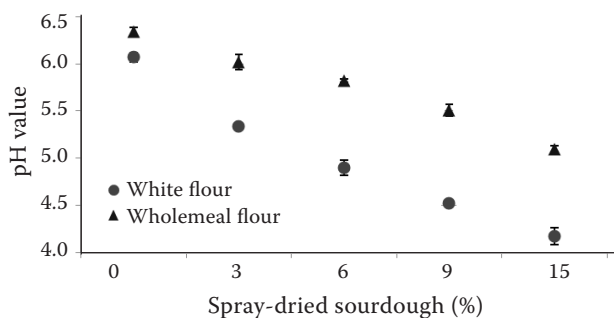


Figure 1. Effect of different levels of spray-dried sourdough on the pH value of flours

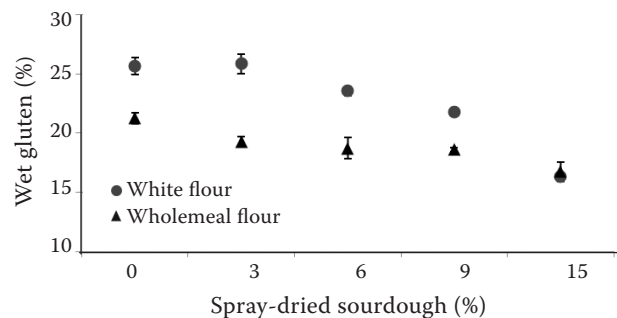


Figure 2. Wet gluten changes of the flours containing various levels of spray-dried sourdough

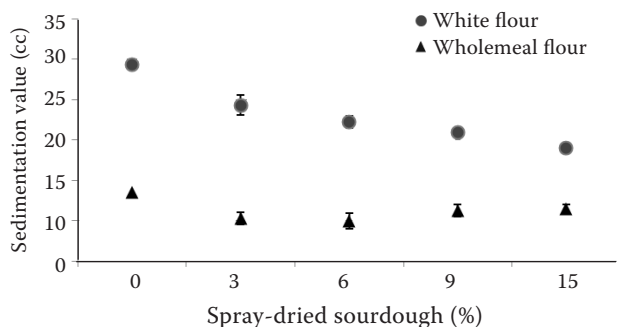


Figure 3. Effect of added spray-dried sourdough on sedimentation values

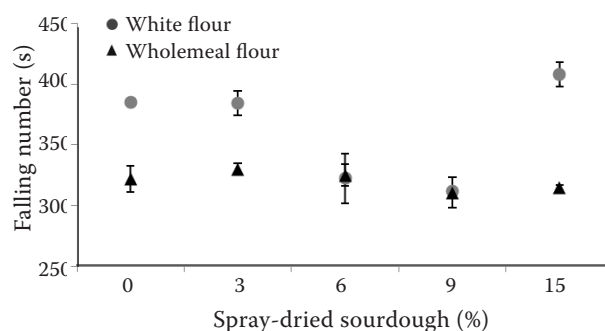


Figure 4. Effect of added spray-dried sourdough on falling number

sourdough powders. Measurement of the falling number is an indirect measure of α -amylase activity. As can be seen in this figure, the wholemeal flour showed higher α -amylase activity compared to that of the white flour. The presence of bran residues in the wholemeal flour accounts for higher α -amylase activity and thereby lower falling numbers. The addition of SD sourdough to the white flour up to 9% significantly reduced falling numbers. However, it was followed by an increase in the falling number at a 15% level. It is reported that lactic acid bacteria produce extracellular α -amylase during sourdough fermentation (KATINA *et al.* 2005). This could explain higher α -amylase activity of SD sourdough added flours at 6 and 9% levels. Reduction of α -amylase activity at a higher sourdough incorporation level (15%) might be explained by the fact that rapid reduction in flour pH could negatively affect α -amylase activity (KATINA *et al.* 2005).

Effect of spray-dried sourdough on dough rheology

Farinograph. The farinograph parameters such as water absorption, dough development time, dough stability, and degree of softening were significantly ($P < 0.05$) different between the two types of flour (Table 1). The water absorption was found in the range of 66.23% to 67.2% and 74.3% to 75.86% in white flour and wholemeal flour blends, respectively. However, the wholemeal flour showed higher water absorption due to more brans. Studies have also shown that the flour extraction rate affects water absorption and gluten strength (ORTH & MANDER 1975). Compared to the control, water absorption was increased by the addition of SD sourdough but there was no significant difference among the levels of SD sourdough (Table 1). Similarly, the dough development time was higher in wholemeal flour blends. It is due to the presence

Table 1. Farinograph characteristics of doughs with various amounts of spray-dried sourdough: A – white flour and B – wholemeal flour

Parameters		Control	3%	6%	9%	15%
WA (%)	A	66.23 ± 0.15 ^b	66.81 ± 0.37 ^a	66.90 ± 0.26 ^a	66.93 ± 0.20 ^a	67.20 ± 0.10 ^a
	B	74.30 ± 0.10 ^c	75.86 ± 0.37 ^a	75.23 ± 0.25 ^b	75.63 ± 0.45 ^{ab}	75.20 ± 0.17 ^b
DDT (min)	A	2.20 ± 0.01 ^b	3.55 ± 0.83 ^a	2.00 ± 0.26 ^b	3.26 ± 1.28 ^{ab}	3.80 ± 0.17 ^a
	B	7.20 ± 0.01 ^a	7.20 ± 0.62 ^a	6.50 ± 0.20 ^b	6.36 ± 0.05 ^b	6.36 ± 0.05 ^b
DS (min)	A	5.43 ± 0.15 ^a	4.73 ± 0.30 ^b	4.10 ± 0.26 ^c	3.76 ± 0.05 ^c	3.23 ± 0.05 ^d
	B	4.50 ± 0.30 ^a	4.03 ± 0.47 ^b	2.23 ± 0.15 ^c	2.43 ± 0.11 ^c	1.96 ± 0.23 ^c
DOS (BU)	A	68.00 ± 1.00 ^e	93.50 ± 5.26 ^d	111.66 ± 3.21 ^c	142.33 ± 4.72 ^b	175.33 ± 5.03 ^a
	B	57.50 ± 1.50 ^d	62.00 ± 4.00 ^c	80.00 ± 2.64 ^b	82.00 ± 2.00 ^b	91.33 ± 1.00 ^a

WA – water absorption; DDT – dough development time; DS – dough stability; DOS – degree of softening; means with similar letters within the same row are not significantly different ($P < 0.05$)

of bran particles in the wholemeal flour which can interfere in gluten hydration (CLARKE *et al.* 2002). An increase in SD sourdough proportions from 3% to 15% did not significantly affect the dough development time in either flour (Table 1). Similar findings were also reported by KULP and LORENZ (2003). They reported that the addition of dehydrated sourdoughs led to an increase in water absorption, while the dough development time was not affected.

The addition of SD sourdough significantly ($P < 0.05$) reduced the stability of dough blends compared to the controls. The highest and the lowest stability were observed at the levels of 3% and 15% SD sourdough in both flours (Table 1). It was in agreement with CLARKE *et al.* (2002), who found a reduction in dough stability with the addition of sourdough prepared from any of the three starter cultures. Other studies using empirical rheological measurements (MAHER GALAL *et al.* 1978) also revealed that the addition of organic acids substantially decreased the mixing time and weakened the wheat dough. HOSENEY (1994) reported that acids strongly affected the mixing behaviour of dough, whereby the dough with lower pH value required a slightly shorter mixing time than the normal dough. WEHRLE *et al.* (1997) also reported that the addition of acids resulted in firmer dough with lower stability. However, low pH conditions promote intramolecular electrostatic repulsion among gluten proteins and lead to the unfolding of gluten proteins. As a result, new bonds will not be formed due to strong intramolecular electrostatic repulsive forces (CLARKE & ARENDT 2005).

Also, significant differences were found in the degree of softening between the flours. The white flour showed a significantly higher degree of soften-

ing than the wholemeal flour after 10 and 20 min ($P < 0.05$). As it was evidenced by farinogram results, the degree of dough softening was increased by increasing the level of SD sourdough addition (Table 1), in agreement with the findings of CLARKE *et al.* (2002) using sourdoughs. They reported that the biologically acidified sourdoughs had a significantly higher degree of softening than the chemically acidified sourdoughs. However, the softening degree of doughs containing 15% SD sourdough was determined to be higher than that of the others.

Extensograph. The results of extensograph analysis are documented in Table 2. Statistical analysis showed that the energy value was not significantly affected by different levels of SD sourdough. The addition of SD sourdough to the white flour significantly reduced its dough extensibility (E) compared to the control ($P < 0.05$). Incorporation of SD sourdough to the wholemeal flour also decreased the dough extensibility but the differences among the treatments were not significant (Table 2). However, the effect of SD sourdough on the white flour dough extensibility was higher than that on the wholemeal flour dough. It might be due to the higher buffering capacity of wholemeal flour. Previous studies by CLARKE *et al.* (2002) showed a significant reduction in dough extensibility with lactic acid and also sourdough from a mixed-strain starter culture, which did not have the same effect in dough with single-strain sourdough addition. A slight decrease in extensibility and deformation energy of the dough containing dehydrated sourdough was also reported by KULP and LORENZ (2003).

There were significant differences ($P < 0.05$) between the flours with regard to resistance to extension (R_{\max}). The resistance to extension in

Table 2. Extensograph parameters of doughs with different levels of spray-dried sourdough: A – white flour and B – wholemeal flour

Parameters		Control	3%	6%	9%	15%
R_{\max} (BU)	A	233.00 ± 6.05 ^b	341.67 ± 45.00 ^{ab}	366.13 ± 8.08 ^{ab}	428.83 ± 48.38 ^a	427.53 ± 25.71 ^a
	B	241.40 ± 1.40 ^d	369.15 ± 24.10 ^b	316.03 ± 51.06 ^c	393.80 ± 28.16 ^a	404.03 ± 38.34 ^a
Extensibility (mm)	A	127.25 ± 1.35 ^a	108.85 ± 7.95 ^b	100.58 ± 13.41 ^b	94.4 ± 13.92 ^b	77.35 ± 7.38 ^c
	B	68.30 ± 0.70 ^a	62.05 ± 2.05 ^{ab}	62.60 ± 5.14 ^{ab}	60.85 ± 2.77 ^{ab}	55.65 ± 4.59 ^b
Energy (cm ²)	A	44.60 ± 0.50 ^a	46.15 ± 5.85 ^a	40.67 ± 9.69 ^a	46.78 ± 6.98 ^a	41.00 ± 2.49 ^a
	B	21.20 ± 0.40 ^b	29.93 ± 1.13 ^a	25.68 ± 2.12 ^{ab}	30.43 ± 2.82 ^a	28.12 ± 2.81 ^{ab}

R_{\max} – maximum resistance; means with similar letters within the same row are not significantly different ($P < 0.05$)

both flours containing SD sourdough was higher than that of the control (Table 2). This is contradictory to the findings of ESTEVE *et al.* (1994) and GOCMEN *et al.* (2007). They determined that as the sourdough level increased, the resistance to extension decreased. However, the proteolytic activity of starter cultures used for the preparation of these sourdoughs and consequently gluten degradation might cause a loss of resistance to extension. Therefore, our results showed that a drop in pH value due to adding SD sourdough can cause an opposite effect in dough rheology. Our results are in agreement with the findings of TANAKA *et al.* (1967), who reported that the addition of acid, in the presence of salt, increased dough resistance.

There were significant differences ($P < 0.05$) between the flours regarding energy values. The energy value of the wholemeal flour was lower than that of the white flour due to its higher extraction rate (Table 2). The results showed that there was no significant difference in energy values among the levels of SD sourdough.

CONCLUSIONS

The addition of SD sourdough had a significant impact on flour characteristics and the rheological properties of wheat flour dough. The obtained data showed that incorporating SD sourdough to flour led to a decrease in wet gluten and sedimentation value. A significant increase in water absorption and degree of softening and a remarkable decrease in stability were also observed in all doughs containing SD sourdough. In addition, dough extensibility was decreased and resistance to extension was increased in the blend doughs. This indicated major changes in the dough structure which were caused by low pH.

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Corresponding author:

Dr SEYED HADI PEIGHAMBARDUST, University of Tabriz, College of Agriculture, Department of Food Science, Tabriz 5166616471, I.R. Iran; E-mail: peighambardoust@tabrizu.ac.ir
