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THE INFLUENCE OF NON-TRADITIONAL FRUITS AND ELDER FLOWERS ON RHEOLOGICAL PROPERTIES OF THE DOUGH

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ABSTRACT

The influence of the addition of flowers (*Flos sambuci* L.) and berries of elderberry (*Sambucus nigra* L.), blackcurrant (*Ribes nigrum* L.) and chokeberry (*Aronia melanocarpa* L.) to wheat flour was characterized by the rheological test Mixolab (Chopin Technologies, France). Twelve types of wheat flour mixture with different fruit and elder flowers addition were prepared for evaluation in the following ratios: 95: 5, 90:10, 85:15. The control represented 100 % wheat flour. Preliminary rheological analyzes indicated a strong influence of the ingredients used on the properties of the dough. The addition of elderflowers, elderberry and blackcurrants significantly increased the values of the dough development time. In the samples with the addition of elder flowers, we also found a higher stability of the dough, on the contrary, the addition of berries of elderberry and also the 15% addition of chokeberry reduced it. The most significant effect of increasing the addition on the development time and stability of the dough was observed in the samples with the addition of blackcurrant. In contrast to the other samples, the properties of the flour with the addition of elder flowers were comparable with the control flours in protein strength, in starch gelatinization and in the estimated amylase activity. Samples of flour with the addition of lyophilized fruits behaved significantly differently rheologically than flour with the addition of elder flowers. The closest relationship ($p < 0.001$) was observed between the torque C3 (starch gelatinization rate) and C4 (stability of the formed gel), also between C3 and the difference C3-C2 ($r = 0.99$).

Keywords: Elder flowers, Elderberry, Blackcurrant, Chokeberry, Mixolab, Chopin+ protocol, Rheological Properties

INTRODUCTION

In recent years, more attention has been focused on evaluating the quality of wheat flour and bakery products. In the technology of baking, composite flours based on wheat and other cereals and non-grain seeds have become popular (**Švec and Hrušková, 2015**). New non-traditional ingredients, for example amaranth, sunflower, quinoa, hemp, chickpeas, lupine, flaxseed, chia, teff, improve the rheological properties of the dough, increase the nutritional value and quality of bread (**Rosell *et al*., 2009; Mironeasa *et al*., 2012; Švec and Hrušková, 2015**). The effect of bioactive substances of several species such as berries - black elderberry (*Sambucus nigra* L.), blackcurrant fruits (*Ribes nigrum* L.) and black chokeberry (*Aronia melanocarpa* L.) (**Karjalainen *et al*., 2009)** reduces oxidative stress and strengthens the body's immune system (**Aksoylu *et al*., 2015; Miletić *et al*., 2019**). Polyphenol-rich plant extracts are emerging as potential ingredients in functional foods and / or beverages (**Prpa *et al.*, 2020**). Phenolic compounds, particularly the flavonoids and phenolic acids, appears to be the major functional components of berries (**Pinto *et al*., 2010**). Numerous studies have shown, that the fruits and flowers of blackberry (*Sambucus nigra* L.) are an important source of bioactive compounds such as polyphenols and anthocyanins with high antioxidant activity, which significantly affects its health benefits. In recent years it was found that elderberry has antibacterial, antiviral, antidepressant, antitumor and hypoglycemic properties, and to reduce body fat and lipid parameters (**Duymus *et al*., 2014; Mlynarczyk *et al*., 2018; Ferreira *et al*., 2020**). The content of ascorbic acid ranges between 6 and 25 mg/100 g of elderberry fruit (**Kaack and Austed, 1998)** and furthermore, elderberry seed flour is a source of alpha-tocopherol and gamma-tocopherol (**Fazio, 2013**). Minerals are located both in berries and flowers which includes relatively large amounts of potassium, phosphorus, calcium, sodium, and magnesium, and various microelements such as iron, zinc, manganese, and copper (**Sidor and Gramza-Michalowska, 2015**). The flowers were found to contain a much higher content of most minerals compared to the fruit. Both the fruit and flower of elderberry can be a good source of healthy and high-value products **(Mlynarczyk *et al*., 2020).**
Similarly, blackcurrant (*Ribes nigrum* L.) fruits are a particularly rich source of biologically active compounds, such as anthocyanins, quercetin, proanthocyanins, myricetin, phenolic acids and isorhamnetin (**Karjalainen *et al.*, 2009**). These flavonoids have been demonstrated to possess neuroprotective activity. In addition, blackcurrant possesses a high content of vitamin C, contributing together with bioactive phenolics to the high antioxidant activity of berries. In addition to antimicrobial, antimutagenic, anti-inflammatory, anti-cancer and antihypertensive properties, blackcurrant berries and leaves showed very strong biological activity, including inhibition of cell proliferation (**Puupponen-Pimiä *et al*., 2005; Tabart *et al*., 2012; Paunović *et al.* 2017**). Black currant is an important berry for the food industry in Europe, especially for its colour and organoleptic properties, making it a suitable material for various food applications (**Karjalainen *et al*., 2009**).
Black chokeberry (*Aronia melanocarpa* L.) is used as an ornamental plant and as a colorant and food. It is rich in the secondary metabolites such as flavonoids and anthocyanins which has been shown to be important for protection against oxidative stress (**Kim *et al*., 2013; Sójka *et al*., 2013; Szopa *et al*., 2017**). Fresh chokeberries have a sour, bitter and astringent taste. The bitter taste is due to the content of polyphenolics (phenolic acids, tannins and hot eriodyctiol glucuronide) (**Duffy *et al*., 2016**). The main anthocyanins in the black chokeberry are cyanidin 3-Oarabinoside, cyanidin 3-O-galactoside, cyanidin 3-O-glucoside, and cyanidin 3-O-xyloside. These compounds are characterized by many pharmacological effects, such as antioxidant defence, antimicrobial, antiproliferative, anti-inflamatory, and modulate hepatic lipid metabolism activities (**Kim *et al*., 2013; Stanisavljevi´c *et al*., 2015; Bhaswant *et al*., 2017; Denev *et al*., 2019**). The health benefits of anthocyanins include the prevention and remedy of cardiovascular disease and liver failure, anti-obesity and antidiabetic activity (**Kim *et al*., 2012; Ho *et al*., 2014; Thilavech and Adisakwattana, 2019).** The dried black chokeberry fruits may be used for various applications, particularly functional food ingredients, for example chips or as food additive to improve the biological value of food (**Sidor *et al.*, 2021**).
However, the stability of anthocyanins depends on many factors, such as structure, presence of solvents, temperature, oxygen and enzymes, pH, and other concomitant substances **(Klisurova *et al.*, 2019**). The largest amount of polyphenols is maintained by freeze-drying, which is considered to be the most desirable drying method (**Sidor *et al*., 2021**). Freeze-drying, to a large extent, allows for considerable preservation of the components in an unaltered state and prevents damage to the structure of the dried material (**Calín-Sánchez *et al*., 2020**).
Wheat flour is the important ingredient in the production of various types of bakery products. Monitoring the rheological properties of dough is very important for the overall technology to estimate the mechanical properties of dough and to imitate

its behaviour during its processing or even to anticipate the quality of the final product (**Torbica *et al.*, 2019**).

The aim of this work was to characterize the rheological properties of dough prepared from wheat flour and with 5 %, 10 % and 15 % additions of flowers (*Flos sambuci* L.) and berries of elderberry (*Sambucus nigra* L.), blackcurrant (*Ribes nigrum* L.) and chokeberry (*Aronia melanocarpa* L.).

MATERIAL AND METHODS

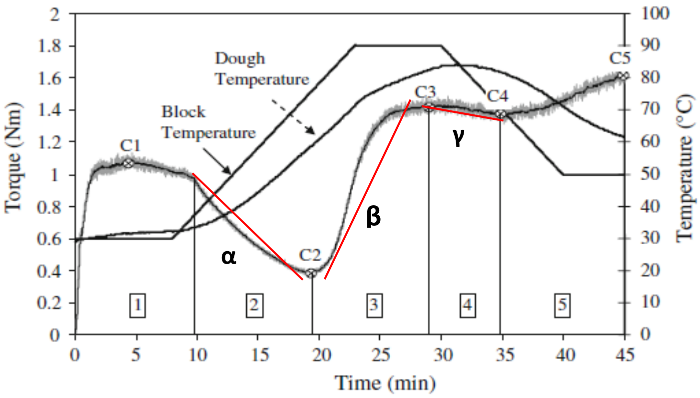
Samples

In this study, commercial wheat flour T650 (ash 0.65 %) (MLYN ZRNO, Miroslav Grznár, Slovak Republic) were used. The elderberry (flowers and berries), black currants and chokeberry came from the Botanical Garden of the Slovak University of Agriculture (August-September 2020). Elder flowers (*Flos sambuci*) were harvested at the end of May 2020 (flat peak 20 cm in diameter) and loosely dried on sieves (14 days, at 23 °C), without direct sunlight, with air circulation. The fruits (berries) were harvested when they were fully ripe (colour is considered the most reliable indicator of ripeness) **(Lysiak *et al*., 2014)**. In the laboratory, the berries were separated from the stems and from the unripe and dry berries. The fruits of elderberry, blackcurrant and chokeberry were lyophilized for 5 days at -58 °C (ilShin Lab Co., Ltd., Korea). Dried elder flower and freeze-dried elderberry, blackcurrants and chokeberry were homogenized using a stainless-steel blender (BOSCH TSM6A01, Germany).

Twelve kinds of a mixture of wheat flour with different ratios (flowers and berries of elderberry, black currant and chokeberry) were prepared for evaluation in the following ratios: 95:5, 90:10, 85:15. As a control (C) was used only pure wheat flour (energy value – 1464 kJ, carbohydrate content – 71 g/100 g of which sugars – 1.59 g/100 g, fibre content – 3.3 g/100 g, protein content – 11 g/100 g, fat content – 1.3 g/100 g of which saturated – 0.3 g/100 g). The data is guaranteed by the manufacturer. Labeling of samples: FS 5 – flour : *Flos sambuci* (95:5), FS 10 - flour : *Flos sambuci* (90:10), FS 15 – flour : *Flos sambuci* (85:15), SN 5 – flour : *Sambucus nigra* (95:5), SN 10 – flour : *Sambucus nigra* (90:10), SN 15 – flour : *Sambucus nigra* (85:15), RN 5 – flour : *Ribes nigrum* (95:5), RN 10 – flour : *Ribes nigrum* (90:10), RN 15 – flour : *Ribes nigrum* (85:15), AM 5 – flour : *Aronia melanocarpa* (95:5), AM 10 – flour : *Aronia melanocarpa* (90:10), AM 15 – flour : *Aronia melanocarpa* (85:15).

Rheological properties testing

The rheological properties of dough were monitored using "Chopin+" protocol on the Mixolab 2 (Chopin Technologies, Villeneuve la Garenne, France) according to ICC No. 173. The experiments were made in duplicate. The Mixolab evaluates in real time the torque (Nm) that is produced by the dough between the blades. The test is based on the preparation of a constant hydrated mass of dough so as, to obtain the target consistency during the first test phase. In the "Chopin +" protocol, the dough weighs 75 grams, and the target consistency is 1.1 Nm (+/- 0.05 Nm) **(Chopin Technologies Application Team, 2009).** Settings of the test: initial state at 30 °C for 8 min, heating to 90 °C for 15 min (4 °C /min), holding at 90 °C for 7 min, cooling to 50 °C for another 10 min (4 °C /min) and holding at 50 °C for 5 min. The mixing speed was kept constant at 80 rpm. The whole analysis takes 45 min. Figure 1 shows a typical Mixolab curve, which distinguishes the different stages of dough changes due to both temperature and mixing force. The parameters highlighted in the curve are: C1 (Nm) - maximum torque during mixing (determines water absorption); C2 (Nm) - measures the protein attenuation based on temperature and mechanical work; C3 (Nm) - expresses gelatinization of starch; C4 (Nm) - indicates the stability of the starch gel formed; C5 (Nm) - measures the retrogradation of starch during the cooling phase; differences: C1–C2 indicates the strength of the protein network with increasing heating; C3–C2 corresponds to the gelatinization rate of starch; C3–C4 shows amylase activity and is linked to falling number; C5–C4 corresponds to the anti-stalling effects (retrogradation of starch in the cooling phase), represents the shelf life of the final products **(Papoušková et al., 2011).**



Stage (1) – dough development (constant temperature 30 ºC);
Stage (2) – thermal weakening of the proteins
Stage (3) – starch gelatinization
Stage (4) – enzymatic activity constant heating rate
Stage (5) – starch retrogradation

Figure 1 A typical Mixolab curve for dough (**Ozturk et al., 2008).** In addition, the slopes and the angles between ascending and descending curves were calculated. α – represents the slope of the curve between the end of the period of 30°C and C2; gives indication about the rate of the proteins thermal weakening; β – represents the slope of the curve between C2 and C3; gives indications about the gelatinisation rate; γ – represents the slope of the curve between C3 and C4; gives indications about the rate of enzymatic hydrolysis.

Statistical analysis

Statistical analysis was carried out using MS Excel 2016 (Microsoft Corporation, Redmond, Washington, USA). The relationships between the parameters (torque points C1, C2, C3, C4, C5, C1-C2, C3-C2, C3-C4 and C5-C4) were assessed by Pearson´s correlation at significance level 0.05.

RESULTS AND DISCUSSION

Strong flours, with a higher content of quality gluten, have a greater ability to bind water (higher yield) with longer swelling of individual ingredients. The dough is more stable, easy to process, shapes and does not stick (**Robertson and Cao, 2001**). Weak flours are less stable and have a lower ability to bind water (lower dough and pastry yield). Conventional types of pastry made from weak flour are usually poorly fermented, have an unsuitable structure and a small volume (**Baik and Lee, 2003**). Therefore, they are more suitable for baking use, where the creation of a compact spatial gluten network is not required during mixing (e.g., biscuits) (**Fustier *et al*., 2009**). The water absorption of the control flour was 65.6 %, which is a high value and indicates the good quality of the control flour used, while with increasing amount of the addition of elder flowers this value increased (FS 5 - 66.7 %, FS 10 – 69 %, FS 15 - 71.5 %), on the contrary, other additions reduced the water absorption (SN 5 - 62.8 %, SN 10 – 61 %, SN 15 – 59 %; RN 5 - 65.3 %, RN 10 - 63.7 %, RN 15 - 62.2 % and AM 5 - 65.3 %, AM 10 - 63.7 %, AM 15 - 62.2 %). In all cases, the addition of water was associated with the creation of an optimal dough consistency.

Adding elder flowers and non-traditional fruits to wheat flour (5 %, 10 %, 15 %), resulted in differences in the viscoelastic properties of the path (Fig. 2). The Mixolab Profiler shows the standard curve of Mixolab into six indexes of flour quality factors, graded from 0 to 9 (mixing, water absorption, gluten strength, maximum viscosity, amylase resistance and retrogradation) **(Chopin Technologies Application Team, 2009).** As an indicator of the overall quality of flour proteins, a mixing index is used, which expresses the flour's resistance to kneading **(Hadnadev *et al.*, 2011).** Flours with added chokeberry reached low mixing values. The mixing index decreased with increasing amount of ingredients (AM 5 - 3, AM 10 - 2, AM 15 - 1). Gluten+ index represents the behavior of the gluten when heating the dough and it is therefore the measure of protein strength. It has to be pointed out that Gluten+ index is not the measure of gluten content. The results showed a weakening of the gluten network in all evaluated samples, except AM 10 and AM 15.

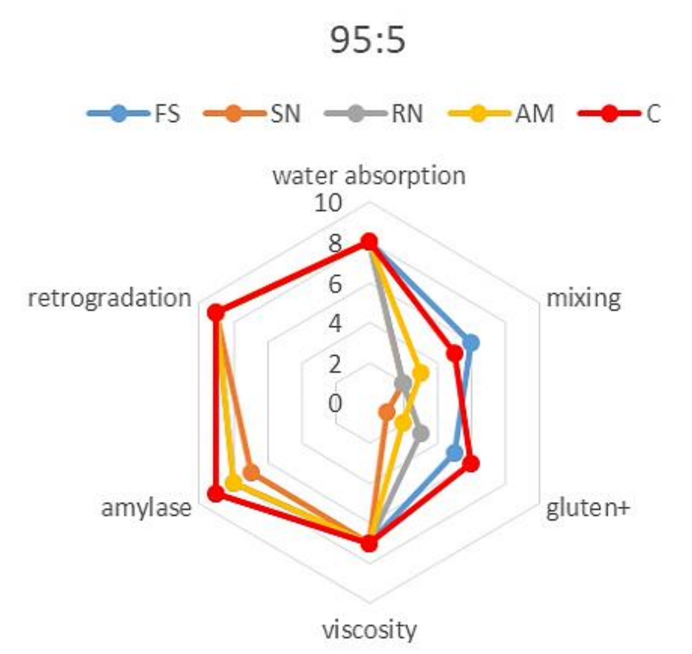
The rheological behavior of wheat flour dough (control) and wheat flour with different additions during the Mixolab test are detailed in Tab. 1. Determined Mixolab C1– C5 values for control flour were 1.11 Nm, 0.56 Nm, 1.92 Nm, 2.15 Nm, and 4.85 Nm, respectively. Similar behaviour of Mixolab was reported by **Papoušková et al. (2011)** in the evaluation of three wheat varieties (C1– C5 averages 1.12 Nm, 0.46 Nm, 2.04 Nm, 1.76 Nm, 2.44 Nm, respectively) and **Švec and Hrušková (2015**) (1.10 Nm, 0.50 Nm, 2.06 Nm, 1.69 Nm, and 2.54 Nm). The difference in the parameter of curve C5 was shown. **Banu *et al*., 2011** published the results of parameter C5 – 3.12 Nm (Romanian commercial samples of wheat flour). Varieties of different technological quality as well as the type of locality and weather conditions contributed to the diverse course of starch retrogradation.

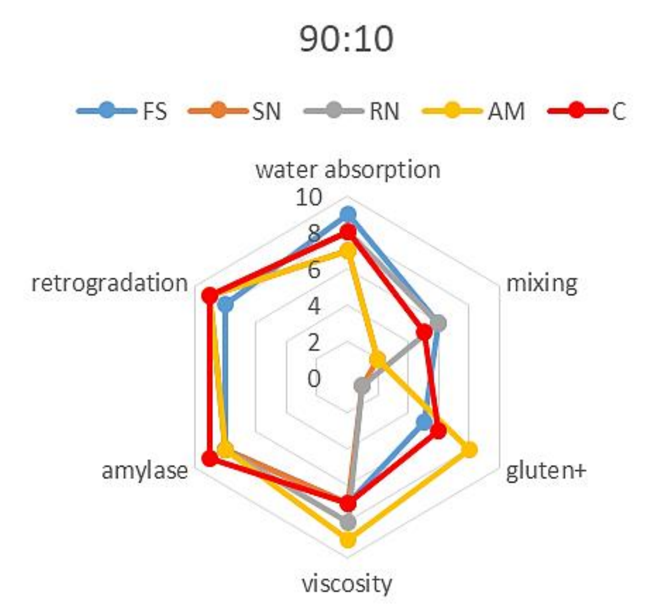
Table 1 Mixolab characteristics of the flours with additions

Sample	C1	C2	C3	C4	C5	Stability ± SD (min: s)
			Nm ± SD			
C	1.11 ± 0.01	0.56 ± 0.01	1.92 ± 0.03	2.15 ± 0.14	4.85 ± 0.07	9:58 ± 0:14
FS 5	1.11 ± 0.03	0.53 ± 0.04	1.94 ± 0.06	2.05 ± 0.13	4.59 ± 0.10	10:34 ± 0:16
FS 10	1.12 ± 0.06	0.54 ± 0.06	1.93 ± 0.09	1.84 ± 0.10	4.10 ± 0.30	10:15 ± 0:58
FS 15	1.14 ± 0.07	0.53 ± 0.04	1.72 ± 0.13	1.40 ± 0.16	2.97 ± 0.23	9:18 ± 0:57
SN 5	1.08 ± 0.06	0.33 ± 0.03	1.93 ± 0.10	1.60 ± 0.11	4.21 ± 0.13	7:02 ± 0:46
SN 10	1.10 ± 0.08	0.32 ± 0.08	1.95 ± 0.13	1.49 ± 0.17	4.15 ± 0.17	6:35 ± 0:28
SN 15	1.06 ± 0.07	0.31 ± 0.10	1.85 ± 0.08	1.24 ± 0.10	3.92 ± 0.15	6:57 ± 0:47
RN 5	1.11 ± 0.04	0.38 ± 0.09	1.91 ± 0.40	2.20 ± 0.06	4.50 ± 0.10	6:12 ± 0:51
RN 10	1.08 ± 0.03	0.37 ± 0.08	2.04 ± 0.21	2.19 ± 0.11	4.61 ± 0.10	7:47 ± 0:41
RN 15	1.03 ± 0.04	0.48 ± 0.07	2.15 ± 0.13	2.08 ± 0.13	4.41 ± 0.06	10:26 ± 0:53
AM 5	1.08 ± 0.03	0.42 ± 0.09	1.83 ± 0.24	2.00 ± 0.08	4.48 ± 0.08	9:13 ± 0:35
AM 10	1.13 ± 0.04	0.53 ± 0.07	4.73 ± 0.04	4.68 ± 0.01	4.74 ± 0.03	9:42 ± 0:51
AM 15	1.22 ± 0.08	0.61 ± 0.04	4.48 ± 0.37	4.42 ± 0.28	4.71 ± 0.11	2:26 ± 0:04

Legend: C – Control, FS (*Flos sambuci*), SN (*Sambucus nigra*), RN (*Ribes nigrum*), AM (*Aronia melanocarpa*)

The dough development time value for control flour was 1:55 min: s, while the additions of elder flowers (FS), elderberry (SN) and blackcurrant (RN) significantly increased this value, the addition of chokeberry reduced this value (Fig.3). We observed the most significant effect of increasing the addition on the development time of the dough in RN samples. In addition to higher time values of dough development with the addition of elder flowers, we also found higher dough stability at FS 5 and FS 10 compared to control flour. The stability of the dough is considered to be an important indicator of the quality of doughs for bakery processing, especially in connection with the technological process of bread production (leavening, translating, dough resting). We found a gradual increase in the stability of the dough with increasing addition in RN samples. Additions of elderberry reduced the value of dough stability. The dough stability values at AM 5 and AM 10 were similar to control flour, but the 15% addition of chokeberry (AM 15) significantly reduced this value (Fig.3). The increase in development time and stability of the dough was found by **Bojňanská *et al.* (2020)**, who researched the effect of adding partially defatted milk thistle flour (5 %, 10 %, 15 %) to a 50:50 mixture of wheat and rye flour.





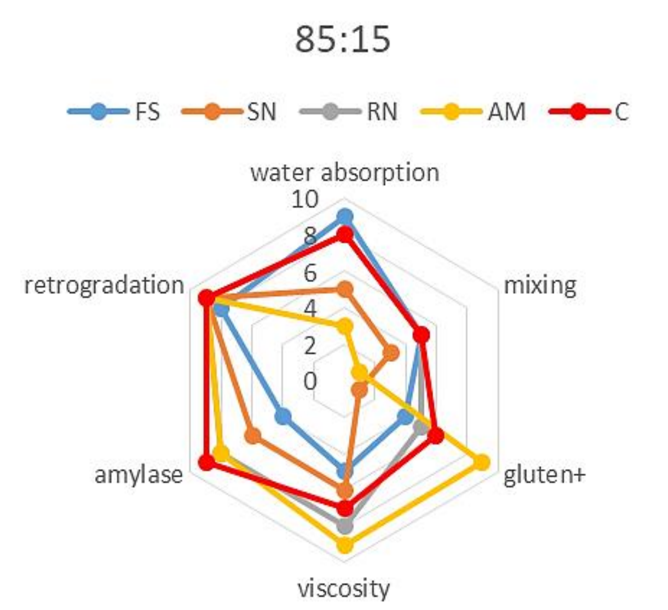


Figure 2 Mixolab profiler (For label legend, see Table 1.)

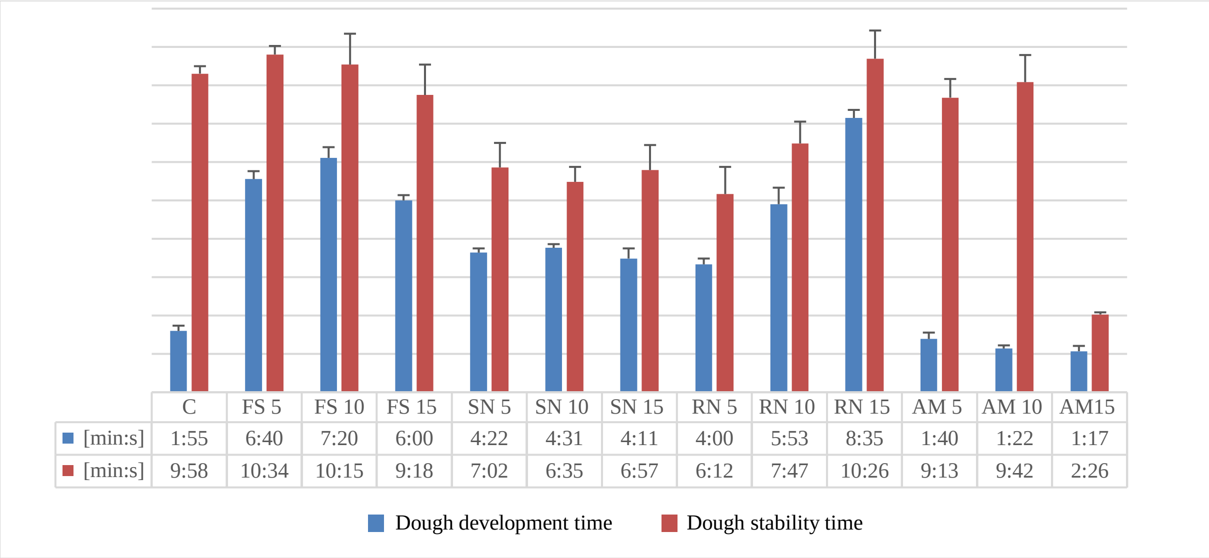


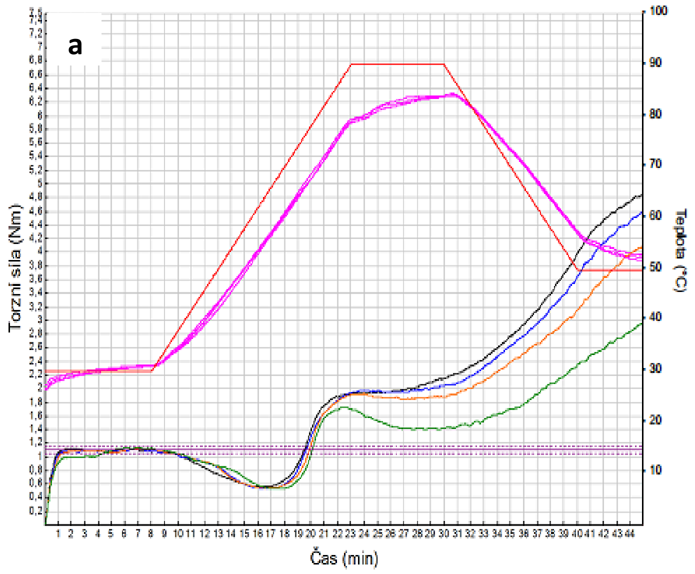
Figure 3 Dough development time and stability

The first part of the Mixolab curve shows the behaviour of the dough during mixing. At this stage, the torque increases until it reaches the maximum (C1). The C1 value was modelled by the controlled addition of water to the required consistency value of 1.1, with minimal deviations (Tab. 1). At this point, the dough resists deformation for certain time, which determines the stability of the dough. The decrease in torque is recorded after the dough stability time, which designate the end of the first phase and the beginning of the second phase. The second phase can start during the initial mixing time, or later, depending on the quality of the flour. At this phase, the proteins are weakened. The longer is the stability time, the better is the protein quality **(Hadnadev *et al.*, 2011).**

Temperature limitation and current mechanical stress (2nd stage) reduce the torque to the minimum value (C2). This value is related to the onset of destabilization of the protein structure **(Rosell *et al*., 2010)**. The increase in dough temperature led to protein denaturation, which released a large amount of water. Proteins become hydrophobic. In the temperature range of the second phase, the proteolytic enzymes have an optimal activity **(Haros *et al*. 2006, Stoenescu *et al*., 2010, Banu *et al*., 2011),** represented by the slope α (recorded between C2 - C1). Proteins that are poor in sulfhydryl groups, affect dough stability. They cause dough softening or even degradation. With a higher protein content, the gluten network is stronger and has a higher resistance to shear stress (**Kaur *et al.*, 2016**). The dough reaches a specific temperature for the start of starch gelatinization, at minimum torque (C2). In the case of the control sample, the minimum torque (C2) was reached faster (16:14 min: s) at a temperature of 54.60 °C. The authors (**Banu *et al.*, 2011**) state that in the case of a blank sample, the minimum torque (C2) was reached faster (17.00 min: s) at a temperature of 55.4 °C compared to samples with α-amylase, where the value C2 was reached after 18:22 min: s was specific for a higher temperature (57.6 – 58.2 °C). We found a similar increase in the time to reach the minimum torque (C2) at a specifically higher temperature in samples FS 15 (17:34 min: s at 58.60 °C), AM 10 (17:26 min: s at 57.8 °C) and the highest increase at AM 15 (18:31 min: s at 60.3 °C). The first difference C1 − C2 is related to proteins quality. In the control flour, the C2 values decreased from 1.11 Nm to 0.56 Nm (the difference C1−C2 is 0.55 Nm). A similar value of torque C2 (0.50 Nm) is reported for composite flours by **Švec and Hrušková (2015)**. Similar C2 values were found in flour with the addition of elder flowers (FS 5, FS 10, and FS 15). In flour with the addition of the fruits of elderberry (*Sambucus nigrus* L.) and blackcurrant (*Ribes nigrum,* L.), the C2 values decreased on average by 0.71 Nm, and in the flour with the addition of chokeberry, the C2 values decreased on average by 0.63 Nm. The Chopin protocol from individual flour measurements with additions is shown in Figures 4 (a, b, c, d).

With increasing temperature (70 ºC) starch gelatinization takes place (3rd stage) and at the same time the torque increases until a new maximum value (C3) **(Ozturk *et al*., 2008).** Swelling starch granules and hydration cause an increase in dough consistency **(Rosell *et al*. 2007**). In the third stage, the starch gelatinization rate is recorded and is defined by the *β* slope **(Hadnadev *et* al., 2011).** The evaluated parameters were slope- *β* (Fig. 5), C3 and difference C3−C2 (Tab.1). Significantly higher values of C3 torque compared to the control flour were observed in the evaluated flour with 10 % and 15 % addition of chokeberry. The difference C3−C2 increased in flours, especially with the addition of lyophilized fruits (SN, RN and AM), so we evaluate the effect of the dough recipe as significant. In stage 4, a decrease in viscosity is observed due to the physical decomposition of the starch granules at temperatures above 80 °C, resulting to a minimum torque value (C4). In this step, the parameters slope-*γ*, C4, and C4−C3 and enzymatic activity were evaluated. The lowest value of C4, which shows the stability of the starch gel formed, we determined in samples FS 15, SN 15, RN 15 and AM 5. The same decrease in C4 was observed in the trial mixture 50:35:15 (15 % milk thistle flour) in the work of **Bojňanská *et al.* (2020)** and also from the studies of authors **Švec and Hrušková (2015),** where for the standard M, C4 parameter reached value of 1.59 Nm, and for others K1 hemp flour composites a gradual diminishing of 7 % was observed. In this case, was proved a dependence of determined values on dough formula. We recorded a significantly higher value of C4 in flour with the addition of chokeberry (AM 10 and AM 15). Viscous behaviour of material heated approximately to 80 °C demonstrated the highest variability. An interesting finding was that in the flour samples with the addition of elderberry (SN) we recorded a sudden decrease in the value of torque with an increase in temperature above 80 ºC (from 29 min.). The decrease was more pronounced with increasing amount of addition (1.6 Nm, 1.49 Nm, 1.24 Nm) (Fig. 4 b) and also had a significant effect on the slope of the curve - slope-γ, which provides data on the rate of enzymatic hydrolysis (Fig. 5).

Maximum torque (C5) is result of the decrease in the temperature produces an enhancement in the dough consistency (stage 5th) **(Ozturk *et al*., 2008). The** degree of starch retrogradation for the tested flours with additions showed similar differences as the stability of the starch gel. We found the lowest C5 values in samples FS 15, SN 15 and RN 15. The lowest difference of C5−C4 compared to the control (2.696 Nm) was found in AM 10 (0.061 Nm) and AM 15 (0.287 Nm).



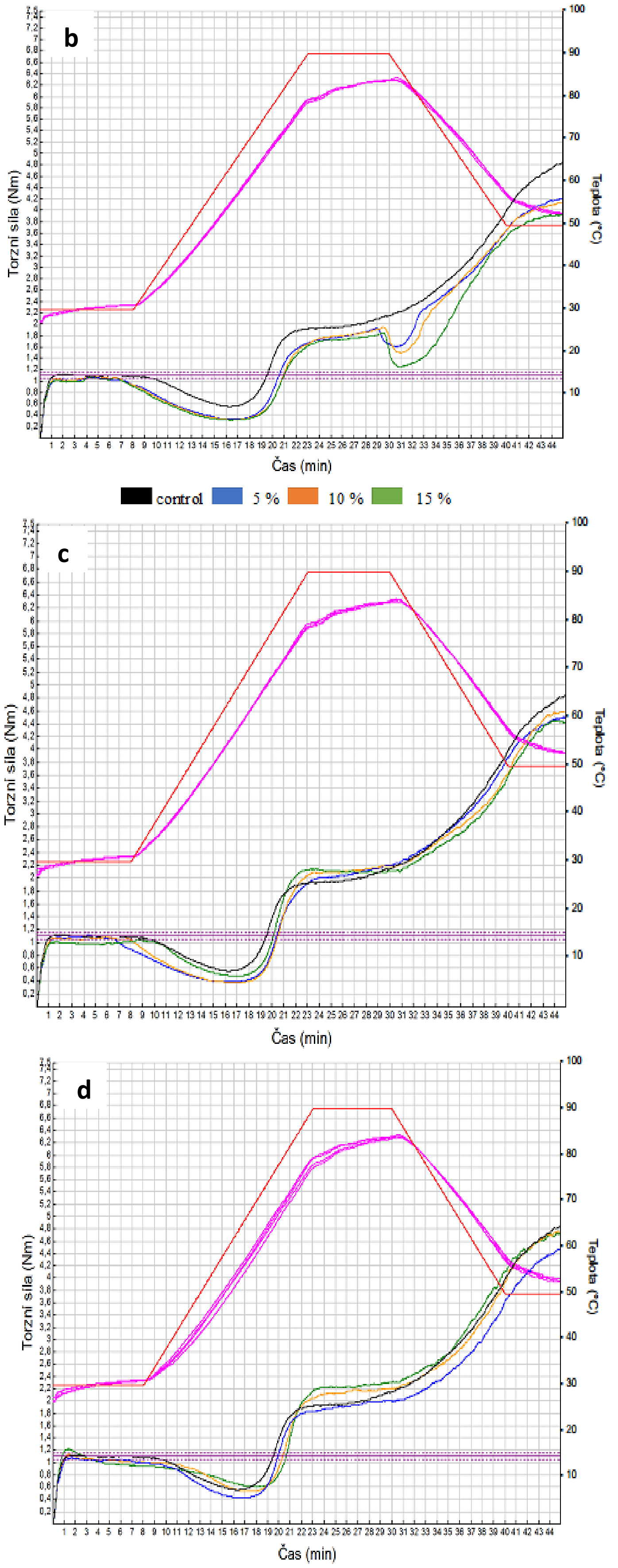


Figure 4 Mixolab curve Chopin+ protocol – **a**: flour + elder flowers (*Flos sambuci* L.), **b:** flour + elderberry (*Sambucus nigra* L.), **b:** flour + blackcurrant (*Ribes nigrum* L.), **d**: flour + chokeberry (*Aronia melanocarpa* L.)

The properties of the flour with the addition of elder flowers (FS) were comparable to control (C) in protein strength (difference C1−C2: 0.57, 0.58, 0.61 Nm vs. 0.56 Nm), in starch gelatinization (C3−C2 between 1.20 and 1.41 Nm vs. 1.36 Nm) and in the estimated amylase activity (C3−C4 between 0.08 and 0.32 Nm vs. 0.22). Among calculated pair subtractions of torque points the SN, RN and AM flour composites different from the control flour in protein strength (C1−C2) and in starch gelatinization (C3−C2), especially AM 10 and AM 15 (4.21 Nm, 4.48 Nm vs. 1.35 Nm).

The difference was also manifested by amylase activity (C3−C4; SN between 0.33 and 0.61 Nm vs. 0.23 Nm; AM between 0.05 and 0.16 Nm) and the rate of retrogradation of starches (C5−C4) mainly in AM 10 samples and AM 15 (0.06 and 0.29 Nm vs. 2.70 Nm).

Figure 5 documents the slopes *α, β* and *γ* during the dough mixing process. The results confirmed significantly different gelatinization characteristics and enzymatic hydrolysis compared to control flour, especially in flours with the addition of elderberry (SN 5, SN 10, SN 15) and also flours with the addition of chokeberry (AM 10, AM 15).

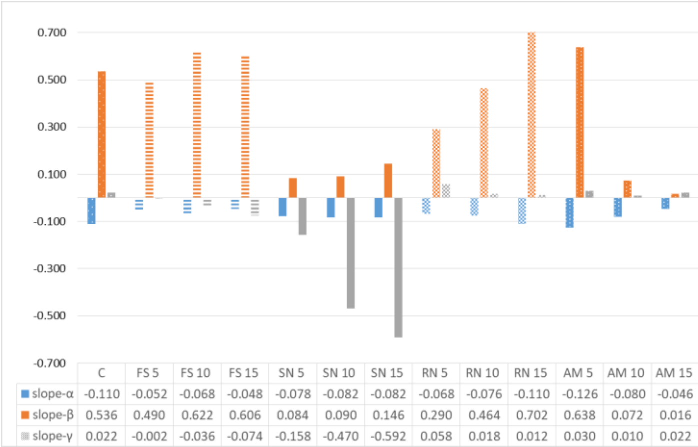


Figure 5 Slope *alpha*, *beta* and *gamma* during the mixing process of dough

Interrelations of the Mixolab parameters

Correlation analysis of evaluated quality features.

Samples of flour with the addition of lyophilized fruits of elderberry, blackcurrant and chokeberry behaved significantly differently rheologically than flour with the addition of elder flowers, so we were interested in mutual correlations in these samples (Tab. 2). To evaluate the exchangeability of Mixolab properties among themselves, a correlation matrix was calculated within a set of 9 monitored items.

Papouskova *et al.* (2011) published a work where all properties of Mixolab, which related to the quality of 24 samples of wheat variety, were correlated with each other - the proven binding is in the intervals <90.93; -0.39> a <0.51; 0.95>. Positive relationships between all five C's were demonstrated by **Xie *et al.* (2011)** within a set of 183 rice varieties (rice flour). The strongest correlation was found for the C1 – C2 pair (r = 0.81, p <0.01) the closest relationship (p <0.001) was observed between the torque C3 (starch gelatinization rate) and C4, also between C3 and the difference C3−C2 (r = 0.99). For the latter features pair, **Švec and Hrušková (2015)** mentioned comparable proximity in hemp composites (r = 0.96, p <0.01). The protein thermal weakening (feature C2) was positively correlated with C3, C4, C5 and the difference C3−C2, on the contrary, a moderately negative correlation was found with the difference C1−C2 and C5−C4. Another relationship between torque points C4 and C5 was moderately significant (r = 0.81, p <0.01). Study of the effect of grape seed flour on wheat flour revealed a middle strong correlation between parameters C4 and C5 (r = 0.63) (**Mironeasa *et al.*, 2012**). Hemp flour addition to those torque points exchangeability was markedly stronger (r = 0.95, p <0.01). Higher evidence was also confirmed in their work by **Papoušková *et al.* (2011)** (r = 0.93, p <0.01). The C5−C4 difference significantly negatively correlated with all torque values and also with the C3−C2 difference (r between -0.72 and -0.99).

Table 2 Correlation analysis between the Mixolab curve features (torque points) – flour + lyophilized berries of elderberry (*Sambucus nigra* L.), Blackcurrant (*Ribes nigrum* L.) and chokeberry (*Aronia melanocarpa* L.)

N= 9	C1	C2	C3	C4	C5	C1−C2	C3−C2	C3−C4	C5−C4
C1	1								
C2	ns	1							
C3	0.75*	0.85**	1						
C4	0.75*	0.89**	0.97***	1					
C5	ns	0.78*	ns	0.81**	1				
C1-C2	ns	-0.85**	ns	ns	ns	1			
C3-C2	0.75*	0.82**	0.99***	0.96***	ns	ns	1		
C3-C4	ns	Ns	ns	ns	-0.78*	ns	ns	1	
C5-C4	-0.76*	-0.87**	-0.99***	-0.98***	-0.72*	ns	-0.99***	ns	1

Legend: *, **, *** - significant at $p < 0.05$, $p < 0.01$ and $p < 0.001$ respectively; ns - non-significant.

CONCLUSION

In this work we characterize the rheological properties of dough prepared from wheat flour and with 5 %, 10 % and 15 % additions of flowers (*Flos sambuci* L.) and fruits of elderberry (*Sambucus nigra* L.), blackcurrant (*Ribes nigrum* L.) and chokeberry (*Aronia melanocarpa* L.). Preliminary rheological analyzes indicated a strong influence of the additives used on the properties of the dough. Adding elder flowers and non-traditional fruits to wheat flour, resulted in differences in the viscoelastic properties of the path. The addition of elder flowers, elderberries and blackcurrants significantly increased the values of the dough development time, but the addition of chokeberry decreased this value. In the samples with the addition of elderflowers, we also found a higher stability of the dough, on the contrary, the addition of elderberry fruits and also the 15 % addition of chokeberry reduced it. The flours with added fruits of elderberry, blackcurrant and chokeberry differed from the pure wheat flour in protein strength and starch gelatinization (values increased). Viscous behaviour of the composite material heated to about 80 °C showed the highest variability. The difference was also manifested by amylase activity in the samples with the addition of black base (more pronounced decrease with increasing amount of addition) and chokeberry (significantly higher values with 10 % and 15 % addition) as well as the rate of starch retrogradation mainly in samples with 10 % and 15 % chokeberry.

Due to the rheological properties of the dough, the results suggest that the verified fruit and elder flower additives can be used for the preparation of bakery products (including sweet variants) as well as long-lasting pastries (biscuits). Even in connection with the color of the dough, this non-traditional fruit can increase the attractiveness of the products. Further evaluation is needed in this area, but the test results obtained can be an important source of information for manufacturers when designing new products with increased health benefits.

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