

Volume and Texture of Brown Rye Bread Fortified with Different Cellulose Fibres Length

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Abstract Fibres have positive effects on human health, if there is sufficient intake. But most people ingest too less amounts of fibres daily. In order to improve this, in present study rye bread was fortified with three different cellulose fibres length (18 µm, 300 µm, 700 µm) for a daily consumption of fibres. For developing and enriched bread with comparable parameters to a standard rye bread, effects of cellulose addition were measured on rye bread volume and crumb texture. Results were that with rising cellulose fibre length rye bread volume decrease and crumb texture became firmer. Changes in bread volume and crumb structure were observed, since with increasing cellulose length, the water binding via cellulose also increased. This bound water was not available for pentosan structures in bread. The result is that the regular swelling processes are hindered and a comparable elastic dough formation as in standard bread could not be attained. Adding cellulose fibres with different fibre length also influenced the firmness of bread crumb and volume of bread.

Keywords: rye bread, cellulose, volume, texture

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1. Introduction

Fibres are an important part of healthy nutrition. Several clinical studies suggest that a sufficient daily intake of fibres has positive effects on prevention of diabetes, coronary heart disease and constipation [1,2]. Fibres are divided in insoluble and soluble fibres. Cellulose (polymer of β-D-Glucose) belongs to the group of insoluble fibres, which raise the volume, weight and frequency of faeces, soften it and decrease time in the intestinal tract [3]. Despite these positive effects, many people ingest not enough fibres daily, especially elderlies in nursing homes [4]. Instead of recommended daily allowance of 30 g fibres (D-A-CH reference value 2012 [5]) older men ingest just 15.1 g and older women only 12.7 g fibres a day [4].

This shows that daily eaten food provides in fact enough calories but not enough fibres. Changing this situation by nutritional advices individually and by media for the whole population did not succeed during the last decades. This proves that smarter ways are needed to bring the fibres to the people. A opportunity might be the enrichment of daily consumed food by fibres e.g. by adding them to the backing process. Bread is one of those products which most people eat day by day. However, enriched breads with fibres are hardly available as it is known that fibres change the baking properties of wheat breads, like loaf volume and crumb firmness [6,7]. Opposed to it Seguchi et al. [8] reported that cellulose smaller than

154 µm and larger than 270 µm reduce loaf volume. Kock et al. [9], Noort et al. [10] and Zhang and Moore [11] showed that with decreasing particle size of fibres wheat bread volume decreased, because the fibres interfered with the formation of the gluten network, whereby the gas-holding capacity of the dough is influenced [6,12,13]. Noort et al. [10] established lower loaf volume with increasing surface of fibre particle, because water binding is reduced [10,14]. Pomeranz et al. [14] also noted that with increasing cellulose length water absorption increased.

In contrast Lai et al. [7] and Moder et al. [16] found out that a smaller particle size caused a higher loaf volume. Curti et al. [17] determined no influence on bread volume because of different particle size of fibres. Pomeranz et al. [15] and Gomez et al. [12] reported that fibres especially cellulose decrease volume. But they noted that different particle size of cellulose had no different effects on loaf volume. Pomeranz et al. [15] determined that cellulose don't influence gassing power. So they assumed that breads with cellulose became smaller because of reduced gas retention. Also Wang et al. [18] supposed that the formation of gluten network is hindered and binding properties of gluten are influenced by fibres. Therefore the dough became stiffer and less elastic, whereby the dough showed a little gas retention.

Beside bread volume changes due to fibres addition, it is supposed that fibres caused a firmer crumb [6,7,13,17]. Curti et al. [17] also measured a firmest crumb by fibres with intermediate particle size bran fraction. Gomez et al. [12] noted a firmer crumb because of addition of cellulose and other fibres.

Because bread is part of basic food in Europe, where the average consumption per person per year is 50 kg [19], and there is a lack of fibres ingestion, rye bread was fortified with fibres in current study. Thereby the aim of the study was to research how bread volume and crumb texture change due to cellulose addition. Therefore three cellulose fibres with different length were baked in rye bread and bread volume and crumb texture were measured.

2. Material and Methods

2.1. Bread Preparation

Breads were baked under laboratory conditions following the formulation shown in Table 1. For bread with fibres three cellulose fibres (Vitacel® LC 600-10, LC 200, LC 1000, J. Rettenmaier & Söhne GmbH & Co.KG, Rosenberg, Germany) with different length (LC 600-10: 18 µm, LC 200: 300 µm, LC 1000: 700 µm) were used. Before cellulose fibres were added to the other ingredients, 118.6 g cellulose fibres were macerated in 200 g pre-warmed water (37°C) for 5 Minute.

Table 1. Bread formulation for two kilograms of dough.

Ingredients	Standard bread		Bread with cellulose	
	Amount in g	Amount in %	Amount in g	Amount in %
Rye flour type 997	830	41.5	678.9	33.9
Wheat flour type 550	270	13.5	220.9	11.0
Dry Auer (Diamalt)	33	1.7	27.0	1.3
Breadcrumbs	23	1.2	18.8	0.9
Yeast (<i>S. cerevisiae</i>)	15	0.8	12.3	0.6
Salt	23	1.2	18.8	0.9
Water (pre-warmed: 37°C)	806	40.3	904.7	45.2
Cellulose fibres*	-	-	118.6	5.9

*cellulose fibres with different length: 18 µm, 300 µm, 700 µm.

Ingredients were kneaded with the dough kneader (Typ S20G3, DIOSNA, Osnabrück, Germany) first for 5 minutes at Level 1 (60 strokes per minute) and further 5 minutes at Level 2 (120 strokes per minute). Dough resting followed for 30 minutes at a temperature of 23°C and was afterwards covered with a moist cloth. The dough was split up to three parts of 800 g-portion. Each part was kneaded cylindrically and added to a fatted iron baking pan. Subsequently, the raw dough was incubated for one hour at 35°C and 80 % humidity in the proofing cabinet (Typ AEG5, Fa. MIWE, Arnstein, Germany) for rising process.

Standard breads and breads with cellulose fibres were baked in conventionally oven (Type CE 416/77H, Winkler Wachtel, Hilden, Germany). The Oven was heated up to 200°C and the baking process proceeded for 50 minutes until the bread with crust had the core temperature of 95°C. For the first 5 minutes the slide damper was opened and steam was added for 5 seconds. All breads were baked triply on three different days.

2.2. Analytics

Crumb firmness was measured using a TA-XT Plus texture analyser (Stable-Micro-Systems, Surrey, Great Britain), which measured maximal force in Newton. Slices of 25 mm were compressed 9.5 mm with a cylindrical probe (diameter: 35 mm, contact: 962 mm², cylinder aluminium) and with test speed of 1.00 mm/sec. Three slices of two breads of each bread type were measured on three days.

Volume of breads was measured using a volume scanner (Volume Scan Profiler VSP 600, Fa. Stable Micro Systems, Great Britain), which measure the volume of rotating bread (rotation velocity: 1 rps) with an optical laser (2 mm vertical step). The volume scanner was calibrated before measuring every series of tests. Three loaves of each bread type were measured on three days.

2.3. Statistical Analysis

All statistical analysis were calculated with SPSS® statistical software (Version 20.0, SPSS Inc., Chicago, USA). The firmness and volume values were analysed for significance using a one-way analysis of variance (ANOVA) with post hoc testing by Tukey-B test with a significance level of $p \leq 0.05$. The mean values of firmness and volume are shown with standard deviations. Normal distribution was determined with Shapiro-Wilk-Test ($p \leq 0.05$) and test of homogeneity of variance was passed by Levene Test ($p \leq 0.05$).

3. Results

Firmness and volume values of the breads are presented in Table 2. Bread with 18 µm cellulose fibres had the softest texture and differed significantly from other breads. In contrast bread with 300 µm cellulose fibres showed similar firmness values like standard bread without fibres. Thus there was no significant difference between both bread types. Bread with 700 µm cellulose fibres led to firmest structure, being significantly from the other tested breads. It was further observed that with rising cellulose fibres length the texture became firmer.

Lowest bread volume were obtained while applying 700 µm cellulose fibres, followed by bread with 300 µm cellulose fibres, which didn't differ significantly. Bread volumes containing 18 µm cellulose fibres were significantly larger than those containing either 300 or 700 µm fibres. Major volumes were measured by standard bread without fibres, which differed significantly. It was identified that volume of breads increase with declining cellulose fibres length and bread without fibres were the largest one.

Table 2. Firmness and volume values.

	Standard bread	Bread with 18 μm cellulose fibres	Bread with 300 μm cellulose fibres	Bread with 700 μm cellulose fibres
Firmness in N	33.67 \pm 4.73ab	26.99 \pm 2.83a	33.18 \pm 2.94 ab	38.42 \pm 3.81 b
Volume in ml	1263.4 \pm 36.3 b	1213.8 \pm 30.1 ab	1166.3 \pm 20.9 a	1150.8 \pm 26.6 a

Mean S.D. values with different letters in the same row are significantly different ($p \leq 0.05$).

4. Discussion

Firmness values of the breads showed that with rising cellulose fibres length the texture became firmer. Firmness of standard bread was firm like bread with 300 μm fibres. Differences in firmness were significant between breads with fibres. These results are in conflict with prior studies [6,7,12,13,17], where it was observed that fibre addition in bread caused a firmer crumb texture. But in present study the addition of cellulose with 18 μm in rye bread softened crumb texture and bread with fibres 300 μm was firm like standard bread. Only in the case of adding largest cellulose fibres, could an elevated firmness than the standard bread could be determined agreeing with prior reported studies [6,7,13,17]. A reason for these different results might be that prior studies fortified wheat bread with fibres whereas in present study rye bread was enriched with cellulose. There are well known differences in the gluten structure between bread of wheat and rye which could lead to these different effects of fibres in those different kinds of breads. Rye bread contains also gluten, but it is not formed to a gluten network like in wheat bread. Instead pentosans are responsible for baking properties in rye bread [20,21].

Dissimilar firmness values of different cellulose length are caused by different water absorption properties. The size of celluloses fibres is reportedly related with higher water binding capacity [10,14,15]. As there was not any additional water provided for breads with cellulose, large cellulose fibres took more water away from dough than the smaller ones. Therefore breads with smaller cellulose fibres had more water for developing the dough than those with longer cellulose fibres. Doughs and breads with more water for pentosans have a softer texture which could be observed in this study.

It has been reported that the addition of cellulose fibres decreases loaf volume [12,15]. Comparison of loaves volumes showed that volume of breads decrease with increasing cellulose fibres length and standard bread was the largest. These results are in conflict with some prior studies. Pomeranz et al. [15] noted that different particle size of cellulose had no different effect on loaf volume. They determined that cellulose don't influence gassing power. So they assumed that breads with cellulose became smaller because of reduced gas retention independent of particle size. But this could not be observed in current study. Furthermore Curti et al. [17] determined no change of volume because of fibre addition with different particle size which is also not observed in the present study. A reason for these different results could be that those authors added bran fraction of wheat to wheat bread instead of adding cellulose fibres as was done here [17]. This suggests that cellulose provides different technological effects than the bran fraction of wheat. Likewise results of de Kock et al. [9], Noort et al. [10] and Zhang and Moore [11] are not in agreement with the

results of present study, because they noted a smaller volume with decreasing particle size of bran fractions in wheat bread. This difference in results could also be caused by the different kinds of bread and the different effects of bran and cellulose.

Noort et al. [10] and Wang et al. [18] assumed that fibres influenced adversely development and physical properties of gluten network by both chemical and physical mechanism. Reason for stronger effect of decreasing fibre particle size, is that small fibres have a larger particle surface and can interact and interfere more with gluten [10,18]. It is also mentioned that the addition of fibre structures disturb the gluten network formation, where consequently also the gas-holding capacity of the dough is effected [6,12,13]. These results were determined in wheat bread which has a strong network of gluten. But present results had been produced in rye bread which builds a much weaker network of gluten. In contrast to gluten in wheat bread, pentosans are responsible for baking properties in rye bread [20,21]. These differences between both bread types could explain that the effects of these authors could not be seen in the present work.

There are structural differences between both non-starch polysaccharides cellulose and pentosans. Cellulose consists of β -D-Glucose units, which are linked with β (1 \rightarrow 4) glycosidic bonds and forms long, unbranched chains [20,21]. In contrast pentosans (=arabinoxylan) are formed by units of xylan, which consists of D-xylose units linked by β (1 \rightarrow 4) glycosidic bonds, with L-arabinofuranose attached randomly by α (1 \rightarrow 2) and/or α (1 \rightarrow 3) linkages to the xylose units throughout the chain [22,23].

It is known that loaf volume decrease with increasing cellulose fibres, because large cellulose fibres absorbed more water than small cellulose fibres [10,14,15]. So it is supposed that cellulose fibres and pentosans contained in high amounts in rye dough are important for the formation of the rye bread crumb, compete for water in the dough. The resulting effect is that pentosans do not bind enough water for the formation of an elastic dough and the gas retention of rye bread with large cellulose fibres is negatively influenced. Hence volume of bread decreases with increasing cellulose fibres.

In contrast Lai et al. [7] and Moder et al. [16] found out that a smaller particle size caused a higher loaf volume, whereby the results of this study are confirmed.

5. Conclusion

It was determined that adding cellulose in rye bread influenced loaves volume and crumb texture. Standard bread showed greatest volume and crumb texture is firm like bread with 300 μm cellulose fibres. With increasing fibre length of cellulose the volume of the rye breads decreased and crumb texture became firmer. This is caused, because small cellulose fibres absorbed less water than large cellulose fibres. Hence there is a competition for water between fibres and pentosans. As a consequence

pentosans adsorbed too less water for formation of an elastic dough. In this way the gas retention of rye bread with large cellulose fibres is influenced negatively. Therefore volume and crumb texture of bread with large cellulose fibres became smaller and firmer, respectively.

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Statement of Competing Interests

The authors have no competing interests.

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