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Rheological properties of whole wheat and whole triticale flour blends for pasta production

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Abstract. Whole grain flour can be considered as a good candidate for pasta fortification due to the health benefits. In the literature it is mentioned, that when pasta dough is fortified with non-traditional ingredients, it behaves differently. Therefore, the purpose of the current research was to investigate the rheological properties of the whole wheat and whole triticale flour blends for pasta production. Whole grain flour made from triticale and wheat grains was used in the present research. Wheat flour type 405 was used as a control. The blends were made from whole triticale and whole wheat flour in combination with wheat flour (type 405) in various proportions (from 10% to 100%). The following quality parameters were analysed by using standard methods: the rheological properties of dough were analysed using Brabender Farinograph-AT; moisture content of flour samples was determined according to AACC (2000) Method No. 44-15A. The results of the present research demonstrate that the rheological properties of dough become worse by increase the amount of whole grain flour in a blend. Water absorption is higher and dough development time of dough with whole grain flour addition is longer than the parameters of control wheat flour (type 405). The same results were obtained during analysing dough stability and development time. However, higher dough stability was obtained for the blends with whole wheat flour, compared to blends with whole triticale flour, what possibly is due to the higher gluten content in whole wheat flour.

Key words: whole wheat, whole triticale, flour blends, pasta, farinograph.

INTRODUCTION

Cereals and their products constitute an important part of the human diet, providing a high proportion of carbohydrates, proteins, fats, dietary fibre, B-group vitamins and minerals. More and more foods are made from whole grain (Okarter et al., 2010). Consumption of whole grain foods has been associated with decreased risk of cardiovascular disease and certain cancers, favourable effects on blood lipids and glucose, improved insulin resistance, and higher intakes of dietary fibre and micronutrients (McKeown et al., 2002). Traditionally pasta products are made from wheat semolina, although more recently other cereals have been used to partially replace it. Common wheat flour also can be useful for pre-cooked pasta products, but because of the low protein content, addition of high protein components such as whole grain flour may enrich the products and result in improved functional properties and quality when the right processing conditions are used (Chillo et al., 2008).

Wheat (*Triticum* spp.) is the main cereal crop used for human consumption in many areas worldwide. Traditionally, pasta is manufactured from durum wheat (*Triticum durum* Desf.) with protein content less than 15%, which results in a product considered to be of superior quality for pasta made from cheaper common wheat (*Triticum aestivum* L.) or a blend of the two species. Pasta is consumed in large quantities throughout the world. Scientific research has been undertaken to understand the parameters influencing pasta processing and the final product quality. Cooked pasta is firm and resilient with no surface stickiness and little if any cooking losses (Troccoli et al., 2000).

Triticale (X *Triticosecale Wittmack*) is a man-made cereal grain species resulting from a plant breeder's cross between wheat (*Triticum*) and rye (*Secale*). Triticale incorporates the functionality and high yield of wheat and the durability of rye. Triticale has a potential for use in bread production. However, because most of the varieties available are not suitable for leavened bread making on their own, due to the production of a weak and sticky gluten, they can only be successfully used for producing a range of unleavened products such as cakes, cookies, biscuits, waffles, noodles, pastas, and breakfast cereals. Recently, efforts to enlarge food resources have resulted in new approaches to expanding triticale's applicability for human consumption. For example, certain triticale varieties have been used to produce bread of the acceptable quality under special bread making conditions (Doxastakis et al., 2002).

Characterization of the rheological properties of dough is effective in predicting the processing behaviour and in controlling the quality of food products (Song & Zheng, 2007). When wheat flour is mixed with water, with the required amount of energy, dough is formed. The behaviour of the resulting dough when submitted to mechanical energy input is determined by dough rheological properties (Bloksma, 1990). Gliadin and glutenin are the two primary types of grain proteins which are responsible for the elastic and viscous properties, respectively, which help to form a continuous spatial network in the dough (Koehler et al., 2010). These properties derive largely from the gluten proteins, which form a continuous viscoelastic network within the dough. Gliadins are monomeric proteins that form only intra-molecular disulphide bonds, if present, whereas glutenins are polymeric proteins whose subunits are held together by inter-molecular disulphide bonds, although intra-chain bonds are also present. Among these storage proteins, glutenins (polymeric proteins) have been shown to be extremely important in determining the rheological properties (Jia et al., 1996). Gluten is the main base of the wheat dough and is the protein that only exists in wheat and rye. Wheat flour dough simultaneously exhibit characteristics of a viscous liquid and of an elastic solid and hence are classed as viscoelastic materials (Bagley et al., 1998). Dough mechanical properties depend on a large variety of factors including flour cultivar, mixing time, temperature, etc. (Bagley et al., 1998; Pastukhov & Dogan, 2014). Bran and germ particles also disrupt the continuity of the protein network, resulting in weaker, less firm pasta (Manthey & Schorno, 2002).

In the scientific literature it is mentioned, that when pasta dough is fortified with non-traditional ingredients, it behaves differently (Roda, 2013; Rayas-Duarte et al., 1996). Therefore, the purpose of the current research was to investigate the rheological properties of the whole wheat and whole triticale flour blends for pasta production.

MATERIALS AND METHODS

The study was carried out at the scientific laboratories of the Faculty of Food Technology at Latvia University of Agriculture (LLU) and at the laboratory of the JSC 'Jelgavas dzirnavas' (Latvia).

Conventional triticale (line ′9405-23′), grains of 2014 cultivated at State Priekuli Plant Breeding Institute (Latvia), wheat (′Zentos′) grain cultivated at LLU Research Centre 'Peterlauki' (Latvia) were used in the experiments. For the flour blend obtaining wheat flour type 405 from JSC 'Dobeles dzirnavnieks' (Latvia) was used. Wheat and triticale grain was ground in a laboratory mill PLM3100/B (Perten, Sweden) obtaining fine whole grain flour. Wheat flour type 405 was used as a control. The flour blends were made from whole wheat or whole triticale flour in a combination with wheat flour (type 405) in various proportions. For the research twenty one flour blends was made: flour blend with whole wheat or whole triticale flour. Experimental flour blends were made substituting part of wheat flour type 405 with whole grain flour in proportion from 10% to 100%.

Moisture content of the flour samples was determined using an air-oven method according to AACC (2000) Method No. 44–15A.

Farinograph analyses were done for wheat flour Type 405 (control), whole triticale and whole wheat flours. For analysis of the rheological properties Brabender Farinograph-AT (GmbH & Co.KG., Germany) was used according to the international standard methods (AACC No. 54–21, ICC No. 115/1). The results of farinograph tests were analysed primarily in the aspect of the dynamics of changes in the consistency of dough during the mixing (D'Appolonia & Kunerth, 1984). For all samples the following parameters were determined: water absorption (WA) of flour and flour blends, stability of dough (S), dough development time of (DDT), degree of softening (DS). Water was added automatically from the farinograph water container to flour and mixed to form the dough. The farinograph was connected to a circulating water pump and a thermostat which operated at 25 ± 2°C. The default speed value for flukes was 63 rpm and the duration of the experiment was 20 min.

Microsoft Excel software was used for the research purpose to calculate mean arithmetical values and standard deviations of the obtained data. SPSS 20.0 software was used to determine the significance of research results, which were analysed using the two-factor ANOVA to explore the impact of factors and their interaction at the significance effect with statistical significance (α) set at $P < 0.05$. Pearson's (r) coefficient was calculated for measure of the strength and direction of the linear relationship between two variables that is defined as the covariance of the variables divided by the product of their standard deviations: close interconnection if $0.7 < |r| < 0.9$; average interconnection if $0.50 < |r| < 0.69$; not significant interconnection if $0.20 < |r| < 0.49$.

RESULTS AND DISCUSSION

Water migration is a common problem in many food products. However, the physical structure of food materials plays a decisive role on their moisture transport properties generally characterized by overall effective moisture diffusivity. For example in a porous product, this effective diffusivity is affected mainly by the volume fraction and distribution of both solid and gas phases (Roca et al., 2007), comparing with compressed products as pasta.

In the present experiments significantly higher (P = 0.004) moisture content (Table 1) was established for wheat flour type 405, compared to whole wheat and whole triticale flour. The moisture content of the control wheat flour was by about 4% higher compared to the whole wheat flour and by about 3% compared to the whole triticale flour.

Table 1. Moisture content of flour samples

No.	Sample	Moisture, %
1.	Wheat flour (control)	14.16 ± 0.03^{b}
2.	Whole wheat flour	10.23 ± 0.05^{a}
3.	Whole triticale flour	10.96 ± 0.03^{a}

Data followed by different letters are significantly ($P < 0.05$) different.

Moisture content of 14% is commonly used as a conversion factor for other tests in which the results are affected by moisture content. Moisture is also an indicator of grain storability. Flour with high moisture content (greater than 14.5%) attracts mould, bacteria and insects, all of which cause deterioration during storage. Flour with low moisture content is more stable during storage. Moisture content can be an indicator of profitability in milling (Keranet al., 2009). Therefore, the moisture content in flour should not exceed 15% (Kunkulberga & Seglins, 2010).

The Farinograph results characterise dough-mixing properties which are ascribed to wheat gluten, starch, lipid and water contents as well as the amount and activity of α-amylase. Gliadins and glutenins are the two primary types of grain protein which are responsible for the elastic and viscous properties, respectively, which help to form a continuous spatial network in the dough. The cohesive strength of wheat flour dough comes from glutenin. The gliadin molecules are known to reduce the stiffness and increase the extensibility of the gluten phase (Koehler et al., 2010).

Water absorption is the most important parameter measured by farinograph, which indicates the amount of water required to develop the standard dough of 500 farinograph units (FU) at the peak of the curve. Stronger wheat flours have the ability to absorb and retain more water as compared to weak flours (Mis, 2005). Water absorption is affected by the protein content of the flour, the amount of starch damaged during milling and the presence of non-starch carbohydrates (Finney et al., 1987). In the current research it was detected, that water absorption of the analysed flour samples increased with the amount of whole flour in the blend (Fig. 1). Close interconnection (r = 0.9586 for whole wheat flour and r = 0.9024 for whole triticale flour) was obtained between the increasing amount of whole flour additive to the wheat flour and the increase of flour water absorption. However, the smaller water absorption was obtained for a control–wheat flour sample (59.1 ± 0.15%), significantly (P = 0.012) higher–for whole wheat flour (69.2 ± 0.17%). The smaller water absorption mainly indicates smaller amount of added water for dough formation. The present results demonstrate that the value of water absorption was increased if the amount of added whole flour increased. However, the inclusion of a higher amount of bran in the dough formulation usually resulted in increased dough water absorption due to the higher levels of pentosans present in bran

(Sanz-Penella et al. 2008) and bran from whole grain flour can interfere with water migration, increasing water retention within the pasta (Villeneuve & Gélinas, 2007).

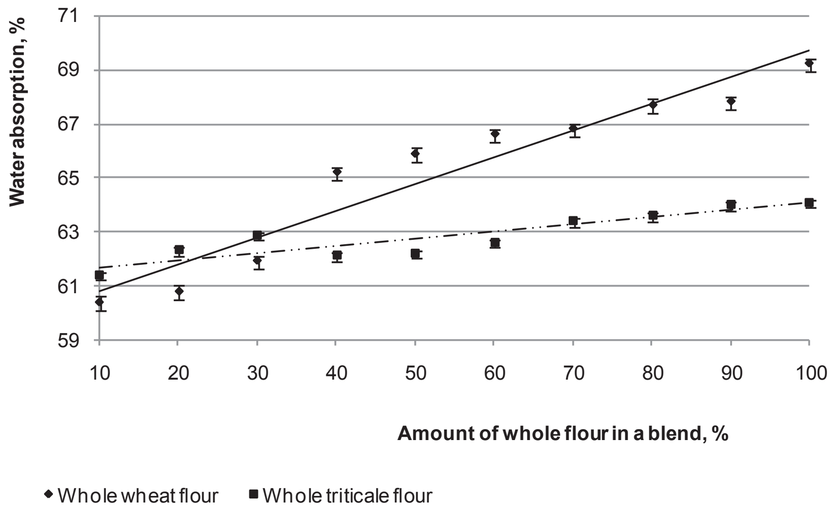

Figure 1. Water absorption for flour blends samples.

Dough stability (DS) is defined as the time difference between the point where the top of the curve first intercepts the 500 FU line and the point where the top of the curve leaves the 500 FU line. Dough stability indicates the time when the dough maintains maximum consistency and is a good indication of dough strength. Good quality dough has stability of 4–12 min (Kulhomäki & Salovaara, 1985). Close interconnection ($r = 0.9341$ for whole wheat flour and $r = 0.8846$ for whole triticale flour) was obtained between increasing amount of whole flour additive to the wheat flour and decrease of the dough stability. In the present experiments it was obtained that stability time of control dough sample was 12:15 min. Dough stability time decreased by increased amount of whole flour (Fig. 2) additive. Such changes mainly can be explained with decrease of gluten content in the analysed whole flour samples. Short dough stability time can mainly indicate non-acceptable dough properties during pasta dough mixing and formation. The stability time is an indication of the strength of flour, a higher value signifying stronger dough. Similar results were obtained by Zhang et al. (2014), where a significant difference was found in the stability time between the two flours ($P < 0.05$), the dough of waxy wheat flour exhibiting a lower stability than normal wheat flour (1.4 min and 2.7 min, respectively).

For obtaining of dough with good properties, the additive of whole triticale flour could be 30%, but of whole wheat flour – 50% (Fig. 2). Both quality and quantity of gluten affect the flour processing quality. Gluten has viscoelastic behaviour in which gliadin and glutenin fractions represent viscous and elastic behaviour, respectively. Variation in protein content alone is not responsible for the differences in dough properties and suitability for end-products amongst the cultivars (Zhu & Khan, 2002). As a result the obtained products for example pasta could have non-acceptable quality properties. The dough stability time less than 4 min is not acceptable.

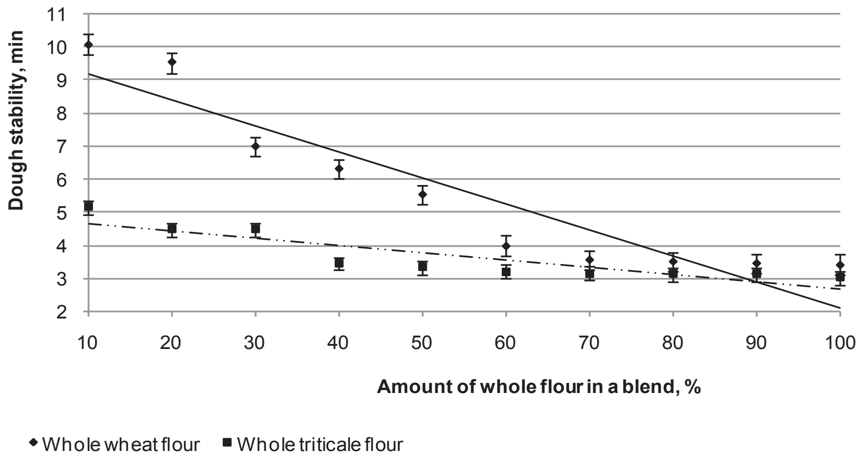

Figure 2. The dough stability of flour blends.

Close interconnection (r = 0.9573 for whole wheat flour and r = 0.8635 for whole triticale flour) was obtained between the increasing amount of whole flour additive to the wheat flour and the increase of dough development time. The shortest dough development time was found for the sample made exceptionally from wheat flour (2:22 min), but the longest dough development time (6:30 min) was observed for whole wheat flour and for whole triticale flour (7:41 min) (Fig. 3).

Figure 3. Dough development time for flour blend samples.

An increased dough development time of dough samples with whole wheat and triticale flour additive, comparing with control flour sample mainly can be due to differences in a chemical composition of whole flour, and its elevated dietary fibre content, especially. Similar results were found in the scientific literature, as the dough development time for wheat flour (1.5 min) was shorter than that of wheat flour

(2.1 min), an advantage for improving output during actual production (Zhang et al., 2014).

The results of the pasta dough rheological properties demonstrate, that maximum of whole flour amount to be added could be for whole wheat flour – 50%, whole triticale – 30%.

CONCLUSIONS

Water absorption of the analysed flour samples increased with the amount of whole wheat or triticale flour increase in the flour blend.

Higher dough stability was observed for the flour blends with whole wheat flour, compared to blends with whole triticale flour, possibly due to higher gluten content in whole wheat flour.

The shortest dough development time (2:22 min) was observed for wheat flour (type 405), but the longest dough development time – for whole wheat flour (6:30 min) and whole triticale flour (7:41 min).

In pasta production, 30% of wheat flour type 405 can be replaced with whole triticale flour or 50% of whole wheat flour still having acceptable characteristics of dough.

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