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The Influence of Arabinogalactan on Wheat Dough Development during Mixing and Leavening Process

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Arabinogalactan (AG) is very promising as a functional additive to foodstuff. The objective of this research was to evaluate the influence of AG content on structural development of wheat dough during mixing and leavening processes. Dough was prepared from wheat flour enriched with 1 – 5 % of AG. The used AG was of plant origin, specifically harvested larch trees. Dough without AG was used as control.
The farinograph characteristics of wheat flour dough enriched with AG provided useful information on the modifying effects of those additions on the behaviour of the dough during its development and mixing. The water absorption capacity was increased each time the AG proportion increased. The dough development time was significantly higher ($p < 0.05$) in the AG enriched doughs than in the control, whereas the Mixing Tolerance Index and elasticity was significantly less ($p < 0.05$) for control in relation to AG enriched doughs which indicates that the enrichment with AG may weaken the dough. Microstructure of doughs was investigated by means of Scanning Electron Microscopy. Dough with high contents of AG had a more compact microstructure compared with doughs with no or low levels of added AG.
The leavening kinetic was investigated by monitoring the variation of volume vs time by means of Image Analysis. The dough was continuously photographed during leavening stage. The area and centre of mass were determined by an Image tool software and the sample volume was calculated.
Experimental results showed that the addition of AG influenced the final volume of dough, mainly at high AG contents. As the AG content increased, the volume expansion of the dough was higher than the volume expansion of control. The experimental evidences are of special importance when formulating novel and functional bakery products.

1. Introduction

Dietary fiber (DF) is reported to have many physiological benefits related to ‘‘western diseases’’ such as coronary heart disease, obesity, diabetes (Lairon et al., 2005) and colon cancer (Hiller et al., 2011). DF is a broad category and includes constituents like non-starch polysaccharides, cellulose, dextrins, pectin, lignin, β -glucan, etc. (DeVries, 2004; Slavin, 2008). Among non-starch polysaccharides, arabinoxylan, arabinogalactan (AG) and β -glucan are of paramount importance (Vietor et al., 1994; Antoine et al., 2003). These components hold structural and functional properties important in food development and play an significant role in improving the health of the consumers.
In cereal science, AGs have received much less attention than AXs. It is a water-soluble proteoglycan, which means that it is the combination of protein and sugar molecules, present in many plant species, namely coffee beans, soy beans broad beans and cereals (Saeed et al., 2011). It is an excellent source of soluble DF and it is characterized by totally safety as a food ingredient and high biological activity (immunomodulating, prebiotic, hypolipidemic, mitogenic, antimutagenic, hepatoprotective, gastroprotective, gastroprotective membranotropism, and others) (Medvedeva et al., 2010). Recent clinical investigations of AG have demonstrated not only benefits to gastrointestinal health and immunity, but also a positive effect reducing glucose levels and insulin resistance in mice (Oki et al., 2011). This opens the

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door to potential heart health label claims and provides an option for consumers looking for foods that are beneficial in terms of body weight, blood glucose or blood insulin control.
This work is integrated in a larger study, in which arabinogalactan is being studied as a possible glycemic index reducer of bread. The glycemic index is a measure of foods' ability to raise blood glucose (Trinidad et al., 2003). Its value is a reflection of several aspects related to the food, including its formulation (Chiu et al., 2011). In this context, diverse food products have been identified as having a positive effect in diverse parameters related to the GI namely flours of different origins (Trinidad et al., 2003; Marinangeli et al., 2009) and fibers (De Angelis et al., 2007). AG benefits, as determined by human and animal clinical trials, have been observed as low as 1.5 g/day, or more specifically 20 mg/kg of body weight. AG has been found to be. On average, finished products containing a minimum of 60 mg/kg of body weight or about 4.5 g/day is recommended for foods (Ohr, 2001).
The purpose of this work was to assess the potential use of AG isolated from larch trees as ingredient in bread making, evaluating its influence on structural development of wheat dough during mixing and leavening processes.

2. Materials and Methods

2.1 Materials

Samples were prepared by using: soft wheat flour (Barilla "00", Italy), deionised water, arabinogalactan (Santa Cruz Biotechnology Inc., Germany), salt and compressed yeast (Mastro Fornaio, Paneangeli®). The used arabinogalactan was of plant origin, specifically harvested larch trees with high molecular weight (> 500.50 Da). In order to avoid the interference of ions deionised water was used for all measurements.

2.2 Dough-making procedure

Dough formulation on a 100-g flour basis was: salt (1.26 %), yeast (1.1 %), deionised water according to farinographic absorption and AG (used at three levels: 1 %, 3 % and 5.0 % of the dough weight). Dough without AG was used as control. All doughs were prepared in a planetary kneader (KitchenAid, USA), equipped with a 4,800 L bowl. Mixing time and temperature were kept constant and equal to necessary time to optimum development of dough (previously obtained from farinograph) and 25 °C, respectively.

2.3 Farinographic study

Dry mixes with a total weight of 50 g were studied in a Brabender Farinograph (O. H. Duisburg, Germany) using a 50 g bowl. For each mix, the amount of water (absorption) required to obtain a stability period at 500 Brabender Units (BU) was determined. The dough development time (DDT, time to reach maximum consistency, in minutes), elasticity (El, band width of the curve at maximum consistency, in BU), Brabender stability (BSt, time dough consistency remains at 500 BU) and Mixing Tolerance Index (MTI, consistency difference between height at pick and that 5 min later) were also determined. This procedure was applied to each dough formulation at least 3 times and the average values were adopted.

2.4 Humidity

The amount of water required for each formulation, determined in 2.3, was utilized in the preparation of the samples for the humidity evaluation. For each formulation, 3 samples weighting 2 - 3 g were dried for 24 h at 105 ºC. The dried samples weight was subtracted to the respective initial weight. The results were calculated as percentage of water per dough weight.

2.5 Volume dough expansion measurements

350 g of dough were taken just after mixing and placed on a flat surface where it could expand in every directions without constrains during leavening stage. The dough was incubated at 36 ± 1°C, 70 % U.R. The following parameters were continuously and automatically recorded:

- internal humidity and temperature by means of data logger (Logger Escort mod. 10D8, Gamma Instrument s.r.l., Naples, Italy)
- volume expansion by means of a camera mounted on a photographic bench.

By assuming axial symmetry, the loaf was considered as of a solid of revolution generated by the revolution of a lamina around the symmetry axis, accordingly its volume V was calculated as:

$$V = 2\,\pi\,A\,r_g \qquad (1)$$

where A is the lamina surface and r_g the distance of the centre of mass of the lamina from the axis. The area and centre of mass were determined by a computer assisted image analyser (Image Pro Plus 6.1 for Windows®, Media Cybernetics Inc.).

Each average value represents the mean of 4 - 7 independent measurements.

2.6 Scanning Electron Microscopy (SEM)

Micrographs of control and samples with AG were taken just after mixing. Samples for microstructural analysis contained no yeast. Small portions of each sample were cut, fixed in 10 % glutaraldehyde and sequentially embedded in acetone solutions of increasing concentration to ensure full dehydration. Samples were dried at the critical point and coated with gold particles. Microstructure was examined by means of Scanning Electron Microscopy (LEO EVO 40 SEM, Zeiss, Germany) with a 20 kV acceleration voltage and a magnification of ×1,500.

2.7 Statistical analysis

Analysis of variance (SPSS v17.0) was performed in order to evaluate the effect of AG on mixing and leavening performance. Significant differences between the treatment means were compared by means of Duncan's multiple comparison test at the 95 % confidence level ($p \leq 0.05$).

3. Results and Discussion

3.1 Effect of AG contents on mixing process

Figure 1 shows the farinogram's curve of doughs having different AG contents.

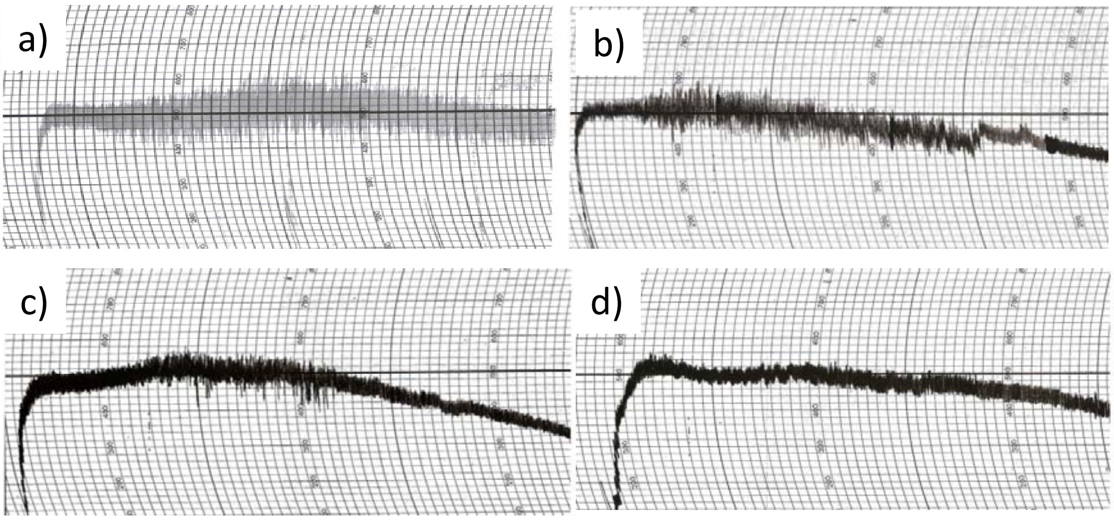

Figure 1: Farinogram of doughs with different AG contents: a) 0 % AG, b) 1 % AG, c) 3 % AG, d) 5 % AG.

The addition of AG promoted differences on the dough mixing parameters evaluated by means of farinograph. Farinographic characteristics include water absorption capacity, dough development time, dough stability time and mixing tolerance index. The results can be seen in Table 1.

Table 1: Farinographic analysis' results[1]: Absorption (mL), Dough Development Time (DDT), Elasticity (El), Brabender Stability (BSt) and Mixing Tolerance Index (MTI) of the analyzed samples.

Sample	Absorption (mL)	DDT(min)	El (BU)	BSt (min)	MTI (BU)
0 % AG	28.8	$1.5 \pm 0.3_a$	$55.0 \pm 19.2_a$	$27.2 \pm 1.3_c$	$0.00 \pm 8.2_a$
1 % AG	31.3	$1.5 \pm 0.2_a$	$76.7 \pm 5.8_b$	$17.5 \pm 0.9_b$	$18.3 \pm 2.3_b$
3 % AG	31.5	$1.9 \pm 0.1_b$	$73.3 \pm 11.6_b$	$16.5 \pm 1.3_b$	$17.7 \pm 2.5_b$
5 %AG	32.3	$3.0 \pm 0.1_b$	$70.0 \pm 0.0_b$	$12.3 \pm 0.8_a$	$26.7 \pm 2.9_b$

[1]Values followed by a different superscript in each column are significantly different ($p < 0.05$)

The quantity of water necessary to obtain a stability period at 500 BU was increased each time the AG proportion improved, this effect, with the addition of isolated pentosans into wheat flour, was also observed by other researchers (Kim and D'Appolonia, 1977; Sefa-Dedeh et al., 1977) because of the capability of pentosans to absorb up to 10 times their weight of water (Hanh and Pasper, 1974).

The dough development time (DDT) was significantly higher ($p < 0.05$) in AG enriched doughs at 3 % and 5 % addition levels than in 1 % AG dough and the control. The mechanism behind AG action on water absorption capacity and dough development time involves competition for water. Such effects depend on the quantity and molecular size of AG (Vanhamel et al., 1993; Sasaki et al., 2004).
According to Brabender stability, there was a significantly decrease ($p < 0.05$) in stability values of doughs with AG, mainly at high AG content. Whereas the Mixing Tolerance Index (MTI) and elasticity was significantly less ($p < 0.05$) for control in relation to AG enriched doughs which indicates that the enrichment with AG may weaken the dough.
The mean humidity significantly ($p < 0.05$) increased when the proportion of AG increases (from 43.4 % control- 45.6 % C), which is an obvious consequence of the added amount of water, as determined by the Brabender tests, in the dough preparation.
Figure 2 shows representative scanning electron microscopy (SEM) micrographs of control and doughs with different AG contents.

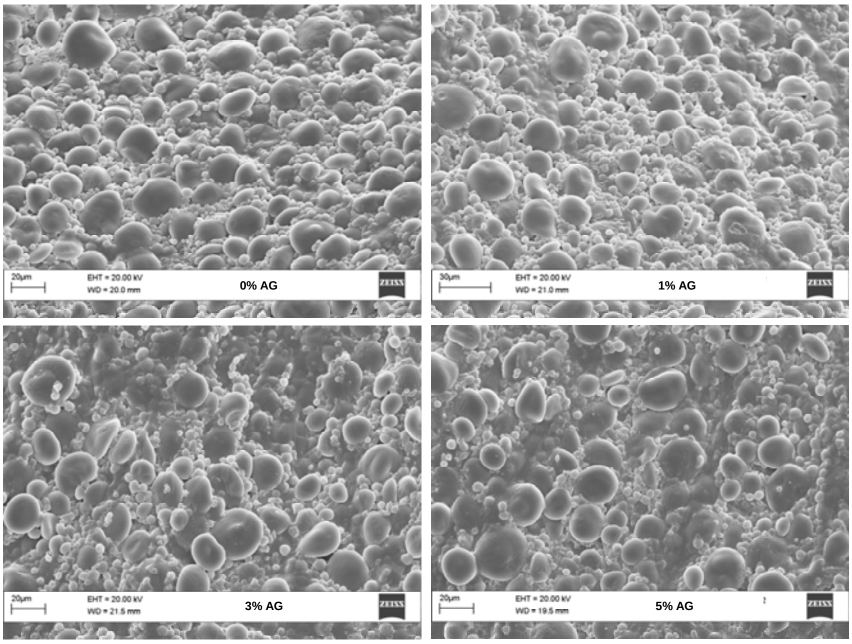

Figure 2: Scanning electron micrographs of doughs with different AG contents: 0 % AG, 1 % AG, 3 % AG, 5 % AG after mixing process.

The control and 1 % AG doughs showed large and small sizes of starch granules coated by gluten network to form a continuous matrix. This appearance agreed with Amend and Belitz' (1991) description of a developed dough. The microstructure of dough with high content of AG presented a more continuous and closed gluten network structure, as compared to the control dough.

3.2 Effect of AG contents on leavening process

The doughs once partitioned and shaped in loaves were placed into the leavening chamber where they could expand in every direction without constraints. Macro-structural development of dough was investigated by monitoring the variation of the dough volume vs. time by means of Image Analysis.
Figure 3 shows the volume expansion on time of doughs having different AG contents during leavening process, evaluated in terms of volume expansion ratio (V_t / V_0), where V_t is the volume at time t and V_0 the volume at time 0.
For all cases investigated, the variation of volume followed same trend. The curve of volume expansion ratio had a classical sigmoid shape (Romano et al., 2007) and it was characterized by three distinct regions: (a) lag phase; (b) growth phase; (c) stationary phase.

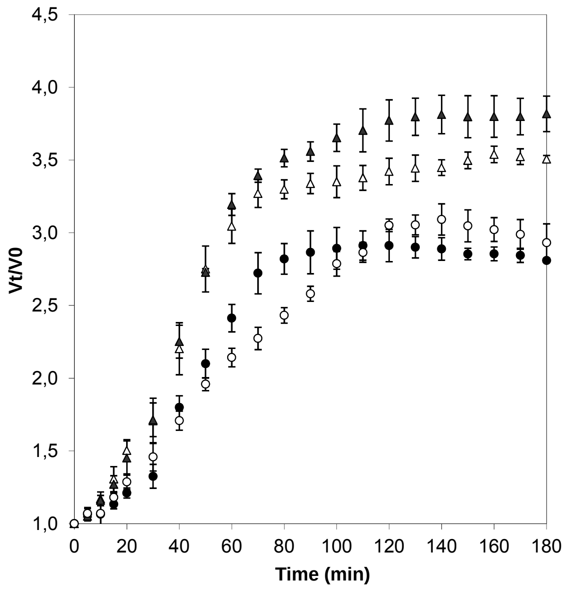

Figure 3: Variation in the volume ratio of doughs with different AG contents: 0 % AG (○), 1 % AG (•), 3 % AG (Δ), 5 % AG (▲) during leavening process.

The addition of AG had a remarkable and positive effect on volume ratio of doughs during leavening as compared to the control, mainly at high AG content.
When 1 % AG was added to flour, the highest increase in volume (ΔVmax) of the dough as compared to the control was slightly smaller (2.9 against 3.1 of control). As the AG content increased, the volume expansion of the dough was significantly higher ($p < 0.05$) than of the volume expansion of control dough. Moreover the volume growth rate, which is related to gas formation process and determined using a nonlinear regression procedure, increased as AG content increased (data not shown).
The time required to reach up to 3/4 of ΔVmax was used as fermentation time. The leavening period for the AG containing doughs was less than for the control, because the maximum volume was reached in a shorter time (about 50 min against 70 min of control). Probably, the time to reach the maximum dough development of control was reduced by the addition of AG, because it can stimulate yeast growth and increase the quantity of carbon dioxide produced by them. This behaviour is reported by Ermakova et al. (2010) in soft wheat flour doughs with the addition of 1 % of AG.

4. Conclusions

Arabinogalactan is very promising as a functional additive to baked products. Experimental evidence showed that the addition of arabinogalactan to dough promotes alterations on structural development of wheat dough during mixing and leavening processes. It had a notorious impact on the farinographic parameters and is associated with a statistically significant increase in the dough’s humidity. The AG addition in flour results in increased water absorption capacity and dough development time as they compete with other constituents for water. In addition, the microstructure of dough with high content of AG presented a more continuous and closed gluten network structure, as compared to the control dough.
The results showed that Image Analysis is an effective method for measuring sample volume expansion in every directions without constrains during leavening process.
The variation of dough volume during leavening depends on AG contents. The addition of 1 % AG had a positive effect on volume ratio during leavening, but the maximum volume expansion ratio (ΔVmax) as compared to the control was lower ($p < 0.05$). The incorporation of AG at concentrations of 3 and 5 % determined a positive effect on volume ratio and the highest final dough volume. For all AG contents investigated, the fermentation time being shorter than control dough.
In order to obtain a good quality final baked product, it is important to consider these modifications and, when possible, establish procedures with the potential to reduce the magnitude of the impact of the AG addition when formulating enriched baking products.

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