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TRADING QUALITY AND BREADMAKING PERFORMANCE OF WHEAT TREATED WITH NATURAL ZEOLITE AND DIATOMACEOUS EARTH

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The aim of study was to investigate the influence of naturally occurring zeolite and diatomaceous earth, as inert dusts approved for insect pest control in certified organic crop production, on trading and breadmaking quality of treated wheat. The treatments significantly reduced the trading quality of wheat which was reflected through lowering of test weight. This effect was more marked in the case of low-vitreous wheat rather than in high-vitreous one. Investigation of rheological properties of flours made from the treated wheat demonstrated that treatments with natural zeolite and diatomaceous earth at all applied doses significantly increased the water absorption, which consequently increased the bread yield. However, these changes in the flour properties were not high enough to modify the quality attributes of bread as was shown by instrumentally measuring crumb hardness and springiness as well as sensory evaluation.

KEY WORDS: inert dust, wheat, flour, bread

INTRODUCTION

Besides having many practical advantages such as good efficacy and relatively low cost, there are attempts to replace classical pesticides with alternative methods for stored-product protection due to the growing awareness of public against food products with chemical residues and increased rate of insect contamination of stored commodities. In addition, quick development of resistance to insecticides among insect populations has been reducing pesticide effectiveness (1, 2).

Natural zeolite (NZ) and diatomaceous earth (DE) are used in reducng pest infestations in storage facilities according to the valid standards of organically certified production (3). This was a reason why researchers started to investigate the efficacy of these agents in controlling insect pests in stored commodities several decades ago. Diatoma-

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ceous earth is an alternative to chemical control of stored-product insects. It is the fossilized remains of phytoplankton (diatoms) composed of amorphous silicon dioxide that is non-toxic to mammals (4) and is registered as a food additive in Canada, the USA, and in many other countries (5). Zeolites are crystalline hydrated tektoalumosilicates consisting of three-dimensional frameworks of SiO_4^{-4} and AlO_5^{-4} tetrahedra linked through shared oxygen atoms. Zeolites are characterized by their ability (a) to lose and gain water reversibly; (b) to adsorb molecules of appropriate cross-sectional diameter; and (c) to exchange their constituent inorganic cations without any major change of their structure (6). Extensive studies have been conducted on the application of DE (2, 5, 7, 8) and natural zeolites (alkaline aluminum silicates) (9) as a stored-grain protectant.

One disadvantage of using these natural insecticides is lowering of the trading quality of wheat grains which is especially marked regarding the test weight of grains. This can be explained as a result of greater friction between kernels, which directly affects their bulk density and flow properties (5, 10).

Preparations based on these natural ingredients have been successfully used to control insect infestations and are commercially available under trade names Dryacide and Protect-It®. Few investigations have been conducted to evaluate the quality of wheat flour obtained from treated wheat. Commercial cleaning of wheat removed about 98±1% of Dryacide, and no Dryacide could be detected in the flour. Dryacide treatment did not affect the flour quality as determined by the volume of sponge cakes and the production of carbon dioxide by fermenting dough (11). Three samples of wheat were mixed with 0.50 and 300 mg/kg of Protect-It®before milling, and a sample of 300 mg/kg was added directly to the flour. There were no significant differences between the samples in: protein content, falling number value, sedimentation value and color. The flour with added 300 mg/kg showed increased dough mixing strength compared to other samples as revealed by increased farinograph development time and increased extensigraph resistance measured at 45 and 90 min. The increase of dough strength was not reflected in increased baking performance (loaf volume) (10).

The objective of this study was to determine the effect of natural zeolite and two types of diatomaceous earth originating from Serbia and to compare their performances with a commercial preparation Protect-It® from Canada. The preparations were applied on soft wheat characterized with different degree of endosperm vitreousness (high- vitreous and low-vitreous (mealy) grains), in relation to the wheat trade quality and quality attributes of the final product, bread.

EXPERIMENTAL

Raw material

Two types of wheat (*Triticum aestivum ssp. vulgare*) were characterized with different degree of endosperm vitreousness: 17.0% (low-vitreous or mealy grains, LVG) and 81.8% (high-vitreous grains, HVG). The material was procured from local producers.

Inert dusts

The experiments were carried out using various samples of inert: 1) inert dust based on NZ originating from Serbia and processed at the Institute for Technology of Nuclear and Other Mineral Materials in Belgrade; 2) two dust samples based on diatomaceous earth (DES-1 and DES-2, originating from Serbia) and 3) registered preparation Protect-It® (Hedley Technologies Inc., Canada).

The dusts used in tests had the following properties:

– NZ contained according to the producer's specification: SiO_2 (65.7%), Al_2O_3 (14.0%), CaO (3.6%), Fe_2O_3 (2.3%) and up to 1.5% of MgO, Na_2O and K_2O. Particle size <50 µm was predominant.

– DE S-1 contained according to the producer's specification: SiO_2 (78.8%), Al_2O_3 (9.4%), K_2O (0.8%), Na_2O (0.08%), MgO (0.1%), CaO (0.6%), Fe_2O_3 (1.1%) and TiO_2 (0.2%).Particle size <50 µm was predominant.

– DE S-2 contained according to the producer's specification: SiO_2 (63.1%), Al_2O_3 (10.3%), K_2O (0.9%), Na_2O (0.08%), MgO (0.3%), CaO (1.0%), Fe_2O_3 (1.7%) and TiO_2 (0.3%). Particle size <50 µm was predominant.

– Protect-It® is a mixture of 90% marine DE, Celite 209, and 10% silica aerogel. It is a buff colored dust with more than 87% of amorphous silicon dioxide. The tested formulation contained about 3% of Al_2O_3, about 1% Fe_2O_3 and below 1% CaO, MgO, TiO_3, and P_2O_3. Moisture content of the dust ranged from 3 to 6%. The mean particle size was between 5 and 6 µm, though more than 80% of the particles had a diameter below 12 µm. The specific gravity was 2000 kg/m^3 and pH in 10% slurry (with doubled distilled water) was between 5.5 and 5.7 (5).

Inert dust deposition

The inert dust NZ was applied at a dose of 1.0 g/kg, dusts DE S-1 and DE S-2 at the dose 0.75 g/kg, and Protect-It® at 0.2 g/kg. Each inert dust was mixed with 500 g of wheat in a 1000-mL glass bottle manually for 1 minute and on a rotating mixer for 10 min. After that, the wheat sample was placed into a plastic bag and kept at ambient temperature until further examination. Untreated wheat was used as the control sample.

Trading quality

Kernel weight was determined on a tester Perten SK CS 4100 (Kernel Hardness Tester, Perten Instruments, Reno, Nevada, USA). Test weight was determined on a Schopper scale.

Samples were analyzed according to the standard ICC (International Association for Cereal Science and Technology) methods for: endosperm vitreousness (12) moisture content of cereals (13) and crude protein content (14).

Milling Procedure

Before milling, wheat grains were cleaned on a laboratory cleaner “Carter Dockage Tester”. Wheat was tempered by adjusting to 15% moisture content. The tempered wheat samples were ground in a Bühler MLU-202 mill according to national official method (15).

Preparation of breads

Farinograph procedure was used to study the rheological properties of dough (16). Experimental bake tests were performed in accordance with straight dough procedure, as described in detail in Kaluđerski and Filipović (16). Breads were made from flour (100%), water (according to water absorption by farinograph), salt (2.0% flour basis) and yeast (2.5% flour basis).

Instrumental Textural Analysis

Bread instrumental textural attributes were measured on a TA.XT2 Texture Analyzer (Stable Micro Systems, Surrey, UK), using a 36 mm flat-end compression disc (probe P/36R). Bread firmness and resilience were measured according to a modified 74-10A AACC method (17). The firmness value is the peak force of the first compression of the product. Resilience is measured as the area during the withdrawal of the first compression, divided by the area of the first compression. It describes how well a product regains its original position. It could be referred as instant springiness. Instrument settings were as follows - mode: measure force in compression, pre-test speed: 1.0 mm sec^{-1}, test-speed: 1.7 mm sec^{-1}, post-test speed: 1.7 mm sec^{-1}, strain: 40%, trigger force: 5g. The samples were tested 24 h after baking. Total crumb thickness was 25 mm. The first three slices from either end were excluded from testing. Triplicate measurements for each of the two loaves were made.

Statistical Analysis

All determinations were performed in triplicate unless otherwise stated. The statistical analyses were conducted using one-way ANOVA procedures. Differences in samples due to wheat treated with natural zeolite and diatomaceous earth were tested for statistical significance at p=0.05 level. Tukey’s Honestly Significant Difference was used to differentiate between the mean values. Analyses were done with Statistica 9.1 statistical software (StatSoft Inc., Tulsa, Oklahoma).

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RESULTS AND DISCUSSION

Low-vitreous wheat (LVG) had lower degree of vitreousness (17.0%) as well as lower protein content and sedimentation value in comparison with high-vitreous wheat. This is in accordance with data reported by Pomeranz (18).

Treatments with NZ and DE did not cause significant changes in the moisture and protein content either in the samples of lowor high vitreous wheat. The only significant change was related to the test weight parameter. This is consistent with the findings of Korunić et al. (5, 10). It seems that the addition of DE to grains creates greater friction between kernels, which affects their test weight and flow properties. The test weight of HVG was greater than that of LVG wheat due to different grain vitreousness degree (12) and this parameter ranged from 79.3 kg/hl in HVG to 71.2 kg/hl in LVG (Table 1).

Table 1. Evaluation of the effects of NZ and DE on physical and chemical parameters of LVG and HVG wheat

Wheat grain	Treatment	Moisture content (%)	Test weight (kg/hl)	Vitreouness (%)	Protein content (%/d.m.)
Low-vitreous wheat	Control	12.8 ± 0.07 a	75.45 ± 0.61 a	17.0 ± 2.52 a	11.6 ± 0.05 a
	DE S-1	12.9 ± 0.08 a	71.25 ± 0.58 b	16.7 ± 3.54 a	11.6 ± 0.04 a
	DE S-2	12.8 ± 0.08 a	71.3 ± 0.42 b	17.0 ± 2.72 a	11.5 ± 0.05 a
	Protect-It®	12.8 ± 0.07 a	71.65 ± 0.55 b	18.7 ± 3.14 a	11.7 ± 0.06 a
	NZ	12.8 ± 0.08 a	71.6 ± 0.48 b	18.0 ± 2.32 a	11.7 ± 0.04 a
High-vitreous wheat	Control	12.2 ± 0.06A	79.3 ± 0.68 A	81.8 ± 2.29 A	13.7± 0.05 A
	DE S-1	12.3 ± 0,06 A	77.65± 0.42 B	79.0 ± 2.45A	13.8 ± 0.07 A
	DE S-2	12.2 ± 0.07 A	77.75± 0.48 B	79.3 ± 2.62 A	13.8 ± 0.05 A
	Protect-It®	12.3 ± 0.07 A	77.70 ± 0.54 B	82.5 ± 2.55 A	13.8 ± 0.06 A
	NZ	12.3 ± 0.07 A	78.60 ± 0.66 AB	82.0 ± 2.78 A	13.7 ± 0.05 A

Mean values in the same column followed by different letters of the same case are significantly different ($P < 0.05$).

Test weight of low-vitreous wheat ranged from 75.45 kg/hl (control) to 71.25 kg/hl (DE S-1), which is a highly significant variation. Within the group of treated low-vitreous wheat no significant differences in the test weights were observed. The percentages of test weight reductions in the treated LVG wheat samples compared to the control were uniform and ranged from 5% (Protect-IT®) to 5.6% (DE S-1) (Table 1).

Similar observations were made in the case of high-vitreous wheat. The only significant difference between the treated samples and control was in the test weight. However, the percentages of reduction were lower than those in LVG wheat and ranged from 2.1% (NZ) to 2.7% (DE S-1) (Table 1).

Water absorption of flour depends on the content of proteins and gluten quality (19), which explains the difference in the water absorption features between LVG and HVG wheat (Table 2). Farinographic measurements showed that the incorporation of NZ and Protect-It in wheat significantly changed one single parameter - water absorption (P<0.05). In the study of Korunić et al. (10), it was found that water absorption of the sample treated with DE was increased, but the variation was neither correlated to the dose nor was found significant. Although Desmarchelier and Dines (11) reported that only 2%

of diatomaceous earth remains in the flour after wheat treatment, significant increase in water absorption found in this study for both soft and hard wheat, over all treatments, could be attributed to the presence of NZ and DE in the samples. This could be supported by the fact that NZ and DE are known as crystalline and amorphous substances with high moisture absorption ability (6) which presumably increased the water absorption of the flour. However, this minimal amount that remained in the samples did not significantly affect other farinograph parameters (Table 2).

Table 2. Evaluation of the effects of NZ and DE on farinograph parameters of LVG and HVG wheat

Wheat grain	Treatment	Farinograph parameters		
		Water absorption value (%)	**15-minute drop (BU)**	**Farinograph Quality Number**
Low-vitreous wheat	Control	52.4 a	75 a	53.3a
	DE S-1	53.3 b	80 a	51.4a
	DE S-2	53.3 b	78 a	51.2a
	Protect-It®	53.2 b	79 a	49.4a
	NZ	53.2 b	80 a	51.6a
High-vitreous wheat	Control	59.7A	65 A	65.9A
	DE S-1	61.6B	60 A	66.2A
	DE S-2	61.5B	60 A	68,3A
	Protect-It®	59.9A	61A	67.4A
	NZ	61.9B	61 A	68.2A

Mean values in the same column followed by different letters of the same case are significantly different ($P < 0.05$).

Water absorption is positively correlated with dough and bread yield (19), which was confirmed by the results obtained in this study: bread yields of the control samples in both wheat groups were significantly lower than those obtained for wheat treated with NZ and DE (Table 3). Considering the baking performance of the tested flours, there were no significant differences in the specific volume of breads or in the crumb texture (firmness and resilience) between the treated samples and the corresponding controls.

Table 3. Evaluation of the effects of NZ and DE on baking performance of LVG and HVG wheat

Wheat grain	Treatment	Loaf weight (g)	Bread yield (g)	Loaf specific volume (mL/g)	TA firmness (g)	TA resilience (%)
Low-vitreous wheat	Control	155.5a	126.5a	4.13a	696.81a	36.65a
	DE S-1	157.2b	126.8b	4.10a	740.89a	35.77a
	DE S-2	157.8b	129.4b	4.00a	776.06a	34.15a
	Protect-It®	157.7b	128.8b	4.08a	753.55a	34.73a
	NZ	157.7b	128.9b	4.18a	771.44a	34.80a
High-vitreous wheat	Control	163.6A	134.9A	3.28A	1502.67A	36.37A
	DE S-1	166.1B	136.4B	3.36A	1456.10A	37.44A
	DE S-2	166.0B	136.3B	3.39A	1422.62A	37.69A
	Protect-It®	164.0AB	134.1A	3.36A	1442.06A	38.32A
	NZ	166.4B	135.6B	3.38A	1496.39A	36.93A

Mean values in the same column followed by different letters of the same case are significantly different ($P < 0.05$).

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Similar findings related to bread volume were reported by Korunić et al. (10), however, published data on other bread quality attributes such as crumb texture are deficient.

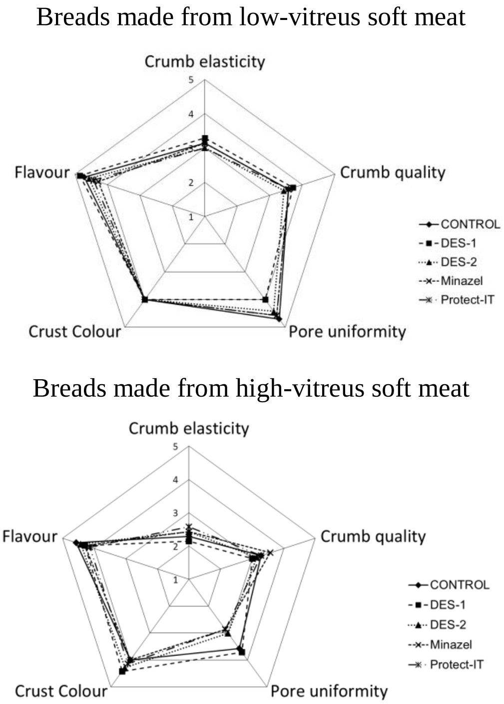

Figure 1. Radar diagrams of the sensory properties of different breads

As seen in Figure 1, there were no differences in the sensory properties of breads as compared to their corresponding controls.

CONCLUSIONS

The results of this experiment confirmed that wheat grains can be treated against insect pests during storage with inert dusts approved in organically cultivated crops such as natural zeolite (NZ) and diatomaceous earth (DE) without having adverse effect on the quality of the final product bread.

However, treatments with NZ and DE significantly decreased the test weight of wheat, which is a major disadvantage of the treatments as it led to significant reduction of the trading quality, but this circumstance can be counterbalanced by a higher organic market price. The percentage of test weight reduction was greater in low-vitreous wheat than in hard wheat.

Treatments with NZ and DE significantly increased the moisture absorption, dough and bread yield. However, bread properties such as specific volume, crumb hardness and resilience, as well as sensory attributes were not significantly affected by the treatments.

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ПРОМЕТНИ КВАЛИТЕТ И ПЕЦИВНА СВОЈСТВА ПШЕНИЦЕ ТРЕТИРАНЕ ПРИРОДНИМ ЗЕОЛИТОМ И ДИЈАТОМЕЈСКОМ ЗЕМЉОМ

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Циљ овог рада је био да се испита утицај природног зеолита и дијатомејске земље као инертних прашива за сузбијање складишних инсеката у органски сертификованој производњи, на прометну вредност пшенице и особине финалног производа, тј. хлеба. Третмани су значајно утицали на пад прометне вредности пшенице, што се највише одразило на пад хектолитарске масе пшенице. Овај ефекат је био много израженији код брашнаве пшенице него код стаклаве. Испитивањем реолошких својстава брашна од третиране пшенице утврђено је да су зеолит и дијатомејска земља у примењеним концентрацијама утицали на значајни пораст моћи упијања воде што је утицало и на пораст приноса хлеба. Међутим, ове промене нису биле таквог интензитета да изазову значајне разлике у квалитету финалног производа хлеба, што је и показано инструменталним методама испитивања чврстоће и еластичности средине хлеба као и његовом сензорском оценом.

Кључне речи: инертна прашива, пшеница, брашно, хлеб

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