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The Effect of Inulin Addition on Rice Dough and Bread Characteristics

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Featured Application: The obtained results may be applied in gluten-free bread production.

Abstract: Inulin may be widely used in in the food industry due to its many health benefits. It has the potential to increase the insufficient nutritional quality of gluten-free bread. Therefore, the aim of this study was to test the applicability of inulin in rice baking. The impact of added inulin (5%, 10%, 20%, 30%, and 40%) on the dough's rheological, bread's textural and sensory characteristics was evaluated. The extensibility of rice dough during uniaxial deformation tests (8.5 mm) was improved by the added inulin (10.2–12.3 mm). The presence of inulin softened the dough and shifted the gelatinization temperature toward higher values. The added inulin also increased the loaf's specific volume (1.16–1.48 mL/g), tenderized the breadcrumbs, increased the crumb porosity (36–58%), and generally improved the crumb structure. The panelists favored the sensory characteristics of breads with inulin. However, baking losses were increased in these breads as well (15.1–18.5%). The effect of the added inulin on the dough and bread characteristics generally rose with an increasing addition of inulin, reaching the maximum in samples with 30% inulin. The presence of 40% inulin deteriorated some characteristics of the bread. Therefore, the addition of up to 30% of inulin seemed to be optimal for rice bread.

Keywords: dough extensibility; bread texture; bread volume; baking losses; sensory characteristics; oligofructose

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1. Introduction

Inulin is widely found in more than 36,000 plant species as a reserve polysaccharide. It is commonly extracted from inulin-containing plant sources, such as chicory roots (*Cichorium intybus* L.) and Jerusalem artichoke tubers (*Helianthus tuberosus* L.), as well as from novel sources, such as globe artichoke inflorescence (*Cynara cardunculus* L.) and its by-products [1]. Inulin is a linear polydisperse carbohydrate material consisting mainly of β-(1$\rightarrow$2) fructosyl-fructose links. Because of the β configuration of the anomeric C2 in its fructose monomers, inulin resists hydrolysis by the digestive enzymes found inside the human small intestine, being classified as nondigestible food fiber [2–4]. Inulin reduces the risk of gastrointestinal diseases, decreases the levels of pathogenic bacteria in the intestine, and relieves constipation. A beneficial effect on bowel function is obtained with a daily intake of 12 g of inulin [2,5,6]. It exhibits many other health benefits; it stimulates the human body's immune system, decreases the risk of osteoporosis by increasing mineral absorption, and does not lead to a rise in serum glucose or stimulate insulin secretion, among other benefits [2,5,7,8].

Inulin may be widely used in the food industry as a prebiotic, a fat and sugar replacer, as well as dietary fiber [5]. It is stable in temperatures up to 140 °C and can, therefore, be processed easily in bread baking [9]. Inulin incorporation into baked goods can increase their nutritional quality as well as technological properties [10]. It is used to replace flour in bread at a rate of 3–10%. Inulin is not considered to be a food additive [11]. Its taste is neutral, being without any off-flavors or an aftertaste [12]. Since it exhibits many health benefits, it can be used ad libitum [9].

Approximately 93% of individuals with celiac disease consume bread daily [13]. Commercially produced breads are often prepared from various blends of starches and flours [14,15]. The absence of gluten presents a technological challenge, as wheat proteins play crucial roles in bread production and quality [16]. During dough preparation, proteins form a continuous matrix with viscoelastic behavior [17]. Wheat dough exhibits a high capacity to retain CO_2 and has low consistency. These properties result in high-quality bread with a large volume and good textural parameters, such as low hardness, high cohesiveness, and resilience [17]. In contrast, gluten-free doughs display different characteristics, which may be attributed to the molecular weight of the protein molecules and variations in chemical composition, primarily a lower content of the amino acid lysine [18]. Rice flour is frequently used in gluten-free bread baking because of its colorlessness, nutritional characteristics, bland taste, and low hypoallergenic properties. Flours with more distinctive colors, tastes, and flavors compared with wheat may not appeal to some consumers [19–21]. Although nutritional quality varies among products, gluten-free bread is usually low in fiber, proteins, micronutrients, vitamins, and minerals such as iron, zinc, magnesium, and calcium [14,19,20,22]. Gluten-free breads have a higher glycemic index than gluten-containing products because of the use of starches and sugars [23,24]. The texture and taste of bread are the most important characteristics and are often the main reasons why people dislike currently available gluten-free bread [13].

Inulin's ability to create a gel might be expected to improve the poor ability of gluten-free dough to trap leavening gas. However, the inulin's ability to form a gel is affected by the length of its chain. Short-chain inulin cannot form a gel, natural inulin forms a gel at concentrations above 30% *w*/*w*, and long-chain inulin forms a gel in the range of 20–40% *w/w* at room temperature due to its lower water solubility [10]. A positive impact of inulin on the crumb structure and volume of gluten-free bread prepared from a blend of rice flour, cassava starch, and soy flour, as well as a mixture of rice and acorn flours coupled with a mixture of corn starch and potato starch, has been previously described [25–27]. Due to its numerous health benefits, neutral taste, and the fact that it is not considered a food additive, inulin has great potential to increase the nutritional value of rice bread, which is a critical issue that needs to be addressed [14]. A higher inulin addition (up to 40%) than the previously published 10% was involved in this study. The aim of this paper is to describe the impact of inulin, ranging from 5% to 40%, on the rheological, textural, and sensory characteristics of rice dough and bread. The applicability of inulin in rice bread baking is also evaluated.

2. Materials and Methods

2.1. Material

Rice flour (89.7 g carbohydrates, 7.7 g protein, 1.3 g fat, and 1.3 g fiber per 100 g of dry flour) was kindly provided by Extrudo Bečice (s.r.o., Týn nad Vltavou, Czech Republic). The natural inulin from chicory roots in the form of white powder with an average particle size of 60–80 µm, inulin content of 90–99%, and degree of polymerization of 2–60 was kindly provided by Brenntag CR (spol. s r.o., Prague, Czech Republic). The substitution of 5%, 10%, 20%, 30%, and 40% inulin in rice flour was tested.

2.2. Dough Behavior during Uniaxial Deformation

The dough samples meant for studying the behavior under uniaxial deformation were prepared using flour or a blend of flour and inulin (10 g) mixed with water. Pure rice flour was mixed with 9 g of water. The amount of water used in the samples made from the blend of rice flour and inulin was determined by experimentation as the amount of water required to obtain a dough capable of holding together and not falling apart before testing. All ingredients were manually mixed inside a beaker. After mixing, the dough was given a rest period of around (40 ± 1) min at a temperature of (30 ± 1) °C. The sample was prepared, and the test was performed according to Smewing [28] using a TA.XT plus texture analyzer (Stable Micro Systems Ltd., Godalming, UK) equipped with an SMS/Kieffer Dough and Gluten Extensibility Rig. The dough was formed into 5 cm-long pieces with a trapezoidal cross-section (3 mm, 5 mm, and 4 mm). Every sample was stretched by the hook until it broke. The hook progressed at a speed of 3.30 mm/s during the test, with a trigger force of 0.5 g. The test measured both the force necessary to stretch the dough sample as well as the hook's displacement over time. The resistance to stretching, represented by R_m (N), was marked at its peak force. Correspondingly, the extensibility, noted as E (mm), was tracked at the point where the peak force was applied. Moreover, the *Area* under the curve was calculated. Each test was performed on dough samples prepared in at least seven replicates.

2.3. Rheological Characterization of Dough during Heating

The samples for testing the dough behavior during the heating test were prepared from flour or a flour/inulin blend (10 g) and water (10 g). All ingredients were mixed manually in a beaker. After the mixture was prepared, the dough was left to relax at an ambient temperature of (30 ± 1) °C for a period of approximately (5 ± 1) min in a beaker covered by a glass plate. The dough was placed between the 35 mm parallel P35 Ti L plates and compressed to a gap adjusted to 1.5 mm. The dough edges were trimmed with a spatula. To prevent the dough from drying out, the exposed side of the dough was coated with a methyl silicone polymer Lukopren N1000 (Lučební závody a.s. Kolín, Czech Republic). An oscillatory temperature ramp of 30–90 °C at 0.058 °C/s was performed using the HAAKE RheoStress 1 (Thermo Scientific, Prague, Czech Republic) to evaluate thermally induced changes in the dough's complex viscosity η^*. The testing procedure was conducted while maintaining a strain of 0.1% and a steady frequency of 1 Hz within the linear viscoelastic region. Each test was performed on dough samples prepared in at least five replicates.

2.4. Bread Preparation

The dough was prepared by mixing rice flour (100%), water (100%), sucrose (1.86%), salt (1.50%), and active dry yeast (1.80%). The part of flour (5%, 10%, 20%, 30%, and 40%) was replaced by inulin. The amounts of all ingredients were related to flour or flour/inulin dry matter.

Dry yeast was reactivated for 10 ± 1 min in a sugar solution (35 ± 1) °C. The ingredients were placed into an Eta Exclusive Gratus mixer bowl (Eta, a.s. Prague, Czech Republic) and mixed for 6 min. The dough (1000 g) was divided into 3 bread pans (12 cm × 26.5 cm × 7 cm) and placed into a proofer for (60 ± 2) min at (30 ± 1) °C and 85% relative air humidity. The loaves were baked for 40 ± 2 min at 180 ± 5 °C (MIWE cube, Pekass s.r.o. Plzeň, Czech Republic). The baked breads were removed from the pans and stored at room temperature (21 ± 3) °C for 2 h. The loaf volume was determined using plastic granulates of rape seed size. The loaf-specific volume (mL/g) was obtained by dividing the bread volume by the bread weight. The baking loss (%) was calculated as [(the weight of dough in pan before baking − the weight of bread after cooling)/(the weight of dough in pan before baking)] × 100. Loaf specific volume and baking loss were determined in at least six repetitions.

2.5. Properties of Breadcrumbs

For texture profile analysis (TPA) measurements, bread samples 35 mm in diameter and 10 mm in height were obtained from the center of each loaf. The sample was placed on the base of a TA.TX plus texture analyzer (Stable Micro Systems Ltd., UK) and squeezed twice to 4 mm with a 75.0 mm diameter P/75 cylinder probe. The probe test speed was 1.00 mm/s. The crumb parameters (hardness, springiness, cohesiveness, resilience, adhesiveness, and chewiness) were calculated. Hardness (N) is the peak force that occurs during the first compression. Springiness is the ability to spring back after the sample was deformed during the first compression and then allowed to rest for the target time. Cohesiveness is how well the sample withstands a second deformation relative to its resistance under the first deformation. Resilience is the sample's ability to regain its original height. Chewiness is the energy needed to chew the sample until it is ready to be swallowed [29]. At least five samples from each loaf were obtained and tested.

The pictures of the breadcrumbs were saved as bitmap files. Their resolution was 300 DPI in real-color format (RGB, 256 million colors). The images were then cropped to a resolution of 420 pixels. The cropped images were duplicated and converted into an 8 bit grayscale image. The grayscale images were thresholded using the software Paint Shop Pro XI (Corel Corporation, Ottawa, ON, Canada), which allowed conversion of the images into black and white colors. The pore number per image was calculated using the histogram tool in Paint Shop Pro. The porosity was determined in two replications.

2.6. Sensory Evaluation

A group of 30 highly motivated employees and students of the department, both male and female and between 19 and 65 years of age, were recruited to form the panel. The panelists were selected based on their availability, attitudes toward the products to be assessed, knowledge and skills, ability to communicate, and other aspects specified by ISO 8586 [30]. Sensory panel training was carried out according to Ellia [31] in sessions of 200 min divided into two parts: (1) training for the general aspects of sensory techniques and analysis and (2) training for the more specific characteristics of the bread. A panel of 20 members was involved in the sensory evaluation of the bread with added inulin. Six panel members were excluded from the evaluation due to disability or economic reasons.

The sensory evaluation was performed under standard conditions (ISO 8589) [32]. A nine-point hedonic scale (from 1 (dislike extremely) to 9 (like extremely)) was used to evaluate the crust appearance and color, crumb appearance and color, porosity, aroma, taste, and overall acceptability of the breads.

2.7. Statistical Analysis

The Shapiro–Wilk test was used to test the distribution of the obtained data sets. If the data set followed a normal distribution, then parametric analysis of variance (ANOVA) was used to test the significance of the differences among the samples. Differences were tested on $\alpha = 0.05$ significance level using the Tukey test. The results were expressed as mean values and a standard deviation.

If the data set did not follow a normal distribution, a non-parametric Kruskal–Wallis test, together with multiple comparison of the z′ values and p values, was used to test the significant differences among samples. The results were expressed as median values.

Statistical analyses were performed using Statistica 13.0 (TIBCO Software s.r.o., Prague, Czech Republic).

3. Results and Discussion

3.1. The Effect of Inulin on Dough Characteristics

The addition of inulin had a notable impact on the dough behavior during uniaxial elongation tests. The presence of inulin weakened the rice dough, which is evident from the significant decrease in the dough's resistance to elongation (R_m) recorded in the samples with added inulin (Table 1). The weakening effect of the added inulin was also apparent in the values of the *Area* parameter, which relates to the energy required for dough deformation. The samples with added inulin required less energy for deformation (306–683 mN mm) than the samples made from pure rice flour (704 mN mm).

Conversely, the added inulin had the opposite effect on the wheat dough with 2–8% added inulin [33,34]. These results were explained by the interaction between inulin and gluten. The proteins in rice flour have a lower molecular weight than those in gluten, and they also differ in chemical composition [18], which may account for our observations. Inulin competed with starch for water in the dough and reduced the available water for starch hydration. Therefore, inulin's water binding ability was probably a key factor in modifying the dough properties [35], and this likely negated the differences between the samples with added inulin.

Table 1. Effect of inulin on rice dough resistance to extension R, area under curve Area, and extensibility E recorded during uniaxial deformation test [1].

Inulin (%)	R_m **(mN)**	***Area*** **(mN mm)**	E **(mm)**
0	131 ± 13 a	704 ± 90 a	8.5 ± 0.4 b
5	57 ± 9 b	683 ± 90 a	10.2 ± 0.9 a
10	60 ± 7 b	472 ± 90 b	12.1 ± 0.9 a
20	64 ± 6 b	382 ± 95 bc	12.3 ± 0.9 a
30	67 ± 6 b	442 ± 80 b	11.4 ± 0.4 a
40	57 ± 2 b	306 ± 70 c	8.9 ± 0.3 b

[1] Mean values ± standard deviation (n = 7) followed by different letters in the column differ significantly ($p < 0.05$).

Extensibility E is another parameter that was recorded during the uniaxial elongation tests. The values of extensibility rose with the increasing amount of inulin and, after reaching a maximal extensibility in a sample with 20% inulin, the extensibility started to decrease. The differences between samples (5–30% inulin) were, however, not significant. The presence of inulin increased the polymerization of proteins present in the rice flour [33], which improved the doughs' ability to elongate. The 40% added inulin was probably higher than optimal, resulting in a negative impact on the dough characteristics. Since gluten-free doughs generally exhibit an insufficient ability to elongate and trap leavening gas, which is crucial for obtaining bread with the desired volume [36], the addition of up to 30% of inulin seems to be optimal to prepare dough with improved elongational characteristics.

The weakening effect of inulin on rice dough was also recorded during the heating tests (Figure 1). The complex viscosity η^* at the beginning of the heating tests was decreased by the presence of 10%, 20%, 30%, and 40% inulin. The thermally induced changes recorded in the dough with 5% added inulin was close to the dough prepared from pure rice flour. The presence of higher amounts of inulin (10–40%) resulted in a shift of the temperature of starch gelatinization toward higher values. This effect rose with a rising amount of inulin. Inulin is known to take part in the competition for water and may bind a part of water during dough mixing. Furthermore, the viscosity of an inulin solution is quite low [9], which may account for the decrease in complex viscosity observed in the samples containing inulin. When water was released from proteins denatured by temperature, inulin bound to a portion of this water, thereby reducing the dough viscosity. Furthermore, due to its hydrophilic nature, inulin competed with starch for the water necessary for starch gelatinization, resulting in an increase in the gelatinization temperature [37–39].

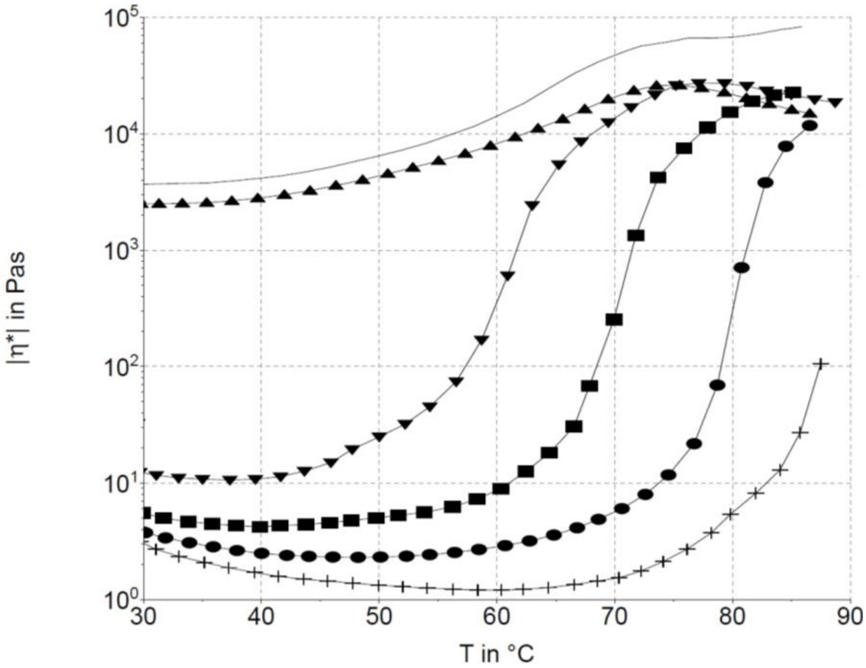


Figure 1. Thermally induced changes of complex viscosity η^* recorded in rice dough with added inulin (— 0%; ▲ 5%; ▼ 10%; ■ 20%; ● 30%; † 40%).

3.2. Effect of Inulin on Bread Characteristics

Baking losses represent the amount of water evaporating from dough during baking and cooling. The values of this parameter rose with an increasing amount of added inulin in samples with 0%, 5%, 10%, and 20% inulin, reaching the maximal value in bread containing 30% inulin (18.5%) (Table 2). The bread containing 40% inulin exhibited a lower value (17.1%). Water plays an important role in bread baking. It is used to hydrate proteins and starch granules during dough mixing. During baking, water is released from denatured proteins and is used for gelatinizing a part of the starch granules [17]. Since the flour was replaced by inulin in the tested samples, the content of starch was lower in these doughs than in the dough made from pure rice flour. Water released from denatured proteins might be used for starch gelatinization or might evaporate. Since the addition of inulin shifted the gelatinization temperature to higher values, a part of the water released from denatured proteins could not be used for starch gelatinization, evaporating from the dough, which was recorded as an increase in baking losses. Gelatinized starch plays a role in retaining gas in the dough and preventing bubbles from coalescing during the baking process [40]. This impacts the bread volume and breadcrumb porosity. The loaf's specific volume generally increased with an inulin content in the range of 0–30%, reaching a maximum in the bread with 30% added inulin (1.48 mL/g). A similar effect of inulin was observed in gluten-free breads prepared from blends of corn and potato starch, as well as in wheat bread. However, the addition of inulin did not exceed 12% in these studies [26,41,42]. The authors explained these observations as a competition between inulin and starch for water during baking. The decrease in water availability retards starch gelatinization, resulting in a delay in the formation of a viscous gel and solid-like behavior in the dough. Prolonged formation of the solid-like dough structure allowed for accumulation of the leavening gas in doughs, even at higher temperatures, until the yeast was inactivated. This effect increased with the addition of inulin. The considerable delay in gelatinization observed in the sample with 40% inulin (Figure 1) shifted the formation of solid-like dough structures to temperatures where the yeast was already inactivated, resulting in a significantly lower loaf-specific volume (1.16 mL/g). Even though the loaf-specific volume increased in the bread with 5–30% added inulin, this parameter remained lower than in wheat bread with added inulin [41].

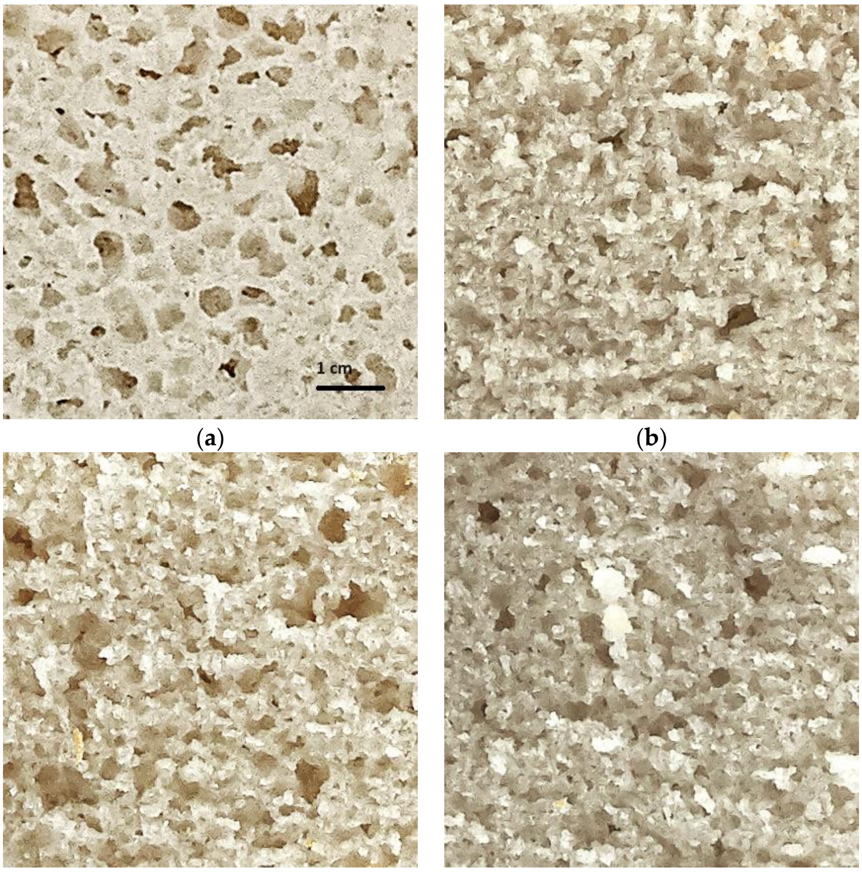
Table 2. Effect of inulin on characteristics of rice bread and breadcrumbs [1].

Inulin (%)	Loaf-Specific Volume (mL/g)	Baking Losses (%)	Hardness (N)	Springiness (%)	Cohesiveness (%)	Resilience (%)	Adhesiveness (N s)	Chewiness (J)	Porosity (%)
0	1.16 ± 0.07 e	15.1 ± 0.2 c	24 ± 4 a	79 ± 6 ab	78 ± 5 a	47 ± 2 a	0.33 ± 0.09 a	15.1 ± 3.5 a	36
5	1.17 ± 0.02 e	15.6 ± 0.2 c	23 ± 3 a	77 ± 6 ab	77 ± 2 ab	45 ± 2 ab	0.16 ± 0.09 ab	13.5 ± 2.9 a	58
10	1.41 ± 0.02 b	16.8 ± 0.3 b	17 ± 2 b	77 ± 6 ab	79 ± 3 a	48 ± 3 a	0.22 ± 0.09 a	12.1 ± 1.7 a	55
20	1.35 ± 0.02 c	16.7 ± 0.2 b	16 ± 3 b	70 ± 8 ab	75 ± 3 ab	41 ± 4 bc	0.05 ± 0.02 b	10.4 ± 2.9 a	57
30	1.48 ± 0.02 a	18.5 ± 0.2 a	18 ± 4 ab	83 ± 2 a	80 ± 5 a	48 ± 3 a	0.02 ± 0.02 b	8.1 ± 0.9 b	55
40	1.29 ± 0.02 d	17.1 ± 0.5 b	20 ± 4 ab	63 ± 8 b	72 ± 4 b	39 ± 3 c	0.04 ± 0.02 b	8.1 ± 1.0 b	33

[1] Mean values ± standard deviation followed by different letters in the column differ significantly ($p < 0.05$).

The presence of up to 30% inulin also had a positive effect on the crumb porosity. This parameter increased with the increasing content of inulin, reaching a maximum value in the bread containing 30% inulin. A similar positive effect from inulin was also observed in breads with 4–12% added inulin [26,42]. The formation of pores may be related to changes in dough gelatinization initiated by inulin. The shift in gelatinization temperature and viscosity changes recorded in doughs with 5–30% added inulin resulted in a better ability of these doughs to accumulate leavening gas inside the pores than that recorded in dough made from pure rice and dough with 40% added inulin. The changes in dough characteristics initiated by the presence of 40% inulin were too extensive, rendering the dough unable to accumulate leavening gas and creating smaller pores (Figure 2f). The greatest difference between the size of the pores situated in the inner and outer parts of the crumbs was observed in the bread without added inulin. Larger-sized pores were situated mainly in the central part of the bread (presented in Figure 2a). The size of the pores decreased toward the outer parts, thereby reducing the average porosity value.

The texture characteristics of the bread were only marginally impacted by the presence of inulin. Nonetheless, the breadcrumb hardness, chewiness, and adhesiveness generally decreased with the inclusion of inulin. This is a positive result, as hard breadcrumbs are a common defect associated with gluten-free bread. The positive influence on the crumb hardness rose slightly with the increasing content of inulin until it reached a minimum in the bread made from a blend containing 20% inulin. In the breads prepared from blends containing a higher amount of inulin (30% and 40%), the crumb hardness began to rise. The presence of small pores surrounded by a thick dough layer might explain the hard crumbs in these breads. A similar effect of inulin on the crumb hardness was also recorded in bread prepared from a blend of rice and acorn flours [27]. However, the impact on wheat bread was the opposite [34,43].



(**a**) (**b**)

(**c**) (**d**)

Figure 2. *Cont.*

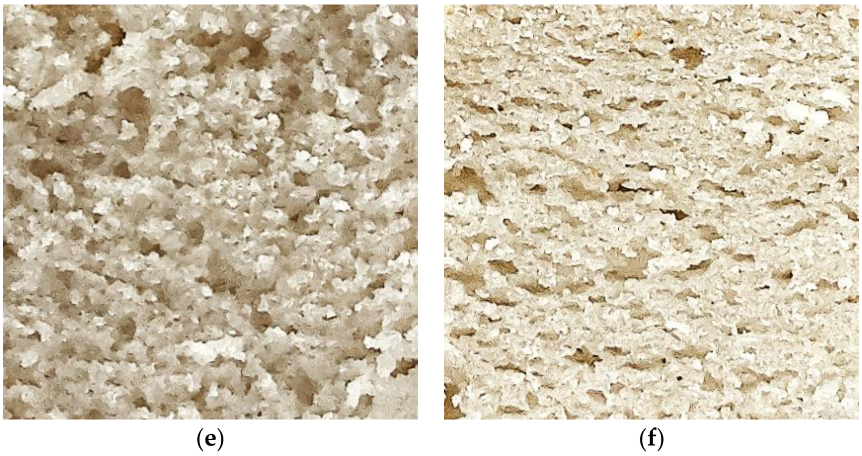

(e) (f)

Figure 2. Crumbs of bread prepared from rice flour with added inulin: (**a**) 0%; (**b**) 5%; (**c**) 10%; (**d**) 20%; (**e**) 30%; and (**f**) 40%.

The positive effect of inulin's addition on the crumb chewiness increased with the rising amount of added inulin. A significant impact on springiness, cohesiveness, and resilience was observed only in the bread prepared from the blend containing the highest amount of inulin (40%). Resilience and cohesiveness were decreased by inulin, suggesting a tendency for this bread to crumble when sliced or spread. A similar negative impact was not observed in the breads with 0%, 5%, 10%, 20%, and 30% added inulin. A similar effect was observed in steamed wheat bread [34], but other authors reported the opposite effect [27,43]. The observed discrepancies support the conclusion [7,10] that the effect of inulin on the textural characteristics is influenced by many factors affecting inulin function, including the degree of polymerization, the level of inulin replacement, type of fermentation, and protein characteristics. Moreover, these discrepancies highlight the need for further investigation into the effect of different types of inulin on the characteristics of bread prepared from various ingredients using different production technologies.

In our study, the addition of 30% inulin seemed to be optimal for producing bread with an acceptable loaf-specific volume, bread porosity, and other breadcrumb characteristics. However, it should be noted that higher baking losses should also be expected at the same time.

3.3. Effect of Inulin on Sensory Characteristics of Bread

Some of the sensory characteristics did not exhibit a normal distribution. Therefore, a Kruskal–Wallis test was applied to the sensory evaluation results, and the results were expressed as median values.

The crust and crumb color were similar in all breads (Figure 2a–f), and the evaluation of these parameters was not influenced by the content of inulin. Differences in crumb and crust color were not observed, as the content of short-chain inulin, which accelerates the Maillard reaction rate and forms a more appealing crust color [10], was not present in substantial amounts in the tested inulin. The panelists had divergent views on the color of the crust and crumb. One group found the pale color unattractive and tended to score it lower (1, 2, or 3 points). Conversely, other panelists found this color appealing and scored it with 7, 8, or 9 points. This resulted in a median value of 4–5 (Table 3). There was no tendency among the panelists to form separate groups with opposing views on any other parameter.

The evaluation of the other sensory characteristics generally rose with an increasing portion of inulin, reaching its maximum in the samples with 30% added inulin (Table 3). The panelists favored the bread with 30% added inulin. The overall acceptability of this sample lays between 7 (like moderately) and 8 (like very much). The panelists liked moderately (7) the crumb appearance and color, liked slightly (6) the crumb hardness and pore size and uniformity, and liked very much (8) the flavor intensity of this bread. Even if the presence of inulin was detected by the panelists in this bread, they found it pleasing and described its presence as "an evidence of healthy food". The panelists favored the bread containing 30% added inulin, which is in general agreement with the results of other tests, in which the samples with 30% added inulin were preferred as well. Even though the composition of the breads was not determined in this study, it can be assumed that the content of fiber in the bread with 30% added inulin was approximately 18 g/100 g. The average per capita bread consumption in Czech Republic is 136 g per day [44], which would equate to a daily intake of 23 g of inulin. This is close to the recommended intake of 25–30 g per day from food [45].

Table 3. Medians of the sensory parameters of breads with added inulin [1].

Inulin (%)	Crust Color	Crumb Color	Crumb Hardness	Pore (Size, Uniformity)	Flavor Intensity	Flavor Aftertaste	Overall Acceptability
0	5 a	4 a	5 ab	4 ab	3 b	3 b	3 ab
5	5 a	4 a	2 b	3 b	3 b	3 b	3 b
10	5 a	4 a	3 ab	6 a	3 b	4 ab	4 ab
20	5 a	4 a	3 ab	5 a	4 b	4 ab	4 b
30	5 a	4 a	6 a	6 a	8 a	5 a	8 a
40	5 a	4 a	2 b	2 b	2 b	3 b	2 b

[1] Score range: 1 = dislike extremely; 9 = like extremely. The median values (n = 20) followed by different letters in the column differ significantly.

The evaluation of the bread with 40% added inulin was even lower than that of the bread without added inulin. The panelists strongly disliked the hard crumb (2), small pores (2), and flavor intensity (2), and they moderately disliked the flavor's aftertaste (3). The small pores in this bread were surrounded by a thick dough layer (Figure 2f), which was perceived as hard crumbs. The characteristics of the breadcrumb can be explained by the low dough viscosity during baking and the delay in starch gelatinization (Figure 1). The dough viscosity required for the accumulation of an appropriate amount of leavening gas was probably reached when the yeast activity had already been retarded by high temperatures. Moreover, the intensity of flavor recognized in the bread with 40% inulin was too strong, thereby decreasing the evaluation of this bread.

4. Conclusions

The presence of inulin softened the dough and shifted the temperature of dough gelatinization toward higher temperatures. The added inulin positively decreased the crumb hardness, chewiness, and adhesiveness. A negative impact was recorded for the baking losses. This parameter, which is used to quantify the amount of water which evaporates from the dough during heating, was higher in the breads with added inulin. The added inulin had no significant effect on the springiness, cohesiveness, or resilience with up to 30% inulin, followed by a decrease in the values of these parameters in the bread with 40% added inulin. The addition of 30% inulin seemed to be optimal for obtaining rice bread with an acceptable loaf-specific volume, bread porosity, as well as other breadcrumb characteristics. The panelists favored this bread as well. It could be concluded that the addition of inulin should not exceed 30% to obtain rice bread with acceptable characteristics. The incorporation of inulin into commercially produced gluten-free bread could expand the range of nutritionally valuable bakery products. Consuming bread with 30% added inulin would equate to a daily intake of 23 g of inulin, which is close to the recommended value. Further research is required to test the applicability of inulin in the production of other types of bread. Given that inulin can replace fat and sugar, research focused on its applicability in pastry production may yield new results that can be applied in commercial bakeries.

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