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Effects of special additives in wheat dough system measured by Mixolab technique

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Abstract: Three novel bread additives were developed, namely wheat bran (WB), wheat aleurone-rich flour (ARF) fraction and germinated soybean [sprouted soy-based additive (YASO)]. Their applications were tested in bread dough systems. The additives showed different chemical compositions targeting different nutritional effects in bread. In each case, three different concentration ranges were used (WB 10–30%, ARF 10–30%, YASO 10–50%). Rheological differences were sensitively detected by the Mixolab technique in the mixed dough. So the rheological effects caused by compositional changes were reflected by the results of the above-mentioned technique. Based on Mixolab curves, optimal levels of applied additives (WB 14%, ARF 25% and YASO 30%) were defined. These are acceptable from a compositional and rheological point of view as well. The optimised mixtures were tested with the measurements of Rapid Visco Analyser (RVA) in slurry form, and characteristic effects of additives were observed. Based on Mixolab and RVA techniques, valuable rheological 'fingerprints' could be generated. These support the conscious and planned modification of rheological properties of bread products and the application of novel bread additives.

Keywords: aleuron rich flour; bread additives; germinated soybean; Mixolab; RVA; wheat bran; YASO

In solving the food and nutrient supply of the growing population of the world, more and more research activity is needed to fulfil specific demands. The quality of the consumed food sometimes is even more important than its quantity. Only cheap food is available in a significant proportion of the population because of financial or other reasons. Specific nutritional problems have to be solved in those populations which are having characteristic lacks in their diet. Therefore, a possible way is to enrich basic food with additives increasing nutritive value. A research project has been supported by European Commission to create healthier, nutritionally improved food products for population groups at risk of poverty with affordable prices (European Commission 2014).

Bread products are widely consumed food and are consumed in significant amounts worldwide. Improving its nutritional quality can help with solving food supply problems. Therefore, nutritionally improved bread products have been created using three new high-quality additives. The amount of *i*) wheat bran (WB) with 400 µm particle size, *ii*) a special milling

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product of wheat industry [aleurone-rich flour (ARF)], and *iii*) sprouted soy-based additives (YASO) were optimised in bread model. These additives are outstanding due to their extremely high protein, dietary fibre, minerals, vitamins and nutritional components (Bartalné-Berceli et al. 2015, 2018).

The application of innovated novel additives (WB, ARF, YASO) has to be optimised primarily from a compositional and sensory point of view. However, their physico-chemical and rheological effects in bread dough systems can determine or even limit their use. Optimisation of physical and sensory properties of the newly developed bread products have been presented earlier (Bartalné-Berceli et al. 2018).

In order to clear the rheological effects of additives in cereal-based products, different approaches were discussed in pasta (Bagdi et al. 2014) and bread models (Bartalné-Berceli et al. 2018; Sun et al. 2019). There are different rheological methods used to follow the effects of additives during the preparation of flour-water-additive systems as well. The Rapid Visco Analyser (RVA) technique (Bucsella et al. 2016) measures the viscosity of the suspension of flour, possibly used additives and water. The viscosity is monitored along with a predetermined temperature profile. The method is typically suitable for starch-containing samples; it is sensitive to changes caused by starches (Juhász and Salgó 2006). Using the Mixolab technique (Švec and Hrušková 2015), the rheological properties of dough systems can be investigated in a complex way. The rheological qualification of bread dough containing various additives can easily and reproducibly be done with a Mixolab instrument. The method is suitable for simultaneous monitoring of the effects of kneading and heat treatment. Thus, changes caused by the properties of proteins beyond changes caused by the properties of starch can be well studied. A comparative study was carried out to clear the relationship between rheological properties of doughs using different additives measured with Mixolab (Chopin) and Brabender (Farinograph) techniques (Xhabirir et al.2016).

This paper deals with the effect of three types and different amounts of additives (WB, ARF, YASO) on rheological properties and with the design of optimised composition of new bread products.

MATERIAL AND METHODS

Material. Commercially available wheat flour was used as a control and was enriched with three special additives. A special milling product of the wheat industry (ARF) and the standard refined wheat flour (*Triticum aestivum* L.) were provided by Gyermelyi Zrt., Hungary. The used flour meets the requirements of Codex Alimentarius Hungaricus (Ministry of Agriculture and Rural Development 2007). WB with 400 μm particle size was prepared by VTT Technical Research Centre of Finland Ltd., Finland. YASO was produced by Fitorex Ltd., Hungary. These additives are prominent from the nutritional point of view. Their nutritional characteristics and their composition are summarised in Table 1.

Mixolab technique. Mixolab technique analyses in one test the water binding capacity, kneading stability, gelling temperature, amylase activity and starch retrogradation. It provides more information than any other rheological method. During kneading and heat treatment, the Mixolab device (Chopin Mixolab 2; Chopin Technologies, France) detects the torque value. A specified time-temperature profile has been applied during the measurement applied by Rosell et al. (2007). This is an internationally accepted standardised methodology described by ICC Standard Method No. 173. The applied hydration base was 14%, the value of target torque was 1.1 nm. After specified moisture content and approximated hydration of the samples, the Mixolab® software 4.1.2.7 determines the weight of the required flour/sample. Measurements were carried out with average and optimal hydration, where average hydration is the amount of water necessary to rich the consistency which is characteristic for the applied flour and additive. Optimal hydration means the amount of water necessary to rich a dough consistency where the kneading torque reaches 1.1 ± 0.07 nm. Along with the predetermined temperature profile, a time-torque curve is detected. The tested sample is reproducibly and accurately characterised by the slope of a particular section of the curve

Table 1. Composition of the three used additives (w/w %)

	ARF	WB	YASO
Moisture	12.1	10.5	62.4
Protein	21.3	17.6	16.3
Total fat	4.3	3.9	8.7
Crude fibre	5.4	21.2	0.8
Ash	3.0	5.5	1.9
Dietary fibre	15.7	42.9	8.3
Soluble fibre fraction	2.0	2.3	4.4

ARF – aleurone-rich flour; WB – wheat bran; YASO – sprouted soy-based additive

Source: Bartalné-Berceli et al. (2015)

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Table 2. Notable points on the time-torgue curve (Mixolab device manufacturer)

Mark	Characteristic effect
C1	water absorption
C2	dough weakening
C3	starch gelatinisation
C4	gel stability
C5	starch retrogradation

and the location of the local minimum and maximum points (Chopin Applications Laboratory 2006; Hódsági et al. 2010). Notable points on the time-torque curve, namely C1–C5 points as well as slope α, slope β and slope γ are exactly determined by the Mixolab device manufacturer, Chopin (Table 2). The Mixolab curves shown in the figures below were drawn using Microsoft Excel 2007 (Microsoft Corporation, USA). Three replicates were performed for each sample. In the case of all three additives, 3 different proportions of the mixture were analysed. In line: WB was used in 10%, 14% and 30% addition, ARF was used in 10%, 25% and 30% addition and YASO was used in 10%, 30% and 50% addition.

Rapid Visco Analyser (RVA) technique. The RVA technique is suitable for testing small amounts of samples mixed with water. Generally, a standard time-temperature profile (ICC Standard Method No. 162) is used during the examination of cereal flour or starch. This standard profile is applied in the measurements presented in this paper. The mixing speed is 900 L min^{-1} in the first 10 s, then 160 L min^{-1} permanently (RVA-4SA; Newport Scientific Ltd., Australia). Three constant temperature sections are included in the temperature program. At the beginning and at the end of the measurement, 50 °C is used, while 95 °C is used at the middle. To measure the control sample, 3.5 g of flour and 25 mL of water were weighed. The 3 additives were tested in 1 : 1 mixing ratio. WB was used in 14% addition, ARF was used in 25% addition and YASO was used in 30% addition. A time-viscosity curve is obtained from RVA measurements. Two parallel measurements were performed for each sample. The notable points of the curve characterise the sample as they are influenced by definable physical and chemical phenomena (Juhász and Salgó 2006, 2008; Martínez 2018). The results were presented using the Microsoft Excel 2007 (Microsoft Corporation, USA) program.

RESULTS AND DISCUSSION

Rheological properties examined by Chopin Mixolab equipment were suitable to analyse the effect of all 3 additives at different levels on bread dough. The effect of the additives was analysed at 2 different hydration values in each case.

Effect of addition of wheat bran (WB) in bread model measured by Mixolab technique. Mixolab curves of bran-enriched bread products applying 10%, 14% and 30% of WB with average hydration are shown in Figure 1. The control and the 3 types of enriched products resulted in significantly different Mixolab curves regarding torque. The resulting significantly higher torque values (compared to the control product) showed a proportional increase as function amount of added WB. The high water absorption (C1) values of WB containing doughs remain high during early mixing, and the hydration 'character' of doughs are unchanged. The weakening of the dough matrix can

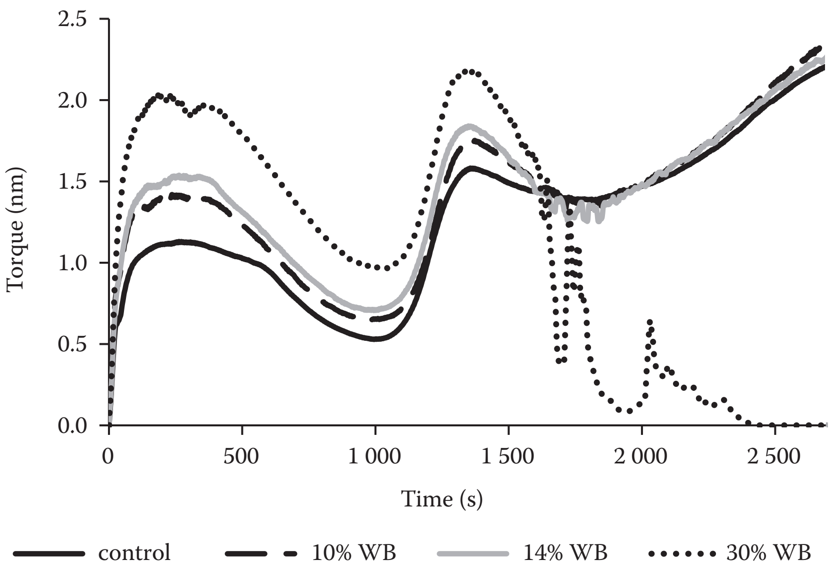

Figure 1. WB addition with average hydration (hydration is 61.3%)

WB – wheat bran

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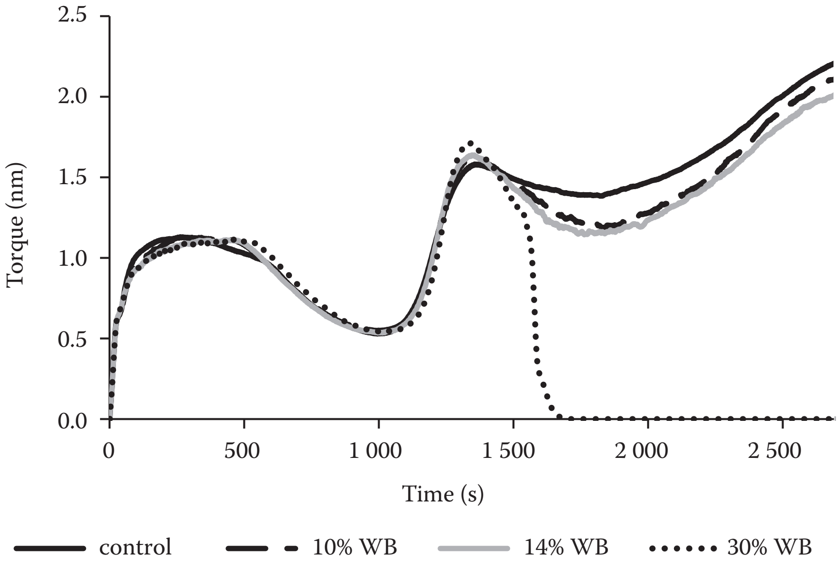

Figure 2. WB addition with optimal hydration (10% WB addition: hydration is 65.5%; 14% WB addition: hydration is 67.0%; 30% WB addition: hydration is 72.5%)

WB – wheat bran

be evaluated by C2 values, which confirm the well-proportion effects of added WB again. Dramatic changes were observed beyond the starch gelatinisation point (C3), where the hot gel stability decreased significantly (C4), and the WB addition over 14% resulted in the disaggregation of gel. The behaviour of the tested dough due to stirring and heating can easier be compared in Figure 2 using optimal hydration than in Figure 1 using average hydration.

The optimal hydration (Figure 2) values were 61.3% for control bread, and 65.5%, 67% and 72.5% for products containing 10%, 14% and 30% WB, respectively. The dough development time, i.e. time required to obtain C1, is increasing with the growing amount of WB in the products. The elasticity of the flour is growing with an increasing amount of WB because the higher curve width at C1 indicates higher dough elasticity. Slope α shows the speed of protein weakening under the effect of heat. As WB content is increasing, this value is increasing too. Slope β shows the speed of starch gelatinisation. It is increasing with the growing amount of WB in the dough. As the WB content of the dough increases, the torque reaches bigger values towards the end of the heating phase at point C3. This signifies a higher gelatine capability of starch with increasing WB dosing. The slope of the curve between C3 and C4 imply the degradation speed of the enzyme. The slope of the curve is bigger in the case of enriched products, and dough containing 30% of WB cannot be evaluated because of the dough disintegration beyond a certain temperature. This is around the end of the heating phase. The torque value falls rapidly to zero, probably due to the large particle size and dietary fibre content of WB. Point C4 gives information on the stability of hot and continuously stirred dough. With the addition of WB, the stability of the enriched doughs (10% and 14%) is getting lower due to the lower level of starch in WB. As a starch, primarily amylose, recrystallises, viscosity increases. Starch retrogradation (C5) value decreases with an increasing amount of WB, indicating decreasing retrogradation during cooling. It can be stated that the addition of WB influence radically the dough characteristics beyond the starch gelatinisation (C3), and its application level cannot be higher than 14% in the bread system. According to Xhabiri et al. (2016), in the case of WB addition to dough system, similar observations were detected using the Mixolab technique, and their Mixolab parameters showed medium correlation with Brabender (Farinograph) characteristics like water absorption, dough development time and dough stability.

Effect of addition of aleurone-rich flour (ARF) in bread model measured by Mixolab technique. ARF (10%, 25% and 30%) was added to bread dough. The Mixolab curves of dough enriched with ARF using average hydration can be seen in Figure 3. The level of ARF addition can easily be followed in Figure 3. With an increasing amount of ARF, the dough becomes harder, and the water absorption increases proportionally. The ARF addition affects longer dough stability and a bit higher protein weakening speed (α). The starch gelatinisation (C3) and its speed (β) are bigger as the amount of ARF is growing. The gel stability (C4) and starch retrogradation (C5) are strongly and proportionally elevated by ARF addition.

Using optimal hydration, the Mixolab curves of doughs with ARF addition are presented in Figure 4.

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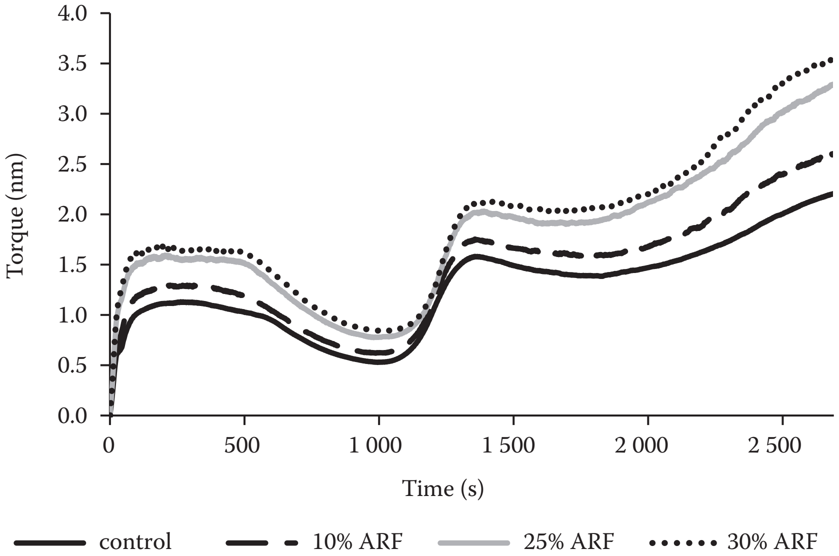

Figure 3. ARF addition with average hydration (hydration is 61.3%)

ARF – aleurone-rich flour

Dough containing 10%, 25% and 30% of ARF requires 64%, 67.5% and 68.9% hydration as an optimal one. With the increasing amount of ARF in the dough, the period of time required to reach point C1 is increasing. That means stronger flour was reached by enhancing the amount of additive. The speed of protein weakening due to heating changed significantly as a result of dosing. Protein weakening due to mechanical work and increasing temperature are indicated with torque value at point C2. A slight increase in C2 by increasing the dosage of ARF is showing a greater protein resistance. By further increasing the temperature, the starch grains start to be gelatinised. As the ARF content of the dough increases, a slight increase in the speed of starch gelatinisation can be observed. As the starch granules are swelling, the viscosity is increasing. The maximum viscosity (at point C3) is increasing with the growing amount of ARF due to increasingly pronounced swelling of starch granules and due to increasing starch stabilisation (probably due to higher level of non-gluten type proteins). No significant difference can be observed in the slope of the curves after point C3. At point C4 the torque value is increasing with the growing amount of ARF. This refers to bigger stability in added products. Increased C5-C4 differences observed at the products enriched with ARF in increasing proportions are showing more pronounced gelling (retrogradation) of the starch. The final viscosity increases with the growing amount of ARF, which also indicates increasing retrogradation and protein-starch interaction.

Because of its special chemical composition, ARF significantly influences the rheological parameters ei-

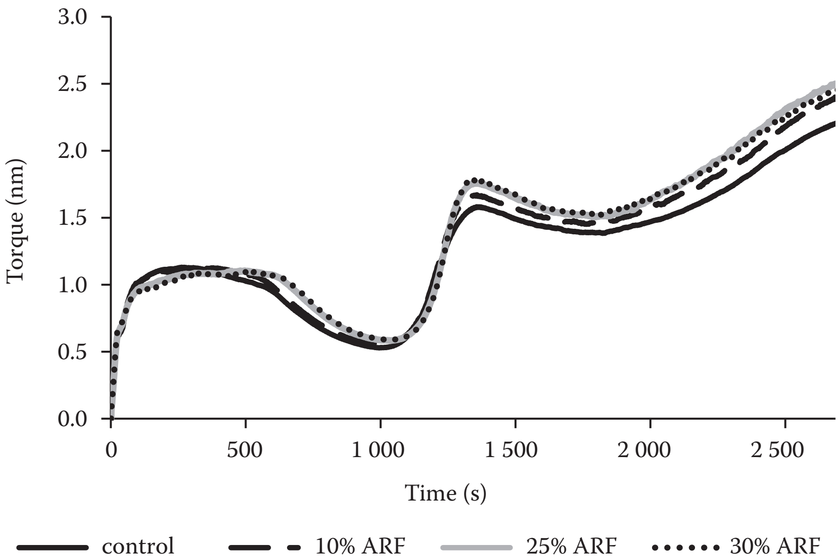

Figure 4. ARF addition with optimal hydration (10% ARF addition: hydration is 64.0%; 25% ARF addition: hydration is 67.5%; 30% ARF addition: hydration is 68.9%)

ARF – aleurone-rich flour

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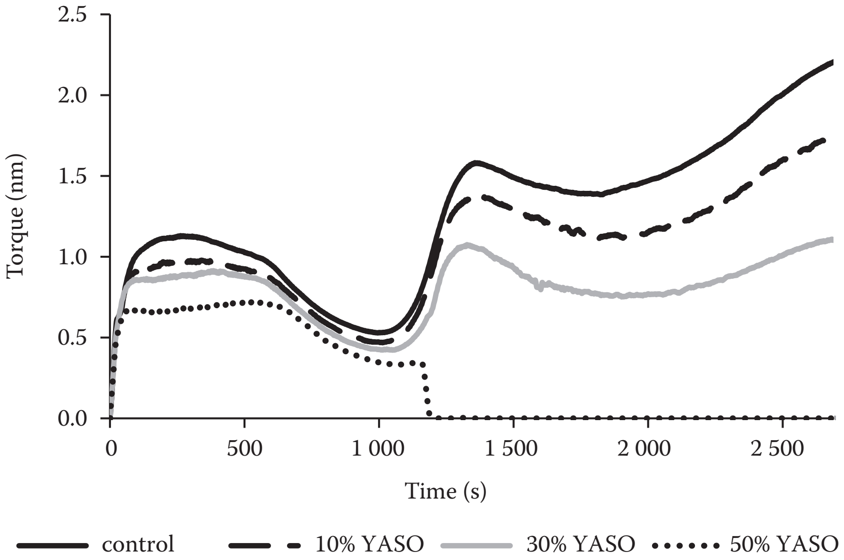

Figure 5. YASO addition with average hydration (hydration is 61.3%)

YASO – sprouted soy-based additive

ther in pasta (Bagdi et al. 2014) or in the bread dough system (Bagdi et al. 2016), and these effects can be sensitively followed by Mixolab and Brabender methods.

Effect of addition of sprouted soy-based additive (YASO) in bread model measured by Mixolab technique. The dosages applied in bread products at YASO were 10%, 30% and 50%. Figure 5 shows the Mixolab curves of dough enriched with YASO by using average hydration. Significantly different torque values can be observed among the four samples during the mixing period. The absorption of water (torque value at C1) is decreasing as the amount of YASO is increasing in dough while the stability of dough improved slightly. The protein weakening effect is pronounced only over 30% YASO addition. More than 30% YASO addition caused the collapse of the gel structure. The application of YASO in 10% and 30% reduce the C3, C4 and C5 values significantly.

The Mixolab curves of dough enriched with YASO using optimal hydration can be seen in Figure 6. Optimal hydration values 60%, 57% and 52.5% were applied for bread containing 10%, 30% and 50% YASO, respectively. At point C1 the curve is getting wider with the increasing amount of YASO in the dough, indicating higher dough elasticity and stability. The value of slope α and the value of C2 do not show significant differences among control and enriched bread (except 50% addition). Towards the middle of the heating phase, the curve of dough containing 50% YASO breaks down; it cannot be longer evaluated. Due to the high oil content of YASO the dough

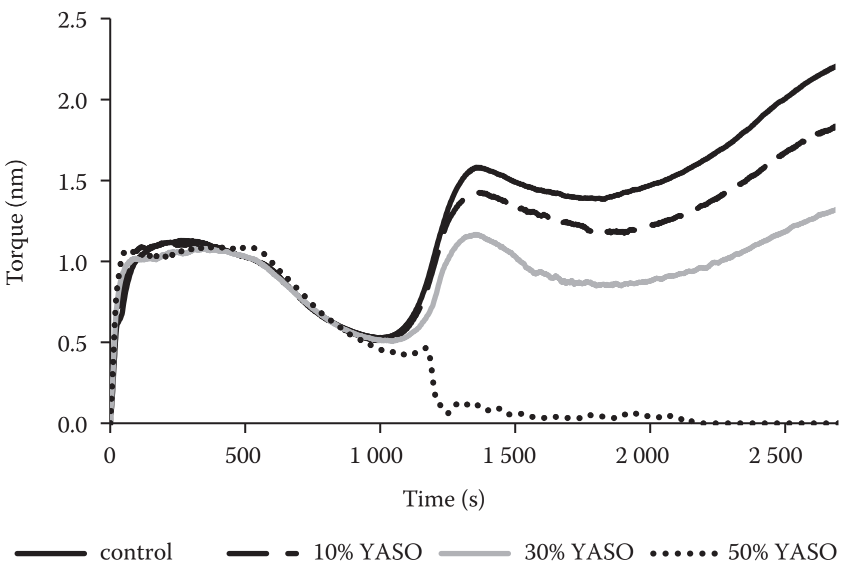

Figure 6. YASO addition with optimal hydration (10% YASO addition: hydration is 60.0%; 30% YASO addition: hydration is 57.0%; 50% YASO addition: hydration is 52.5%)

YASO – sprouted soy-based additive

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slips on the mixing paddles, the adhesion ceases; thus, torque falls close to zero. The value of slope β, characteristic of starch gelatinisation speed, decreases with increasing YASO dosing. The Mixolab curve rises all the way to point C3, which shows the degree of starch gelatinisation. A clear drop in C3 by increasing the amount of YASO is indicating the effects of high protein addition besides the effect of starch hydrolysis. With increasing YASO dosage slope γ is increasing, showing a faster reduction in gel stability. The C5-C4 difference and C5 values are decreasing with the increasing amount of YASO, showing that starch retrogradation is less significant in dough enriched with YASO (even because of 'dilution' effects of high protein YASO additive).

Because YASO is a newly patented product innovation (Bartalné-Berceli et al. 2016), there are no available literature citations about its application as a food additive, so these rheological observations have a certain underlying character.

Comparing the effects of three additives in Mixolab curves using them in optimal level with optimal hydration can be followed in Figure 7. The effects of WB addition in the cobweb diagram (Figure 7A) confirm the improved water absorption and mixing properties while the amylase effect was reduced. The ARF addition (Figure 7B) had a general improvement in all Mixolab characteristics. YASO addition (Figure 7C) showed very specific improvement in mixing properties while the water absorption, retrogradation and amylase effects were extremely decreased. Data of Figure 7 confirm that using the three different additives, different rheological 'target values' can be planned and/or reached.

Effect of addition of various additives in bread model measured by Rapid Visco Analyser (RVA) technique. RVA technique was applied to examine the rheological properties of the 3 additives also in slurry form. The time-temperature profile used for the measurements is specified in the ICC standard method (Method No. 162). For RVA measurement, a certain 'optimal' dosage was selected from each additive analysed by Mixolab. In the case of all three additives, the middle dosage quantity has been selected because these levels of addition are realistic from a product development and organoleptic point of view (Bartalné-Berceli et al. 2018). The average values of triplicate measurements were presented and analysed.

Figure 8 shows the RVA curves of all 3 types of additives. In sequences WB, ARF and YASO were applied in 14%, 25% and 30% for RVA analysis. The first notable point of the RVA curve is the pasting temperature. No differences can be observed in this value among control and various enriched products. However, significant differences can already be observed in peak viscosity. Peak viscosity indicates the degree of water-binding capacity, a higher value indicates higher water-binding capacity. The highest viscosity value is reached by the control product. Then a product con-

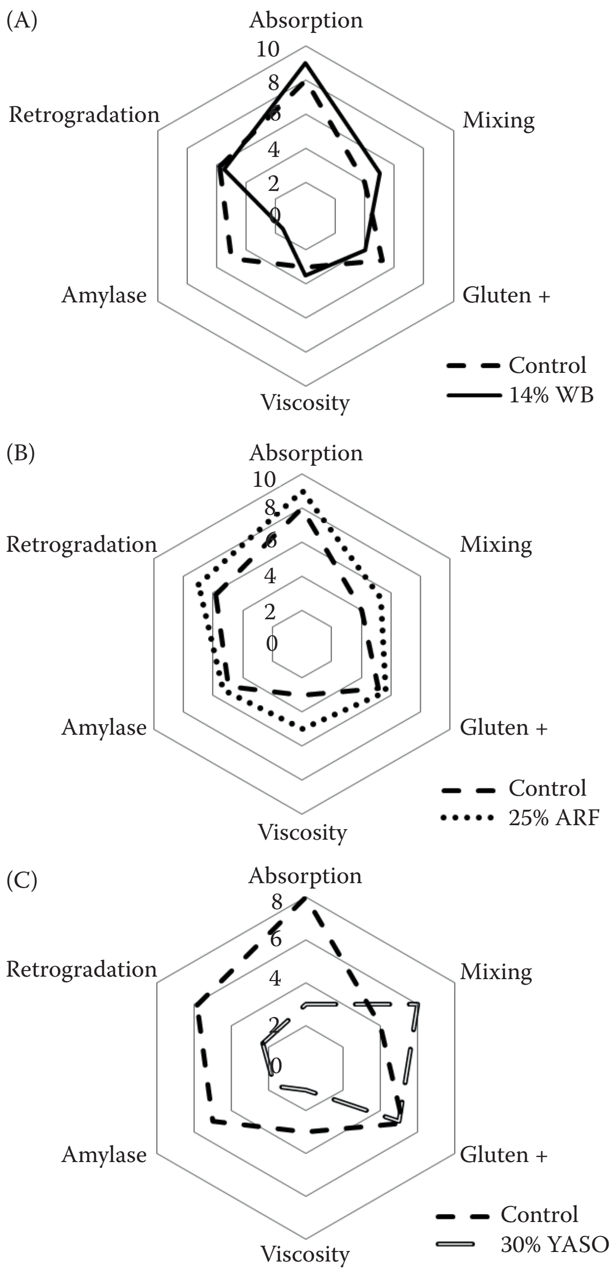

Figure 7. Characteristic points of the Mixolab curve at (A) control and 14% WB addition, (B) control and 25% ARF addition and (C) control and 30% YASO addition by using optimal hydration

WB – wheat bran; ARF – aleurone-rich flour; YASO – sprouted soy-based additive

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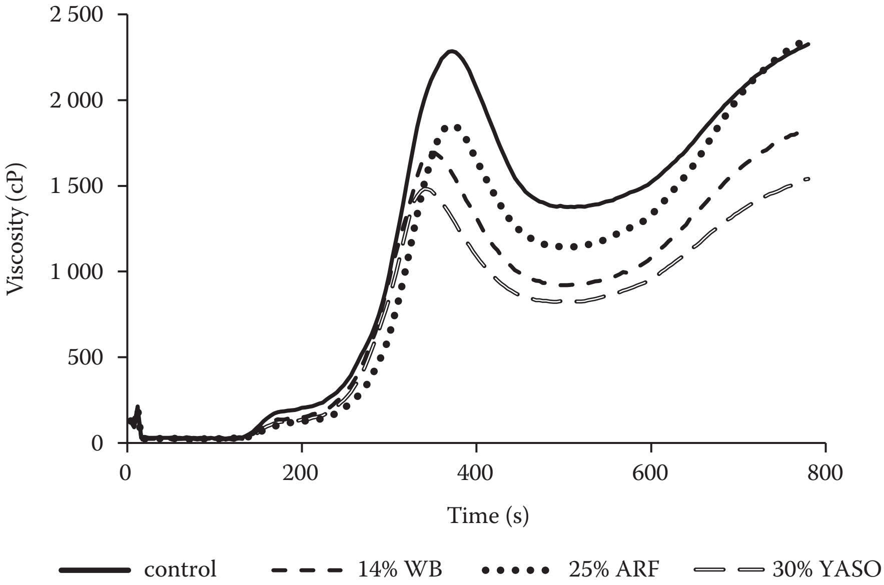

Figure 8. RVA curve of 3 types of additives

RVA – Rapid Visco Analyser; WB – wheat bran; ARF – aleurone-rich flour; YASO – sprouted soy-based additive

taining 25% of ARF (with high protein level), a product containing 14% WB (with a high level of crude and dietary fibre) and a product containing 30% YASO (with extremely high moisture and protein content) are followed. The value of peak viscosity is determined primarily by starch, but its value is also influenced by the presence of gluten or other proteins, lipids and pentosans (Morris et al. 1997). It can be seen that the effects of different chemical characters and compositions of additives are reflected in RVA curves. The peak time is the time when the peak viscosity appears; it decreases the same way as peak viscosity does among samples. The viscosity of the hot suspension stirred at constant temperature decreases. The trough value shows significant differences among samples. At this minimum point, the viscosity of the control product is the highest. It is followed by enriched ARF, then by enriched WB, and finally by enriched YASO samples. The breakdown values change in exactly the same way as the trough values. During the cooling period, the viscosity will increase because a gel structure can be formed due to the reassociation of starch and also protein molecules. High final viscosity indicates good gelling properties. Suspension enriched with 25% ARF reaches the same final viscosity value as the control one has. Slurry with 14% WB addition resulted in a significantly lower final viscosity value, and the slurry with 30% YASO addition showed even lower final viscosity value due to the lower level of starch content. The difference between the final viscosity and the viscosity of the hot dough is the setback value which is the highest by using ARF addition. In the case of control, the setback value is lower, furthermore, a little bit lower in slurry enriched with WB and even lower in slurry enriched with YASO. A decrease in the setback value indicates a decrease in retrogradation capacity at WB and YASO addition (due to lower starch content) compared to the control product.

Results indicate that RVA, as a compositional and rheological 'fingerprint', can provide good orientations in the conscious and planned modification of rheological properties of bread products and in the application of novel bread additives. According to Cozzolino et al. (2012), the RVA, as the approach, is very useful, considering the rich data generated by this analytical tool and maintaining a novel challenge on smart data evaluation.

CONCLUSION

The innovated novel additives (WB, ARF, YASO) can be applied in bread production in a broad concentration range, but their applications are targeted and limited due to their compositional and rheological characteristics and consequences. The rheological effects of novel bread additives can be measured either in dough or in slurry form. Both Mixolab and RVA technologies are sensitive enough to be used in product planning and development.

As outlook of our investigations, hereby, we would recommend the transformation of rheological curves (e.g. first or second derivatives or others) to make the rheological information of curves more sensitive and quantitative.

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