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Rheological parameters of dough with inulin addition and its effect on bread quality

T Bojnanska[1], M Tokar[1] and A Vollmannova[2]
[1]Department of Storing and Processing Plant Products - Faculty of Biotechnology and Food Sciences - Slovak University of Agriculture in Nitra - 94976 Nitra - Slovak Republic
[2]Department of Chemistry - Faculty of Biotechnology and Food Sciences - Slovak University of Agriculture in Nitra - 94976 Nitra - Slovak Republic

tatiana.bojnanska@uniag.sk, alena.vollmannova@uniaf.sk, marian.tokar@uniag.sk

Abstract. The rheological properties of enriched flour prepared with an addition of inulin were studied. The addition of inulin caused changes of the rheological parameters of the recorder curve. 10% and more addition significantly extended development time and on the farinogram were two peaks of consistency, what is a non-standard shape. With increasing addition of inulin resistance to deformation grows and dough is difficult to process, over 15% addition make dough short and unsuitable for making bread. Bread volume, the most important parameter, significantly decreased with inulin addition. Our results suggest a level of 5% inulin to produce a functional bread of high sensory acceptance and a level of 10% inulin produce a bread of satisfactory sensory acceptance. Bread with a level over 10% of inulin was unsatisfactory.

1. Introduction
Food industry aims at the development of new products towards functional foods and ingredients with regard to the consumer´s demands on healthy nutrition. Being a source of proteins, dietary fibres, vitamin and micronutrients, bread is considered to be of global importance in nutritional equilibrium. As a response to public health problems innovative bread formulations have been in progress [1].

Wheat bread is a major component of people´s diet all over the world. Its consumption in Western Europe is stable, although it varies greatly between states. The Germans, Austrians and Scandinavians eat the most bread at about 70 – 80 kg per person per year while the UK, Ireland, France and Benelux are at the bottom of the list with an annual consumption of less than 60 kg [2]. In Slovakia consumption of bread (including bread under 400 g) has been recently about 70 kg per person per year. There has been increasing demand for food products with additional health benefits. In this respect, the enrichment of bread with the functional fibre (inulin) is of interest to the consumer as well as the cereal industry.

Contrary to whole bread, which is relatively high in fibre content (7 – 8 % of dry matter), white bread contains only 2 – 3 % fibre on a dry matter basis. Fibres, and more particularly the soluble ones, like inulin and oligofructose, might help to prevent diseases such as intestinal infection, colorectal cancers, obesity, cardiovascular diseases and type II diabetes [3], [4]. Bread represents a suitable food product for the addition of functional ingredients, such as the prebiotic inulin.

Water-soluble fibre predominantly consists of non-starch polysaccharides. Soluble fibre inhibits passing of the chime through the intestines, hampers the stomach discharge, reduces the absorption of glucose and sterols in the intestines, and decreases serum cholesterol, blood glucose, and the content of insulin in the human body [5], [6]. Inulin and oligofructose are not hydrolysed in the gastrointestinal tract, except in the colon where they have a specific effect on the microflora, more specifically by promoting very selectively the growth of bifidobacteria to the detriment of other (potentially pathogenic) microorganisms [7], [8].

Inulin is a storage carbohydrate found in many various plants like chicory and Jerusalem artichoke and contains fructan chains of different degree of polymerization. Inulin is a mixture of fructose polymers of various lengths with β(2-1) glycosidic bonds, terminated generally by a single glucose unit. Native inulin has the degree of polymerisation (DP) of 2 – 60 but high performance inulin has an average DP of about 23 – 25, depending on the manufacturer [9]. It is used to increase the amount of dietary fibre or as prebiotic ingredient in particular in dairy and bakery products [10]. Industrially it is nearly exclusively produced from chicory.

In food inulin presents a hydroscopic property and is able to reduce the available water contents during gelatinization of starch, causing carbohydrates to be less absorbed, leading to a lower glycemia rate. Besides the physiologic effect on glycemia outlined, the addition of these fructans is promising as they do not alter the appearance of flavour of foods [11].

Inulin influences bread quality characteristics too. Fibre addition increases mixing time and dough stability and decreases softening degree and farinograph water absorption [12], which depend on DP [13]. Inulin in bread produced a significant reduction in loaf and specific volume in relation to the standard sample and the most evident effect is the increase of crumb firmness and the dark crumb appearance [12].

Rheological measurements are often used to predict the behaviour of wheat dough during processing and the quality of the final product (bread). The aim of the present research was to incorporate this soluble fibre (inulin) into wheat and evaluate its effects on rheological properties of the dough and bread quality.

2. Materials and Methods

Mixes of wheat flour (T650) and inulin from chicory (Deracel CF 20, Dera Food Technology, Belgium) were prepared by substitution of wheat flour by 5 %, 10 %, 15 %, 20 % and 25 % of inulin.

2.1. Rheological measurements

Farinograph – E, Brabender OhG, Duisburg, Germany (ICC-Standard 115/1, 1992, AACC Method 54T21, 1995) was used for the study of the rheological properties of dough. The mixing curve is characterised by an ascending part that indicated the changes during the dough development process, while the subsequent decline in the resistance is taken as a sign of a steady breakdown of the dough structure upon mixing beyond the point of optimum development. Optimum development from the standpoint of bread quality may occur slightly past "mixing peak". The following parameters were determined:

Water absorption capacity – defined as the amount of water required to centre the highest part of the mixing curve on the arbitrary 500 FU (farinograph units) line.

Mixing time – dough development time – time interval in minutes from the first addition of water until the curve reaches its maximum height.

Stability – time in minutes for which the top of the curve remains over 400 line.

Degree of softening in FU – the distance between the centre of the mixing curve and the 500 line after 10 min mixing.

Elasticity in FU – defined as the width of the recorder curve after 10 min mixing.

2.2. Bread-making procedure

Six different bread were formulated following a full experimental design. 1000 g of wheat flour (T650) or flours mixes were used for the preparation of test breads with water quantity determined by farinograph, and 4 % yeast, 1.8 % salt and 1 % sugar. Dough was mixed in an spiral mixer SP 12 Diosna (program: 10 sec. 20 Hz, 120 sec. 25 Hz, 300 sec. 50 Hz) and divided into 4 samples. For fermentation, samples were placed in a teflonplate iron form of 8.5 x 11 x 13 cm in a proofing cabinet for 40 min at 30°C, 95 % relative humidity. At the end of proofing the dough samples were baked in a static sole oven (MIWE Condo, Arnstein, Germany) 10 min at 240 °C (with 0,08 l of steam at the beginning of baking) and 25 min at 220 °C (without steam).

Bread quality was evaluated 24 hours after baking: weight (g), loaf volume (cm³) - *was determined by the method of millet seeds displacement (OBK-03, Mezos)*, specific loaf volume (cm³/100 g loaf), volume efficiency (cm³/100 g flour), baking loss, height/width ratio (cambering), crumb acidity - determined *by titration method with sodium hydroxide and indicator phenolftalein.*

2.3. Bread sensory analysis

The sensory evaluation was conducted in line with ISO 8589 according to sensory descriptor. Following parameters were evaluated: general appearance and shape (significance coefficient 1), surface and properties of the crust (significance coefficient 2), fermentation and crumb appearance (significance coefficient 4), structure and flexibility of breadcrumb (significance coefficient 4), smell and taste (significance coefficient 9. The maximum possible score to achieve was 100. The sensory quality was analysed using sensory profiling and hedonic tests. Five experts have examined and tasted the samples and recorded their perceptions.

3. Results and Discussion

3.1 Mixing properties

Mixes of wheat and inulin were prepared by substitution of wheat flour by 5 %, 10 %, 15 %, 20 % and 25 % of inulin. The rheological properties of the doughs produced from these flour mixes were studied by Farinograph. Low addition of inulin (5 % and 10 %) decreased water absorption capacity of mixes in comparison to wheat flour but increasing of inulin addition (15 % - 25 %) proportionately increased water absorption capacity of mixes (Figure 1).

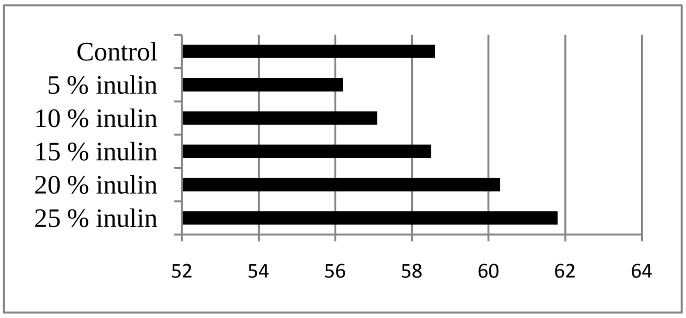

Figure 1. Effects the addition of 5 %, 10 %, 15 %, 20 % and 25 % inulin on Farinograph water absorption capacity

Dough is made from wheat flour to which an amount of water, based on the initial moisture content of the flour is added in order to reach a constant hydration level on a dry matter basis. During the kneading of this dough, the pressure on one side of the mixer is continuously monitored. The peak pressure recorded during kneading is used to calculate the water absorption of the flour at a given consistency (target pressure) [14].

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The water absorption capacity is important parameter, which influences not only dough consistency but also economy of bread production. It is determined by the protein content of the flour, the amount of starch damaged during milling and the presence of non-starch carbohydrates. It is desirable that flours for bread-making possess a high water absorption capacity at normal working consistencies so that the yield of dough, and hence bread, will be relatively high [15]. Because the farinograph test measures a rheological quality of dough prepared from the tested flour, the relationship may be affected by any treatment or addition of material that alters the rheological character of dough [16].

Table 1. Rheological parameters of dough as affected by addition of inulin to wheat flour

Parameter	Control	5 % I	10 % I	15 % I	20 % I	25 % I
Water absorbing capacity	58.6^{b}	56.2^{b}	57.1^{b}	58.5^{b}	60.3^{ab}	61.8^{a}
Development time	2.3^{d}	2.4^{d}	20.0^{a}	16.5^{b}	11.0^{c}	10.5^{c}
Stability	2.3^{c}	8.9^{b}	7.2^{b}	8.0^{b}	4.2^{b}	4.4^{b}
Degree of softening	48^{a}	25^{b}	0^{c}	0^{c}	0^{c}	0^{c}

The values of the parameters determined by farinograph for control wheat flour and flour mixes containing 5 %, 10 %, 15 %, 20 % and 25 % of inulin are given in Table 1. The addition of inulin caused significant changes of the rheological parameters of the recorder curve (statistical analysis was carried out using Kruskal-Wallis test). A higher change is observable in the case of more than 5 % inulin flour addition. The addition of 20 % of inulin caused important significant changes in all parameters measured, and consequently negatively affected the quality of the final product.

The addition of inulin causes extension of the dough development time. Dough stability is influenced as well by the degree of polymerization of inulin [12], [17], [18]. With the increased addition of inulin acceleration of hydration and decrease of consistency at the start of the kneading was recorded in comparison to control samples. On farinograms there are two peaks of consistency observed in samples with a portion of inulin. The first peak is at the beginning of processing of the mixture and it is caused by the primary hydration, the second peak represents the maximum consistency. Control samples showed the farinogram curve standard for wheat flour (Figure 2).

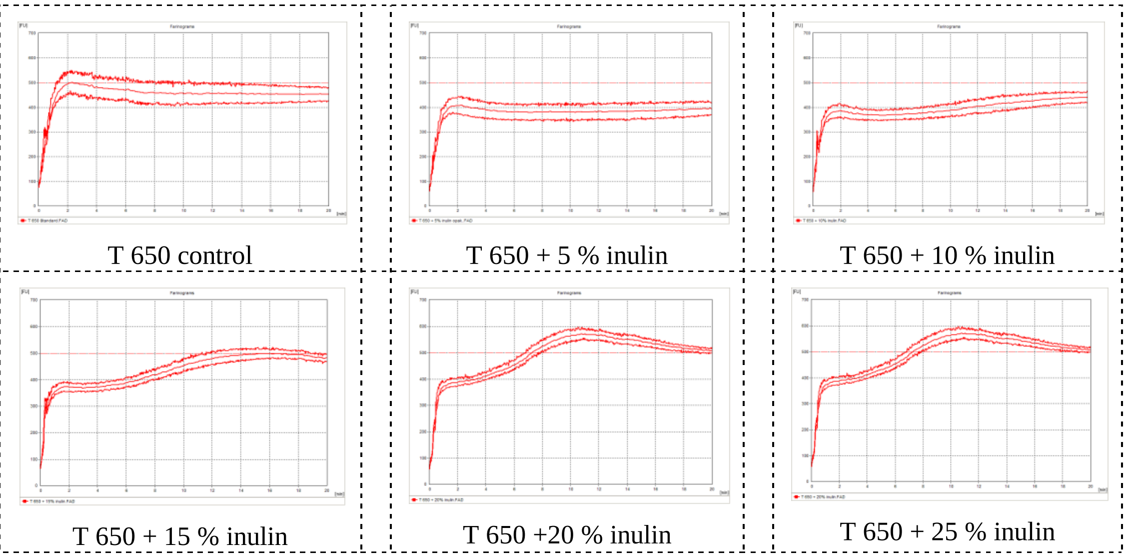

Figure 2. Farinograms of control samples and samples with inulin addition

Considering the curves of the samples with the addition of inulin, it is clear that there have been changes in the structure of the glycoprotein matrix. The intensity of these changes was affected by the increased portions of inulin in the flour. Inulin may have a potential to replace a portion of wheat flour without causing detrimental consequences for dough quality. The addition of inulin to wheat flour improved the strenght of the respective doughs, and the effect was especially prominent in the case of weaker flour [19].

Inulin might influence dough properties in various ways: it may affect dough consistency formation of elastic networks, which contribute to the overall dough elasticity and strength and interaction with gluten [19].

3.2 Bread quality

The impact of different levels of inulin on bread properties is presented in Figure 3. The addition of inulin 10 % and more led to a decreased bread quality. Loaf volume and specific loaf volume decreased by the incorporation of inulin, which could be due to gelatinization delay that may promote higher dough expansion during the baking stage. Regarding the bake loss, the addition of inulin did not have a significant influence.

Hager et al. [20] state that addition of inulin darkened the crust of wheat loaves. The partial breakdown of the polysaccharides as well as the monosaccharides present in the inulin powder leads to a stronger Maillard reaction and, therefore, to a darker products [21]. However, in our experiments the additions of inulin in an amount of 5 % to 25 % did not cause darkening of crumb or crust.

Crumb hardness is correlated with the perception of bread freshness. Crumb hardening, which is one of the most obvious manifestations of bread staling, is caused by starch retrogradation as well as differences in vapour pressure between crumb and crust resulting in moisture migration. Additions of inulin did not significantly affect crumb hardness in comparison to control samples which is considered as positive [20].

Our results suggest a level of 5 % inulin to produce a functional bread of high sensory acceptance and a level of 10 % inulin to produce bread of satisfactory sensory acceptance. Bread with a level over 10 % of inulin was unsatisfactory (Figure 4). Similar results were reported by Brasil et al. [11]; bread with addition of inulin (6 %) was classified as good quality bread.

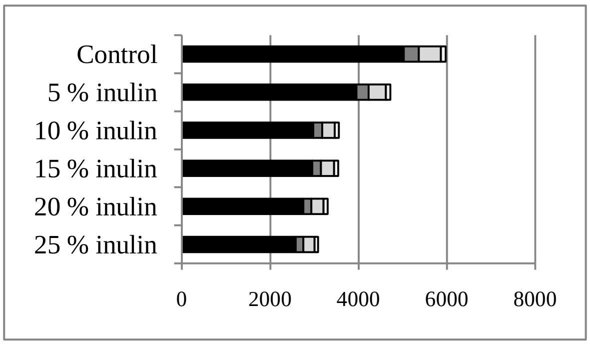

Figure 3. Bread properties
(**Bread properties**: loaf volume + specific loaf volume + volume efficiency + cambering x 100)

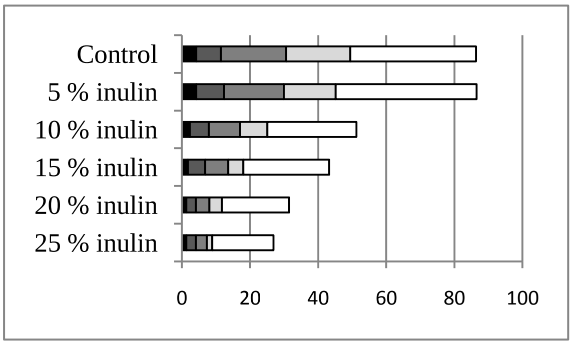

Figure 4. Sensory evaluation
(**Sensory evaluation**: general appearance and shape + surface and properties of the crust + fermentation and crumb appearance + structure and flexibility of breadcrumb + smell and taste)

4. Conclusion

Flour replacement at different levels (from 5 % up to 25 %) by inulin changed dough machinability, viscoelasticity and bread-making performances. Low addition of inulin (5 % and 10 %) decreased water absorption capacity of mixes in comparison to wheat flour but increasing of inulin addition (15 % - 25 %) proportionately increased water absorption capacity of mixes. The addition of inulin caused significant changes of the rheological parameters of the recorder curve, on farinograms there are two peaks of consistency observed in samples with a portion of inulin. The addition of 10 % and more of inulin led to a decreased bread quality, including the sensory quality. The present study has indicated that breads made with about 5 % inulin had high sensory acceptance.

Therefore, the addition of inulin could be an effective way to produce functional white flour bread without changing negatively its desirable physical properties. The incorporation of inulin has a positive effect on the nutritional value of wheat breads. European consumer prefers foods with properties strengthening human health. This study showed that several technological and textural properties are altered upon the inclusion of this dietary fibre.

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