INVESTIGATION OF PHYSICALLY-CHEMICAL PARAMETERS OF CONVENTIONAL AND ORGANIC HULL-LESS BARLEY HARVESTED IN LATVIA

Solvita Kalnina, **Tatjana Rakcejeva**, **Daiga Kunkulberga**
Latvia University of Agriculture
solvita.kalnina@inbox.lv

Abstract
The main purpose of the research was to investigate the physically-chemical parameters of organic and conventional hull-less barley (*Hordeum vulgare*) harvested in Latvia. In the experiment the following hull-less barley harvested in 2012 from the State Priekuli Plant Breeding Institute (Latvia) was used: 'Irbe', PR4651, PR3808.21 and PR5099. The following quality parameters of grain – protein, starch, the bulk density and β-glucan content – were measured by standard methods – Infratec™ 1241 Grain Analyser (Denmark) corresponding to ISO 12099; thousand-grain weight (TGW) (ISO 520:2010); the falling number (ISO 3093:2009); moisture content (LVS 272:2000) were also determined. In the present experiments no significant differences in protein, moisture, starch, β-glucan content and TGW were detected, however, significant differences in the bulk density of all analyzed hull-less barley samples were established. The lower analyzed parameter value of 780 ± 1 g L^{-1} was obtained for the conventional and organic hull-less barley PR 5099. However, the higher bulk density value of 821 ± 1 g L^{-1} was obtained in the conventional hull-less barley variety 'Irbe'. No significant differences in the bulk density of conventional and organic hull-less barley 'Irbe', PR4651 and PR3808.21 were found. Significant differences in the falling number were detected in the analyzed hull-less barley samples harvested in the conventional and organic farming. The lower falling number value was obtained in the organic hull-less barley line PR 5009 – 81 ± 4 s, the higher in the conventional and organic hull-less barley line PR 3808.21 as 362 ± 5 s and 373 ± 2 s, respectively.
Key words: physically-chemical parameters, hull-less barley, organic and conventional farming.

Introduction

Cereal-based foods have been staples for humans for millennia. Cereal grains contain the macronutrients (protein, fat and carbohydrate) required by humans for growth and sustenance. They also supply important minerals, vitamins and other micronutrients essential for optimal health. However, it is becoming apparent that cereals in general have the potential for health enhancement beyond the simple provision of these nutrients and that their consumption can lower the risk of significant diet-related diseases quite substantially. This is an important attribute given the social and personal impact of these conditions (Topping, 2007).

Barley (*Hordeum vulgare* L.) is the fourth largest cereal crop produced in the world (Damiran and Yu, 2012). Cultivated barley (*Hordeum vulgare*) is the fourth largest cereal grain crop produced worldwide and the most under-utilized cereal grain in terms of human consumption. About 90% of barley grain is used in alcoholic beverage production and as a livestock feed. Barley is an excellent source of complex carbohydrates, which constitute about 80% of barley grain weight (Lia et al., 2001). Barley grains used as food for pearl barley, grits, flour (in small quantities), malt, barley coffee, alcohol and yeast. Although barley has been of little importance in the modern diet, when compared to other cereals, like wheat (*Triticum*), rye (*Secale*) and oats (*Avena sativa*), recent evidence about considerable amounts of nutritionally important β-glucan found in barley has focused a lot of attention on the matter of designing new foods containing barley. β-glucans are recognised as having an important positive health impact, centred on their benefits in case of coronary heart disease, cholesterol lowering and reducing the glycaemic response. Compared to wheat and rye grain, the highest content of natural antioxidants (copherol and tocotrienols) and of vitamin E was established in barley grain. Inclusion of barley flour in plain wheat bread formulation enhances the β-glucan content of bread, which may have a beneficial effect on human health (Škrbić et al., 2009; Lazaridou et al., 2006).

In food industry, hull-less barley is considered as more valuable and more economical compared to hulled barley. Protein content in hull-less barley is from 9 to 20% from total dry matter (Rakcejeva et al., 2007). The hull-less barley flour has a little darker colour, because compared to flour from soft wheat it has a higher ash value, and a higher protein and β-glucan content. Soluble dietary fiber, mainly β-glucan, provides a promoted viscosity. As a result, digestion, cholesterol and fat absorption are decreased. Compared with hulled barley, hull-less barley has the major diferences in the β-glucan content. Barley contains 70 mg 100 g^{-1} arabinoxylan and 25 mg 100 g^{-1} β-glucan, but hulless barly contains 75 mg 100 g^{-1} β-glucan and 20 mg 100 g^{-1} arabinoxylan. It can be expained by the fact that the hull- less barley flakes are not coalescing with a grain threshing and peeling process, reducing the amount of fiber (cellulose and arabinoxylans), while increasing β-glucan content and reducing the required energy consumption (Fastnaught, 2009).

In organic farming systems under temperate climatic conditions, cereals have lower yields compared with similar conventional systems. In organic cereal production, the management practices adopted to control weeds, pests and diseases and the optimization of nutrient availability to the crops to a large extent determine the yields obtained. As the best management practices for organic systems are still being tested for specific crop species and sites, there is a high potential to improve the organic cereal grain yields. This is in contrast with the intensive systems using high amounts of fertilizers and pesticides, where evidences of yield stagnation are now being reported (Doltra and Olesen, 2013).

The main purpose of the research was to investigate physico-chemical parameters of organic and conventional hull-less barley harvested in Latvia.

Materials and Methods

The study was conducted at the Agronomy Research Laboratory of Latvia University of Agriculture and JSC Jelgavas dzirnavas.

In the present experiment the following conventional and organic hull-less barley was harvested from the experimental and certified organic fields of the State Priekuli Plant Breeding Institute (Latvia) in 2012 – ‘Irbe’, PR4651, PR3808.21 and PR5099 – according to LVS 271:2000 standard method. The conventional hull-less barley used was: Podzols sod (Pv), sandy loam (ms), plant available P_2O_5 208 mg kg^{-1}, K_2O 215 mg kg^{-1} soil., pH 5.8 and 2.3% compast, embedded in the basic complex fertilizer NPK 5:20:30 150 kg ha^{-1} and ammonium nitrate 244 kg ha^{-1}. The conventional hull-less barley were sowing on 4 May. In addition on Decis Mega 0.125 l ha^{-1} and herbicide Sekators 0.1 l ha^{-1} and esthete 1.0 l ha^{-1}.

Organic hull-less barley used previous plants pea green manure. The organic hull-less barley used was: Podzols sod (Pv), sandy loam (ms), plant available P_2O_5 160 mg kg^{-1}, K_2O 93 mg kg^{-1} soil, pH 5.7 and 2.3% compost. Sowing took place on 28 May and harvested on 20 August.

- Protein, starch, bulk density and the content of β-glucan in the hull-less barley were measured by “Infratec™ 1241 Grain Analyser” (Denmark) according to ISO 12099.
- Thousand-grain weight (TGW) was measured in grams as the average weight of two different samples of 1000 grains from each line ISO 520:2010.
- The falling number of grains was analyzed using standard Hagberg-Perten method ISO 3093:2009.
- Grain moisture content was analyzed according to LVS 272:2000 standard method.

Data are expressed as mean ± standard deviation; for the mathematical data processing p-value at 0.05 (ANOVA) was calculated.

Results and Discussion

The reported values indicate that relatively small differences exist within and between varieties and that these are amplified by environmental factors (Shewry, 2007). In the present experiments protein content of analyzed grain samples range from the conventional 123 ± 1 g kg^{-1} to organic 141 ± 2 g kg^{-1} hull-less barley (Table 1). The higher protein content was found in organic hull-less barley compared to the conventional one. However, no significant differences in protein content ($p=0.448$) were established between the analyzed hull-less barley samples.

Water migration is a common problem in many food products in the baking industry, such as mixes of food products. Water diffuses from the wet component to the dry cereal-based one (Roca et al., 2007). Therefore, elevated moisture content in cereals could be a negative factor influencing quality parameters and shelf-life mainly, because it demands the harvest grain drying. In the present experiments the moisture content of the analyzed hull-less barley samples does not exceed 150 g kg^{-1} (Table 1). However, it is necessary to indicate, that the legislation of the Republic of Latvia (Requirements of the Cabinet of Ministers, No. 1455 from 15.12.2009) regulate that the maximum moisture content in barley cannot exceed 140 g kg^{-1}. Therefore, to provide the quality for the analyzed hull-less barley additional drying is necessary.

It is necessary to indicate, that barley endosperm is mainly composed of starch, and has many genotypes, waxy, normal and high amylose varieties, similar to other cereals (Tang et al., 2002). The amount of starch in the analyzed hull-less barley ranged from 615 ± 8 g kg^{-1} to 643 ± 11 g kg^{-1} (Table 1); significant differences were not detected ($p=0.119$).

Barley β-glucan is a water-soluble dietary fibre that can form highly viscous aqueous solutions at concentrations as low as 50 g kg^{-1} (Faraj et al., 2006). Research on barley β-glucan has demonstrated its multiple human health benefits. Thus, the industrial demand for this natural cereal based compound is fast growing. Functional food products containing β-glucan are now being commercially introduced to the market. Since starch is one of the major components of foods, understanding the mechanism of interaction of β-glucan with native starch and its hydrolytic products and its implication for rheological properties is highly important in order to achieve a product with a high sensory appeal (Faraj et al., 2006). No significant differences ($p=0.224$) were found in β-glucan content between the analyzed grain samples. However, it is

Table 1

Chemical composition of hull-less barley

Parameter	In conventional farming harvested grain				In organic farming harvested grain			
	Irbe	PR 4651	PR 3808.21	PR 5099	Irbe	PR 4651	PR 3808.21	PR 5099
Protein, g kg^{-1}	125±1	125±2	138±1	123±1	134±3	126±2	141±2	132±1
Moisture, g kg^{-1}	143±8	157±9	150±9	150±7	151±9	152±8	149±5	148±5
Starch, g kg^{-1}	626±12	635±11	615±8	643±11	621±10	641±10	619±9	640±4
b-glucan, g kg^{-1}	48±1	63±1	56±03	65±4	53±1	63±1	54±4	68±2
1000 grain weight, g	43.5±1.2	43.0±1.9	40.6±1.8	43.6±1.4	41.9±1.7	43.3±1.1	41.5±1.4	41.4±1.8

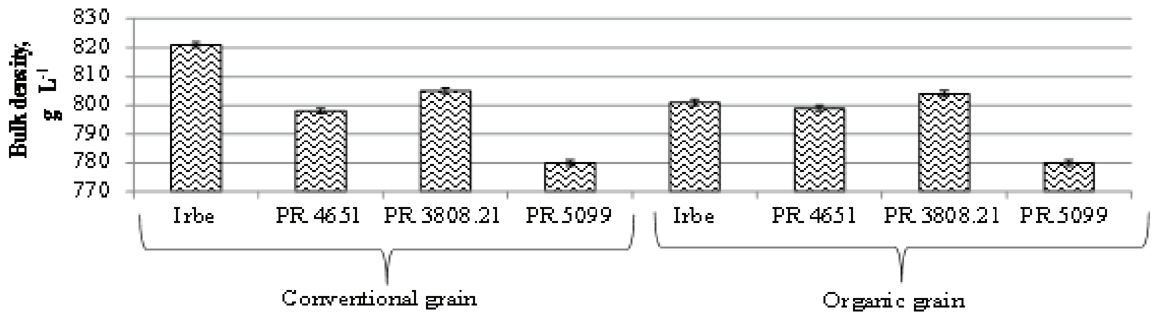

Figure 1. Bulk density of the analyzed hull-less barley.

necessary to indicate, that higher β-glucan content was detected in the organic hull-less barley (Table 1).

Thousand-grain weight (TGW), one of the three main agronomic (or numerical) components of grain yield in involved in the emergence of agriculture and crop domestication. Automatic selection due to planting and harvesting seeds of cereals may have increased seedling vigour through an increase in seed size. The TGW of the analyzed grain samples range from 40.6 ± 1.8 to 43.6 ± 1.4 g (Table 1), which is not substantially different (p=0.558).

Bulk density is a direct measure of the closeness of packing of particles in a defined volume; it depends on the local conditions when the measurement is made, and unlike a density or the skeletal density of a specified material, does not have a unique value (Davies et al., 2005). In the literature (Korunic et al., 1998) it is mentioned that bulk density of barley could be minimum of 750 g L^{-1} (Figure 1).

In the present research significant differences (p=0.009) in bulk density of all analyzed hull-less barley samples were established. Lower analyzed parameter content of 780 ± 1 g L^{-1} (Fig. 1) was obtained for conventional and organic hull-less barley line PR 5099. However, the higher bulk density value of 821 ± 1 g L^{-1} (Fig. 1), was obtained in the conventional hull-less barley variety 'Irbe'. Still, no significant differences (p=0.139) were found in the bulk density of conventional and organic hull-less barley 'Irbe', PR4651 and PR3808.21 (Fig. 1). Differences in the bulk density of the analyzed hull-less barley samples can mainly be explained with specific properties of the analysed line and variety.

The falling number traditionally is used widely in grain classification, quality control and marketing. Grain with a low falling number due to high α-amylase activity causes substantial economic losses to growers, significant processing and storage problems and is generally reflected in poorer quality end-products. Indeed with the advent of highly automated food production plants, particularly bakeries, variation in α-amylase in the starting material is now even more undesirable. Low falling number is generally associated with pre-harvest sprouting; however, it is now clear that there are a number of additional causes of low falling number (Mares and Mrva, 2008). There is no information in the legislation of the Republic of Latvia for falling number value in hull-less barley. The only information about wheat which can be found: the falling number of wheat grain could be 220–350 s, but

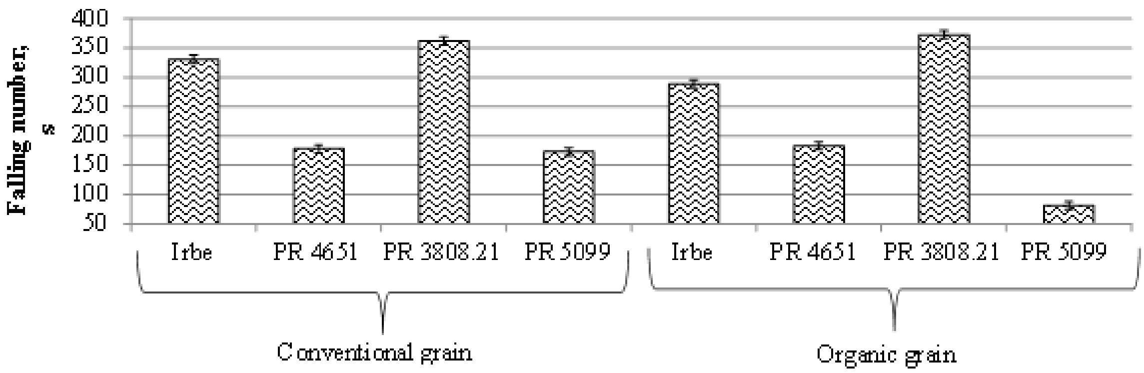

Figure 2. The falling number of the analyzed hull-less barley.

for rye it is stated that the falling number of rye grain could be 120-250 s (Requirements of the Cabinet of Ministers, No. 1455 from 15.12.2009). In the present experiment the falling number values of the analyzed hull-less barley were detected in range from 81 s to 373 s (Fig. 2).

Significant differences (p=0.116) in the falling number were found in the analyzed hull-less barley samples harvested in the conventional and organic farming. The lower falling number value was obtained in the organic hull-less barley grain line PR 5009 – 81 ± 4 s, the higher in the conventional and organic hull-less barley line PR 3808.21 as 362 ± 5 s and 373 ± 2 s respectively (Fig. 2). Low falling number value indicates possible elevated α-amylase activity; as a result quality properties of the analyzed grain worsen. The falling number can be influenced by crop conditions and weather. Weathering of the grain begins to germinate and the falling number significantly declines (German, 2006). It is necessary to indicate, that the falling number of organic hull-less barley 'Irbe' and PR 3808.21 was very close to the falling number of wheat grain 220–350 s mentioned in the literature (Requirements of the Cabinet of Ministers, No. 1455 from 15.12.2009), which mainly proves the excellent quality parameters of the grain.

Conclusions

1. In the present experiments no significant differences in protein, moisture, starch, β-glucan content and 1000 grain weight were found between the analyzed conventional and organic hull-less barley 'Irbe', PR4651, PR3808.21 and PR5099.
2. In the present research significant differences in the bulk density of all analyzed hull-less barley samples were established. Lower analyzed parameter content of 780 ± 1 g L^{-1} was obtained for the conventional and organic hull-less barley line PR 5099. However, the higher bulk density value of 821 ± 1 g L^{-1} was obtained for the conventional hull-less barley variety 'Irbe'. No significant differences were found in the bulk density of conventional and organic hull-less barley 'Irbe', PR4651 and PR3808.21.
3. Significant differences in the falling number were found in the analyzed hull-less barley samples harvested in both the conventional and organic farming. The lower falling number value was obtained in the organic hull-less barley line PR 5009 – 81 ± 4 s, higher in the conventional and biological hull-less barley line PR 3808.21 as 362 ± 5 s and 373 ± 2 s respectively.

Acknowledgement

This research and publication has been prepared within the State Research Programme "Sustainable use of local resources (earth, food, and transport) – new products and technologies (NatRes)" (2010.-2013.) Project No. 3. "Sustainable use of local agricultural resources for development of high nutritive value food products (Food)".

References

1. Damiran D., Yu P. (2012) Metabolic characteristics in ruminants of the proteins in newly developed hull-less barley varieties with altered starch traits. *Cereal Science*, 55(2), pp. 351-360.
2. Davies C.E., Tallon S.J., Brown N. (2005) Continuous monitoring of bulk density and particle size in flowable powders and grains. *Chemical Engineering Research and Design*, 83(A7), pp. 782-787.
3. Doltra J., Olesen J.E. (2013) The role of catch crops in the ecological intensification of spring cereals in organic farming under Nordic climate. *European Journal of Agronomy*, 44, pp. 98-108.
4. Fastnaught E.C. (2009) Fiber Ingredients: Food Applications and Health Benefits. *CRC Press*, pp. 323-357.

5. Faraj A., Vasanthan T., Hoover R. (2006) The influence of α-amylase-hydrolysed barley starch fractions on the viscosity of low and high purity barley β-glucan concentrates. *Food Chemistry*, 96(1), pp. 56-65.
6. Korunic Z., Cenkowski S., Fields P. (1998) Grain bulk density as affected by diatomaceous earth and application method. *Postharvest Biology and Technology* 13, pp. 81-89.
7. Lia J.H., Vasanthana T., Rossnagel B., Hoover R. (2001) Starch from hull-less barley: I. Granule morphology, composition and amylopectin structure. *Food Chemistry*, 74(4), pp. 395-405.
8. Lazaridou A., Costas G.B., Izydorczyk S.M. (2006) Cereal beta-Glucans: Structures, Physical Properties, and Physiological Functions. *Functional Food Carbohydrates*, pp. 1-72.
9. Mares D., Mrva K. (2008) Late-maturity α-amylase: low falling number in wheat in the absence of preharvest sprouting. *Journal of Cereal Science*, 47(1), pp. 6-17.
10. Rakcejeva T., Skudra L., Iljins U. (2007) Biological value changes in wheat, rye and hull-less barley grain during biological activation time. Proceedings *of the Latvia University of Agriculture*, 18(313), pp. 25-33.
11. Requirements of Cabinet Minister (2009) Requirements for food quality schemes, their implementation, operation, monitoring and control procedures No. 1455, from 15.12.2009, 21 p.
12. Roca E., Broyart B., Guillard V., Guilbert S., Gontard N. (2007) Controlling moisture transport in a cereal porous product by modification of structural or formulation parameters. *Food Research International*, 40, pp. 461-469.
13. Shewry P.R. (2006) Improving the protein content and composition of cereal grain. *Journal of Cereal Science,* 46(3), pp. 239-250.
14. Škrbić B., Milovaca S., Dodig D., Filipčev B. (2009) Effects of hull-less barley flour and flakes on bread nutritional composition and sensory properties. *Food Chemistry*, 115(3), pp. 982-988.
15. Tang H., Watanabe K., Mitsunaga T. (2002) Structure and functionality of large, medium and small granule starches in normal and waxy barley endosperms. *Carbohydrate Polymers*, 49(2), pp. 217-224.
16. Topping D. (2007) Cereal complex carbohydrates and their contribution to human health. *Cereal Science*, 46:3, pp. 220-229.
17. German L. Carl (2006) Understanding the Falling Number Wheat Quality Test. ER06-02, *University of Delaware, www.ag.udel.edu/frec/.* 2 p.