Quality Parameter Changes in Wheat Varieties During Storage at Four Different Storage Conditions

Ivica STRELEC [1] (✉)
Daliborka KOCEVA KOMLENIĆ [1]
Vlatka JURKOVIĆ [1]
Zorica JURKOVIĆ [2]
Žaneta UGARČIĆ-HARDI [1]

Summary

Changes in seed quality parameter of three wheat varieties during one year storage at four different storage conditions, were studied. Applied storage conditions adversely affected quality changes in wheat seeds during one year storage. The most pronounced changes were observed for seeds kept at 40°C, RH = 45%, followed by seeds stored at 25°C, RH = 45%, while seeds kept at 4°C, RH = 45% or at warehouse conditions mostly showed minimal or statistically insignificant changes. Elevated temperature of seed storage caused a significant decrease of starch content, hectolitre weight, and wet gluten content, accompanied with increase in flour acidity, and fluctuating in Zeleny sedimentation value. The intensities of observed changes showed strong dependence on wheat variety.

Key words

quality parameters, storage conditions, variety, wheat

[1] University of Osijek, Faculty of Food Technology, Franje Kuhača 20, 31000 Osijek, Croatia
✉ e-mail: Ivica.Strelec@ptfos.hr
[2] Croatian Food Agency, Ivana Gundulića 36b, 31000 Osijek, Croatia

Received: July 28, 2010 | Accepted: August 25, 2010

Introduction

Deteriorative processes within seeds, free radical generation/oxidation and non-enzymatic glycosylation, occurring during seed storage, lead to molecular damage, fragmentation and/or cross-linking of constitutive proteins, lipids and sugars, subsequently affecting chemical and quality parameters of wheat seeds and wheat milling products (McDonald, 1999). The extent of molecular impairments, as well as chemical composition and quality parameter changes within seeds, is highly dependent on length of storage, storage temperature, relative humidity and resulting seed moisture content. Elevated storage temperatures, high relative humidities, as well as elevated seed moisture content, increases the degree of changes, increasing with the duration of storage.

Strelec et al. (2008) observed molecular alterations due to accumulation of Amadori and Maillard products in wheat seeds during storage, especially at elevated storage temperatures. Increase or decrease of total soluble sugars, decrease of soluble amylose, phytic acid and carotenoids and increase of ash content, was reported for wheat stored at various storage conditions, while observed functional and quality characteristic changes included loss of viscoelastic properties of gluten, slight increase or significant decrease of wet or dry gluten content, decrease of Zeleny sedimentation, hectolitre weight and alveographic W values (Karaoglu et al., 2010; Mezei et al., 2007; Calucci et al., 2004; Galleschi et al., 2002; Rehman and Shah, 1999; Srivastava and Rao, 1994). However, most of the above-mentioned quality changes in wheat were reported only for one variety at various storage conditions, so data on varietal differences are still lacking.

The present study investigated changes of protein and starch content, as well as other quality parameters in three wheat varieties stored for one year at four different storage conditions.

Materials and methods

Seeds of wheat varieties 'Žitarka' and 'Srpanjka' harvested in 2005 were generously supplied by Agricultural Institute in Osijek, and Divana variety by College of Agriculture, Križevci. Seeds of examined varieties, containing 13.7% moisture, were divided in batches (four ageing conditions x 12 months; 1 kg of seed per batch), packed in paper bags, bags sealed, and storage of wheat seeds performed at four different conditions of environmental temperature and relative humidity (% RH): (1) 40°C, RH = 45%; (2) 25°C, RH = 45%; (3) 4°C, RH = 45%; (4) the range of warehouse conditions chosen on the basis of local environmental conditions, varying from 2 to 25°C and RH = 40-74%. Storage was carried out in thermostatic incubator Heraeus (Heraeus, Germany) (1), in a storage box placed in conditioned warehouse (2), in a refrigerator (3), and on a shelf positioned 20 cm from the floor of an unconditioned warehouse (4). Samples were taken monthly over a period of 12 months.

Total protein content, starch content, hectolitre weight, wet gluten content, and Zeleny sedimentation were measured in whole grains by Near Infrared Transmission (NIT) using Foss Tecator 1241 Grain Analyzer (Foss Tecator AB, Sweden). Every month four bags of seeds of each variety differing in applied storage conditions were examined by NIT. After measurement, seeds were used for determination of flour titratable acidity.

Flour titratable acidity was measured by the official methods of the Republic of Croatia and expressed as mL of 1 M sodium hydroxide (NaOH) required to neutralise acids in a 100 g of sample using phenophtalein as indicator (Ministry of Agriculture, Forestry and Water Management of the Republic of Croatia, 2005). Flours were prepared from aged seeds using laboratory mill Brabender (Brabender, Germany). All determinations were carried out in a triplicate.

Differences in temporal changes of examined parameters for each variety at applied storage conditions were analysed for significance using analysis of variance (ANOVA). When ANOVA indicated significant differences in means, post hoc analysis was performed by Duncan's multiple-range test. For varietal differences in the extent of observed changes, Friedman ANOVA and Kendall coefficient of concordance were used. All statistical analyses were performed by statistical software Statistica (Stat Soft Inc., USA) at a level of significance of $p < 0.01$.

Results and discussion

During one year storage of wheat seeds under different storage conditions there were no significant changes in total protein content (Table 1). On average, Divana variety contained 14.25%, 'Žitarka' 13.36%, and 'Srpanjka' 10.52% of total protein. These results are consistent with findings of Mezei et al. (2007) who reported absence of changes in total protein content of four wheat varieties during 129 days of storage at 10-13°C. However, constant level of total protein in wheat seeds during storage at different storage conditions does not imply lack of changes in protein characteristics, such as water or buffer solubility, rearrangement of disulfide bridges, lysine bioavailability, and protein digestibility. Decrease of protein solubility in buffer or water

Table 1. Total seed protein content of three wheat varieties during storage at different conditions. Results are expressed as mean values ± standard deviations, while values in brackets present coefficient of variation (CV%) for each applied storage condition

Storage conditions	Protein content in dry matter (%)		
	Divana	Žitarka	Srpanjka
40°C, RH = 45%	14.24 ± 0.24 (1.69)	13.31 ± 0.18 (1.35)	10.56 ± 0.18 (1.70)
25°C, RH = 45%	14.23 ± 0.16 (1.12)	13.38 ± 0.16 (1.20)	10.49 ± 0.19 (1.81)
4°C, RH = 45%	14.27 ± 0.17 (1.19)	13.34 ± 0.14 (1.05)	10.48 ± 0.14 (1.34)
2-25°C, RH = 40-74%	14.25 ± 0.13 (0.91)	13.39 ± 0.20 (1.49)	10.54 ± 0.15 (1.42)
Average protein content	14.25 ± 0.18	13.36 ± 0.17	10.52 ± 0.17
Average CV%	1.23	1.27	1.57

was reported for stored wheat and rice seeds (Calluci et al., 2004; Galleschi et al., 2002; Zhou et al., 2002), and rearrangement of disulfide bridges for rice (Zhou et al., 2002). Reduction in total available lysine and decrease of protein digestibility was observed for wheat seeds stored at three different temperatures (Rehman and Shah, 1999). Loss of protein solubility, as well as reduction in lysine bioavailability and protein digestibility during seed storage are attributable to molecular alterations and cross-linking of proteins, sugar and lipids by non-enzymatic glycosylation reactions. Increase of Amadori and Maillard products content, due to non-enzymatic glycosylation within seeds during storage was detected in wheat, soybean and mung been seeds (Strelec et al., 2008; Murthy et al., 2003; Murthy et al., 2002, Murthy and Sun, 2000; Sun and Leopold, 1995; Wettlaufer and Leopold, 1991). All these "hidden" changes within wheat seeds during storage, non-distinguishable by determination of total protein content, could affect the quality parameters.

Storage of wheat seeds at elevated temperatures (40°C and 25°C, respectively) resulted in variety-dependent decrease of starch content (Figure 1). On the other hand, there were no significant changes in starch content for wheat seeds of either varieties stored at 4°C, RH = 45%, or at fluctuating warehouse conditions (2-25°C, RH = 40-74%). Reduction of seed starch content was observed after 30 days of storage at 40°C, RH = 45%, for 'Žitarka', and after 30 day of storage at 25°C, RH = 45% for 'Srpanjka'. Subsequently, starch content remained at similar level until the end of storage (Figure 1). The highest decrease in starch content was observed for Srpanjka variety, which at 360 days of storage at 40°C, RH = 45% showed 5% reduction, and at 25°C, RH = 45%, 2% reduction in starch content (Figure 1). Žitarka variety at 360 days of storage showed 3% reduction in starch content at 40°C, RH = 45%, while there was no significant changes at 25°C, RH = 45%. Contrary to 'Žitarka' and 'Srpanjka', there were no significant changes ($p < 0.01$) in starch content of Divana variety at elevated temperatures. Obtained results indicate variety dependent reduction in starch content at elevated storage temperatures. Variety dependent decrease of starch content, followed by an increase of reducing sugar level was reported for pigeonpea seeds during accelerated ageing (Rao and Kalpana, 1994). Degradation of starch due to significant increase in number of small starch granule was suggested during accelerated ageing of French bean seeds (Begnami and Cortelazzo, 1996). Decrease of starch content during accelerated ageing of seeds is expected since high moisture content of seeds (> 14%) and elevated temperatures (45-50°C) favour endogenous α- and β-amylase starch degrading activity, as well as free radical oxidation/reduction reactions. However, if seed moisture content is lower (< 14%), as was in this work , α- and β-amylase starch degrading activity should be inhibited (McDonald, 1999; Bewley and Black, 1985), which imply free radical oxidation/reduction reactions as probable reason for observed starch content reduction in wheat seeds at elevated temperatures. Free radicals increase in wheat seeds was reported during accelerated and natural ageing (Calluci et al., 2004; Galleschi et al., 2002; Pinzino et al., 1999). The findings of this work suggests that starch content reduction during wheat seeds storage could be dependent on variety, which is probably related to differences between varieties in level of endogenous antioxidants such as carotenoids, tocoferols, reduced glutathione, available cysteine side chains, ascorbic acid, polyphenols, flavonoids, and free amino acids that act as free radical scavengers preventing oxidation reactions and subsequent starch content decrease.

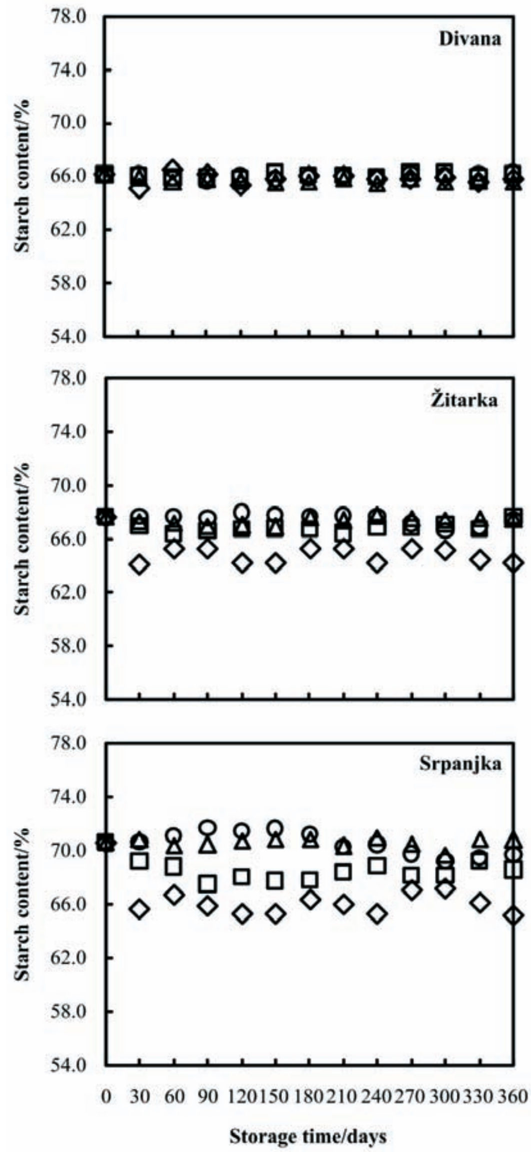

Figure 1. Seed starch content of three wheat varieties during storage at different conditions. Storage conditions: 40°C, RH = 45% (◇); 25°C, RH = 45% (□); 4°C, RH = 45% (△); 2-25°C, RH = 40-74% (○)

Hectolitre weight is grain quality indicator used as an approximate measure of the expected flour yield. The better flour yield and quality would be achieved if wheat seeds have the greater hectolitre weight (Karaoglu et al., 2010). During one year storage there was a slight decrease in hectolitre weight of 'Žitarka' and 'Srpanjka' varieties at all applied storage conditions. On the other hand, no significant changes ($p < 0.01$) in hectolitre weight could be observed for seeds of Divana variety (Figure 2). The highest reduction in hectolitre weight was ob-

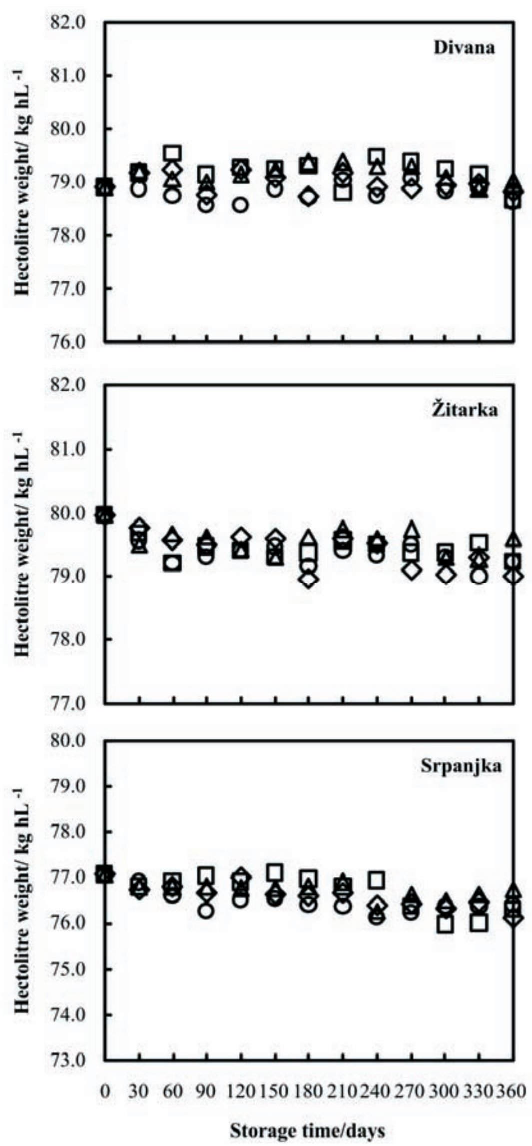

Figure 2. Hectolitre weight of three wheat varieties during storage at different conditions. Storage conditions: 40°C, RH = 45% (◇); 25°C, RH = 45% (□); 4°C, RH = 45% (△); 2-25°C, RH = 40-74% (○)

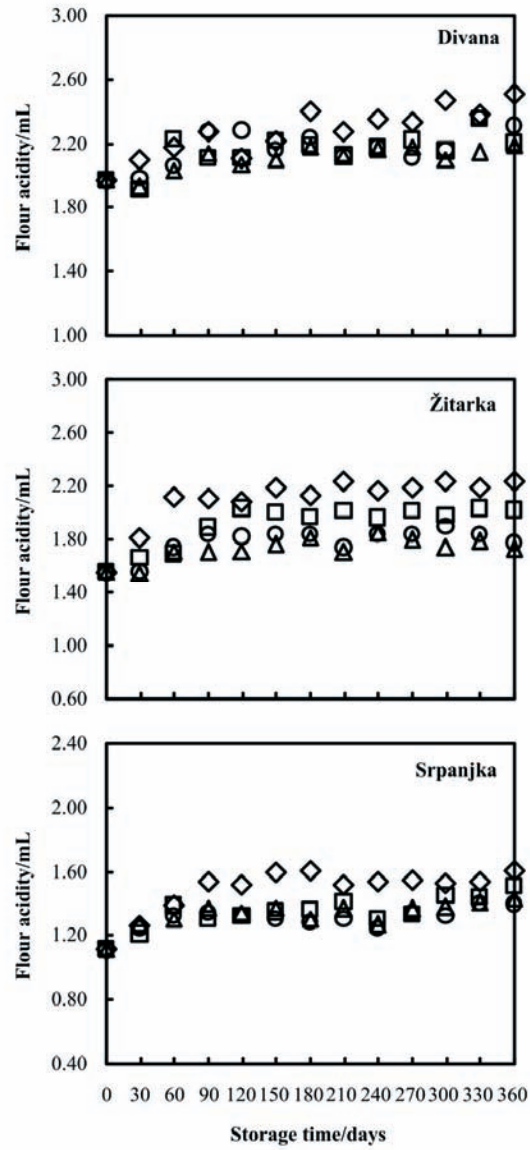

Figure 3. Titratable acidity of flours prepared monthly from seeds of three wheat varieties during storage at different conditions. Storage conditions: 40°C, RH = 45% (◇); 25°C, RH = 45% (□); 4°C, RH = 45% (△); 2-25°C, RH = 40-74% (○)

served for 'Žitarka' (1.0 kg/hL) and 'Srpanjka' (0.9 kg/hL) wheat seeds stored at 40°C, RH = 45%, while the lowest reduction of 0.4 and 0.3 kg/hL, respectively, at 4°C, RH = 45% after one year storage was observed for the same varieties. Hectolitre weight of 'Žitarka' and 'Srpanjka' wheat seeds stored at 25°C, RH = 45% and fluctuating warehouse conditions decreased for 0.7 kg/hL after one year of storage (Figure 2). Similar results were found by Karaoglu et al. (2010) who stored wheat seeds for nine months at 10, 20 and 30°C. Obtained data of this work indicate that storage of wheat could be accompanied with the slight reduction in hectolitre weight, which is dependent on storage conditions applied. However, it seems that some varieties, especially those of superior quality, such as 'Divana', which is improver wheat, does not change hectolitre weight during storage.

Titratable acidity of wheat flours (flour acidity) prepared from seeds of wheat varieties stored at different storage conditions increased to various extents during storage, dependent on storage conditions applied as follows 40°C, RH = 45% > 25°C, RH = 45% > 4°C, RH = 45% ≥ 2-25°C, RH = 40-74% (Figure 3). Significant increase in flour acidity ($p < 0.01$) appeared only after 30 days of wheat seed storage at all storage conditions, and from this point on, continued to rise until the end of storage (Figure 3). In general, the increase of storage temperature resulted in higher spike of flour acidity. However, there were no significant differences ($p < 0.01$) in flour acidity between varieties at the same storage condition. Obtained results are consistent with previous studies of flour acidity during storage of wheat and wheat products (Karaoglu et al., 2010; Hruškova and Machova, 2002; Rehman

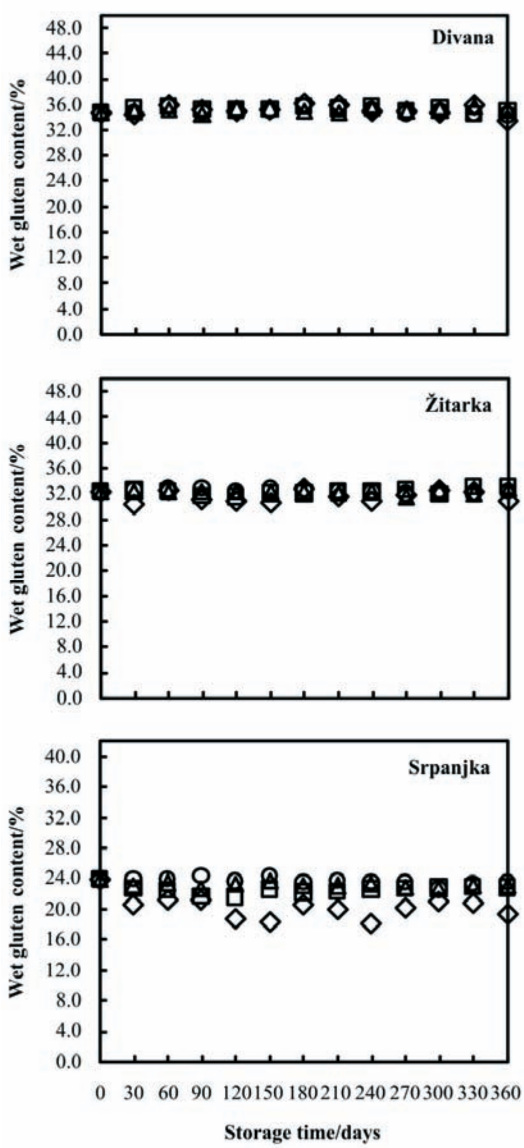

Figure 4. Wet gluten content of three wheat varieties during storage at different conditions. Storage conditions: 40°C, RH = 45% (◇); 25°C, RH = 45% (□); 4°C, RH = 45% (△); 2-25°C, RH = 40-74% (○)

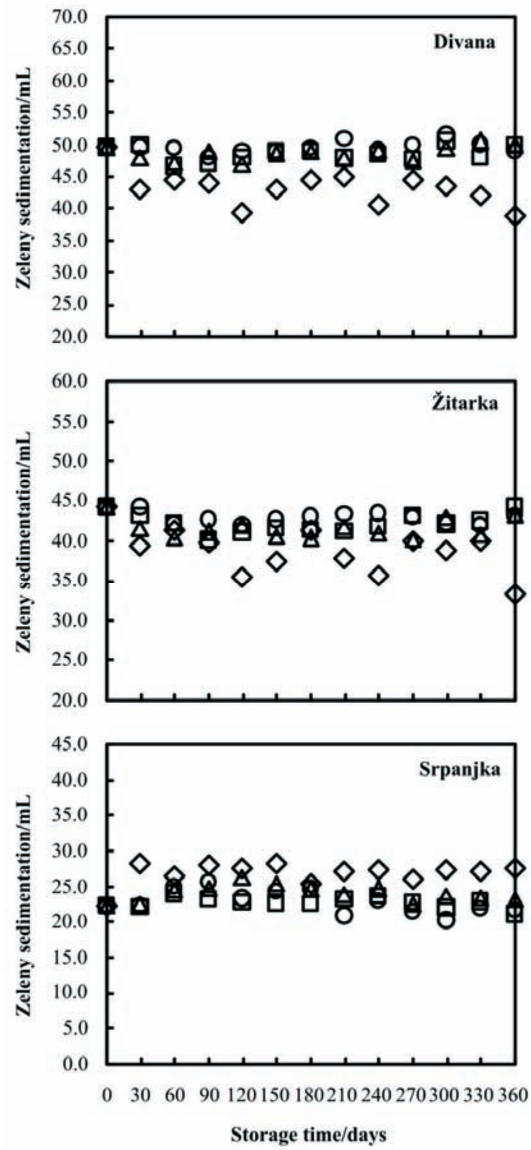

Figure 5. Zeleny sedimentation of three wheat varieties during storage at different conditions. Storage conditions: 40 °C, RH = 45 % (◇); 25 °C, RH = 45 % (□); 4 °C, RH = 45 % (△); 2-25 °C, RH = 40-74 % (○)

and Shah, 1999). The increase of flour acidity could be attributed to the increased concentration of free fatty acids and phosphates resulting from increased seed deterioration due to molecular alterations and free radical induced oxidation, as well as to the presence of acid by-products of advanced Maillard reactions (Karaoglu et al., 2010; Rehman and Shah, 1999).

Disulfide bridge rearrangement of seed storage proteins, gliadins and glutenins, respectively, could affect the changes in wet gluten content and Zeleny sedimentation during seed storage. Wet gluten is highly swollen colloidal gel containing 60-70% of water, and 30-40% of dry matter being made up of gluten proteins, gliadins and glutenins (75-90%), respectively (Karaoglu et al., 2010). This quality parameter gives quantitative measure of the gluten forming proteins in flour that are mainly responsible for its dough mixing and baking properties. During one year of storage significant decrease in wet gluten content ($p < 0.01$) was observed only for Srpanjka variety stored at 40 , 25 and 4°C and RH = 45%, respectively (Figure 4). After 30 days storage at 40°C, RH = 45% wet gluten content in seeds of Srpanjka variety decreased 16%, and 5% in seeds stored at 25°C and 4°C and RH = 45%. Subsequently, wet gluten content remained at the same level in seeds stored at lower temperatures (25 and 4 °C, respectively), and slightly decreased in seeds stored at 40°C, RH = 45% until the end of storage period. Observed data indicate varietal dependence of wet gluten content changes during storage of wheat seeds, as well as temperature dependence of wet gluten content in the case of Srpanjka variety. Contradictory literature data on changes in wet gluten content during storage of wheat seeds or wheat flours can be found. Srivastava and Rao (1994) reported complete reduction in wet gluten content during five months storage of wheat seeds at 50°C. Mezei et al. (2007) observed about 10% increase of wet gluten content after 129 days of wheat seeds storage at 10-13°C. Karaoglu et al. (2010) noted slight tendency in wet gluten decrease during nine months of wheat seed storage, being greater at higher storage temperatures, while Hruškova and Machova (2002) found minimal changes in wet gluten levels during three months of wheat flour storage at temperatures varying between 2 and 20°C.

Lack of changes in wet gluten content during storage of wheat varieties 'Divana' and 'Žitarka', and decrease in case of Srpanjka variety should be reflected on changes in Zeleny sedimentation, since Zeleny sedimentation volume is dependent on gluten quantity. However, different changes in sedimentation value could be observed during storage of wheat seeds (Figure 5). 'Divana' and 'Žitarka' varieties showed significant decrease in Zeleny sedimentation volume (22 and 25%, respectively), while Srpanjka variety significant increase (23%) during one year storage at 40°C, RH = 45% ($p < 0.01$). At other applied storage conditions there were no statistically significant changes in Zeleny sedimentation ($p < 0.01$) for none of examined varieties (Figure 5). Obtained data indicate varietal dependence of Zeleny sedimentation value during storage of wheat seeds at 40°C, RH = 45%. Observed increase in Zeleny sedimentation is contradictory to findings of Karaoglu et al. (2010) who reported decrease of Zeleny sedimentation and its dependence on wet gluten content during wheat storage. However, Zeleny sedimentation is influenced not only by gluten quantity (wet gluten content), but also by gluten quality (Karaoglu et al., 2010). Increase of Zeleny sedimentation indicates increased gluten strength and reduced gluten extensibility, opposite to Zeleny sedimentation decrease (Pinzino et al., 1999; Lasztity, 1996). Additionally, gluten strength and extensibility define gluten quality, another determinant of Zeleny sedimentation (Karaoglu et al. 2010; Lasztity, 1996). Gluten strength and extensibility are strongly influenced by disulfide bridge rearrangement between cysteine residues of gliadins and glutenins. Decrease of extensibility (increase of gluten strength) could be attributed to the lower level of high molecular polymers of gliadins and glutenins caused by disulfide bridge rearrangement, and *vice versa* (Pinzino et al., 1999; Lasztity, 1996). However, these changes do not necessarily affect wet gluten content. This might be the main reason for observed differences in changes of wet gluten content and Zeleny sedimentation during storage of wheat varieties examined in this work. It should be pointed out that these discrepancies might results from the fact that NIT measurement of Zeleny sedimentation value is not perfectly correlated with the standard method of determination.

Conclusion

Storage of wheat seeds at different storage conditions is accompanied with quality changes. Decrease of starch content, hectolitre weight, and wet gluten content, increase in flour acidity, and fluctuating Zeleny sedimentation value were observed during one year storage of wheat seeds. Intensity of these changes was adversely affected by applied storage condition, and was dependent on variety. The highest changes in quality parameters were observed for seeds kept at 40°C, RH = 45%, followed by seeds stored at 25°C, RH = 45%. Wheat seeds kept at 4°C, RH = 45% or at warehouse conditions in most cases showed minimal or insignificant changes. Total protein content of examined wheat varieties remained unchanged during storage at various storage conditions, while starch content decreased from 2 to 5% for 'Srpanjka' and 'Žitarka' varieties stored at elevated temperatures. Slight decrease of hectolitre weight for 'Žitarka' and 'Srpanjka' varieties occurred during one year storage at all applied storage conditions, being the greater at elevated storage temperatures. Increased temperatures of storage caused the higher increase of flour titratable acidity of all examined varieties. Decrease of wet gluten content occurred only in seeds of Srpanjka variety stored at elevated storage temperature, at which Zeleny sedimentation value increased for 'Srpanjka', and decreased for 'Žitarka' and 'Divana' varieties. Therefore, it can be concluded that elevated temperatures during wheat seed storage can cause significant changes in quality parameters, what can negatively affect the quality of final products. Intervarietal differences in starch content, hectolitre weight, wet gluten content and Zeleny sedimentation value indicate that quality parameter changes during storage could be highly dependent on cereal variety probably due to varietal differences in total protein content, as well as level of endogenous antioxidants.

References

Begnami C. N., Cortelazzo A. L. (1996) Cellular alterations during accelerated ageing of French bean seeds. Seed Sci Technol 24: 295-303

Bewley J. D., Black M. (1985) Seeds: Physiology of development and germination. Plenum Press, New York

Calucci L., Capocchi A., Galleschi L., Ghiringhelli S., Pinzino C., Saviozzi F., Zandomeneghi M. (2004) Antioxidants, free radicals, storage proteins, puroindolines and proteolytic activities in bread wheat (Triticum aestivum) seeds during accelerated aging. J Agric Food Chem 52: 4274-4281

Galleschi L., Capocchi A., Ghiringhelli S., Saviozzi F. (2002) Antioxidants, free radicals, storage proteins, and proteolytic activities in wheat (*Triticum durum*) seeds during accelerated aging. J Agric Food Chem 50: 5450-5457

Hruškova M., Machova D. (2002) Changes of wheat flour properties during short term storage. Czech J Food Sci 20: 125-130

Karaoglu M. M., Aydeniz M., Kotancilar H. G., Gercelaslan K. E. (2010) A comparison of the functional characteristics of wheat stored as grain with wheat stored in spike form. Int J Food Sci Tech 45: 38-47

Lasztity R. (1996) The chemistry of cereal proteins. CRC Press, Inc., Boca Raton

McDonald M. B. (1999) Seed deterioration: physiology, repair and assessment. Seed Sci Technol 27: 177-237

Mezei Z., Sipos P., Gyori Z. (2007) Variations in quality parameters of forage and medium quality winter wheat varieties in storage. Agris Conspec Sci 72: 221-225

Ministry of Agriculture, Forestry and Water Management of the Republic of Croatia (2005): Pravilnik o žitaricama, mlinskim i pekarskim proizvodima, tjestenini, tijestu i proizvodima od tijesta. NN 78/05

Murthy U. M. N., Kumar P. P., Sun W. Q. (2003) Mechanisms of seed ageing under different storage conditions for *Vigna radiata* (L.) Wilczek: lipid peroxidation, sugar hydrolysis, Maillard reactions and their relationship to glass state transition. J Exp Bot 54: 1057-1067

Murthy U. M. N., Liang Y., Kumar P. P., Sun W. Q. (2002) Non-enzymatic modification by the Maillard reaction reduces the activities of scavenging enzymes in *Vigna radiata*. Physiol Plantarum 115: 213-220

Murthy U. M. N., Sun W. Q. (2000) Protein modification by Amadori and Maillard reactions during seed storage: roles of sugar hydrolysis and lipid peroxidation. J Exp Bot 51: 1221-1228

Pinzino C., Capocchi A., Galleschi L., Saviozzi F., Nanni B., Zandomeneghi M. (1999) Aging, free radicals, and antioxidants in wheat seeds. J Agric Food Chem 47: 1333-1339

Rao K. V. M., Kalpana R. (1994) Carbohydrates and the ageing process in seeds of pigeonpea (*Cajanus cajan* (L.) Millsp.) cultivars. Seed Sci Technol 22: 495-501

Rehman Z. U., Shah W. H. (1999) Biochemical changes in wheat during storage at three temperatures. Plant Food Hum Nutr 54: 109-117

Srivastava A. K., Rao P. H. (1994) Changes in the functional characteristics of wheat during high temperature storage. J Food Sci Tech Mys 31: 36-39

Strelec I., Ugarčić-Hardi Ž., Hlevnjak M. (2008) Accumulation of Amadori and Maillard products in wheat seeds aged under different storage conditions. Croat Chem Acta 81: 131-137

Sun W. Q., Leopold A. C. (1995) The Maillard reaction and oxidative stress during aging of soybean seeds. Physiol Plantarum 94: 94-104

Wettlaufer S. H., Leopold C. A. (1991) Relevance of Amadori and Maillard products to seed deterioration. Plant Physiol 97: 165-169

Zhou Z., Robards K., Helliwell S., Blanchard C. (2002) Ageing of stored rice: Changes in chemical and physical attributes. J Cereal Sci 35:65-78

acs75_15