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SCIENTIFIC PAPER

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THE RHEOLOGICAL PROPERTIES OF WHEAT DOUGH CONTAINING ZEOLITE RESIDUE

Article Highlights

- Zeolite residues affect rheological properties of dough made from treated grains
- Zeolite strengthened the dough made of conventional and spelt wheat
- Na-enriched zeolite exerted higher improving effect than parent zeolite
- Movable cations in zeolite structure have a role in influencing dough performance

Abstract

The use of natural zeolite - clinoptilolite, to protect wheat grain from storage insects within environmentally-friendly storage techniques can lead to the presence of small amounts of zeolite residues in flour. This study investigated the influence of as-received zeolite clinoptilolite (Z) and sodium-rich clinoptilolite (NaZ) in wheat dough on the dough rheological properties. Zeolites were added to dough at 0.5-1.5 wt.% flour basis level, which is a range expected to remain in the grain (flour) after treatment to control storage pests. The effects were studied in two types of wheat, conventional (Triticum aestivum) and spelt (T. aestivum spp. spelta) because they initially differ in rheological properties. NaZ was used to discern whether the presence of increased concentration of Na^+ in the zeolite was able to exert a higher strengthening effect as compared to as-received zeolite (Z). NaZ exerted the highest dough strengthening effect which was mainly reflected as decreased dough softening and increased water absorption. The fact that the presence of NaZ was the most effective factor in improving the dough rheological profile suggested that the presence of movable cations in the zeolite lattice might have a pronounced role in the mechanism by which zeolite affects dough behaviour.

Keywords: zeolite, wheat, spelt, dough, mixing properties.

Application of inert dusts in environmental-friendly grain storage strategies has gained renewed interest in recent times. Inert dusts are possible alternatives to chemical insecticides and are attractive for use on organic grain, mostly due to their low mammalian toxicity and chemical inactivity. The Codex Alimentarius standards [1] have approved the use of inert dusts instead of chemicals for post-harvest handling of organically produced grains. Various types of inert dusts have been used: mineral dusts (rock phosphates, lime, limestone, salt), earths and ashes (powdered clay, diatomaceous earth), and synthetic silica [2]. Natural zeolites are alkaline aluminium silicates which are most similar to diatomaceous earth and can be classified in the same group - dusts with natural silicates [3]. Kljajić *et al.* (2011) [4] reported similar insecticidal activity of natural zeolites to diatomaceous earth in stored wheat and proposed their use in the protection of wheat against most prevalent insects such as rice weevil, lesser grain borer and red flour beetle.

However, if inert dust is applied in storage facilities, it can be expected that a certain amount of dust residue will remain in the treated grains. The effect of these remains on the quality of stored grains and end-products has to be considered. According to literature data, around 2% of a diatomaceous earth preparation remained in wheat flour after the grain treatment [5].

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Korunić (2016) [6] gave an overview of undesirable effects associated with the use of diatomaceous earths directly mixed with grains. Among the greatest disadvantages, the negative impact on grain flowability and grain bulk density was accentuated. However, Bodroža-Solarov *et al.* (2012) [7] reported some positive effects of inert dust treatments (diatomaceous earth and zeolite) applied on infested and non-infested wheat grains, which were mainly reflected through partial improvement of dough rheological parameters like moisture absorption and dough energy (extensigraph area). This finding was quite unexpected and its mechanism has been unrevealed. The explanation of this effect might be related to the specific composition of natural zeolites and presence of metal cations in its structure.

Natural zeolites are aluminoslicate minerals with an open-framework three-dimensional structure forming by a connection of AlO_4 and SiO_4 units. The porous zeolite structure contains cages and channels occupied by water molecules, alkali and/or earth-alkaline cations which are movable. Unique structural features provide zeolites unique adsorbing and ion-exchange properties. The chemical composition of zeolites can be expressed by following general formula: $M_{x/n}[Al_xSi_yO_{2(x+y)}]\cdot pH_2O$ where M is Na, K or Li and/or Ca, Mg, Ba or Sr, n is cation charge; y/x = 1-6, p/x = 1-4. Among more than 50 different structural types of natural zeolites, clinoptilolite is the most abundant natural zeolite. Its tabular morphology shows an open reticular structure of easy access exhibited by channels up to 0.7 nm in diameter [8]. The specific structure of zeolite allows its versatile use in food industry: in active packaging systems and food sanitation practise in the form of silver zeolite as antimicrobial agent [9], as a nano-membrane in sea water desalination techniques [10], or complexed with flavonoids to enhance their stability [11].

Moreover, zeolites can be used as ingredients in edible coatings on fruits and vegetables to prevent or lessen weight loss, respiration rate, rate of fungal decay, etc. during their storage [12]. Ion-exchanged copper and zinc zeolite was found to be excellent foliar fertilizer for wheat which allowed slow mineral release and better mineral fertilization efficiency [13].

The molecular effects of salts on dough rheology are elusive and yet not fully understood. From breadmaking practise, it is known that the addition of NaCl to dough (normally at a dose of 1.8-2.2% flour basis) exerts its strengthening and tightening [14]. This effect was firstly explained by the inhibitory effect of NaCl on proteolytic enzymes, but further studies pointed to more direct interaction between the salt and dough proteins affecting their aggregation. Noort *et al.* (2012) [15], investigated the partial replacement of NaCl with different salts in wheat dough and reported that KCl and Na_2SO_4 salts strengthened the dough whereas $CaCl_2$ and $MgCl_2$ weakened the dough properties. He concluded that cations distinctively separated from the sodium and those placed at the end in the lyotropic series of ions (Ca^{2+} and Mg^{2+}) have a weaker stabilization effect on protein configuration. In contrast, cations, physically and chemically more similar to sodium (Li^+, K^+), have identical action in dough like Na^+. Effects of chloride salts of Li, Na and K on the rheological properties of wheat dough were studied by Tuhumury *et al.* (2014) [16]. They observed that, regardless of cationic type, salt addition increased dough strength and stability. The effect of smaller cations ($Li^+<Na^+<K^+$) was greater regarding the increase in mixing time, resistance to extension and stability of resistance breakdown.

Other studies found in the literature mainly focussed on the impact of various sodium salts, but mostly NaCl, on dough rheology [16-19]. The results of large deformation tests indicated that the presence of NaCl increases the time to optimum dough development, resistance to extension, dough stability and extensibility which generally reflect a dough strengthening effect. It seems that the presence of NaCl affects the level of hydration and thus the structure of the gluten protein and their interactions [16]. It was proposed that the mechanism of the effect of NaCl on gluten microstructure is dependent on the concentration of salt. At lower concentrations, salt shields electrostatic charge of gluten proteins, reduces the electrostatic repulsion between proteins, thereby allowing their association and formation of stronger dough [20,21]. At higher concentrations, the effect of salt is more related to the interaction of salt with solvent environment, a subsequent change in solvent quality and protein solubility, which result in different molecular conformation and the network structure of gluten proteins [16]. According to McCann, Day (2013) [19], NaCl delayed the formation of gluten networks as a consequence of the reduction in the gluten hydration rate, which affected the protein unfolding, the alignment of protein polymers and their structure. Presence of NaCl allowed the formation of an elongated fibrous protein network, which improved dough strength and stability.

The objective of this study was to gain an insight into the influence of natural zeolite – clinoptilolite, on dough rheological properties. For that purpose, as--received zeolite (Z) was enriched with sodium by a simple ion-exchange procedure. Z or NaZ was added to dough in different amounts (in a range expected to remain in the flour after grain treatment with inert dust) and their effects on wheat dough rheological properties were compared.

MATERIAL AND METHODS

Material

In this investigation, flour of two subspecies of *Triticum aestivum*: common wheat (CW) and Spelt (SW) were used. Grain material was collected after the harvest in 2016. Wheat grain samples were tempered by adjusting to 15 g/100 g moisture according to AACC method 26-95 [22]. The tempered wheat samples were ground in a Bühler 202 mill according to AACC approved methods 26-21A and 26-30A [22].

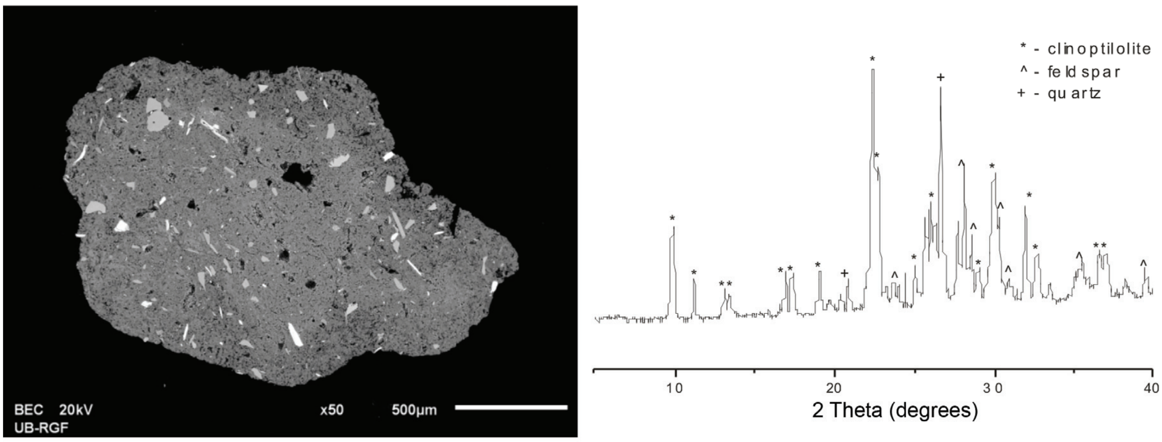
Z obtained from the sedimentary Zlatokop deposit (Vranjska Banja, Serbia) was used in the experiments. A previous detailed X-ray powder diffraction analysis showed that the zeolitic tuff contains 72.6% zeolite - clinoptilolite, 14.6% feldspar - plagioclase, and 12.8% quartz [8]. Z was converted into Na-rich form (NaZ) by treating Z with 2 mol dm^{-3} of NaCl at 60 °C for 5 days. Prior to its further use, the NaZ was filtered off, washed with distilled water until a negative test on chloride ions and dried at 105 °C. The conversion does not affect the crystallinity, which was confirmed by an X-ray powder diffraction (XRPD) of NaZ. The chemical composition of the clinoptilolite phase in NaZ expressed by oxide mass% is as follows: Z: SiO_2 – 65.7, Al_2O_3 – 13.2, Fe_2O_3 – 1.04, Na_2O – 0.95, K_2O – 1.33, CaO – 1.41 and MgO – 1.41, loss of ignition - 12.86; NaZ: SiO_2 – 66.6, Al_2O_3 – 12.9, Fe_2O_3 – 1.04, Na_2O – 10.3, K_2O – 0.14, CaO and MgO – 0.04, loss of ignition - 8.96.

Prior to further use Z and NaZ were finely ground (Pulverisette 6, Fritsch/1 h at 250 rpm) to obtain the particle size of 0.5-1.5 µm.

Elemental analysis of the clinoptilolite phase in the zeolitic tuff sample was performed using the energy dispersive X-ray spectroscopy (EDXS) analysis and Jeol JSM-6610LV. For the EDXS analysis the samples were carefully prepared by embedding grains in an epoxy film, polishing crystallites, cutting them with a fine grid diamond cut and coating them with gold. In this manner an intersection view of the crystallite grains is obtained which allows for a detailed EDXS analysis of major mineral phases. A typical SEM photo is given in Figure 1.

Dough mixing properties

Flour sample (4 g) was mixed with water containing different amounts of Z or NaZ (0.5, 1.0 and 1.5 mass%) at 63 rpm using a Newport Micro-dough LAB mixer (Perten Instruments, Australia). The dough consistency was recorded using the DLW version 1.0.0.56 software. To assess the dough mixing properties, standard farinological parameters were collected during mixing such as water absorption (*WA*), arrival time (*AT*), departure time (*DT*), dough stability (*DS*) and degree of dough softening (*DSO*). The amount of water required to achieve a dough consistency of 500 B.U. represented WA. AT is the time from the first addition of water and the point at which the top of the curve first intersects the consistency line at 500 B.U. DT is the interval between the initial moment and the point at which the top of the curve leaves the 500 B.U. DS represents the time the dough can be mixed before its consistency weakens. DSO is the difference in dough consistency from the 500 B.U.



a) b)

Figure 1. a) Typical SEM photo of NaZ. The shape and colour contrast indicate the presence of different mineral phases which were examined by EDXS in detail. The phases marked 1, 2 and 3 belong to feldspar, quartz and clinoptilolite, respectively; b) XRPD pattern of NaZ.

line to the centre of the curve measured at 15 min from the addition of the water.

Statistical analyses

Descriptive statistical analyses of all the obtained results were expressed by means, standard deviation (*SD*), for each sample. Collected data were analysed by ANOVA and significant differences were calculated according to post-hoc Tukey's test (HSD) at $p<0.05$ significance level *i.e.*, 95% confidence limit.

The principal component analysis (PCA) was performed on mean dough data sets in order to classify and discriminate the different samples. A pattern recognition technique has been applied within descriptors to characterize and differentiate all varieties of the samples.

The second order polynomial (SOP) model was used to fit the experimental data. Five mathematical models of the following form were developed to relate five responses (Y) and three variables (X):

$$Y_k = \beta_{k0} + \sum_{i=1}^{3}\beta_{ki}X_i + \sum_{i=1}^{3}\beta_{kii}X_i^2 + \sum_{i=1,j=i+1}^{3}\beta_{kij}X_iX_j \quad , \quad k = 1\text{-}5 \tag{1}$$

where: β_{k0}, β_{ki}, β_{kii}, β_{kij} are constant regression coefficients; Y_k, either *WA*, *DT*, *AT*, *DS* or *DSO*; X_1 - type of wheat (CW or SW); X_2 - Z content; X_3 - NaZ content.

All statistical analyses were carried out using StatSoft Statistica 10.0® software.

RESULTS AND DISCUSSION

The assessment of the traditional rheological profile of dough was performed by measurements on the Microdough Lab mixer under conditions that mimicked standard farinological analyses. The effects of two forms of zeolite (Z and NaZ) and two wheat types (conventional *T. aestivum* and spelt wheat) on dough properties were analysed using two statistical techniques, *i.e.*, principal component analysis and second order polynomial model.

The results on the effects of Z and NZ addition to CW and SW are presented in Tables 1 and 2.

The CW and SW doughs differed regarding rheological profile as expected; CW was a stronger dough. SW had lower stability and short departure times, but the dough softening was at a similar level. Rheological profile reflects the protein quality of the flours which markedly affects their baking/cooking performance and the quality of end-product. Protein quality parameters of wheat flour, as well as protein content, showed a significant relationship with hard-

Table 1. Dough rheological properties of CW samples treated with natural and sodium-rich zeolite; $^{a-d}$ - different letters in subscript in the columns indicate that there is a significant difference at p < 0.05, according to Tukey's HSD test. Data are presented as a mean±standard deviation of 3 replicates; CW-conventional wheat; Z-natural zeolite; NaZ-sodium-rich zeolite; WA- water absorption; AT-arrival time; DT -departure time; DS - dough stability; DSO -dough softening

Treatment	*WA* (%)	*AT* (min)	*DT* (min)	*DS* (min)	*DSO* (B.U.)
1.5% NaZ	51.200±0.161^{c}	0.633±0.009^{c}	5.767±0.122^{b}	5.200±0.098^{ac}	118.333±0.559^{a}
1.0% NaZ	50.867±0.064^{bc}	0.567±0.008^{a}	5.533±0.101^{ab}	5.367±0.094^{a}	120.000±1.076^{a}
0.5% NaZ	50.767±0.107^{bc}	0.567±0.012^{a}	5.500±0.035^{ab}	5.700±0.163^{d}	120.333±2.819^{a}
1.5% Z	50.033±0.070^{a}	0.533±0.004^{b}	5.567±0.142^{ab}	5.267±0.068^{a}	117.333±1.120^{a}
1.0% Z	50.350±0.376^{ab}	0.550±0.003^{ab}	5.450±0.107^{a}	5.400±0.147^{ad}	119.000±2.010^{a}
0.5% Z	50.533±0.214^{ab}	0.567±0.011^{a}	6.100±0.099^{d}	4.933±0.046^{bc}	120.000±0.723^{a}
Control	50.100±0.205^{a}	0.533±0.004^{b}	5.067±0.055^{c}	4.700±0.047^{b}	129.000±2.090^{b}

Table 2. Dough rheological properties of SW samples treated with natural and sodium-rich zeolite; $^{a-f}$ - different letters in subscript in the columns indicate that there is a significant difference at p < 0.05, according to Tukey's HSD test. Data are presented as a mean±standard deviation of 3 replicates; SW- spelt wheat; WA- water absorption; AT-arrival time; DT -departure time; DS - dough stability; DSO -dough softening

Treatment	*WA* (%)	*AT* (min)	*DT* (min)	*DS* (min)	*DSO* (B.U.)
1.5% NaZ	52.533±0.565^{b}	0.467±0.006^{a}	1.667±0.017^{b}	1.533±0.038^{f}	110.333±1.622^{a}
1.0% NaZ	52.033±0.214^{ab}	0.433±0.005^{d}	1.667±0.029^{b}	1.333±0.020^{a}	111.667±1.449^{a}
0.5% NaZ	51.200±0.785^{ab}	0.467±0.007^{a}	1.700±0.038^{b}	1.333±0.015^{a}	112.000±1.224^{a}
1.5% Z	51.233±0.434^{ab}	0.400±0.007^{c}	1.500±0.042^{ac}	1.233±0.017^{d}	116.333±0.933^{b}
1.0% Z	50.800±0.150^{a}	0.467±0.007^{a}	1.567±0.018^{c}	1.400±0.019^{e}	117.667±1.566^{b}
0.5% Z	51.267±0.537^{ab}	0.500±0.007^{b}	1.467±0.008^{a}	1.033±0.018^{c}	116.667±0.747^{b}
Control	50.833±0.357^{a}	0.500±0.003^{b}	1.467±0.026^{a}	0.867±0.013^{b}	130.667±2.104^{c}

ness, cohesiveness, springiness, adhesiveness, chewiness, and gumminess of the cooked noodles [23]. The addition of two fractions of gluten protein (glutenin and gliadin) produced opposite effects on dough behaviour: glutenin improved the mixing properties whereas gliadins decreased dough stability and increased softening of the dough [24]. However, dough rheological properties also depend on the starch pasting properties, as shown in the work of Mudgil *et al.* [25]; various added ingredients added to dough (like hydrocolloids) that affect starch gelatinization may modify the properties of the dough system.

Analysis of variance showed that statistically significant differences existed in most cases, as expected. In both CW and SW samples (Tables 1 and 2), the addition of both zeolite forms significantly and gradually increased dough stability and decreased dough softening. This enhancing effect was more pronounced in weak SW dough, which is in line with the finding of McCann, Li (2013) [19], that NaCl had a more efficient strengthening effect in weaker (low protein) flour.

WA was significantly increased in the NaZ treatments, while the arrival time in CW doughs (Table 1) was significantly increased in the treatments with 1.5% NaZ whereas Z did not contribute to significant change in this parameter. In SW doughs, arrival times were decreased by Z and NaZ addition as compared to the SW control. Departure times were increased, more pronounced in case of NaZ addition. In the study of Bodroža-Solarov *et al.* (2012) [7], it was reported that various inert dust treatments caused a significant increase in dough water absorption in both low and high vitreous grains, whereas dough softening and flour quality number were not significantly affected. Marked dough improving effects were registered in the case of insect-infested low vitreous wheat, which was explained as a consequence of greater accumulation of inert dust and the rise of the relative proportion of protein and crude fibre in the damaged kernels [7]. Increased farinograph development time and extensigraph resistance (measured at 45 and 90 min) proved higher dough mixing strength of samples in which 0.3 g/kg of commercially available and registered diatomaceous earth preparation, “Protect-It”, was added [23]. However, this improvement did not lead to improved baking performance, as far as loaf volume was considered. There is little information on the effect of zeolite addition on bread quality in the scientific literature. In a patent that describes the method of producing bread enhanced with zeolite to improve its mineral pattern and therapeutic properties, it was mentioned that zeolite applied at 5% doses deteriorated the sensory properties of bread whereas zeolite dose up to 3% yielded bread with acceptable quality [24]. In the present study, sensory evaluation of breads was not displayed as it was not suitable to discern differences among breads prepared with flours that contained any of the studied zeolite forms (Z or NaZ) at the applied doses (0.5--1.5% flour basis).

Principal component analysis (PCA)

The PCA of the presented data explained that the first two principal components accounted for 90.31% of the total variance (70.56 and 19.75%, respectively) in the five-variable space (*WA*, *DT*, *AT*, *DS* and *DSO*). Considering the map of the PCA performed on the data, *DT* (which explained 25.1% of total variance, based on correlations), *AT* (22.1%), *DS* (24.3%) and *DSO* (11.0%) exhibited positive scores according to first principal component, whereas WA (which contributed 17.5 of total variance) showed a negative score values according to the first principal component (Figure 2). The positive contribution to the second principal component calculation was observed for *DSO* (52.2% of total variance, based on correlations), while the most evident negative impact was observed by WA (21.3%) and *DS* (11.1%).

The position of CW and SW wheat samples treated with Z and NaZ in the multivariate factor space of the first two Principal Components is displayed in Figure 2. PCA showed a clear separation between different wheat types as well as between differently treated samples. The scores for SW control and CW control were separated due to differences in the initial dough rheological profile. The scores related to treated dough were distinctively arranged in two areas showing separation due to wheat type. Within each area, samples treated with Z were separated from those treated with NaZ. The map of PCA graphic showed that the first principal component described the differentiation among the wheat cultivars, while the second principal component described the variations in type of zeolite and also zeolite content between samples. According to ANOVA data discussed above, NaZ dough showed better improvement in the rheological profile which is clearly revealed in the PCA biplot.

The points shown in the PCA graphics, which are geometrically close to each other, indicate the similarity of patterns that represent these points. The orientation of the vector describing the variable in factor space indicates an increasing trend of these variables, and the length of the vector is proportional to the square of the correlation values between the fit-

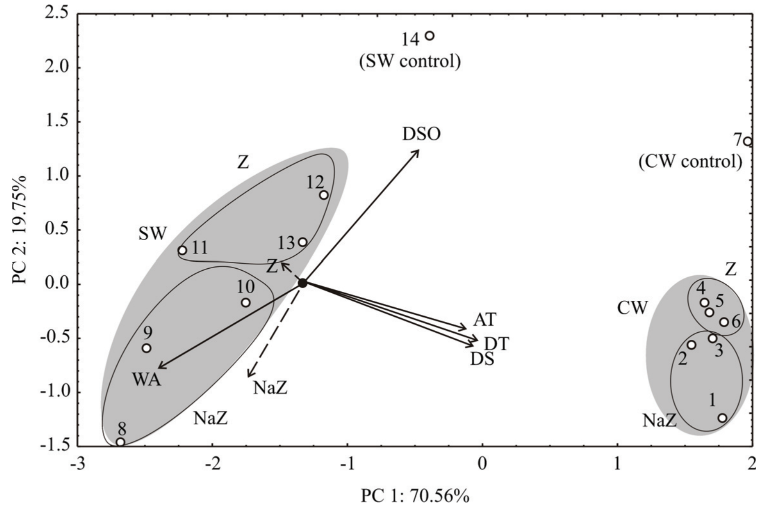


Figure 2. PCA ordination of WA, DT, AT, DS and DSO of common and spelt wheat dough with added zeolite (Z or NaZ), based on component correlations.

ting value for the variable and the variable itself. The angles between corresponding variables indicate the degree of their correlations (small angles corresponding to high correlations). Having this in mind, it can be observed that high correlations exist between *AT*, *DT* and *DS* which is expected as these parameters actually all reflect dough stability and essentially carry the same information. *DSO* showed no correlation to dough stability (*DS*) and *WA* was almost inversely correlated to *DSO* indicating that the samples characterized with higher *WA* were generally lower in *DSO*.

Second order polynomial model

The experimental data were fitted to the second order polynomial (SOP) model (Eq. (1)) to better reveal the influence of zeolite type and wheat quality on the dough rheological profile. As confirmed by high R^2 values and insignificant lack-of-fit, the statistical accuracy of the models was verified (Table 3).

The analysis revealed that the linear term of wheat type was the most influential in the SOP model for *DT*, *AT* and *DS* evaluation, statistically significant at $p<0.01$ level. The wheat type was very influential variable for *WA* ($p<0.01$) and *DSO* ($p<0.05$), however, substantially greater linear effect of NaZ content on *WA* and *DSO* was observed, statistically significant at $p<0.01$ level. The linear term of zeolite content influenced *AT* and *DSO*, statistically significant at $p<0.05$ level, while non-linear terms of Wheat type×NaZ and Wheat type×*Z* have been found influential for *AT* calculation ($p<0.05$ level). These results clearly denote that NaZ was the most influential factor which affected *WA* and *DSO*. Natural zeolite did not influence WA but did *DSO*. This confirms the hypothesis of the capability of Na^+ to significantly influence the improvement in dough rheology and implies that the presence of cations in the zeolite structure might be involved in the mechanism of affecting dough rheology. However,

Table 3. The effect of observed factors (wheat type, NaZ and Z content) in SOP models for prediction of responses (sum of squares); $^+$ - sgnificant at p<0.01 level; * - significant at p<0.05 level; ** - significant at p<0.10 level; error terms have been found statistically insignificant; df - degrees of freedom; NaZ - sodium-enriched zeolite content; Z - natural zeolite content; WA- water absorption; AT - arrival time; DT - departure time; DS - dough stability; DSO - dough softening; R^2 - coefficient of determination

Term	*df*	Response				
		WA	*AT*	*DT*	*DS*	*DSO*
Wheat type	1	1.798$^+$	0.031$^+$	22.809$^+$	21.109$^+$	76.055*
NaZ	1	2.067$^+$	0.001	0.160	0.327**	245.616$^+$
NaZ^2	1	0.001	0.001	0.000	0.173	30.624
Z	1	0.003	0.003*	0.017	0.252	164.103*
Z^2	1	0.072	0.001	0.187	0.111	55.412**
Wheat type×NaZ	1	0.220**	0.005*	0.010	0.004	27.232
Wheat type×*Z*	1	0.079	0.003*	0.019	0.004	3.358
Error	6	0.318	0.003	0.371	0.419	75.118
R^2		0.948	0.948	0.993	0.993	0.846

there also existed significant interactions between wheat type, zeolite type and zeolite content in relation to WA and AT which underlines the complexity of the problem. Obviously, the most affected parameter of dough quality was dough softening (*DSO*). Both zeolite types were capable to significantly decrease *DSO*. Lower degree of dough softening is important because it is an indicator of stronger and better machinable dough. For example, Mailhot, Patton (1989) [28], recommended flours with *DSO* less than 75 B.U. as adequate for bread making. From the aspect of bread-making, good quality flours have higher water absorption, and higher dough stability. They require longer mixing times and are more tolerant to over-mixing due to higher stability.

CONCLUSION

The elementary hypothesis of the research that Na^+ ions from the zeolite lattice may contribute to the improvement of dough rheological properties has been confirmed. The findings in this study showed that the zeolite residues in grain (flour) (up to 1.5%) were not detrimental to the dough rheological profile; on the contrary, they may contribute to the improvement of dough properties especially in the case of weak doughs. This conclusion favours utilization of natural zeolite - clinoptilolite as an environmental-friendly insecticide in cereal storage.

So far, it seems that from the standpoint of flour technological quality, the utilization of zeolite as insecticide in storage strategies should not be considered objectionable. However, additional investigations are necessary to better resolve the effect of zeolite composition (effect of other cations present in its structure) on dough properties in conjunction of various aspects of processing performance (bread, biscuit, pasta-making properties) of treated grains.

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NAUČNI RAD

REOLOŠKE OSOBINE PŠENIČNOG TESTA SA REZIDUAMA ZEOLITA

Upotreba prirodnog zeolita - klinoptilolita, u zaštiti pšeničnog zrna od insekata pri skladištenju je ekološki prihvatljiva tehnika, ali njegovo korišćenje može dovesti do prisustva malih ostataka zeolita u brašnu. U ovoj studiji ispitivan je uticaj prirodnog zeolita klinoptilolita (Z) i natrijumom obogaćenog klinoptilolita (NaZ), dodatih u pšenično brašno, na reološka svojstva testa. Zeolit je dodat u količini od 0,5 do 1,5% brašna, što je u skladu sa očekivanim rasponom vrednosti koji zaostaje u zrnu (brašnu) nakon obrade zrnene mase radi suzbijanja štetočina pri skladištenju žita. Efekat rezidua zeolita na reološke osobine testa su proučavani za dve vrste pšenice, za konvencionalnu pšenicu (Triticum aestivum) i speltu (T. aestivum spp. Spelta), uzimajući u obzir da postoji razlika u reološkim svojstvima brašna ovih žita. Uticaj povišene koncentracije Na^+ u NaZ zeolitu dovodi do poboljšanja reoloških svojstava brašna u poređenju sa zaostalim prirodnim zeolitom Z. Dodatak NaZ zeolita je ispoljio najveći efekat ojačavanja testa, što se ogledalo u smanjenom stepenu omekšavanja testa i povećanoj moći upijanjanja vode. Činjenica da je prisustvo NaZ najefikasniji faktor u poboljšanju reološkog profila testa nagovestila je da bi prisustvo pokretnih katjona u rešetki zeolita moglo imati izraženu ulogu u mehanizmu kojim zeolit utiče na reološko ponašanje testa.

Ključne reči: zeolite, pšenica, spelta, testo, reološka svojstva.