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Effect of Inulin, Polydextrose, or Resistant Starch on the Quality Parameters of Prebiotic Bread

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Abstract: This study aimed to evaluate the effect of the addition of prebiotic components (resistant starch, inulin, or polydextrose, 10% of flour weight) on the flour characteristics and quality parameters of bread. Prebiotic addition increased the particle size of the flour. Inulin addition did not impact the physicochemical and texture characteristics of the bread, while resistant starch addition resulted in bread with higher crumb firmness, moisture content, and specific volume. However, both components improved the sensory characteristics (chewiness, crust, aroma, taste, and total acceptability) of the bread. They decreased the staling of the products, maintaining the quality parameters for a longer period of time. Polydextrose could also be used as a prebiotic component, resulting in products with similar sensory characteristics to the control but higher crumb firmness and specific volume. In conclusion, the most suitable prebiotic components in bread would be inulin and resistant starch because of improved sensory scores and prolongation of the shelf life.

Keywords: prebiotic; bakery; sensory; crumb; shelf life.

1. Introduction

Prebiotics are defined as substrates that are selectively utilized via host microorganisms conferring a health benefit [1]. The most recognized prebiotic components are the inulin-type fructans (fructooligosaccharides (FOS), oligofructose, and inulin) and galactooligosaccharides (GOS), but other components are also studied, such as resistant starch (RS) and polydextrose [2]. RS is a polysaccharide of (1 → 4) α-D-glucan with linear configuration, a natural component in many foods [3]. Inulin is a polysaccharide with fructose units that are naturally found in many vegetables, mainly in Jerusalem artichoke (Helianthus tuberosus) and chicory roots (Cichorium intybus) [4]. Polydextrose is a polymer of glucose, sorbitol, and citric acid [5].

One of the most important characteristics of these compounds, mainly from carbohydrates and the family of GOS and FOS, is that they are resistant to enzymes and other secretions of saliva, stomach, small intestine, pancreas, and gallbladder, so they can reach into the colon without confirmation and be available to the beneficial probiotic bacteria of the colon such as Lactobacilli and Bifidobacteria [6-9].

The consumption of prebiotic components has been associated with many health benefits, such as improvements in the digestive system [10], reduction of the cholesterol levels in the blood [10], improvement in the inflammatory and metabolic biomarkers of type 2 Diabetes Mellitus [11], increase in the calcium bioavailability and deposition in bones [12], among others. The prebiotic effect can be observed in low dosages, such as 2.5-5 g/day for RS [3], 1-6 g/day for inulin [13], and 2-7.5 g/day for polydextrose [14].

Bread is a staple food worldwide, but a decline in bread consumption was reported in recent years, mainly due to the low-carb and gluten-free diets. Therefore, the bakery industry has been reinvented by incorporating artisan methods, including health components in their recipes, and the development of products that pleasure the consumers [15]. The inclusion of prebiotic components could boost breads' health property and increase sales, as the prebiotic bread would be an innovative product [13]. The addition of prebiotic components to bread can result in improved sensory properties (flavor, texture, and crispness) and increased shelf life, as it can retain the wetness and freshness for a longer time. However, as they are dietary fibers, they can negatively impact the products' textural and organoleptic/sensory characteristics [16]. The prebiotic component's impact on the quality parameters of bakery products is prebiotic-specific [17]; therefore, studies should be conducted considering each prebiotic component, the dosage, and the type of bakery product [18].

Previous studies have already evaluated the incorporation of prebiotic components in bread, such as RS [3], inulin [4, 13], and polydextrose [18]. However, as far as the authors know, there is no study comparing the effects of different prebiotic components on the bread's properties, aiming to select the most suitable one. Therefore, this study's objective was to study the effect of the addition of RS, inulin, or polydextrose as prebiotic components on the dough particle size and quality parameters of bread.

2. Materials and Methods

2.1. Wheat flour quality assessment.

The quality of the wheat flour was examined by the methodologies described by the American Association of Cereal Chemists [19], being moisture (AACC, 44-16), protein (AACC, 46-12), ash (AACC, 08-01), wet and dry gluten, gluten index (AACC, 38-12A), Falling number (AACC 56-81B), and Zeleny number (AACC 56-60).

2.2. Preparation of prebiotic wheat flours.

Commercially soft white flour was provided by Maragheh Flour Factory (Altin Flour, Maragheh, Iran). In a special blender, 10 g of inulin (PYSON CO. LTD. China), polydextrose (PYSON CO. LTD. China), or resistant starch (Hi-maize 260, National Starch, USA) were added to 90 g the wheat flour, entirely blended and homogenized. The control flour was not added with any prebiotic component. The concentration of the prebiotic components was selected in order to obtain suitable prebiotic concentrations in a portion of the bread, as previous studies reported health effects after consumption of 2.5-5 g/day of RS [3], 1-6 g/day of inulin [13] and 2-7.5 g/day of polydextrose [14].

2.3. Particle size.

The particle size distribution of the control and prebiotic flours was determined by passing a portion of 100 g of the flour through different-sized standard sieves (106, 125, 180, or 450) (BADI, Model 161, Iran). The particles were collected in each sieve, weighed, and the total weight percentage was calculated.

2.4. Bread processing.

The bread was processed according to Figure 1. Four formulations of bread were prepared: Control, RS (with resistant starch), In (with inulin), and PD (with polydextrose). The formulations consisted of 2000 g of control or prebiotic flours, 20 g of salt (sodium chloride), 60 g of compressed yeast, 40 g of sucrose, and water in sufficient amount to obtain 500 BU of constancy by the farinograph. Then, the mass was fermented for 12 min, divided into portions (100 g), hand-molded and sheeted. Doughs were proofed at 32 °C and 85% humidity up to optimum bulk growth and baked at 260 °C for 17 min. After baking, the bread was kept at 25 °C to cool down, packed in polyethylene bags, and evaluated during storage for 5 days at 25 ^{o}C, the conventional shelf life of bread [20].

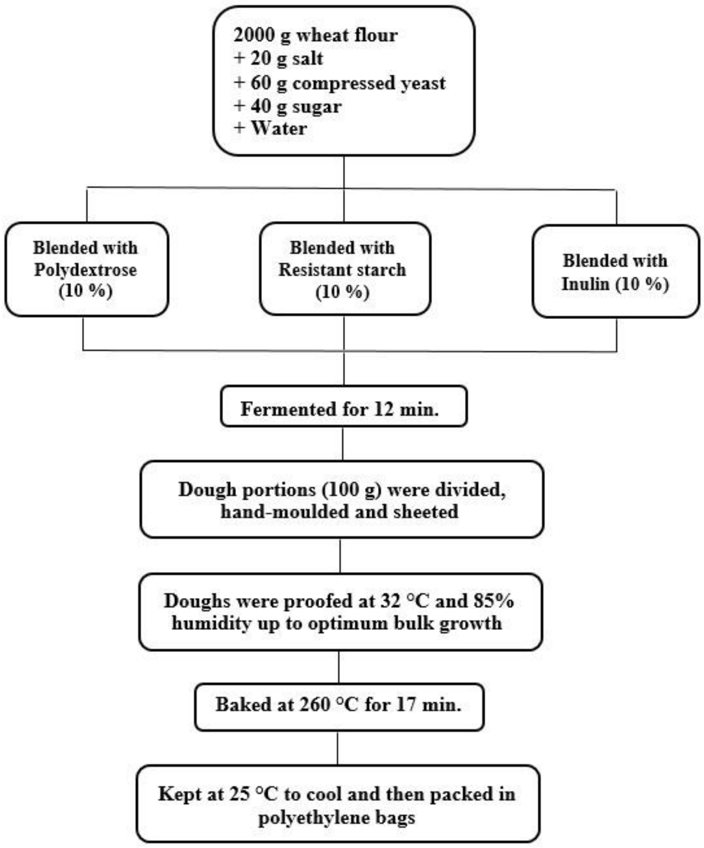


Figure 1. Schematic representation of the dough preparation and prebiotic baking bread.

2.5. Characterization of the bread.

The breads' moisture content and crumb firmness were determined by the 44-16 AACC and 74-09 AACC methodologies [19] on days 1, 3, and 5 of storage (25 °C). The bread volume was determined by the AACC 10-05 method after 2 h of processing. The mass was determined using a semi-analytical balance. The specific volume (cm3/g) of the bread was calculated using the ratio between the volume and the mass.

2.6. Sensory analysis.

The sensory properties of bread prepared from control and prebiotic flours were performed on days 1, 3, and 5 of storage by a panel of 12 trained assessors (20-40 years old, non-smokers) at room temperature. The maximum scores for each attribute were: appearance 10, color 10, chewiness 15, crust 15, texture 15, aroma 15, and flavor/taste 20 [3]. Furthermore, total acceptability was calculated by the sum of the scores of all evaluated attributes.

2.7. Statistical analysis.

All tests were performed with three replications. The Kolmogorov-Smirnov test was carried out to test the normality of data, being all the variables normally distributed. For the analysis performed during storage (bread specific volume, moisture content, and crumb firmness), a Repeated Measures Analysis of Variance (ANOVA) was carried out, followed by the Tukey test ($p=0.05$).

3. Results and Discussion

3.1. Physicochemical characterization of the wheat flour.

The wheat flour presented the following physicochemical characteristics: 0.70 g/100g total ash content, 14.52 g/100g moisture content, 11.15 g/100g protein content, 6.10 pH, 23 Zeleny I, 28 Zeleny II, 26.5 wet gluten, 8.6 dry gluten, 86 Gluten Index, and 360 (s) falling number value, previous corroborating studies [3, 21].

3.2. The particle size of control and prebiotic flours.

The results of the particle size of flour samples are shown in Fig. 2. The particle size of flour is one of the most important features to be evaluated, as it can impact dough and bread quality. The flours presented > 60% of particles of small size (< 125 µm), approximately 20% of particles with 125-180 µm, and low percentages (<5%) of particles with high sizes (180-475 and >475 µm).

The prebiotic flours (In, RS, and PD) presented a lower percentage of particles with small size (< 125 µm and 125-180 µm), and a slightly higher percentage of particles of the medium (180-475 µm) and high (> 475 µm) sizes than the control flour ($p \leq 0.05$). The presence of particles of low size (125 µm) is related to the dough's increased water absorption due to the increased contact of these particles with water. Furthermore, it is associated with flours with suitable strength, allowing more gas retention during fermentation and bread with better characteristics. However, suppose the percentage of these particles is too high. In that case, the water holding capacity will be reduced, resulting in difficulties in the formation of the dough and bread with undesirable characteristics. If the particle size is too large, the flour cannot absorb the amount of liquid required, as well as other ingredients used, such as oil. Furthermore, the coarse particles can break the dough, resulting in bread with poor quality parameters.

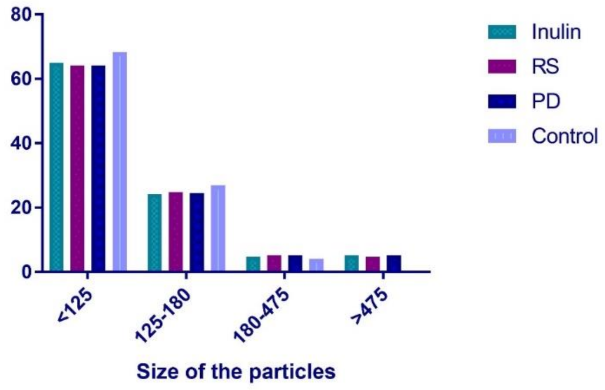


Figure 2. Particle size of control flour and flours supplemented with polydextrose (PD), inulin (In), and resistant starch (RS).

The present study results suggest that the addition of the prebiotic components impacted the flour characteristics, resulting in a higher concentration of large particles and a lower concentration of particles of small size. The impact of these alterations on the quality parameters of the bread should, therefore, be evaluated.

Table 1. Crumb firmness, moisture content of bread loaves stored for 1, 3, and 5 days at 25 °C, and specific volumes of bread (Mean±SD).

Sample	**Crumb firmness (N)**			**Moisture content (%)**			**Specific volume (cm^3/g)**
	1 day	**3 day**	**5 day**	**1 day**	**3 day**	**5 day**	
RS	$0.82\pm0.91^{1,c,d}$	$0.97\pm0.07^{1,a,b}$	$2.66\pm0.35^{2,b,c}$	$37.32\pm0.90^{1,c}$	$36.22\pm1.30^{1,a}$	$30.34\pm0.65^{1,c}$	$3.17\pm0.55^{b,c}$
In	$0.53\pm0.04^{1,a}$	$0.62\pm0.06^{1,a}$	$3.88\pm0.05^{2,c,d}$	$34.76\pm1.89^{1,a}$	$33.16\pm1.54^{1,a}$	$27.03\pm0.22^{1,a}$	2.89 ± 0.84^{a}
PD	$0.76\pm0.99^{1,b}$	$0.88\pm0.30^{1,a}$	$2.08\pm0.68^{2,a,b,c}$	$36.07\pm0.47^{1,a,b,c}$	$34.85\pm1.26^{1,a}$	$28.44\pm0.78^{1,a,b}$	$3.06\pm0.02^{b,c}$
Control	$0.52\pm0.90^{1,a}$	$1.70\pm0.22^{2,c}$	$4.94\pm0.03^{3,e}$	$35.04\pm1.22^{1,a}$	$33.32\pm1.47^{1,a}$	$27.26\pm0.42^{1,a}$	2.75 ± 0.58^{a}

Same small letters within the same column or same numbers in the same line are not significantly different ($p>0.05$).

3.3. Quality parameters of the bread.

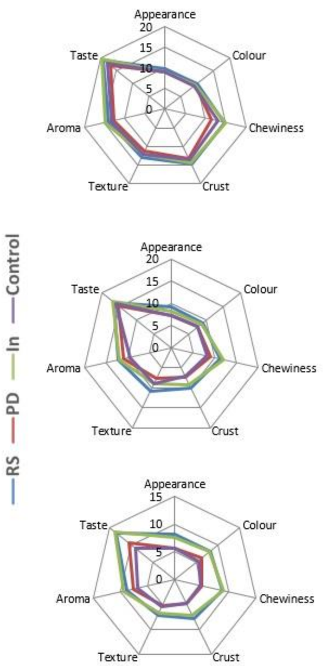
Table 1 presents the results of crumb firmness and moisture content of the bread on days 1, 3, and 5 of storage and the specific volume of the bread. The bread presented firmness from 0.52 to 4.94 N, moisture content from 27.26 to 37.32 g/100g, and specific volume from 2.75 to 3.17 cm3/g, previous corroborating studies [13, 20]. The addition of inulin to the flour (In) did not impact the crumb firmness, moisture content, and specific volume of the bread ($p > 0.05$) compared to the control bread at day 1. The addition of the resistant starch (RS) increased the parameters ($p \leq 0.05$); therefore, the products added with RS had higher moisture content and presented higher specific volume and crumb firmness than the control bread at day 1. The increase in the moisture content of the bread added with RS is related to the amylose content, as this component has high water-binding capacity, while the increase in the firmness can be a consequence of the thickening of the wall of the surrounding gas cells [3]. Finally, the bread with polydextrose (PD) presented higher crumb firmness and specific volume than the control ($p \leq 0.05$). The increase in the specific volume of the bread added with RS and polydextrose could be related to the fact that some kinds of soluble fibers can create a mesh that envelops the starch and the particles of the flour, increasing the cohesiveness of the dough and enhancing the gas retention [18].

During storage, the prebiotic bread (In, RS, and PD) had similar behavior to the control bread, being observed an increase in the crumb firmness ($p \leq 0.05$) and maintenance of the moisture content (p > 0.05). However, it can be observed that the increase in the crumb firmness was more prominent in the control bread than in the prebiotic bread (p ≤ 0.05), suggesting that the prebiotic bread would be staled later than the control bread. During staling, there is starch retrogradation, diffusion of moisture between crust and crumb, and interactions among starch and gluten, which are responsible for the firmness increase [22]. The addition of prebiotic components can improve the proteins' emulsification properties and the disulfide bonds' stability, resulting in a network with higher stability and retarding the staling process [13]. Furthermore, prebiotic components can slow the starch's retrogradation present in the crumb and increase the hydrophilic characteristics, keeping the products' freshness for a longer time [17].

The present study results suggest that the utilization of inulin as a prebiotic component did not impact the physicochemical and texture parameters of the bread, resulting in products similar to the control. The addition of the resistant starch and polydextrose resulted in products with improved specific volume and increased crumb firmness, and the product with RS also presented higher moisture content. All prebiotic components retarded the staling process in the bread. Therefore, the impact of the alterations provided by the prebiotic components on the sensory properties of the bread should be evaluated.

3.4. Sensory properties.

Figure 3 presents the results of the sensory evaluation of the bread. Bread presented scores of 5.6-9.9 for an appearance on a 10-point scale, 5.4-9.9 for color on a 10-point scale, 4.7-15 for chewiness on a 15-point scale, 4.7-14.9 for the crust on a 15-point scale, 5.2-12.9 for texture in a 15-point scale, 6.87-14.7 for aroma in a 15-point scale, 9-19.4 for taste in a 20-point scale, totaling 41-95.6 scores in the total acceptability.



Day 1	Appearance	Colour	Chewiness	Crust	Texture	Aroma	Taste	Total Acceptability
RS	9.9±0.2	9.9±0.2	14.7±0.5	14.9±0.2	12.9±1.0	14.1±0.8	19.2±0.9	**95.6±1.8**
PD	9.1±0.6	9.2±0.3	11.5±1.3	13.4±0.5	11.4±1.1	12.7±0.9	16.9±0.8	**84.2±2.3**
Inulin	9.1±0.6	9.4±0.5	15.0±0.0	14.5±0.4	12.2±0.5	14.7±0.3	19.4±0.7	**94.4±1.1**
Control	9.1±0.2	9.0±0.4	13.0±0.8	13.5±0.7	12.0±0.7	13.2±0.6	17.7±0.9	**87.6±1.9**

Day 3	Appearance	Colour	Chewiness	Crust	Texture	Aroma	Taste	Total Acceptability
RS	9.1±0.2	9.0±0.0	11.2±0.9	10.0±0.8	10.7±0.9	12.1±1.5	16.4±1.1	**78.6±3.3**
PD	7.4±0.5	7.6±0.5	8.9±0.8	7.4±0.5	7.6±0.5	10.9±0.8	15.1±0.8	**64.9±1.6**
Inulin	8.2±0.3	8.6±0.5	12.0±0.9	9.2±0.5	9.0±0.8	11.9±0.6	16.9±1.0	**75.9±2.2**
Control	7.4±0.5	7.6±0.7	8.2±0.5	7.1±0.2	9.0±0.8	9.5±0.4	15.9±0.6	**64.7±1.5**

Day 5	Appearance	Colour	Chewiness	Crust	Texture	Aroma	Taste	Total Acceptability
RS	8.1±0.2	8.1±0.2	8.7±0.9	7.9±0.6	7.1±0.6	8.9±0.8	13.5±1.3	**62.4±2.8**
PD	5.6±0.5	6.1±0.6	4.9±0.6	4.9±0.8	5.2±0.5	7.6±0.5	10.6±0.9	**45.0±2.4**
Inulin	7.6±0.7	8.0±0.4	9.0±0.4	7.125±0.2	6.6±0.7	9.5±0.6	13.7±1.2	**61.6±1.5**
Control	5.6±0.7	5.4±0.5	4.7±0.3	4.7±0.9	5.5±0.6	6.875±0.6	9.0±0.8	**41.875±2.2**

Figure 2. Sensory scores (Mean±SD) of control bread and loaves of bread supplemented with polydextrose (PD), inulin (In), and resistant starch (RS) on days 1, 3, and 5 of storage.

At the first day measurements, bread with RS and inulin gained significantly higher scores for chewiness, crust, aroma, taste, and total acceptability compared with the control group (P<0.05). There was no impact on the appearance, color, and texture (p > 0.05). The results indicate that the bread's highest specific volume and moisture content with resistant starch contributed to the increase in chewiness's sensory score, and the highest firmness did not impact negatively (Table 1). Furthermore, the absence of the effect of inulin on the texture sensory scores is corroborated by the instrumental firmness (Table 1). The higher score in the taste and aroma attributes could be related to the fact that inulin is a fructose polymer that can contribute slightly to the sweet taste of bread, contributing to the increase in the products' taste scores [4]. Increased taste scores after RS addition to bread were also reported by Mohebbi et al. (2018).

The addition of polydextrose (PD) resulted in products with similar scores to the control ($p > 0.05$), except for chewiness. The lower chewiness score of the prebiotic product could be associated with its higher crumb firmness (Table 1).

During storage, all bread scores decreased, probably related to the products' staling, with increases in crumb hardness (Table 1). However, the prebiotic bread (In or RS) retained higher scores than the control bread for all sensory attributes (appearance, color, chewiness, crust, texture, aroma, taste, and total acceptability) ($p \leq 0.05$), indicating that the prebiotic bread staled later. These results are corroborated by the physicochemical analysis (Table 1). Bread with inulin and RS presented total acceptability higher than 60 in a total of 100-point after 5 days of storage, while those with PD or the control sample presented only 41-45. Therefore, for suitable sensory scores (total acceptability > 60), the control bread and the bread added with polydextrose should be consumed before 3 days of storage, while the products with inulin or RS could be consumed for at least 5 days of storage.

4. Conclusions

The results of the present study indicate that inulin and resistant starch could be used as prebiotic components in bread, resulting in products with superior sensory characteristics than the control bread, although alterations in the dough characteristics and/or bread physicochemical characteristics could be observed. Both prebiotic components were able to decrease the breads' staling, maintaining the quality parameters for a longer period of time. Polydextrose could also be used as a prebiotic component, resulting in products with similar sensory characteristics to the control. The bread would have suitable prebiotic amounts to provide the health benefits associated with prebiotic components.

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Conflicts of Interest

The authors declare no conflict of interest.

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