

# Rheological properties of dough and quality of bread supplemented with emulsifying polysaccharides

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## Abstract

The aim of present study was to evaluate the effects of emulsifying starches used as additives in breadmaking. In order to achieve this, the partial replacement (5-10%) of wheat flour with starch sodium octenyl succinate (OSA starch), pregelatinized starch sodium octenyl succinate (Pregel OSA starch) and hydrolyzed spray-dried starch sodium octenyl succinate (Hydrol OSA starch) was prepared. The quality characteristics of obtained bread were compared to control wheat flour bread and bread containing 0.5% hydroxypropyl methylcellulose (HPMC). The obtained results indicated that addition of Pregel and OSA starches influenced the increase in water absorption, whilst addition of Hydrol OSA starch exhibited the opposite effect. Moreover, the addition of all chosen starches influenced the decrease in dough stability. On the other hand, the positive effects of implementation of emulsifying starches on specific volume and texture were observed, where Pregel OSA and OSA starch have expressed the best effect.

**Keywords:** bread; emulsifying starches; HPMC; Mixolab simulator.

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Wheat bread is a widely consumed product and staple food in many countries, especially in Serbia where bread consumption per capita is far above EU average. Recently it was found that in Serbia 25 tons of bread per day are discarded due to its reduced quality caused by staling [1]. Starch as a major component of flour (about 75–85%), significantly affects the textural properties and quality of dough and bread. Starch retrogradation during storage is responsible for bread staling and product texture changes, where both amylose and amylopectin behavior upon baking play important role. Unlike amylose, which is almost completely recrystallized after cooling, recrystallization of amylopectin requires more time and due to that it is considered the main reason for staling [2]. This phenomenon is a very complex process that involves physical and chemical changes such as loss and redistribution of water between crumb and crust, firming of crumbs and decrease in starch solubility [3–6].

Modified starches, initially developed to suppress undesirable properties of native starches, have found wide application in food processing as they are able to improve water retention capacity, texture, thickness, freeze-thaw stability, retardation of retrogradation, etc. [7,8]. Modification of starches with octenyl succinic anhydride (OSA) was firstly patented by Caldwell and

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Wurzburg [9]. OSA starch is obtained by esterification reaction between starch and anhydrous octenyl succinic acid under alkaline conditions. Due to its amphiphilic nature, containing both hydrophilic and hydrophobic groups, OSA starch could act as an effective emulsifier. Therefore, aqueous solutions of OSA starches have been successfully used to stabilize oil in salad dressings and food flavor concentrates in beverages, to encapsulate flavors and vitamins in sauces, puddings and baby foods [10]. Moreover, it has been reported that OSA starch exhibits resistance to digestive enzymes, so it could act as a functional dietary fiber. It implies that products supplemented with OSA starches have additional nutritional value, being significantly different to other additives commonly used in breadmaking [11].

Based on our knowledge and available literature, the utilization of OSA starches, as additives in breadmaking has not been studied so far. This study was performed to estimate the suitability of partial replacement of wheat flour with OSA starches in breadmaking, where the main focus was on improving bread texture and structure in order to reduce the impact of bread staling. Therefore, the quality characteristics of bread supplemented with OSA starches (starch sodium octenyl succinate, pregelatinized starch sodium octenyl succinate and spray-dried hydrolyzed starch sodium octenyl succinate) were compared to control bread and bread containing hydroxypropylmethylcellulose (HPMC), with already proven ability to improve bread volume, strengthen bread crumbs, increase crumb moisture and reduce crumb hardening rate [4,12].

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## MATERIALS AND METHODS

### Materials

Wheat flour (moisture content 13.8%; protein content 12.0% d.m.; ash content 0.50% d.m.) was provided from Žitobačka, Kula, Serbia. Hydroxypropylmethylcellulose (HPMC) was purchased from Alfa Aesar GmbH & Co KG, Germany and starch sodium octenyl succinate starhes (OSA) were donated by Cargill, France. Three types of OSA starches, obtained from waxy maize, were used: starch sodium octenyl succinate (C\*EmTex 06328), pregelatinized starch sodium octenyl succinate (C\*EmTex 12688) and hydrolyzed and spray-dried starch sodium octenyl succinate (C\*EmCap 12633), which were referred to as OSA starch, Pregel OSA starch and Hydrol OSA starch, respectively. Salt and yeast were purchased from local market.

### Methods

#### Rheological properties of dough

Rheological properties of dough made of wheat flour sample (control sample), wheat flour/HPMC mixture (benchmark sample) and wheat flour/OSA starch mixtures were investigated using Mixolab (Chopin Technologies, France). Measurements were performed in duplicates by Chopin Simulator protocol (Table 1) whose results correspond to values and units obtained by Brabender Farinograph. However, in contrast to

Table 1. Chopin simulator protocol

Setting	Value
Mixing speed, rpm	80
Dough weight, g	75
Tank temperature, °C	30
Dough temperature	30
Total analysis time, min	30

Farinograph which operates with the constant flour mass (50 or 300 g), Mixolab flour mass depends on flour water absorption, where the parameter which is fixed is the dough mass (75 g) [13,14]. The obtained parameters from recorded curves were water absorption (Wabs), dough development time (min), dough

stability (min), degree of softening (BU) and initial maximum consistency, C1 (Nm) which was used to determine the water absorption.

#### Breadmaking procedure

Dough formulation that consisted of different flour/flour mixtures, fresh yeast and salt is given in Table 2. The amount of water required to reach the consistency of 500 Brabender Units (BU) was determined by Mixolab Simulator protocol. After kneading, the dough was rounded, and rested in a fermentation cabinet for 60 min ( $T = 30\text{ °C}$ ,  $RH\ 80\text{--}85\%$ ). Afterwards, the dough was divided (350 g), kneaded and mechanically sheeted and rolled. Cylinder-shaped dough pieces were placed into teflon pans ( $L \times W \times H$ : 240 mm  $\times$  85 mm  $\times$  65 mm, Tefal, France) and proofed up to the optimum volume increase at 35 °C and the relative humidity of 85% RH for final fermentation. The bread loaves (4 per formulation) were baked in MIWE deck baking oven (MIWE Condo, Germany) at 220 °C until the mass loss of 9% was reached. Finally, bread was cooled at room temperature for 2 h and stored (at 23 °C, 40% RH) for further bread quality evaluation.

#### Bread physicochemical characteristics

Bread volume was evaluated 24 h after baking by using the millet displacement method, while the specific volume was calculated as volume/weight ( $\text{cm}^3/\text{g}$ ) of four loaves. Moisture content was monitored 24 h after baking according to ICC 110/1 [15]. Breadcrumb firmness was measured by TA.XTPlus Texture Analyzer (Stable Micro Systems, UK) according to standard method for determination of bread firmness AACC (74-09) [16] using a P/36 probe (HDP/P/36) and 5 kg load cell in compression mode. Bread loaves were sliced at 25 mm thickness and compressed up to 40% of strain at a test speed of 1.7 mm/s. Textural analyses were conducted after 6, 24 and 48 h, at 23 °C, in nine replicates per batch.

#### Statistical analysis

The obtained results for specific bread volume and crumb moisture were analyzed by one-way analysis of variance (ANOVA), whilst the effects of additives and storage time were analyzed by two-way ANOVA using software XLSTAT, version (2012.2.02). ANOVA was fol-

Table 2. Bread dough formulation

Sample	Wheat flour %	HPMC %	Pregel OSA starch	Hydrol OSA starch %	OSA starch %	Yeast %	Salt %
Control	100	–	–	–	–	2	2
Control+HPMC	99.5	0.5	–	–	–	2	2
Control+Pregel OSA starch	95	–	5	–	–	2	2
Control+Hydrol OSA starch	90	–	–	10	–	2	2
Control+OSA starch	90	–	–	–	10	2	2

lowed by Fisher's Least Significant Difference (LSD) test. The analysis of the differences between the categories was performed with a confidence interval of 95%.

## RESULTS AND DISCUSSION

### Rheological properties of dough

The monitoring of rheological properties of dough is of great importance for the whole processing chain in order to assess the mechanical properties of dough, molecular structure and composition of the material, to imitate behaviour during dough processing and to anticipate the quality of the final product [14].

In the last decade, HPMC addition to wheat dough was studied by many authors [4,12,17]. It has been proven that HPMC addition exhibits positive effects on water absorption, dough stability during processing, increasing bread volume, and prolonged freshness of bread. OSA starches used in this experiment were modified in three different ways, where different physical and chemical properties of added modified starches caused differences in the rheological behaviour of wheat dough (Figure 1).

The addition of selected additives caused the increase in water absorption of formulation containing 0.5% HPMC (benchmark sample), 5% Pregel OSA starch and 10% OSA starch, with the exception of formulation containing 10% Hydrol OSA starch which exhibited the

decrease from 56.9 and 57.5 to 52.6% in relation to control and benchmark samples. The decrease in water absorption of system containing 10% Hydrol OSA starch was due to starch hydrolysis, which caused the decrease in amylopectin molecular weight and thus lowered the ability of Hydrol OSA starch granules to absorb water [18]. On the other hand, the increase in water absorption of Pregel OSA and OSA starch containing samples could be attributed to the structure of starch granules. Namely, starch modification process influences the increase in ratio of amorphous region of starch granule in relation to its crystal counterpart which resulted in increased water absorption of Pregel OSA and OSA starch granules. Therefore, they act as damaged starch granules which are able to bind more water than intact ones.

Regarding dough development time, only sample containing 10% Hydrol OSA starch exhibited the increase in dough development time from 2.0 to 4.5 min, whilst the addition of HPMC and OSA starch did not significantly influence the time required for dough to reach the maximum consistency. Namely, due to physical modification of spray-drying and hydrolysis, Hydrol OSA starch became cold water soluble and thus it dissolved in contact with water, while during mixing the uptake of water by diluted gluten was slow. On the contrary, Pregel OSA starch was only pregelatinized and not hydrolyzed, and thus it swelled even in cold water,

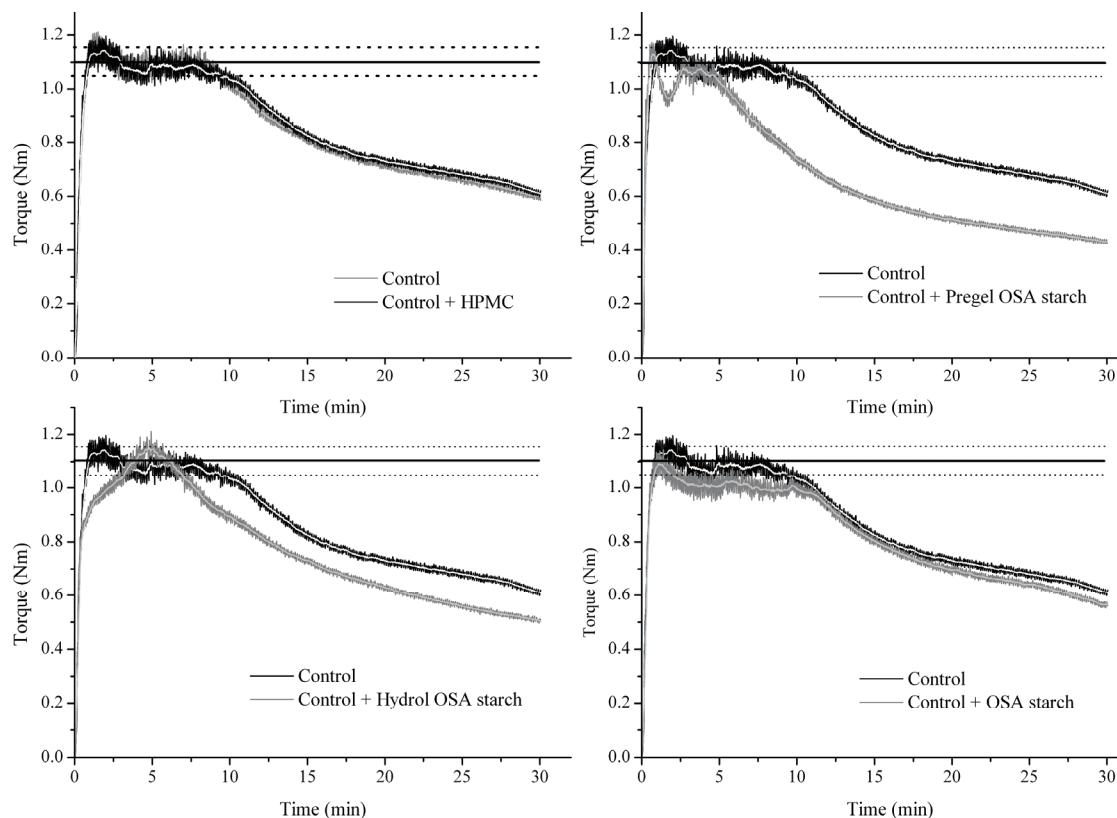


Figure 1. Dough rheological properties of wheat flour, wheat flour/HPMC as well as wheat flour/emulsifying starch mixtures.

*i.e.*, it had the ability to bind water. Therefore the Mixolab curve of dough supplemented with 5% of Pregel OSA starch was characterized by the presence of sharp peaks during dough development phase, which corresponded to modified starch water absorption, whilst the second peak corresponded to diluted gluten water absorption [19].

Dough stability of control and benchmark sample decreased from 9.0 and 9.5 to 2.0 min for 5% Pregel OSA starch formulation, 3.5 min for 10% Hydrol OSA starch formulation and 6.5 min for 10% OSA starch formulation, indicating that the inclusion of modified starches decreased the time during which the dough maintains maximum consistency. Moreover, softening degree was significantly influenced by the addition of 5% Pregel and 10% Hydrol OSA starches. However, the addition of 10% OSA starch did not significantly influence above mentioned parameter in comparison to control and benchmark sample. The physical properties of dough prepared with Pregel and Hydrol OSA starches could be attributed to their property of being soluble in water during dough formation phase, which increases dough extensibility, softness and stickiness [19]. Furthermore, during large mixing deformation Pregel OSA starch granules could not retain the absorbed water, which could not be taken up by diluted gluten either, and thus these systems expressed the lowest stability and the highest softening effect. On the other hand, the physical properties of dough prepared with OSA starch could be attributed to preserved crystalline structure of starch granules that act as a rigid filler contributing to the formation of starch-gluten network and thus making the stronger dough [19].

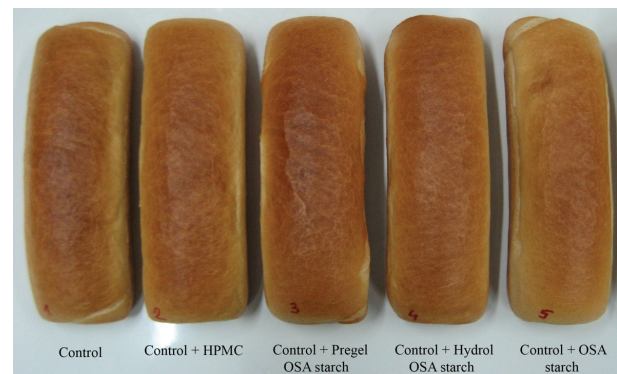
### Bread quality characteristics

A white loaf of bread of good quality is characterized by having sufficient volume, an attractive appearance and evenly developed crumb that is soft enough for easy chewing and firm enough for thin slicing [20].

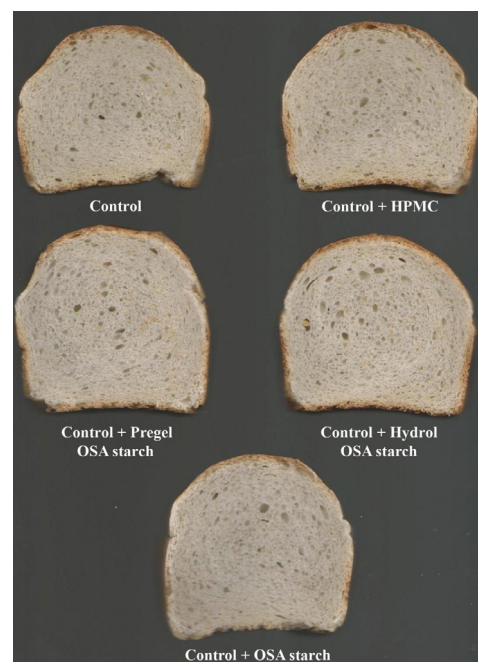
### Specific bread volume

The volume and texture of the final baked product is dependent on the size, distribution, growth, and gas cells burst during proofing and baking [21,22]. The appearance of obtained bread loaves and bread crumb is shown in Figure 2. The obtained effect of selected additives on specific bread volume and crumb moisture is shown in Table 3. In general, the specific bread volume was significantly enhanced by addition of selected additives in comparison to the control, regardless of their type and concentration used ( $P < 0.05$ ). The improved quality of HPMC to bread volume could be attributed to the formation of temporal HPMC network during baking, which strengthens the gas cells of the dough at the beginning of baking, improves the gas cells expansion during baking, and prevents the gas

losses, thus affecting the bread volume increase [4]. On the other hand, the incorporation of OSA starches into bread formulation significantly improved specific bread volume in comparison to benchmarking bread ( $P < 0.05$ ), with the exception of formulation with 10% Hydrol OSA starch, being at the same level as benchmark bread ( $P > 0.05$ ).



(a)



(b)

Figure 2. Appearance of a) bread loaves and b) bread crumbs made of wheat flour, wheat flour/HPMC as well as wheat flour/emulsifying starch mixtures.

The largest effect on specific bread volume was achieved by incorporation of 5% Pregel OSA starch. This phenomenon could be attributed to the nature of starch which has already been gelatinized and thus can easily develop dough structure and high bread volume [23]. The improving effect of OSA starches on the bread volume could be also attributed to the presence of hydrophobic groups affecting enhanced interfacial activity within dough during proofing, and gel network for-

Table 3. The effect of selected additives on specific loaf volume and crumb moisture; mean value  $\pm$  standard deviation of three replicates; values followed by the different letter in the same column are significantly different ( $P < 0.05$ )

Sample	Specific volume, cm <sup>3</sup> /g	Crumb moisture, %
Control	2.97 $\pm$ 0.06 <sup>a</sup>	41.96 $\pm$ 0.10 <sup>a</sup>
Control+HPMC	3.23 $\pm$ 0.01 <sup>b</sup>	42.48 $\pm$ 0.01 <sup>b</sup>
Control+Pregel OSA starch	3.50 $\pm$ 0.03 <sup>c</sup>	43.60 $\pm$ 0.01 <sup>c</sup>
Control+Hydrol OSA starch	3.20 $\pm$ 0.01 <sup>b</sup>	39.17 $\pm$ 0.02 <sup>d</sup>
Control+OSA starch	3.39 $\pm$ 0.04 <sup>d</sup>	43.36 $\pm$ 0.08 <sup>e</sup>

mation during breadmaking process [24]. Moreover, it was found that waxy starches, due to high amount of amylopectin, are more susceptible to  $\alpha$ -amylase degradation during fermentation, where the products of enzymatic degradation such as water-soluble sugars and/or high DE value maltodextrin may improve the yeast fermentation [25–27]. Gas cells are incorporated during dough mixing and due to CO<sub>2</sub> release caused by yeast fermentation [22]. It was found that OSA substitution increased the air incorporation into dough as well as stabilized the air-incorporated texture that resulted in larger final cake volume [23,28].

#### Bread crumb moisture

Crumb water content determines the shelf life of bread, crumb softness, crumb hardening and crumb-iness, influencing the overall consumer acceptance [29]. Bread crumb moisture significantly depended on the type of improver used (Table 3). After 24 h of storage, formulation with HPMC exhibited higher crumb moisture in comparison to the control bread ( $P < 0.05$ ) due to higher water retention ability of HPMC resulting from its hydrophilic nature [4,12,17]. The significant increase in bread crumb moisture in comparison to those of control and benchmark bread was achieved by formulation with 5% Pregel OSA and 10% OSA starch, whilst incorporation of 10% Hydrol OSA starch exhibited the opposite effect, which is in agreement with the results of Mixolab water absorption (Table 3). The obtained results confirmed previous findings of Morita *et al.* [30] and Sabanis and Tzia [31] who reported that higher water absorption of flour resulted in higher crumb moisture. Hung *et al.* [32] reported that incorporation of waxy wheat starch affected the retention of moisture in breadcrumbs thus influencing the retardation of bread staling. Crumb moisture has the influence on the mechanical properties of crumb which are commonly used for monitoring of bread staling process. He and Hosney [33] and Morita *et al.* [30] indicated that moisture content significantly affects bread firming, where higher crumb moisture affected slower firming rate and lower final firmness. However, there are certain conflicting reports which indicated that moisture content of bread crumb was not related to hardness [26].

#### Bread firmness

The firmness of bread crumb is an important bread feature because it directly affects the consumer preference. Firming of bread crumb is associated with bread staling which essentially means getting harder, more dry and crumbly. The changes in crumb firmness determined immediately after baking and over 48 h of storage are shown in Figure 3. The incorporation of OSA starches decreased initial crumb firmness in relation to the control sample. However, the addition of Pregel OSA starch and OSA starch yielded softer bread crumbs in comparison to that containing HPMC, whilst addition of Hydrol OSA starch did not exhibit a decrease in firmness in comparison to benchmark bread. The lower crumb firmness of all samples containing certain improver could be related to the higher crumb moisture content due to inverse relation between firmness and crumb moisture content that has been previously reported [4]. Moreover, firmness measurements are largely influenced by the volume and density of bread loaves, where the decrease in bread firmness may be attributed to an increase of total area of gas cells and consequently to decrease in the force needed to compress the sample [34,35]. Due to its emulsifying properties it is possible that added modified starches increased the strength and elasticity of gluten-starch matrix surrounding gas cells in dough, which affected the higher retention rate of CO<sub>2</sub> present in the gas cells, resulting in fine and homogeneous crumb texture as shown in Figure 2b [36]. Addition of emulsifying starches into wheat flour dough presumably reduced the gel forming properties of the amylose polymers, which led to weaker gel structure and, consequently, to a softer bread crumb. Regardless of the type of improver used, the firmness of all investigated crumbs increased rapidly over 48h of storage ( $P < 0.05$ ). Firmness during storage is a result of moisture loss, moisture redistribution and starch retrogradation [37]. Firmness values of bread crumb prepared with OSA and Pregel OSA starch after 24 and 48 h of storage, remained significantly lower than those of control and benchmark bread, whilst the crumb firmness of bread prepared with Hydrol OSA was similar to that of benchmark bread. Two-way ANOVA indicated that both storage time and selected additives influenced changes in tex-

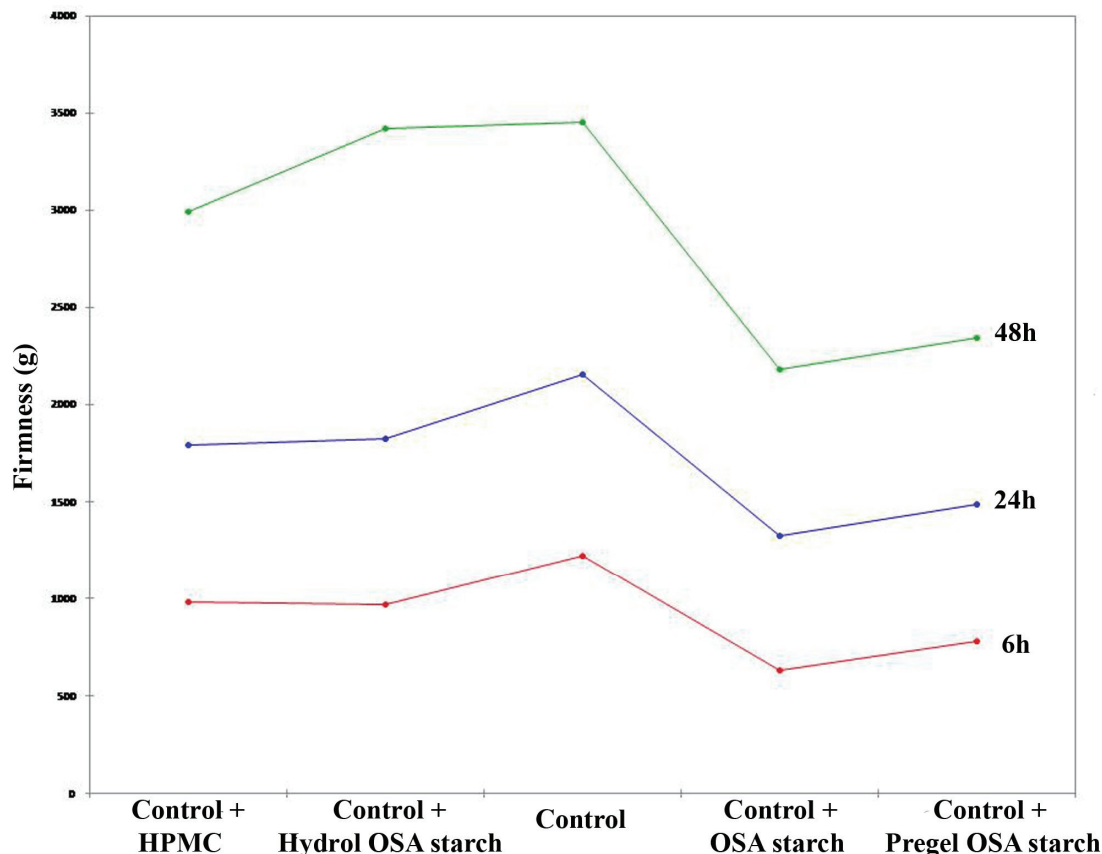


Figure 3. Influence of storage time and different additives on bread crumb firmness.

tural properties of bread crumb ( $P < 0.05$ ) where storage time revealed dominant effect (Figure 3).

## CONCLUSION

The results of this study revealed that emulsifying starches could be used as bread improvers, since their incorporation into wheat flour led to bread of similar or even improved quality in comparison to bread containing already well investigated bread improving emulsifier (HPMC). The investigated emulsifying starches (OSA starch, pregelatinized OSA starch and hydrolyzed spray-dried OSA starch) showed different impact on dough rheological properties depending on type of modification performed on starch granule structure. However, all investigated starches significantly improved bread specific volume and crumb texture, where the highest effect was observed for pregelatinized OSA starch due to its ability to incorporate and stabilize the gas cells formed during fermentation.

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**IZVOD****REOLOŠKA SVOJSTVA TESTA I KVALITET HLEBA PROIZVEDENIH SA DODATKOM EMULGUJUĆIH POLISAHARIDA**Tamara Dapčević Hadnađev<sup>1</sup>, Ljubica Dokić<sup>2</sup>, Milica Pojić<sup>1</sup>, Miroslav Hadnađev<sup>1</sup>, Aleksandra Torbica<sup>1</sup>, Slađana Rakita<sup>1</sup><sup>1</sup>Univerzitet u Novom Sadu, Naučni institut za prehrambene tehnologije, Novi Sad, Srbija<sup>2</sup>Univerzitet u Novom Sadu, Tehnološki fakultet, Novi Sad, Srbija

(Naučni rad)

Cilj ovoga rada je bio ispitivanje uticaja emulgujućih skrobova kao nove vrste aditiva u pekarstvu. U skladu sa tim, deo pšeničnog brašna je zamenjivan sa tri vrste emulgujućih skrobova (5-10%): skrob-natrijum-oktenilsukcinat (OSA starch), preželatizirani skrob-natrijum-oktenilsukcinat (Pregel OSA starch) i hidrolizovani skrob-natrijum-oktenilsukcinat (Hydrol OSA starch). Reološka svojstva testa i kvalitet hleba dobijeni sa dodatkom emulgujućih skrobova su upoređena sa kontrolnim testom, odnosno hlebom proizvedenim bez dodataka, kao i sa testom odnosno hlebom proizvedenim sa dodatkom hidroksipropil-metilceluloze (0,5%) (HPMC), koja je u pekarstvu već dobro poznat aditiv. Dobijeni rezultati su pokazali da je dodatak preželatiziranog skrob-natrijum-oktenilsukcinata (Pregel OSA starch) i skroba-natrijum-oktenilsukcinata (OSA starch) uticao na povećanje moći upijanja vode, dok je dodatak hidrolizovanog skrob-natrijum-oktenilsukcinata (Hydrol OSA starch) imao suprotan efekat. Međutim, pozitivan efekat upotrebe emulgujućih skrobova se ogleda u kvalitetnim karakteristikama krajnjeg proizvoda – hleba, i to povećanju specifične zapremine i poboljšanju teksturnih svojstava hleba, pri čemu je najveći uticaj pokazao dodatak preželatiziranog skrob-natrijum-oktenilsukcinata (Pregel OSA starch) i skroba-natrijum-oktenilsukcinata (OSA starch).

*Ključne reči:* Hleb • Emulgujući skrobovi • HPMC • Miksolab simulator