

Soy sourdough fermented by lactic acid bacteria starter (*L. plantarum*, and *L. sanfranciscensis*) concentration effect on dough fermentation, textural and shelf life properties of wheat bread

Abstract

Soy sourdough fermented by lactic acid bacteria (LAB), *Lactobacillus plantarum* and *Lactobacillus sanfranciscensis*, added at 10 and 30% effect on dough fermentation, textural and shelf life properties of wheat bread was investigated. The sourdough formula (100g soy flour, 130g of water (dough yield, 230), fermentation time of 30h) used exhibited angiotensin-I inhibitory activity and emulsifying properties in a recent study.

The LAB count was adequate and similar for all samples after mixing and proofing stages, but increased ($p < 0.05$) by one log cycle for SDLS30 compared to SDLP30. Dough development parameters were lowered ($p < 0.05$) by sourdough addition especially the 30%. However, LAB strain used had no effect on these properties. A mixed trend was observed for the gaseous release when sourdough was added compared to the control sample. Hardness and chewiness values at 10% sourdough addition was lower ($p < 0.05$) than control, but higher ($p < 0.05$) at 30%. Compared to the control bread, a mixed effect on specific volume was observed with increase in sourdough concentration. The moisture content at start of storage was highest ($p < 0.05$) for bread with 30% then 10% sourdough and least in control. However, increase in storage time decreased the moisture content of all samples. For hardness, except for breads with 30% sourdough fermented by *L. plantarum*, all sourdough breads had lower values compared to control. Chewiness values for the sourdough breads were lower than the control bread. These findings have shown the beneficial role played by soy flour sourdough fermentation in bread quality improvement.

Keywords: soy sourdough, lactic acid bacteria, dough fermentation properties, textural properties, shelf life, bread

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Research highlights

- i. Dough development parameters (T1 and Hm) decreased ($p < 0.05$) compared to the control.
- ii. H'm; SDLS10 and SDLP30, higher ($p < 0.05$) than control, R3; SDLS30 and SDLP10, similar to control.
- iii. Hardness, chewiness: at 10% addition lower ($p < 0.05$) than control, higher ($p < 0.05$) at 30%.
- iv. Apart from SBLP10, all sourdough breads had similar or higher specific volume than control.
- v. Anti-staling sourdough effect: maintain high moisture content, low hardness and chewiness values

Introduction

Consumer preference for nutritious and healthy foods has not only posed new challenges to the baking industry, but encouraged development of new and novel bakery products. Market research and development trends for alternative cereals such as buckwheat or legume flours such as soy flour or in combination with wheat flour such as soy wheat flour in the baking industry have continued to rise.^{1,2} This

has primarily been done to compensate the wheat flour deficiencies.³ For instance, soybean a rich source of quality vegetable proteins has been used to improve the nutritional and functional properties⁴ of the end product. However, in wheat bread preparation, addition of both low and high levels of alternative flours such as soy flour has been associated with a decline in bread quality parameters like loaf volume, poor crumb characteristics⁵⁻⁷ and overall lowering acceptability. Therefore, the use of techniques such as fermentation and enzyme treatment have been explored to improve their functionality.

Sourdough, a leavening bread agent in ancient times, is now used industrially to improve technological and functional properties of baked products. This shift that has enabled development of novel fermentation products, technologies and starter cultures with defined metabolic properties.^{8,9} Sourdough addition in bread has been found to positively improve the flavour, textural, anti-staling and biological value of the end product. All resulting from microbial and enzymatic conversions associated with the lactic acid bacteria and yeasts during sourdough fermentation.^{9,10} During sourdough fermentation, microbial metabolism creates a favourable acidic environment which activates numerous enzymes produced by the LAB proteolytic system thus enable synthesis of microbial metabolites.¹¹ The metabolites released

during and after fermentation are responsible for the sourdough functionalities observed in baked products.^{11–15}

In our previous study,¹⁶ soy flour enriched with wheat bran sourdough fermented by two selected LAB strains (*Lactobacillus plantarum* and *Lactobacillus sanfranciscensis*) was found to enhance the inhibition of angiotensin-I converting enzyme (ACE-I) activity, an enzyme in the renin-angiotensin system (RAS) and the emulsifying properties. Two formulas, S₁: 60g of tap water (dough yield, 160), 97g of soy flour, 3g of wheat bran, fermentation time of 30h, S₂: 130g of tap water (dough yield, 230), 100g of soy flour, but without wheat bran, fermentation time 12h were used. However, S₂ formula was significantly ($p < 0.05$) superior to S₁ in both properties. The aim of this study was therefore to investigate the effect of addition of soy sourdough (S₂) fermented by *L. plantarum* and *L. sanfranciscensis* starters on dough fermentation and textural properties of wheat bread. Also, the moisture content and changes in crumb firmness as a measure of shelf were determined at three storage points. Two sourdough concentrations of 10% and 30% were used in bread preparation.

Materials and methods

Soy flour (defatted) and wheat flour were used for sourdough and sourdough bread preparation respectively. Both were purchased from the local market, no information provided on cultivar type. The proximate composition for soy and wheat flour (dry basis) was 7.9% and 12.4% moisture content, 4.3% and 0.55% ash and 43.9% and 12.4% crude protein, according to AACCI (2010) methods 44-15A, 08-01, and 46-12, respectively. All chemical reagents used were of analytical grade.

Microorganisms, growth conditions and inoculum preparation

Two strains of lactic acid bacteria of *Lactobacillus plantarum* and *Lactobacillus sanfranciscensis* previously isolated from different sourdoughs were used in this study. The strains were used singly as culture starters in sourdough fermentation. The strains were cultivated in MRS broth and incubated at 30°C for 24h and cultured to their late exponential phase. Biomass was collected by centrifugation at 5000 rpm for 10min at 4°C, the supernatant was discarded, the residue washed twice in NaCl solution (0.85%, w/v) and suspended in tap water for use as starter culture in sourdough.

Soy flour Sourdough fermentation

The sourdough was prepared using tap water, soy flour, and LAB inoculum. Based on our previous study,¹⁶ the sourdough formula used in this study was; 130g of tap water (dough yield, 230), 100g of soy flour, LAB inoculum (*L. plantarum* and *L. sanfranciscensis*) added and fermented at 30°C for 30h.

Sourdough bread preparation

The ingredients for sourdough bread were added based on percentage wheat flour. The sourdough bread recipe included; 500g of wheat flour, 8.75g of NaCl, 6.25g of instant dry yeast (*S. cerevisiae*), 300g of water, 15g of sugar and sourdough fermented by *L. plantarum* and *L. sanfranciscensis* added at 10(50g) and 30% (150g). After ingredient weighing, mixing was done in a spiral mixer (Sinmag Bakery Equipment, Wuxi Co., Ltd., Wuxi, Jiangsu, China) in two steps. In the first step, all ingredients except the sourdough were mixed for 3min low speed and 3.5min high speed. In the second step,

the sourdough inoculum was added and altogether the ingredients were mixed for 0.5min low speed and 3min high speed. The overall mixing time was 3.5min at low speed and 6.5min high speed. The dough was then divided into 100g each by Sinmag bread divider (Sinmag Bakery Equipment, Wuxi Co., Ltd., Wuxi, Jiangsu, China). Dough pieces were optimally proofed for 60min at 38°C and 85% relative humidity in an electric proofer (Sinmag Bakery Equipment, Wuxi Co., Ltd., Wuxi, Jiangsu, China) and baked for 25min in an electric oven (Sinmag Bakery Equipment, Wuxi Co., Ltd., Wuxi, Jiangsu, China). The oven temperature used were; top and bottom, 180°C and 200°C respectively. The control bread was fermented with active dry yeast without sourdough added. Each dough treatment was prepared in duplicate.

pH, Total Titratable Acidity (TTA) and microbial counts of samples

The pH and TTA values of samples were determined in 10g of sample, which were homogenised with 90mL of distilled water. The TTA was expressed as the mL of 0.1N NaOH needed to achieve a pH of 8.6. The microbial counts in the samples analysed were determined in 10g of sourdough samples, which were homogenised with 90 ml NaCl (0.85%, w/v). Followed by serial dilutions and plating appropriate dilutions on MRS agar for 48h at 30°C (*L. plantarum* and *L. sanfranciscensis*). Colonies between 35 and 350 were counted. All tests were performed in duplicate.

The samples to be analysed were collected from the sourdough after inoculation with the LAB strains, after sourdough fermentation (30h at 30°C), after dough mixing with other ingredients, and after dough proofing. All experiments were performed in triplicate.

Fermentation properties of the dough

A Rheofermentometer F3 (Chopin, Villeneuve-La-Garenne Cedex, France) was used to measure the final dough fermentation T1; maximum dough fermentation height Hm; maximum gas fermentation height H'm; total gas volume R1; retention volume R2 and retention coefficient R3, using the method described by Kim et al.¹⁷ Briefly, a dough piece (300g) was placed in a movable basket of the gas meter with a 2000g cylindrical weight, and the cover of the vat was fitted tightly with an optical sensor. The test was conducted at 38°C for 3h. All experiments were performed in triplicate.

Texture Profile Analysis (TPA) of sourdough breads

The textural characteristics of the sourdough bread was measured 2 h after baking using a Texture Pro CT V 1.4 Build 17 (Brookfield Engineering Laboratory, Middleboro, MA, USA) equipped with an aluminium 36mm diameter cylindrical probe. The breads were sliced transversely using an electric bread slicer (Sinmag Bakery Equipment, Wuxi Co., Ltd., Wuxi, Jiangsu, China) to obtain uniform slices of 12.5mm thickness each. The slices from the centre of each loaf were used to evaluate crumb texture. A stack of 2 slices (25mm total) was prepared and compressed to 50% its original thickness. The test conditions were pre-test speed, 2mm/sec; test speed, 0.5mm/sec; return speed, 0.5mm/sec; and trigger load, 7g. The parameters obtained and recorded are; hardness, adhesiveness, resilience, cohesiveness, chewiness, springiness and gumminess. Each sample was measured twice and the final result was an average.

Bread weight, bread volume and specific volume of bread

The loaf volume was measured using the seed displacement method according to AACC method (AACC 10-05.01). The cooled bread loaves were placed in a container of known volume into which rapeseeds were run until the container was full. The volume of seeds displaced by the loaf was considered as the loaf volume. Bread specific volume was calculated according to the following formula:

$$B.S.V = \text{Loaf volume} / \text{Loaf weight.}$$

Specific volume was expressed as mL/g.

Moisture content as a measurement of shelf life

The moisture content of the samples was determined by the gravimetric method. The bread samples were stored and analysed after 0, 2, 7 days of storage. Briefly, the bread samples were oven dried at 100°C and accurately weighed at regular time intervals until constant weight was reached. Three measurements were performed for each sample. The moisture content was expressed as grams of water over grams of total weight (g/100g).

Crumb hardness and chewiness as a measurement of shelf life

The crumb hardness and chewiness of bread were tested using the Texture Pro CT V 1.4 Build 17 (Brookfield Engineering Laboratory, Middleboro, MA, USA) at different storage periods (0, 2, 7 days). The same procedure used in texture profile analysis above was used.

Statistical analysis

Experimental results are reported as mean value \pm standard deviation. Experimental results were analysed with one way ANOVA and Duncan's test for pair comparisons of treatment means at $p \leq 0.05$ using SPSS software (SPSS Inc. 17.0, Chicago). All treatments were performed at least in duplicate.

Results and discussion

The physicochemical characteristics of the sourdough and dough

The pH, TTA and microbial counts results of the sourdough and dough samples fermented by *L. plantarum* and *L. sanfranciscensis* are presented in Table 1. The pH ranged from 4.2 to 6.7. At the time of inoculation, the pH was highest ($p < 0.05$), followed by a rapid decrease after fermentation where the pH reported was lowest ($p < 0.05$). However, after mixing and proofing, the pH value ranged from 4.4 to 5.1 for all samples. Sourdough concentration significantly affected the pH of sourdough after mixing, but LAB strain used had no effect. Increase in sourdough concentration significantly decreased ($p < 0.05$) the pH of the samples after mixing. A similar trend was observed after proofing, however, in this case, the LAB strain used had significant effects ($p < 0.05$) on the pH. The pH of sourdough based on the process and starter culture used, generally ranges from 3.5 to 4.3,^{10,18} however, depending on the rate of sourdough addition, the pH may vary.¹⁹ Therefore, the sourdough samples after proofing were adequately acidified prior to the baking stage of sourdough bread. The TTA ranged from 4.6-41.5 mL, and followed the same but negative trend as the pH for all the samples at the different time intervals.

LAB count ranged from 3.95×10^6 to 8.4×10^{10} colonies forming units per gram of sample (Table 1). The highest count was observed after fermentation, followed by after inoculation, but similar counts were seen after mixing and proofing (Table 1). At higher sourdough concentration, the LAB count significantly increased ($p < 0.05$) for dough samples after mixing and proofing, with SD_{LS30} dough samples increasing ($p < 0.05$) by one log cycle compared to SD_{LP30} samples. All dough samples with *L. sanfranciscensis* fermented sourdough had higher counts than *L. plantarum* fermented sourdough. The dough samples in this study were considered to have adequate cell density for fermentation to take place. LAB counts after baking of bread were too few to count, hence, not included. This might be due to the high baking temperature which denatured and killed all viable forms of the bacteria.²⁰

Effect of sourdough concentration on the dough fermentation properties

Sourdough addition significantly lowered ($p < 0.05$) the final dough fermentation time and height of bread dough compared to the control sample (Table 2). Sourdough concentration significantly lowered ($p < 0.05$) the dough development parameters for all samples. However, LAB strain used had no effect on these properties. A mixed trend in the results was observed for the gaseous release when sourdough was added compared to the control sample. The maximum gas fermentation height was highest in SD_{LS10} followed by and SD_{LP30} and C_0 , and lowest in SD_{LS30} and SD_{LP10} . The control (C_0) and SD_{LS10} had significantly similar and high ($p < 0.05$) total gas volume compared to SD_{LS30} and SD_{LP10} which were significantly low ($p < 0.05$) (Table 2). However, the control dough (C_0) significantly ($p < 0.05$) retained its gas volume as indicated by the high retention coefficient of 97.1% followed by dough of SD_{LS30} and SD_{LP10} at 94.5% and 91.2% respectively. Dough samples of SD_{LP30} and SD_{LS10} had the lowest coefficient. This might be attributed to the decrease in the amount of wheat flour caused by addition of sourdough, hence diluting the gluten network. The decline of dough fermentation height might be due to a decrease in gas production and immoderate tenacity that prevents extension as well as lowering gluten matrix development.²¹⁻²³

Effect of sourdough concentration on the texture of bread

The effect of sourdough concentration on the bread crumb texture is represented in Table 3 (hardness, resilience, cohesiveness, springiness, gumminess and chewiness). During the bread preparation step of mixing, the water added to wheat flour enables the formation of a strong gluten protein network through stretched and bonded protein strands. However, starch granules remain trapped within the protein matrix.²⁴ A fully developed gluten network gives bread a unique structure and texture, hence resulting in optimum loaf volume and palatability.²⁵ Addition of soy flour sourdough fermented by either *L. plantarum* or *L. sanfranciscensis* at different concentrations had less significant effect on the texture properties especially at low ($p > 0.05$) compared to higher concentrations ($p < 0.05$). The results are in agreement with previous studies where addition of sourdough improved the texture properties of bread.^{10,26} Higher bread values of hardness and chewiness are associated with poor bread quality.²⁷ Therefore, Table 3 results indicate SB_{LP30} followed by SB_{LS30} bread samples are of poor quality relative to others. This might be related to the increasing sourdough concentration which has been found to negatively affect bread texture quality.¹⁹

Effect of sourdough concentration on the specific volume of bread

Generally, compared to the control bread, increase in sourdough concentration had a mixed effect on the bread specific volume (BSV) (Table 4). This may be due the extreme effect of acidification known to decrease bread volume.¹⁹ For sourdough breads fermented by *L. plantarum*, the BSV significantly increased ($p < 0.05$) with increase in

sourdough concentration (Table 4). This could be due to the effect of *L. plantarum* fermentation on wheat bran added to the sourdough. This might have produced other functionally active metabolites⁹ that countered the negative effect of acidification. However, more studies may be required to fully explain this trend. However, sourdough breads fermented by *L. sanfranciscensis*, BSV significantly decreased with increase in sourdough concentration, but interestingly the BSV values were similar to the control samples.

Table 1 pH, TTA and microbial count of sourdough and dough samples¹

| Time intervals | Sample ² | pH | TTA ³ (ml) | CFU/g |
|--------------------|---------------------|-------------------------|-------------------------|-------------------------------------|
| At inoculation | SD _{LS} | 6.48±0.042 ^a | 9.15±0.354 ^a | 3.95x10 ⁶ ^a |
| | SD _{LP} | 6.71±0.007 ^b | 8.40±0.141 ^a | 7.4x10 ⁶ ^b |
| After fermentation | SD _{LS} | 4.24±0.007 ^b | 41.5±1.273 ^a | 8.408x10 ¹⁰ ^a |
| | SD _{LP} | 4.21±0.000 ^a | 39.2±0.283 ^a | 5.30x10 ⁸ ^a |
| | SD _{LS10} | 5.12±0.042 ^b | 4.60±0.141 ^a | 2.785x10 ⁷ ^a |
| After mixing | SD _{LS30} | 4.69±0.007 ^a | 9.45±0.636 ^c | 1.62x10 ⁸ ^c |
| | SD _{LP10} | 5.12±0.035 ^b | 6.45±0.212 ^b | 1.305x10 ⁷ ^a |
| | SD _{LP30} | 4.68±0.021 ^a | 11.3±0.424 ^d | 6.5x10 ⁷ ^b |
| | SD _{LS10} | 4.62±0.000 ^c | 8.55±0.071 ^a | 2.255x10 ⁷ ^a |
| After proofing | SD _{LS30} | 4.50±0.000 ^b | 10.3±0.354 ^c | 1.66x10 ⁸ ^c |
| | SD _{LP10} | 4.85±0.021 ^d | 9.15±0.071 ^b | 1.155x10 ⁷ ^a |
| | SD _{LP30} | 4.43±0.000 ^a | 10.4±0.707 ^c | 8.8x10 ⁷ ^b |

¹Means (n=4±standard deviation) with different superscripts in the same column indicate significant differences at $p < 0.05$. ²SD_{LP} and SD_{LS}: sourdough fermented by *L. plantarum*, and *L. sanfranciscensis* respectively. SD_{LP10} and SD_{LP30}: bread dough having sourdough started by *L. plantarum* at 10 and 30 % addition rate, respectively, SD_{LS10} and SD_{LS30}: bread dough having sourdough started by *L. sanfranciscensis* at 10 and 30 % addition rate, respectively. ³TTA = Total Titratable Acidity; CFU/g total bacteria count (lactic acid bacteria) in MRS agar.

Table 2 Fermentation properties of sourdough bread dough samples¹

| Sample ² | Dough development ³ | | Gaseous release ⁴ | | | |
|---------------------|--------------------------------|------------------------|------------------------------|---------------------------|-----------------------------|-------------------------|
| | T1 (min) | Hm (mm) | H'm (mm) | R1 (mL) | R2 (mL) | R3 (%) |
| SD _{LS10} | 126±10.1 ^b | 70.9±0.75 ^b | 87.1±3.05 ^c | 1731.7±33.1 ^c | 1718.67±63.01 ^d | 78.5±3.63 ^a |
| SD _{LS30} | 92.3±6.35 ^a | 43.7±0.76 ^a | 78.2±5.20 ^{ab} | 1377.7±56.6 ^{ab} | 1227.67±28.73 ^{ab} | 94.5±1.95 ^{bc} |
| SD _{LP10} | 141±12.5 ^b | 68.1±0.89 ^b | 70.8±1.56 ^a | 1345±2.7 ^a | 1197.67±66.50 ^a | 91.2±1.55 ^b |
| SD _{LP30} | 89.7±16.0 ^a | 45.2±3.48 ^a | 83.3±6.54 ^{bc} | 1436.3±45.0 ^b | 1357.67±48.00 ^c | 83.4±4.09 ^a |
| C ₀ | 178±2.9 ^c | 83.5±0.93 ^c | 81.3±2.70 ^{bc} | 1769.3±54.2 ^c | 1301±28.81 ^{bc} | 97.13±0.64 ^c |

¹Data are represented as means±SD (n=2), different letters in a column are significantly different at $P < 0.05$. ²SDLP10 and SDLP30: bread dough having sourdough started by *L. plantarum* at 10 and 30 % addition rate, respectively, SDLS10 and SDLS30: bread dough having sourdough started by *L. sanfranciscensis* at 10 and 30 % addition rate, respectively. C₀: control dough sample without added sourdough. ³T1: final dough fermentation, Hm: maximum dough fermentation height. ⁴H'm: maximum gas fermentation height, R1: Total gas volume, R2: Retention volume, R3: retention coefficient.

Table 3 Texture properties of sourdough bread and control samples

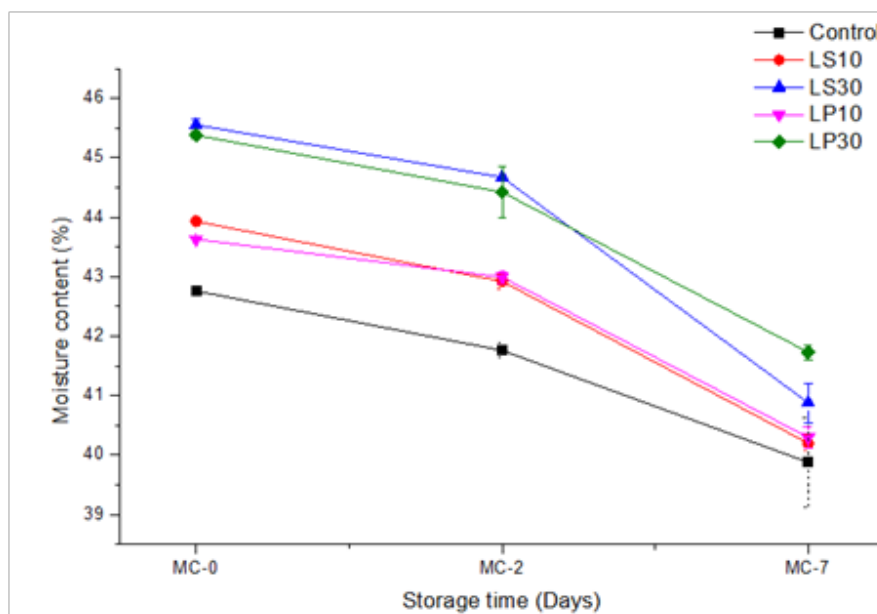
| Sample | Hardness | Resilience | Cohesiveness | Springiness | Gumminess | Chewiness |
|--------------------|------------------------|-------------------------|------------------------|-------------------------|-------------------------|--------------------------|
| SB _{LS10} | 335±19.8 ^a | 7.53±0.16 ^{ab} | 0.86±0.01 ^b | 0.47±0.01 ^{ab} | 295±20.5 ^a | 21.9±1.91 ^a |
| SB _{LS30} | 574±74.3 ^{bc} | 7.54±0.00 ^b | 0.83±0.00 ^a | 0.49±0.01 ^b | 477±58.7 ^{bc} | 35.3±4.31 ^{bc} |
| SB _{LP10} | 497±31.8 ^{ab} | 7.50±0.06 ^{ab} | 0.87±0.01 ^b | 0.46±0.01 ^{ab} | 432±22.6 ^{abc} | 31.8±1.91 ^{abc} |
| SB _{LP30} | 698±146.4 ^c | 7.41±0.01 ^{ab} | 0.83±0.01 ^a | 0.47±0.00 ^{ab} | 582±112.4 ^c | 42.3±8.77 ^c |
| C ₀ | 476±5.66 ^{ab} | 7.45±0.12 ^a | 0.86±0.02 ^b | 0.45±0.00 ^a | 411±5.66 ^{ab} | 29.8±0.01 ^{ab} |

Data are represented as means ±SD (n=2), different letters in a column are significantly different at P<0.05. SB_{LP10} and SB_{LP30}: bread having sourdough started by *L. plantarum* at 10 and 30 % addition rate, respectively, SB_{LS10} and SB_{LS30}: bread having sourdough started by *L. sanfranciscensis* at 10 and 30 % addition rate, respectively. C₀: control bread sample without added sourdough.

Table 4 Sourdough bread specific volume

| | Samples | | | | |
|-------------|-------------------------|--------------------------|------------------------|-------------------------|-------------------------|
| | SB _{LS10} | SB _{LS30} | SB _{LP10} | SB _{LP30} | C ₀ |
| Weight (g) | 87.0 ±0.68 ^a | 86.9±0.49 ^a | 88.8±0.48 ^b | 86.8±1.10 ^a | 89.0±0.04 ^b |
| Volume (ml) | 363±17.68 ^c | 321±24.79 ^{ab} | 290±7.07 ^a | 305±0.00 ^{ab} | 335±7.07 ^{bc} |
| BSV (ml/g) | 4.17±0.24 ^c | 3.69±0.31 ^{abc} | 3.27±0.06 ^a | 3.51±0.04 ^{ab} | 3.76±0.08 ^{bc} |

Data are represented as means±SD (n=2), different letters in a column are significantly different at P<0.05. SBLP10 and SBLP30: bread having sourdough fermented by *L. plantarum* at 10 and 30 % addition rate, respectively, SBLS10 and SBLS30: bread having sourdough started by *L. sanfranciscensis* at 10 and 30 % addition rate, respectively. C0: control bread sample without added sourdough.



Data are represented as means±SD (n=3). SB_{LP10} and SB_{LP30}: bread having sourdough started by *L. plantarum* at 10 and 30 % addition rate, respectively, SB_{LS10} and SB_{LS30}: bread having sourdough started by *L. sanfranciscensis* at 10 and 30 % addition rate, respectively. MC-0, MC-2 and MC-7: moisture content after zero, two and seven days of storage, respectively.

Figure 1 Effect of addition of soy sourdough concentration on moisture content of wheat bread during storage.

Effect of sourdough addition and concentration on moisture content of bread during storage

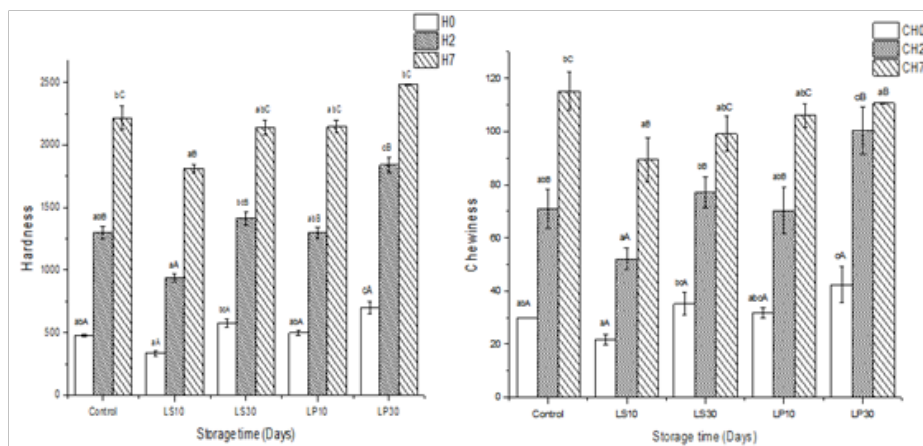
In most baked goods such as bread, the time between baking and consumption is known to be very short.²⁸ With increase in storage time, the outer crumb has been reported to lose its moisture to the crust,²⁹ thereby increasing the hardness and chewiness values of bread.²⁷ This phenomenon, referred to as staling, is complex and still not fully understood.^{30–32} The staling process occurs both in the crumb and crust. In this study, soy sourdough were added at two concentration (10 and 30%) and their effects were evaluated on three parameters of moisture content, hardness and chewiness at three storage times of 0, 2 and 7 days.

The addition of soy sourdough fermented by either *L. plantarum* or *L. sanfranciscensis* at different concentrations resulted in higher moisture content in the final bread compared to the control (Figure 1). At the start of the storage period (zero days), the moisture content of sourdough breads was significantly higher ($p < 0.05$) than control bread in the range of 43.9–45.6% and 42.8%, respectively. Generally, increase in the storage time decreased ($p < 0.05$) the moisture content for both the sourdough bread and the control as shown in Figure 1 to values in the range of 40.2–41.73 and 39.88% respectively. Sourdough concentration had a significant ($p < 0.05$) effect on moisture content at all storage times. In that breads with 30% added sourdough (LP30 and LS30) had the highest values followed by those with 10% added sourdough (LP10 and LS10) and the least was the control. Strain type had a less significant effect on moisture at the start of the storage period but became more significant with increase in storage period. The results observed suggest sourdough breads had much higher moisture contents during storage and in theory might be fresher than the control bread. This is in agreement with by Torrieri et al.¹⁹ reported that high sourdough concentration in bread positively improved the

volume, mechanical properties and had higher moisture contents during storage period. This was further attributed to metabolites produced such as exopolysaccharides^{19,33} which were able to reduce redistribution of moisture in the bread thereby keeping the moisture content in the crumb higher than the control over the storage period.

Effect of sourdough addition and concentration on hardness and chewiness of bread during storage

High values of hardness and chewiness have associated with poorer bread quality.²⁷ The effect of storage time on hardness and chewiness of sourdough bread are presented in Figure 2. Compared to the control bread, hardness significantly ($p < 0.05$) increased as storage time increased especially after two days (Figure 2). However, bread with 10% of sourdough fermented by *L. sanfranciscensis* had significantly ($p < 0.05$) lower hardness than the control sample. LS30 and LP10 breads had slightly higher but similar hardness values to the control. After seven days of storage, apart from LP30 bread, all the other breads had significantly lower hardness than the control bread. The chewiness values for the sourdough bread were comparably lower ($p < 0.05$) than the control samples with an increase in storage time, except for LS30 and LP30 at 2 days of storage (Figure 2). This suggested an anti-staling effect of addition of sourdough to bread. Several studies have reported the anti-staling role played by sourdough in bread during storage.^{9,18,19,30} As shown in Table 1, the LAB counts were considered adequate during the mixing and proofing stages for sourdough fermentation to take place to make a contribution to the end product. Hence, microbial and enzymatic conversions during sourdough fermentation were ably achieved. This might have led to the release of metabolites such as exopolysaccharides, organic acids and peptides which contributed to bread quality through anti-staling activity.^{9,19,34} The low pH (Table 1) which created the acidic conditions might have also played a role in reducing the staling rate of bread.



Data are represented as means \pm SD (n=2), different small letters denote significant differences ($p < 0.05$) in the same storage period but different sample; different capital letters denote significant differences ($p < 0.05$) in the same sample but different storage period. LP10 and LP30: bread having sourdough started by *L. plantarum* at 10 and 30 % addition rate, respectively, LS10 and LS30: bread having sourdough started by *L. sanfranciscensis* at 10 and 30 % addition rate, respectively.

Figure 2 Effect of addition of soy sourdough concentration on texture properties (hardness and chewiness) of wheat bread during storage.

Conclusion

Addition of sourdough fermented by *Lactobacillus plantarum* and *Lactobacillus sanfranciscensis* to wheat bread at 10 and 30%, compared to control; had significantly ($p < 0.05$) lowering effects on dough fermentation properties such as dough development and gaseous release parameters as sourdough concentration increased. However, the strain used had no effect. A similar trend was also observed for textural properties and specific volume of the bread.

Sourdough addition to wheat bread significantly increased the moisture content of sourdough bread during storage, hence kept the bread fresh for longer periods. Except for breads with 30% sourdough fermented by *L. plantarum*, for hardness, all sourdough breads showed lower values compared to control. Also, all chewiness values for the sourdough bread were lower than the control bread. These findings have shown the beneficial role played by soy flour sourdough fermentation in bread quality improvement.

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Conflict of interest

The author declares no conflict of interest.

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