INFLUENCE OF JERUSALEM ARTICHOKE POWDER ON DOUGH RHEOLOGICAL PROPERTIES

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Abstract

Wheat flour products are the most common and traditional foods around the world. Fresh backed products all day long and a w ide variety of pastry products with new flavors, shapes, and sizes are some of the consumers' demands (Rossell, 2010). The perennial vegetable plant *Helianthus tuberosus L.* (Jerusalem artichoke) is an interesting plant regarding functional food constituents because it is a rich source for fructooligosaccharides (e.g., inulin), minerals, and vitamins (Kays, Nottingham, 2008). Jerusalem artichoke powder (JAP) is a valuable product which is convenient in use and its addition to bread and pastry product increases their nutritional values.

Quality control equipment Mixolab for flour from French firm Chopin Technologies is a new generation device which allows the complete characterization of the flours in terms of proteins' quality by determining their water absorption, stability, elasticity, and weakening properties; starch behaviour during gelatinization and retrogradation; consistency modification when adding additives and enzy matic activity of the proteases, amylases (Mixolab, 2010). Mixolab could play a key role in ensuring flour performance matches customers' expectation in finished product (Partos, 2009). The aim of this study was to evaluate how the addition of JAP in different concentration levels influences thermo-mechanical properties of the wheat flours and dough.

Partial replacement of wheat flour with JAP at different levels (10, 20, 30, 40, and 50%) significantly changed the qualitative and quantitative thermo-mechanical properties of enriched dough. Results indicated relationships between the terms - water absorption capacity, mixing time, dough stability, dough resistance to kneading - and JAP concentration.

Key words: Jerusalem artichoke, wheat flour, rheological properties, Mixolab

Introduction

Commercial bakeries have today understood the changes in consumer lifestyles and have shifted their production processes, products, and even distribution channels to meet the new requirements. Consumers demands and needs become more important and bakeries are facing new challenges for satisfying them. Fresh backed products all day long and a wide variety of pastry products with new flavors, shapes, and sizes are some of the consumers' demands (Rossell, 2010).

Jerusalem artichoke is a plant with distinctive chemical properties. Inulin is stored as a reserve carbohydrate in the tubers, whereas starch is the storage form of carbon in most plants. Together with a low–fat and mineral–rich profile, inulin gives Jerusalem artichoke tubers their unique value in the human diet (Kays, Nottingham, 2008). Jerusalem artichoke processed in powder could be well applied in bakery products to increase their nutritional value. Also, despite the large amount of information available on the nutritional and physiological properties of fructans, very little information is available on their effects on dough and bakery products (Partos, 2009).

Flour is the primary and important raw material in the preparation of bakery products, their quality is dependent of flour properties and quality (Kunkulberga, Seglins, 2010).

The Mixolab of Chopin Technologies is an instrument that obtains in a single test comprehensive data on the behaviour of all flour components. It is a new generation device which allows the complete characterization of the flours in terms of proteins' quality by determining their water absorption, stability, elasticity, and weakening properties; starch behaviour during gelatinization and retrogradation. Mixolab could play a key role in ensuring flour performance matches customers' expectation in finished product.

The aim of this study was to evaluate how the addition of JAP in different concentration levels influences thermo-mechanical properties of the flours and dough.

Materials and Methods

Experiments were carried out in the Laboratory of Food Analysis and Laboratory of Packing Material Investigations at the Department of Food Technology in the Latvia University of Agriculture.

Materials used in the study were: commercial high quality wheat flour „Ekstra" (type 405) – produced in joint-stock company „Dobeles Dzirnavnieks" (Latvia); JAP produced in local Ltd. "Herbe" (Latvia).

The investigated samples were obtained by mixing the wheat flour with JAP in concentrations 10, 20, 30, 40, and 50% of total flour amount, as well was studied wheat flour (control sample) and JAP.

Content of moisture (%) was carried out using oven–dried *PRECISA XM 120* at 0.01 g / 0.01%. Method was based on samples (3 grams) drying at temperature 140±1 °C and measuring the moisture of the wheat flour, wheat flour and JAP mixes, and JAP.

The preparation and characterization of the dough's was according to the standard method (ICC-Standard Method No. 173, 2006; AACC 54-60.01; adapted ISO 5530–1:1997). Dough rheological investigations were performed by Mixolab (Chopin Technologies, Villeneuve la Garenne, France) which simultaneously determinates dough characteristics during the process of mixing at constant temperature, as well as during the period of constant heating and cooling (Mixolab, 2010).

All the measurements were performed using the Mixolab "Chopin+" protocol. The Mixolab analyser measures in real time the torque (expressed in Nm) by passage of the dough between the two kneading arms thus allows the study of the physically-chemical behaviour of the dough. The wheat flour, flour's mixes, and JAP was placed into the Mixolab bowl, mixed at 80 rpm for sample homogenization and heated up to 30 °C. At this moment, the apparatus adds the distilled water to achieve pre-fixed hydration. Special attention was paid to the determination of the water absorption to ensure the complete hydration of all the components. Required amount of flour for analysis was calculated by Mixolab software according to input values of flour mixtures moisture as well as water absorption. The total mass of flour and distilled water placed into bowl was 75g. After dough mixing stage samples temperature increase with the speed 4°C min^{-1} until the mixture reached 90 °C; at this point, there was a holding period for 8 min at 90 °C, followed by a temperature decrease with the speed 4°C min^{-1} until the mixture reached 50 °C. The mixing speed during the entire assay was 80 rpm. Total analysis time was 45 min.

The following parameters were recorded: water absorption (%) or the percentage of water required for the dough to produce a torque of 1.1±0.07 Nm, and this allows for comparison of different samples at the same optimal consistency; dough development time (min) or the time to reach the maximum torque at 30 °C; stability (min) or the elapsed time at which the torque produced is kept at 1.1 Nm; mechanical weakening (Nm) or the torque difference between the maximum torque at 30 °C and the torque at the end of the holding time at 30 °C; ripening stability (Nm), which is calculated as the ratio of the torque after the holding time at 90 °C and the maximum torque during the heating period; and setback (Nm), which is defined as the difference between the torque produced after cooling at 50 °C and the torque after the heating period.

The experiment was realized in four reiterations for each flour type.

The Figure 1 shows a typical Mixolab Standard curve. The explanation of parameters that were obtained from the recorded curve was following: parameter C1 placed in tolerance levels in all samples and used to determine absorption; C2 measures the weakening of the protein based on the mechanical work and the temperature, C3 measures starch gelatinization, C4 measures the stability of the hot-formed gel and amylase activity, C5 measures starch retrogradation during the cooling period. It was also measured the stability and curve between points C3 and C2 and also between points C3 and C4 (Figure 1.).

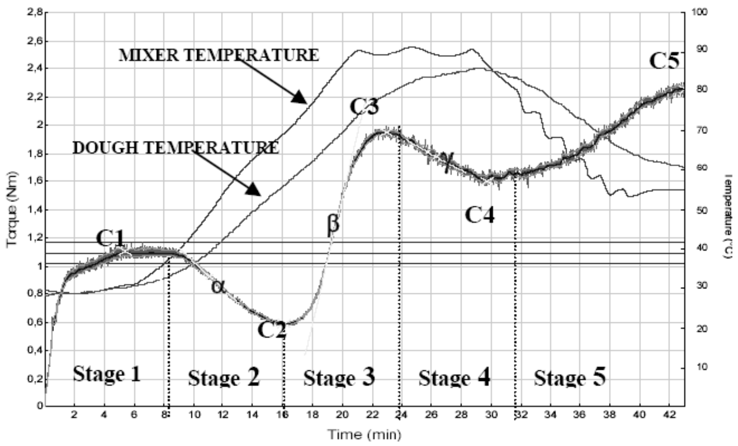

Figure 1. Typical Mixolab Standard curves (Mixolab, 2010)

In a typical Mixolab curve can be distinguished five different stages: 1st dough mixing, 2nd gluten strength, 3rd dough viscosity, 4th amylase activity, 5th starch retrogradation.

Results and Discussion

Mixolab Standard offered a complete and detailed characterisation of raw materials - wheat flour, wheat flour and JAP mixes, and JAP, including the behaviour of the warm dough, and all the results are represented graphically in Figure 2.

The first stage lasts 8 minutes at temperature 30 °C that includes the initial mixing wherein the hydration of the flour compounds occurs together with the stretching and alignment of the proteins, leading to the formation of the viscoelastic structure. During this stage an increase in the torque was observed until a maximum was reached and resisted the deformation. The studies showed that dough formation time increases in the concentrations 30, 40, 50, and 100% of JAP of total flour content significantly in comparison with 100% wheat flour ($p \leq 0.05$). The flour mixtures with 10% and 20% of JAP, and 100% wheat flour dough formation time is similar and almost two times shorter than flour mixtures with 30, 40, 50% of JAP and more than four times as 100% of JAP (Figure 2). Addition of JAP in concentration greater than 20% of total flour content was bringing prolonged time of dough development that is connected with increasing of dietary fiber.

The parameters that were obtained from the recorded curve describe Table 1.

Table1

Mixolab's results

Samples	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Amplitude (Nm)	Dough stability (min)
Wheat flour	1.04	**0.37**	**1.66**	1.11	1.51	0.07	7.80
JAP 10%	1.04	0.35	1.50	**1.39**	**1.71**	0.08	**11.02**
JAP 20%	1.06	0.28	0.78	0.84	0.95	0.11	7.00
JAP 30%	1.10	0.26	0.27	0.33	0.55	0.08	7.46
JAP 40%	1.12	0.23	0.25	0.24	0.40	0.07	5.47
JAP 50%	1.04	0.00	0.23	0.18	0.00	0.06	8.34
JAP	1.01	0.00	0.00	0.00	0.00	0.04	6.84

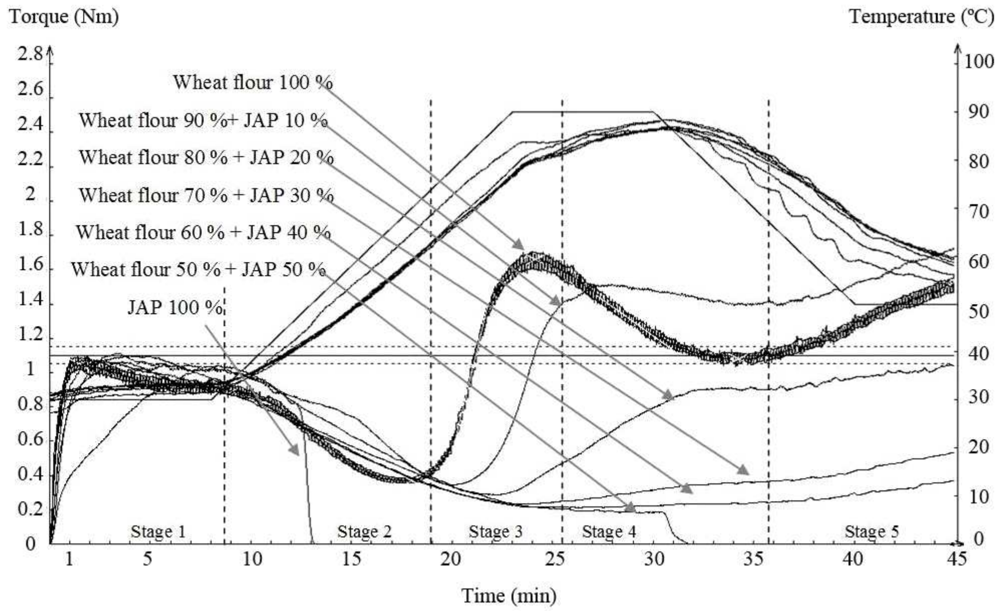

Figure 2. Rheological properties of flours in the Mixolab

Water absorption is 54% of wheat flour used in the experiments. The partly substitution of wheat flour by JAP is changed water absorption in flour's mixtures. The greater part of the wheat flour was replaced with JAP, the more flour mixture decreased absorption (Figure 4) that go with previous other authors studies. Water absorption of fibre–enriched dough decreased because JAP contains low molecular weight sugars and oligosaccharides (Rouille et al., 2005). If 10% wheat flour replace with JAP, then flour mixture water absorption is 47%, which is 13% lower than wheat flour. By contrast, a mixture of flour made from 50% wheat flour and 50% JAP have water absorption 33% that is about 38% less than wheat flour (100%). Comparison between wheat flour (100%) and Jerusalem artichoke flour, water absorption of JAP is almost twice smaller and is only about 31%. Water absorption decreasing in samples with JAP is connected with inulin which content in JAP is about 50% on dry matter. Inulin forms a barrier around the starch grains and thus limits the possibility of water fixation (Karolini-Skaradzinska et al., 2007).

The wheat flour, wheat flour and JAP mixes, and JAP between have different moisture content too (Figure 3). Linear correlation coefficient are observed a strong linear correlation (r=0.87) between moisture content and water absorption in flours, this means that rising flour's moisture content, increases the water absorption of flour. Addition of JAP decreases wheat flour and JAP mixes water absorption.

Dough stability are substantially ($p \leq 0.05$) reduced during mechanical kneading if amount of JAP is 20% and more it could be conected with dietary fiber content increasing and inability to keep the dough structure. Dough resistance to kneading was excellent, when wheat flour was subsitute by JAP in concentration 10% that may be related to increasing of pentose, which enhances the flour technological properties and improves dough structure formation and dough stability. The values of parameter Amplitude shows that the flour stability increases with JAP addition in concentration up to 40% (Table 1).

The gluten protein's large molecular size and low charge density appear to allow them to interact by both hydrogen and hydrophobic bonds (Hoseney, Rogers, 1990). JAP is made from vegetable which does not have gluten at all. Wheat flour substitution with JAP changed dough elasticity significantly during mixing and heating ($p \leq 0.05$). Addition of JAP reduces the gluten content and, therefore, the resistance to kneading goes down. The thermal weakening of protein was take time more in samples with JAP, and the higher amount of JAP, the more thermal weakening of protein lasted, and it is can explain with dietary fiber content to high level. If JAP content is 50% and more, gluten content is deficiency, and in result them a formation of homogeneous dough is not possible, because the protein-chain under the mechanical-pressure force has brocket down. Dough from 50% wheat flour and 50% JAP loosed the protein-chain structure at all after approximately 30 minutes, but dough from JAP - after just approximately 13 minutes (Figure 2). According before observed data it is possible explain mechanical weakening values decreasing gradually with JAP concentration increasing.

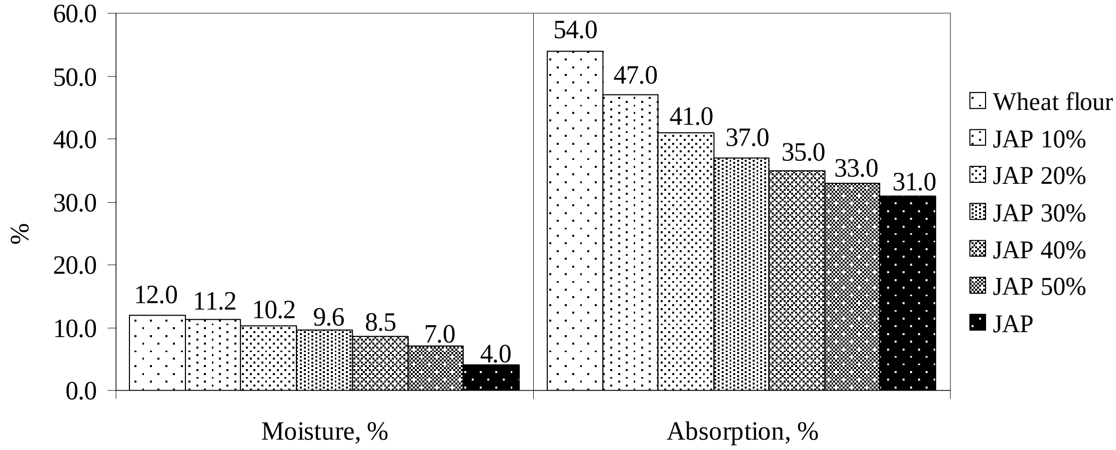

Figure 3. Wheat flour, wheat flour and JAP mixes, and JAP moisture content and water absorption capacity

The temperature increases and the third stage starts with the gelatinisation of starch, the granules absorb the water available in the medium and they swell, so the viscosity increases. Wheat flour sample formed viscoelastic dough and torque used for dough mixing was 1.69 Nm. Addition of JAP starch gelatinising process altered radical. Viscosity of dough with 10% JAP only was satisfactory, but in dough's, which comprise JAP more than 10%, viscosity doesn't forms. This situation is related with starch amount decreasing and pentoses content increasing, as well as inulin content increase. Pentosans are swelling and form a gel, so the dough is more sticky and moist (Kunkulberga, Seglins, 2010). Because pentosans bind large quantities of water, so influence of the JAP dough is formed heavier and denser then dough from wheat flour. In addition heating the inulin at 60 °C for 30 minutes slightly changed the gel structure; however, heating at 80 °C caused drastic change in the structure of the inulin gels (Glibowski, Wasko, 2008).

The amylase activity and the physical breakdown of the starch granules are associated with a reduction in the viscosity in the fourth stage. The highest stability of the hot – formed gel was observed in samples with 10% of JAP that is thanks to the inulin which stabilizing dough structure at this concentration of JAP (Karolini-Skaradzinska et al., 2007). In constant heating rate go on enzymatic activity which is the highest in dough from wheat flour, but with addition of JAP the starch's ability to withstand amylolysis decrease at least twice as much.

A decrease of the temperature resulted in an increase of the torque, which is referred to setback and corresponds to the gelatinising process. This last stage is related to the retrogradation. The dough with 10% of JAP is the strongest during starch retrogration time in the cooling period (Figure 2). According literature the Mixolab's results allow imagining the appearance of the finished product (Partos, 2009). Mixolab's results of this experiment shows that addition of JAP in concentration 10% of total amount of flour in pastry products would be the most desirable from several aspects – dough formation time is the shorter, dough resistance to kneading is the higher, dough retain viscosity, and gives a thick structure of dough, also dough is the strongest during starch retrogration time in the cooling period. From experiment measured flours was backed cakes and among them the cake with 10% JAP really looks the best and that volume is the largest in comparing with other samples.

Conclusions

1. The addition of JAP was inducing a decrease in water absorbability of flour.
2. Correlation between water absorption and flour moisture of all experimental samples exist a strong linear correlation: rising flour's moisture content, increases the water absorption of flour.
3. Addition of JAP in concentration greater than 20% of total flour amount was bringing prolonged time of dough development.
4. JAP influenced positively the rheological properties of dough, bringing about its strengthening in concentration up to 10% of total amount of flour.
5. According to Mixolab's results is possible the appearance of the finished products quality predict.
6. The samples with JAP in concentration 50% and 100% was observed disintegration of the protein–chain under the mechanical-pressure force (respectively, after 30 minutes, and 13 minutes).

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