



Journal of Food Science and Technology (Iran)

Homepage: www.fsct.modares.ir

Scientific Research

P Investigating the Effect of Adding *Lactobacillus plantarum* and Oat Flour on the Quality Characteristics of Barbari Bread

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ARTICLE INFO

Article History:

Received:2024/9/28

Accepted:2025/4/22

Keywords:

Sourdough,
Lactobacillus plantarum,
bread,
oat flour

DOI: 10.22034/FSCT.22.166.30.

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ABSTRACT

This study investigated the effects of different sourdough formulations and varying replacement levels of wheat flour with oat flour on the technological and sensory properties of bread. The experimental design included nine sourdough formulations (W-Lb, O-Lb, W-O-Lb, W-Sc [control sample], O-Sc, W-O-Sc, W-Lb-Sc, O-Lb-Sc) and four wheat flour substitution levels with oat flour (0%, 5%, 10%, and 15%). The results showed that bread samples without *Lactobacillus plantarum* exhibited the highest moisture content. The presence of *L. plantarum* significantly affected pH, leading to a noticeable reduction. Additionally, sourdough fermented with *L. plantarum* significantly decreased the specific volume of bread compared to the control. Texture profile analysis revealed that sourdoughs containing wheat flour, oat flour, *Saccharomyces cerevisiae*, and *L. plantarum* exhibited the lowest firmness levels, ranging between 2098–3993 gf. In contrast, sourdoughs without *Saccharomyces cerevisiae* showed significantly higher firmness levels (6300–12162 g.f). Sensory evaluations indicated that breads produced with sourdough containing wheat flour, oat flour, *S. cerevisiae*, and *L. plantarum* received the highest overall scores for taste, aroma, texture, appearance, and overall acceptance. Conversely, yeast-free samples received the lowest ratings. Based on these findings, the optimal bread formulation consisted of sourdough containing wheat flour, oat flour, *L. plantarum*, and *S. cerevisiae*, with 15% wheat flour substitution by oat flour.

1-Introduction

The use of sourdough in bread baking has recently received much attention due to the different quality and long shelf life of sourdough products compared to yeast breads. The growing interest in increasing the shelf life of bread using traditional technologies has led the industry and researchers to return to the use of sourdough starter cultures. To optimize sourdough, many factors can be considered, such as the properties of the starter culture, the type of flour, and the ability of microorganisms to excrete enzymes. However, the most important parameter is the appropriate selection of the starter culture [1]. The bakery industry currently tends to start sourdough fermentation with commercially defined starter cultures with specific properties and *Lactobacillus plantarum*. It is one of the most desirable lactic acid bacteria species in sourdough production [2]. Lactic acid bacteria from sourdough, by producing metabolites such as exopolysaccharides and peptides, in addition to technological effects, can affect allergic reactions and intolerance in people sensitive to cereals due to their proteolytic activity [3]. It has been shown that the strain *L. Plantarum* LD4 It ribosomally synthesizes antimicrobial peptides that have potential applications in enhancing the safety of bread [4]. DM616 *L. plantarum* It reduced the hardness and increased the whiteness of steamed bread [5] and the strain *L. plantarum* PON100148 Used in sourdough fermentation, it produced high concentrations of organic acids and increased bread quality parameters [6].

Given the increasing incidence of malnutrition-related diseases, as well as the increase in cardiovascular diseases and diabetes, since bread is the dominant food in our country, enriching bread with oats, considering its nutritional value, is one of the best ways to include this nutrient in the diet. Wheat protein shows low levels of the essential amino acids lysine, valine, and tryptophan [7]. While oat protein shows higher levels of lysine, threonine, tyrosine,

and tryptophan. In addition, oat protein contains soluble fiber fractions that are rich in beta-glucan [8].

Since oat protein is gluten-free, bread produced with oat flour alone does not have desirable organoleptic properties. Therefore, using oat flour together with wheat flour in bread preparation seems more appropriate to achieve the desired quality characteristics. Therefore, the aim of the present study was to investigate the effect of Commercial yeast *Saccharomyces cerevisiae* and ATCC 8014 *L. plantarum* Physicochemical, textural, and sensory properties of semi-solid bread containing wheat flour and oat flour without a cover. This study also evaluates the effect of replacing wheat flour with oat flour at four levels (0, 5, 10, and 15%) on moisture, pH, specific volume, texture firmness, and sensory acceptance of the final product. For this purpose, nine different sourdough formulations containing the following ingredients were investigated:

- W-Lb (wheat flour + *L. plantarum*)
- O-Lb (oat flour + *L. plantarum*)
- W-O-Lb (wheat flour + oat flour + *L. plantarum*)
- W-Sc (wheat flour + *S. cerevisiae*)
- O-Sc (oat flour + *S. cerevisiae*)
- W-O-Sc (wheat flour + oat flour + *S. cerevisiae*)
- W-Lb-Sc (wheat flour + *L. plantarum* + *S. cerevisiae*)
- O-Lb-Sc (oat flour + *L. plantarum* + *S. cerevisiae*)
- W-O-Lb-Sc (wheat flour + oat flour + *L. plantarum* + *S. cerevisiae*)

The results of this research can be used to optimize the formulation of semi-solid and oat-rich breads while maintaining organoleptic quality and consumer acceptance.

2-Materials and methods

1.2-Preparation of microbial strain

Bacteria *Lactobacillus Plantarum* ATCC 8014 It was obtained from the Iranian Industrial Fungi and Bacteria Collection Center and cultured under sterile conditions. MRS broth The inoculated cultures were incubated at 37°C for 24 hours.

2-2-Preparation of microbial suspension for inoculation into sourdough

The required volume of activated *L. plantarum* culture was centrifuged at 8000 rpm for 10 minutes at 4°C. Then, the cell masses were separated from the supernatant and, after washing twice with sterile distilled water, were added to the initial paste substrate [9].

3-2-Preparing sourdough

Sourdough samples were prepared using active bacterial cultures of *L. plantarum* and commercial yeast *S. cerevisiae*. First, water and wheat or oat flour were mixed in the ratios of 100:0, 0:100, and 50:50 to prepare the dough. Then, the selected starter was added in the amount of cfu/ml 10^7 (with McFarland standard) and inoculated with commercial yeast at ratios of 100:0, 0:100 and 50:50. Fermentation was carried out in an incubator at 30°C for 24 hours.

4-2-Baking bread

The different formulas in Table 1 were used to produce bread dough. The addition rates of raw materials including sourdough, salt, sugar, oil, and yeast based on the percentage of flour were 0.6, 0.4, 0.4, 1.15, and 1% of the dough, respectively. The amount of oat flour used was 0, 5, 10, and 15% of wheat flour. The resulting mixture was mixed in a mixer at room temperature after adding water (60% w/w) for 10 minutes. After fermenting 200-gram loaves for 55 minutes at 37°C and 75% relative humidity, the doughs were spread out and reached a final thickness of about 1.5 cm. Then, the loaves were baked at 220°C for 12 minutes. After cooling, the loaves were packaged in polyethylene bags for evaluation [10].

Table 1- Different formulations in the preparation of semi-bulky bread

Treatment	Sourdough	Wheat flour%	Oat flour%
T1	IN- <i>Lb</i>	100	0
T2	O- <i>Lb</i>	100	0
T3	W-O- <i>Lb</i>	100	0
T4 (control)	IN- <i>Sc</i>	100	0
T5	O- <i>Sc</i>	100	0
T6	W-O- <i>Sc</i>	100	0
T7	IN- <i>Lb- Sc</i>	100	0
T8	O- <i>Lb- Sc</i>	100	0
T9	*W-O- <i>Lb- Sc</i>	100	0
T10	IN- <i>Lb</i>	95	5
T11	O- <i>Lb</i>	95	5
T12	W-O- <i>Lb</i>	95	5
T13	IN- <i>Sc</i>	95	5
T14	O- <i>Sc</i>	95	5
T15	W-O- <i>Sc</i>	95	5
T16	IN- <i>Lb- Sc</i>	95	5
T17	O- <i>Lb- Sc</i>	95	5
T18	W-O- <i>Lb- Sc</i>	95	5
T19	IN- <i>Lb</i>	90	10
T20	O- <i>Lb</i>	90	10
T21	W-O- <i>Lb</i>	90	10
T22	IN- <i>Sc</i>	90	10
T23	O- <i>Sc</i>	90	10
T24	W-O- <i>Sc</i>	90	10
T25	IN- <i>Lb- Sc</i>	90	10
T26	O- <i>Lb- Sc</i>	90	10
T27	W-O- <i>Lb- Sc</i>	90	10
T28	IN- <i>Lb</i>	85	15
T29	O- <i>Lb</i>	85	15
T30	W-O- <i>Lb</i>	85	15
T31	IN- <i>Sc</i>	85	15
T32	O- <i>Sc</i>	85	15
T33	W-O- <i>Sc</i>	85	15

T34	IN- <i>Lb- Sc</i>	85	15
T35	O- <i>Lb- Sc</i>	85	15
T36	W-O- <i>Lb- Sc</i>	85	15

*W=wheat flour, O=oat flour, *Lb*=*Lactobacillus plantarum*, *Sc*= *Saccharomyces cerevisiae*

5-2-Physicochemical tests of bread

1-5-2-Measurement pH

For measuring pH according to the standard AACC(2000) No. 21-4 10 g of each sample was mixed with 90 ml of distilled water and the amount pH. This solution with pH meters (Metrohm 827-Switzerland) It was measured [11].

2-5-2-Humidity measurement

Measuring the moisture content of bread according to the standard AACC, 2000 No. 16-44 was carried out. For this purpose, the ground samples were placed in an oven at 105°C for 3 hours at an interval of 2 hours after baking, and their moisture percentage was calculated based on the following formula [11].

Moisture content(%)

= 100

$\times \frac{\text{Bread sample weighed} - \text{dry sample weight}}{\text{Bread sample weight}}$

3-5-2-Measuring the specific volume of bread

Specific volume of bread produced immediately after production in accordance with the standard AACC No. 05-10 was performed by filling a graduated cylinder with flax seeds [11].

6-2-Bread texture test

Bread crumb firmness at 2, 24, 48 and 72 hours after production using a model texturometer TVT-6700. The breads were prepared with a thickness of 25 mm. Then, the penetration test was performed using a cylindrical probe TA41. It was performed at a speed of 1 mm/s and a compression rate of 50% of the total height.

7-2-Sensory evaluation of bread

According to the standard AACC Method 91-10 Twenty trained male and female raters

between the ages of 25 and 35 were selected and the 5-point hedonic method was used. The influencing factors of bread including appearance, smell, taste, texture and overall acceptability were evaluated [11].

8-2-Statistical analysis

The independent variables used in this study included 9 levels of sourdough variable (with different formulas) and 4 levels of independent variable of oat flour amount (0, 5, 10 and 15%), and the parameters under study were also the dependent variables of this study. Treatment T4 was also used as a control sample. All experiments were performed in triplicate. Analysis of the results was performed in the form of a factorial design. Two-way analysis of variance was used to analyze the data. Side ANOVA And to compare the mean of test Duncan and software SPSS Version 22 was used.

3-Results and Discussion

1-3-The effect of flour type and sourdough formula on pH, moisture and volume of bread

The results showed that the lowest pH It was observed in breads produced with sourdough containing *L. plantarum*. The reason for this is that the fermentation activity of *L. plantarum* produces organic acids such as lactic acid, which increases acidity and reduces pH Dough and finally reduction pH Bread is produced. Results Hearing et al. (2021) regarding pH This was consistent with the results of this study [12]. Cakiret al. (2021) also showed that breads produced with sourdough contained *Lactobacillus plantarum*. pH They had less [13].

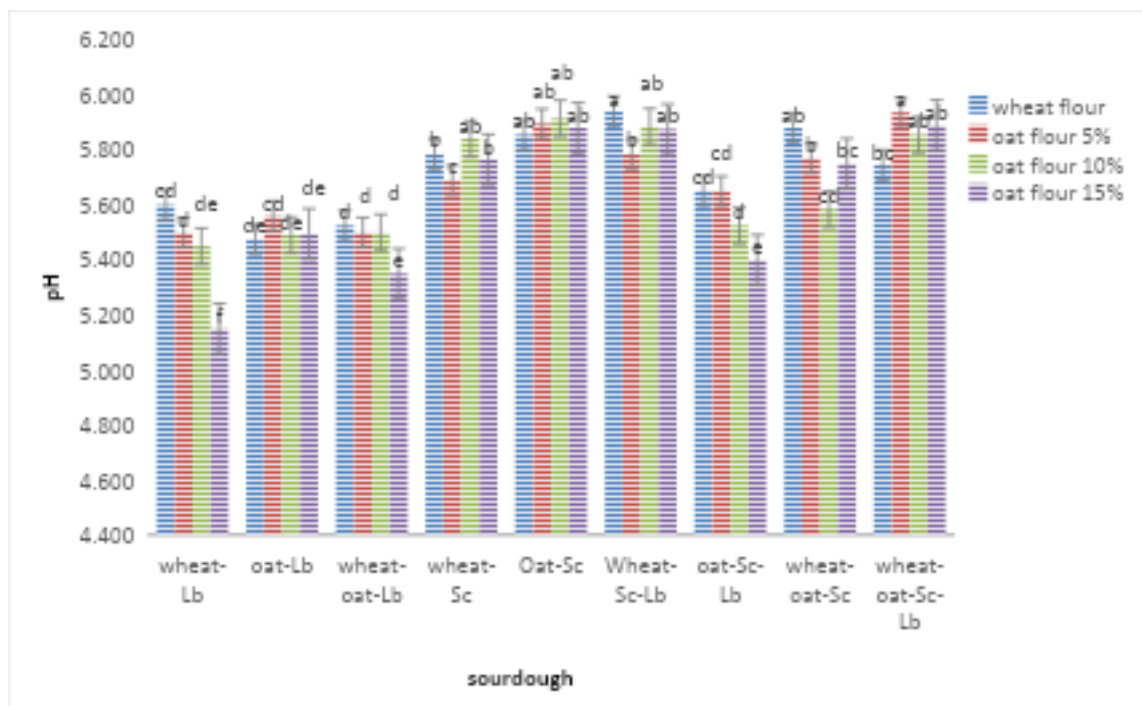


Fig. 1. The interaction effect of sourdough and flour type on the pH of bread

W=wheat flour, O=oat flour, Lb=*Lactobacillus plantarum*, Sc= *Saccharomyces cerevisiae*

The significance level was set at 0.05, and different letters indicate significant differences among the treatments.

The results of variance analysis on the effect of sourdough and oat flour content in the bread formula on moisture content showed that the highest moisture content was in the samples T14 (Content of *S. cerevisiae*, oats and 95% wheat flour) (34.25%) and T5 (Content of *S. cerevisiae*, oats and 100% wheat flour) (33.5%) was observed ($0.05 < p < 0.001$). While the lowest moisture content was found in the samples T26 (Content of *S. cerevisiae*, *L. plantarum*, oats and 90% wheat flour), T27 (Contents: *S. cerevisiae*, *L. plantarum*, oat flour, wheat flour and 90% wheat flour), T35 (Content of *S. cerevisiae*, oat flour and *L. plantarum* and 85% wheat flour) and T36 (Content of *S. cerevisiae*, *L. plantarum*, oat flour, wheat flour and 85% wheat flour) with values of 27.5, 27.35, 27.5 and 27.5% ($0.05 < p < 0.001$) was observed. An examination of the mean results showed that samples lacking *L. plantarum* showed the

highest moisture content. Yeast fermentation increases dough hydration by increasing the water-holding capacity of the dough. As the yeast cells consume sugars and produce metabolites, the dough becomes more flexible and elastic, allowing it to retain more water. This improved hydration results in a softer and moister texture in the baked bread [14]. Results of Ogunsakiet al. (2015) showed that the highest moisture and protein content was observed in sorghum bread produced with baker's yeast [15]. Therdthai and Jitrakbumrung (2014) reported that the moisture content of sourdough bread was 43.60% [16]. Results of Hearing et al. (2021) also showed that the moisture content of bread produced with a mixture of lactic acid bacteria and commercial yeast was 35%, which was the lowest compared to treatments containing commercial yeast alone and lactic acid bacteria alone [12].

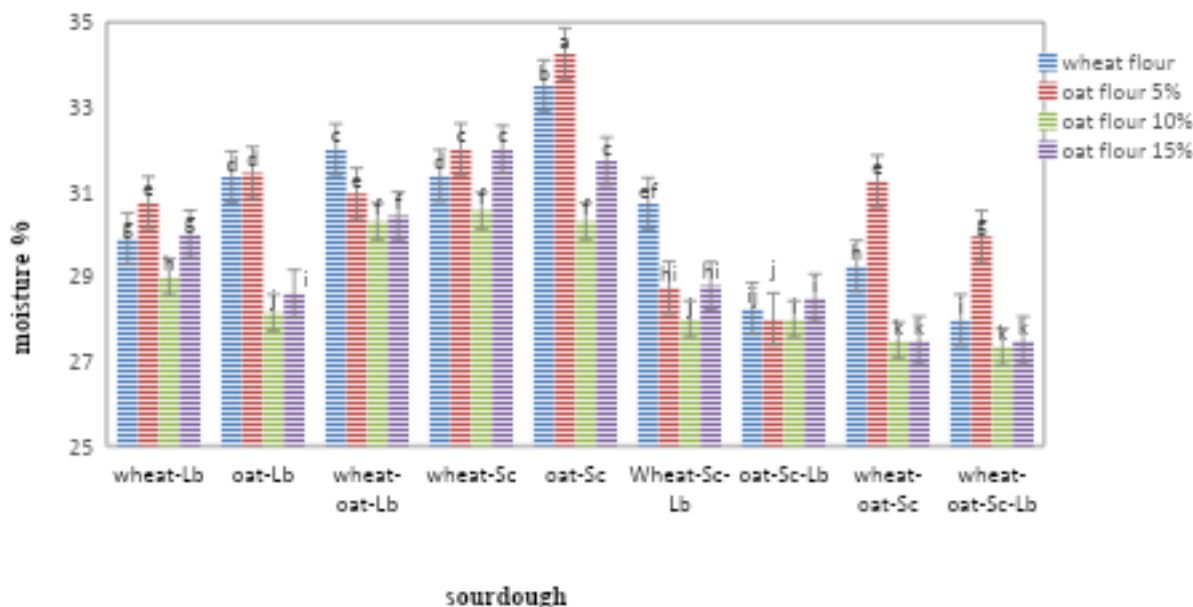


Fig. 2. The interaction effect of sourdough and flour type on the moisture of bread

W=wheat flour, O=oat flour, Lb=*Lactobacillus plantarum*, Sc= *Saccharomyces cerevisiae*

The significance level was set at 0.05, and different letters indicate significant differences among the treatments.

The results showed that bread made from 100% wheat flour and *S. cerevisiae* yeast (control) showed the highest specific volume, while the use of sourdough fermented with *L. plantarum* starter caused a decrease in the specific volume of the bread. Also, breads containing yeast and wheat flour showed a higher specific volume compared to breads containing yeast and oat flour, which is because the gluten in wheat flour may strengthen the network structure of the dough and increase its volume. *S. cerevisiae* is very efficient in fermenting sugars and rapidly producing gas under optimal conditions. This gas is trapped in the dough and causes it to rise and expand during fermentation and baking. The abundant production of carbon dioxide by the yeast leads to increased gas retention in the dough, which leads to a higher specific volume [17]. The decrease in the volume of bread when using sourdough containing *L. plantarum* is

because during the incubation of sourdough and dough fermentation, biochemical changes occur in the carbohydrate and protein components of flour as a result of the action of microbial enzymes. It is possible that the proteolytic activity of lactobacilli that occurs during the incubation period of sourdough and dough fermentation affects gluten proteins and weakens the gluten network, leading to the production of breads with a lower specific volume [18]. Findings Huet al. (2022) showed that breads produced solely with commercial yeast exhibited higher specific volume compared to breads produced with sourdough containing yeast and *L. plantarum* [19]. In a review Cakiret al. (2021) Uncoated barley-wheat bread samples containing starter culture *Lb. plantarum* SAB15⁺ *Lb. brevis* SAB31 and *S. yeast* SAM1-4 Higher specific volume than breads containing spontaneous sourdough¹ They had [13].

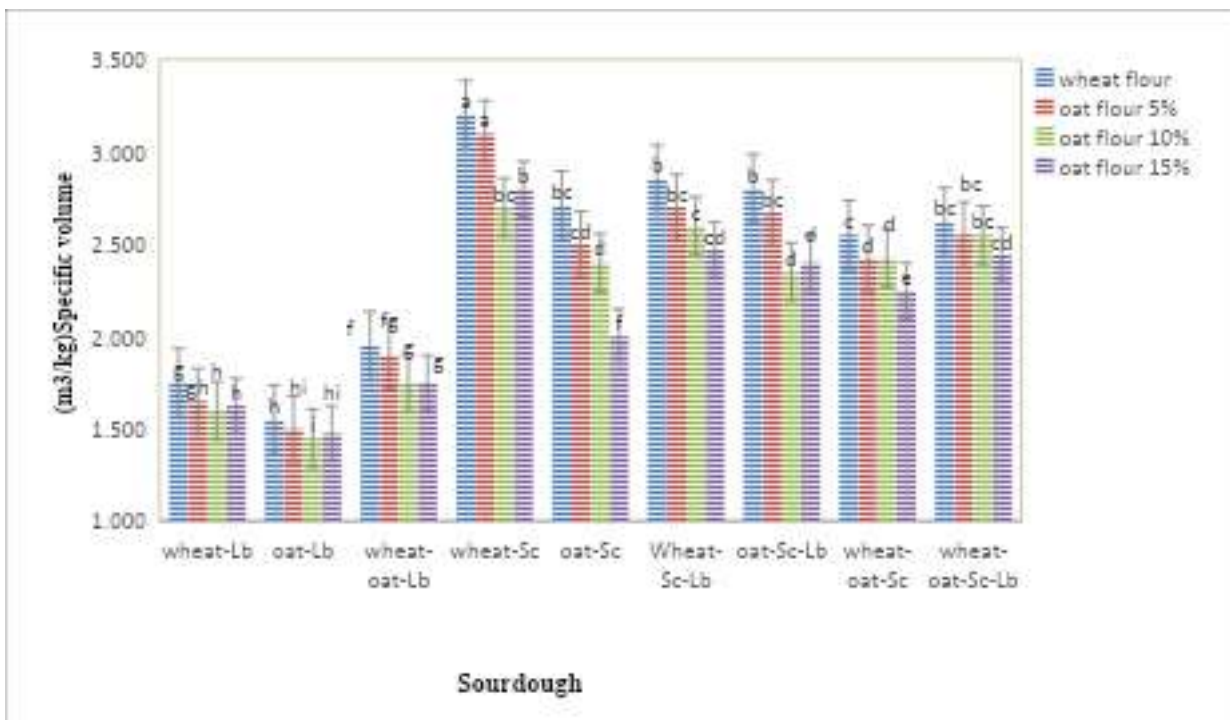


Fig. 3. The interaction effect of sourdough and flour type on the specific volume of bread
W=wheat flour, O=oat flour, Lb=*Lactobacillus plantarum*, Sc= *Saccharomyces cerevisiae*
The significance level was set at 0.05, and different letters indicate significant differences among the treatments.

2.3-Evaluating bread texture

Analysis of the results showed that yeast-free sourdoughs had the highest firmness levels ranging from 6300 to 12162 for 2 to 72 hours, while sourdoughs containing wheat flour, oat flour, *S. cerevisiae*, and *L. plantarum* showed the lowest firmness levels ranging from (3993–2098). During fermentation, yeast affects the development of the gluten network by releasing enzymes that break down proteins into smaller peptides. When gluten is well developed, it contributes to the texture of the bread and makes the bread crumb softer. In yeast-free breads, the lack of gas production and gluten development can lead to a denser and firmer texture [20]. In examining the effect of different formulas on the firmness of bread, it was observed that the firmness of the breads increased with time up to 72 hours. In the first two hours after baking, the lowest firmness was found in the sample containing wheat flour, oat flour, *S. cerevisiae*, and *L. plantarum* the highest stiffness in the sample contained Flour Wheat, Flour Oats and Plantarum. It was observed that this trend

was the same over 72 hours. The reason for the increase in bread texture firmness is related to the decrease in bread moisture and the phenomenon of starch reversion. The increase in firmness of breads containing Flour Wheat, Flour Oats and *L. plantarum* This could be due to the lower specific volume of these breads. Also, the reduction pH Breads containing *L. plantarum* and without yeast, it increases the activity of natural proteases in flour, the activity of proteolytic enzymes present in flour can lead to the breakdown of gluten proteins and a decrease in the strength and integrity of the gluten network. This process reduces the elasticity of the dough, reduces the gas holding capacity, changes the bread texture and increases the stickiness of the dough, all of which can lead to increased bread stiffness and, as a result, faster staleness of these breads [21]. Toet al. (2022) in their study investigated the effect of adding commercial peptidase to wheat bread. Their results showed that adding fluorescein to bread dough increased bread firmness. This confirms the effect of increasing the activity

of proteolytic enzymes in increasing bread firmness [22].

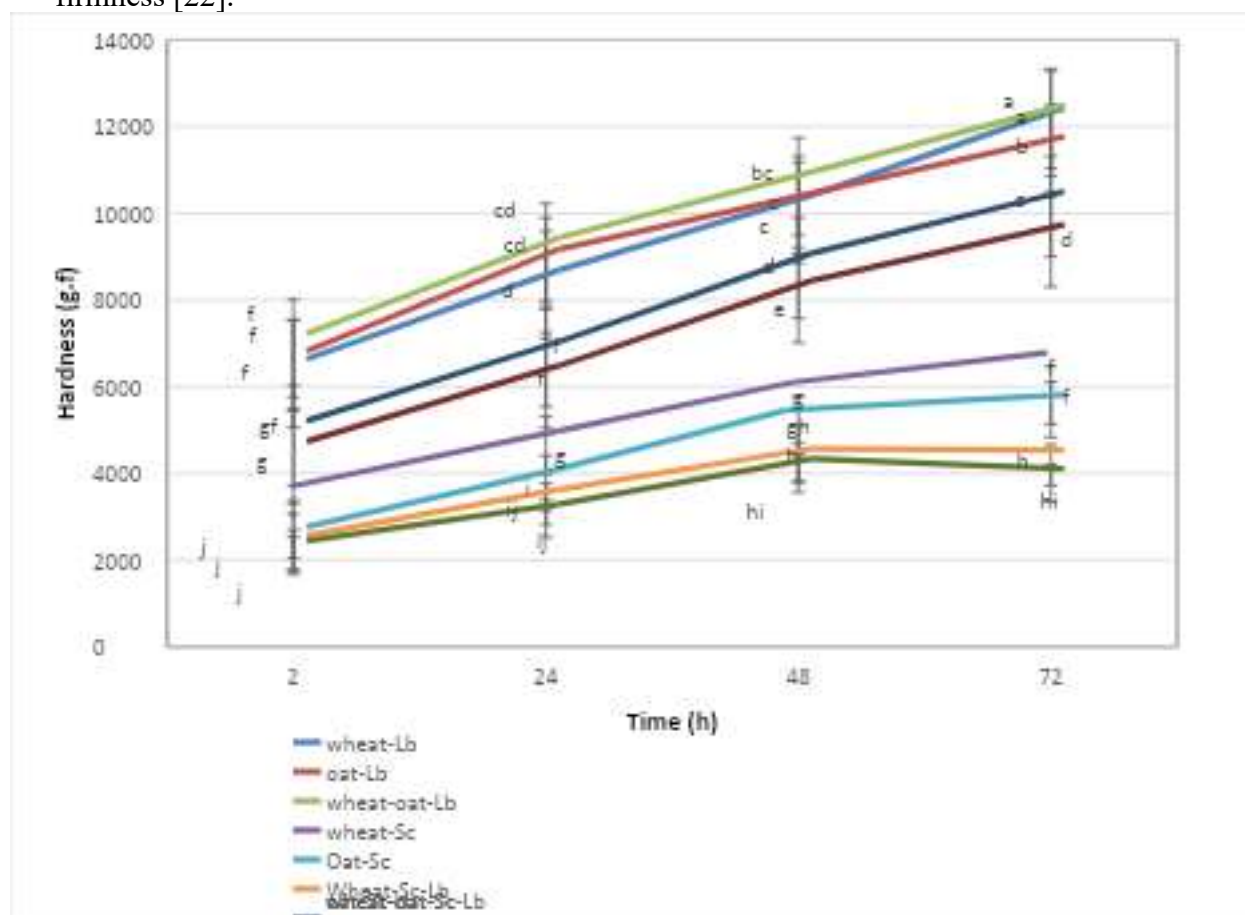


Fig. 4. The effect of sourdough and flour type used on the hardness of bread during storage

W=wheat flour, O=oat flour, Lb=*Lactobacillus plantarum*, Sc= *Saccharomyces cerevisiae*

The significance level was set at 0.05, and different letters indicate significant differences among the treatments.

3-3-Sensory evaluation of bread

The sensory characteristics of the studied breads, as shown in Table 2, showed a significant increase in sensory evaluation scores for taste, aroma, appearance, texture, and overall acceptability with the addition of sourdough (oat flour, wheat flour, *S. cerevisiae*, and *L. plantarum*). These findings are due to the complex flavor profile of the bread, improved texture and crumb structure, pleasant aroma, moisture retention properties, and an overall pleasurable eating experience. The chemical interactions between the ingredients and the fermentation processes result in a bread product that is highly satisfying and desirable to consumers [8]. ResultsFlanderset al. (2011) also showed that breads produced with oat flour and wheat flour obtained higher sensory

evaluation scores compared to bread produced with wheat flour [23].Recent results show that the transfer of flour components through the dough to the crust and core of the bread, the production of odors from volatile compounds and flavor precursors during the fermentation process that contribute to a complex combination of flavors, as well as the thermal effect of baking on Maillard and caramelization reactions, make fermented cereal-based products more palatable to the consumer [24].

Table 2- The effect of sourdough and flour on sensory evaluation of bread

Treatment	Taste	Odor	Appearance	Texture	Total acceptance
T1	2 ^j	2.75±0.07 ^j	2 ^l	2 ^l	2 ^p
T2	2 ^j	2.8 ^j	2 ^l	2.05±0.04 ^{at}	2 ^p
T3	2 ^j	2.5±0.07 ^k	2 ^l	2.05±0.07 ^{at}	2 ^p
T4 (control)	4.6±0.1 ^a	4.5±0.07 ^a	4.55±0.06 ^b	4.25±0.05 ^b	4.5 ^a
T5	4 ^d	4.2 ^c	4.35±0.06 ^d	4.35±0.06 ^a	4.2 ^c
T6	4.2 ^c	4.05±0.07 ^d	4.75±0.05 ^a	4.2 ^b	4.3 ^b
T7	3.7±0.2 ^{and}	3.9±0.14 ^{of}	3.95±0.08 ^f	3.85±0.07 ^d	3.8±0.1 ^f
T8	3.3 ^g	3.55±0.07 ^g	3.65±0.21 ^g	3.5 ^d	3.4±0.1 ^j
T9	4.2 ^c	4.35±0.05 ^b	4.25±0.06 ^{and}	4.35±0.06 ^a	4.3 ^b
T10	2 ^j	2.8 ^j	2.15±0.2 ^l	2.1±0.07 ^k	2 ^p
T11	2 ^j	2.75±0.05 ^j	2.05±0.03 ^l	2 ^l	2 ^p
T12	2 ^j	2.95±0.07 ⁱ	2 ^l	2 ^l	2 ^p
T13	3.7±0.1 ^{and}	4.2 ^c	4.45±0.08 ^c	3.55±0.08 ^d	3.9 ^{and}
T14	3.5 ^f	3.85±0.07 ^{and}	3.6±0.14 ^{gh}	2.95±0.07 ^g	3.5±0.1 ⁱ
T15	4.1±0.1 ^d	4 ^d	4.5±0.14 ^{bc}	4.25±0.06 ^b	4.1±0.1 ^d
T16	3.3±0.2 ^g	3.55±0.07 ^g	3.9±0.1 ^f	2.95±0.06 ^g	3.3±0.1 ^k
T17	3.1±0.1 ^h	3.35±0.05 ^h	3.7±0.09 ^g	2.7±0.14 ^h	3 ^m
T18	4.4±0.2 ^b	4.35±0.09 ^b	4.2 ^{if}	4.35±0.05 ^a	4.2 ^c
T19	2 ^j	2.75±0.04 ^j	2.15±0.02 ^l	2 ^l	2 ^p
T20	2 ^j	2.6 ^k	2 ^l	2 ^l	2 ^p
T21	2 ^j	2.75±0.07 ^j	2.2±0.3 ^l	2 ^l	2.1±0.1 ^{the}
T22	3.7±0.1 ^{and}	4.05±0.07 ^d	4.3±0.2 ^{and}	3.150.05 ^f	3.7 ^g
T23	3.1 ^h	3.55±0.04 ^g	2.65±0.07 ^k	3.1±0.1 ^f	3 ^m
T24	3.6±0.1 ^{if}	3.65±0.07 ^f	3.65±0.07 ^g	3.95±0.06 ^c	3.7 ^g
T25	3.4±0.1 ^f	3.45±0.06 ^g	3.35±0.05 ⁱ	3.55±0.04 ^d	3±0.1 ^m
T26	3±0.06	3.25±0.05 ⁱ	3.05±0.03 ^j	3.3 ^{and}	2.7±0.1 ⁿ
T27	4.1±0.01 ^d	4.4 ^b	4.2 ^{if}	4.35±0.07 ^a	4.2 ^c
T28	2 ^j	2.9±0.1 ⁱ	2.1±0.06 ^l	2.15±0.21 ^k	2 ^p
T29	2 ^j	2.85±0.03 ^{ij}	2.05±0.06 ^l	2 ^l	2 ^p
T30	2 ^j	2.75±0.07 ^j	2 ^l	2 ^l	2 ^p
T31	3.7±0.08 ^{and}	4 ^d	4.25±0.08 ^{and}	2.75±0.07 ^h	3.7±0.1 ^g
T32	3.3 ^g	3.55±0.05 ^g	2.65±0.05 ^k	2.55±0.05 ⁱ	3.1±0.1 ^l
T33	3.7 ^{and}	3.65±0.07 ^f	3.75±0.04 ^f	3.6±0.15 ^d	3.6 ^h
T34	3.1 ^h	3.3 ^{hi}	3.9±0.14 ^f	2.75±0.04 ^h	3.1±0.1 ^l
T35	2.7±0.2 ⁱ	2.95±0.04 ⁱ	3.55±0.07 ^{gh}	2.45±0.08 ^j	2.7±0.2 ⁿ
T36	4.2 ^c	4.35±0.07 ^b	4.25±0.06 ^{and}	4.25±0.07 ^b	4.3 ^b

4- Conclusion

This study investigated the effect of different sourdough formulas on bread quality. The results showed that the addition of a sourdough mixture containing wheat flour, oat flour, *S. cerevisiae* and *L. plantarum* significantly improved the sensory properties of the bread, including taste, aroma, appearance, texture and overall acceptance. These improvements were due to a more complex flavor profile and better bread crumb structure. In contrast, breads containing *L. plantarum* without yeast had

the highest firmness, which was due to a reduction in pH and proteolytic enzyme activity, which led to the degradation of gluten proteins and reduced gluten network strength. Also, replacing 15% of wheat flour with oats using sourdough containing *L. plantarum* and yeast can be effective in achieving desired results. Because the sensory evaluation results showed that there was no significant difference between the 100% wheat flour treatment and the 15% oat flour sample, and the overall acceptance score of the 15% treatment was higher than the 5 and 10% oat flour treatments. Overall,

the findings indicate that the use of mixed sourdough can lead to the production of bread with superior sensory and quality characteristics, but there is a need for careful

5-Resources

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مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی-پژوهشی

بررسی اثر افزودن لاکتوباسیلوس پلانتاروم و آرد یولاف بر ویژگی های کیفی نان بربری

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اطلاعات مقاله

چکیده

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۳/۷/۷

تاریخ پذیرش: ۱۴۰۴/۲/۲

کلمات کلیدی:

خمیر ترش،

لاکتوباسیلوس پلانتاروم،

نان،

یولاف.

DOI: 10.22034/FSCT.22.166.30.

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این مطالعه به بررسی تاثیر فرمول های مختلف خمیر ترش و درصدهای متفاوت آرد گندم و یولاف بر ویژگی های تکنولوژیکی و حسی نان پرداخته است. سطوح متغیرها شامل ۹ متغیر خمیر ترش ($W-Lb$ ، $W-O-Lb$ ، $O-Lb$ ، $W-O-Sc$ ، $O-Sc$ ، $W-Sc$ ، $W-Lb-Sc$ ، $O-Lb-Sc$ و $O-Sc$) و ۴ متغیر درصد جایگزینی آرد گندم با آرد یولاف (۱۰، ۱۵، ۵۰، ۱۰۰) بود. نتایج نشان داد نمونه های نان فاقد لاکتوباسیلوس پلانتاروم بالاترین میزان رطوبت را نشان دادند. تاثیر استفاده از لاکتوباسیلوس پلانتاروم بر روی pH معنادار بود و منجر به کاهش pH محصول شد. استفاده از خمیر ترش تخمیر شده با آغازگر لاکتوباسیلوس پلانتاروم باعث کاهش معنادار حجم مخصوص نان در مقایسه با نمونه شاهد شد. تجزیه و تحلیل مشخصات بافت نان نشان داد که خمیر ترش های حاوی آرد گندم، آرد یولاف، ساکارومایسس سرویزیه و لاکتوباسیلوس پلانتاروم کمترین سطوح سفتی در محدوده (۳۹۹۳-۲۰۹۸) گرم-نیرو را نشان داد و خمیر ترش بدون حضور ساکارومایسس سرویزیه سطوح سفتی بالاتری (۱۲۱۶۲-۶۳۰۰) گرم-نیرو را نشان دادند. ارزیابی های حسی نشان داد که نان های تولید شده با خمیر ترش آرد گندم، آرد یولاف، ساکارومایسس سرویزیه و لاکتوباسیلوس پلانتاروم بالاترین امتیاز کلی را برای طعم، عطر، بافت، ظاهر و پذیرش کلی از ارزیابان دریافت کردند. در مقابل، نمونه های فاقد مخمر کمترین امتیاز را دریافت کردند. بنابراین، فرمول نان بهینه شامل استفاده از خمیر ترش متشکل از آرد گندم، یولاف، لاکتوباسیلوس پلانتاروم و ساکارومایسس سرویزیه با جایگزینی ۱۵ درصدی آرد گندم با آرد یولاف بود.