

Crop Yields and Baking Qualities of F1 Winter Rye Hybrids Grain in the Forest-Steppe of the Republic of Bashkortostan

Rafael R. Ismagilov, Lyutsiya F. Gaysina, Luise M. Ahiyarova, Dayan S. Ayupov,
Razit B. Nurlygayanov, Bulat G. Ahiyarov, Rishat R. Abdulvaleev, Katerina V. Malyutina,
Kamil R. Ismagilov and Valichon K. Abdulloev
Federal State Budgetary Educational Institution of Higher Education,
Bashkir State Agrarian University, Ufa, Russian Federation

Abstract: The results of the research on carop yield and baking qualities of F1 Winter rye hybrids grain in conditions of the forest-steppe of the Republic of Bashkortostan are presented. The rather high baking properties of Picasso hybrid grain are shown. The comparative values of the falling number, the content of water-soluble pentosans, the viscosity of grain water extract, the shape stability and the bread volume from the grain of 5 F1 hybrids and from the population variety Chulpan 7 are given. The form and the degree of the effect of the content of water-soluble pentosans in the grain of hybrids on the shape stability of bread are quantified. The possibility of using the viscosity of the water extract for quantifying the content of water-soluble pentosans and accordingly, the baking properties of grain of Winter rye hybrids is shown.

Key words: Rye, F1 hybrids, baking qualities, grain falling number, water-soluble pentosans, viscosity of water extract of grain, shape stability of bread, bread volume

INTRODUCTION

Winter rye grain is the second most important raw material for the production of bread and bakery products after wheat. In the Russian Federation, rye bread is a traditional food product and about 1 million tons of rye grain are used for bakery annually. Different kinds of bread with special taste and nutritional qualities are baked from rye flour. Baking properties of the population varieties of Winter rye grain and the special aspects of their formation have been studied in detail by Stepniewska *et al.* (2018), Bai *et al.* (2016), Buksa *et al.* (2010), Goncharenko *et al.* (2005), Ismagilov and Wanueschina (2007). It has been established that unlike wheat grain the baking properties of rye grain are determined by the state of the carbohydrate-amylase complex in 2001. With the excessive activity of amylolytic enzymes or pre-damaged starch granules, baking qualities deteriorate. To measure the state of starch and the activity of amylolytic enzymes, the "Falling number" index was adopted.

Along with amylolytic enzymes, the baking qualities of rye grain are largely influenced by water-soluble pentosans in the grain. Pentosans are mainly composed of arabinose and xylose. Arabinoxylans are an important component of wheat and rye dough. They bind water,

promote the formation of viscous dough and improve the quality of bread (Buksa *et al.*, 2016; Yang *et al.*, 2017). Water-soluble pentosans form very viscous solutions and due to this property they structurize rye bread. They help to strengthen the spatial structure of the dough and crumb by crossing its macromolecule with the protein macromolecule (Kucerova, 2015). At the same time, a number of authors have obtained data on the absence of a connection between the content of water-soluble pentosans and the baking properties of rye grain (Lavrentieva *et al.*, 2016).

It was shown that the more water-soluble pentosans are found in the grain, the better are its baking qualities (Ismagilov *et al.*, 2001). Viscosity of the water extract of grain is a proxy index of the content of water-soluble pentosans in rye grain. The quality of rye and triticale grain is reliably evaluated by the viscosity of the water extract (Goncharenko *et al.*, 2005; Rodehutsord *et al.*, 2016). Depending on the viscosity of the water extract and regardless of the weather conditions of the year it is possible to predict reliably the slackness (shape stability) of toppling bread ($r = 0.59-0.62$) (Fras *et al.*, 2016).

Bread volume is one of the important indices of its quality. The research showed that the grain of Winter rye varieties with high dynamic viscosity of water extract

(12.9-20.8 cps) had a low bread volume. Brammer indicates that the volumetric yield of bread depends on the water retention capacity of pentosans and the properties of the crumb depend on the degree of activity of α -amylase and the properties of starch. With the addition of partially purified arabinoxylans from wheat bran the water absorption of the dough increases (Koegelenberg and Chimphango, 2017).

In recent years, along with new varieties, F1 hybrids have been included into the state register of plant variety. It is known that heterotic F1 hybrids are more productive and more resistant to diseases, pests and stressful situations than their parent plants (Goncharenko *et al.*, 2005). Due to heterosis with the use of appropriate technology, F1 hybrids can generate high yields. So, for example, according to the results of registration tests in Canada, the yield of hybrids exceeded the yield of Hazlet by 23% (Wilde *et al.*, 2017). A number of works (Kunkulberga *et al.*, 2017; Laidig *et al.*, 2017) have shown that the quality of Winter rye hybrids grain (protein content, falling number, viscosity of water extract, height of amylogram) is not inferior to population varieties and is suitable for baking bread.

To evaluate the feasibility of cultivating Winter rye hybrids and determining the suitability of their grain for baking purposes in the natural conditions of the forest-steppe of the Republic of Bashkortostan, real productivity and quality characteristics of their grain are needed. At the same time, there is no scientific information on the baking properties of the grain of heterotic hybrids of Winter rye grown in the natural conditions of the Russian Federation and in particular in comparison with the quality of the currently cultivated crop varieties. The Republic of Bashkortostan of the Russian Federation is one of the largest regions for the production of Winter rye grain; It is sown on the area of 300-350 thous. ha. In this connection, we conducted a study of the yield and quality of grain of new Winter rye hybrids in conditions of the forest-steppe of the Republic of Bashkortostan.

MATERIALS AND METHODS

Grain quality of five F1 Winter rye hybrids (selection KWS Lochov, Germany) and the population variety Chulpan 7 (selection Chishminkaya breeding station, Russian Federation) was the object of the study. Chulpan 7, included in the State Register of plant variety and admitted to use in the Russian Federation was taken as the control. To solve the tasks, a field experiment, laboratory analysis of grain quality and statistical analysis of experimental data were conducted.

The field experiment was carried out on the experimental field of the Plant Cultivation and Farming Department of the Educational and Research Center of Bashkir State Agrarian University located in the forest-steppe of the Republic of Bashkortostan. The scheme of the experiment consisted of the following options: population variety of Winter rye Chulpan 7 (control), Picasso F1 hybrid, Visello F 1 hybrid, Brasetto F 1 hybrid, Palazzo F 1 hybrid, Guttino F 1 hybrid. The options of the experiment were placed randomly in a four-fold repetition. The area of the registered plot was 6 m². Winter rye was cultivated according to the recommended technology for the forest-steppe of the Republic of Bashkortostan, except for the seeding rate of hybrids (2 million pieces/ha). The harvest was recorded by continuous threshing with the Terrior 2012 combine in the phase of solid grain ripeness. The yields were brought to 14% moisture and 100% purity.

The analysis of grain was carried out in the Laboratory of Biochemical Analysis and Biotechnology; Bread was baked in the Research Laboratory of the Department of Technology of Storage and Processing of Plant Production of Bashkir State Agrarian University. The falling number was determined by Hagberg-Perten method (GOST 27676-88), the kinematic viscosity of the water extract of grain was determined by the capillary clear fluids viscometer VPZh-1 with the internal capillary diameter of 1.52 mm (Fras *et al.*, 2016). The content of pentosans in grain was determined by the orcinol-chloride method. Trial rye bread was baked by express method. The quality of the bread was evaluated by shape stability (the ratio of height to diameter, H:D) and volume (the principle of the volume of loose filler displaced by bread).

Evaluation of the significance of the difference between the experimental data of different variants as well as the share of the effect of an individual factor on the value of one or another index was carried out by dispersion analysis using standard computer programs Statistica 6.0.

RESULTS AND DISCUSSION

Hybrids of rye Winter in conditions of the forest-steppe of the Republic of Bashkortostan formed a relatively high yield of grain. Depending on the year, the yield of the hybrids studied was 1.50-8.47 t/ha. The highest grain yield was formed in all hybrids in 2017 (7.56-8.47 t/ha), the lowest in 2012 (1.50-3.47 t/ha). The low yield in 2012 was due to the extremely arid weather conditions of Winter rye plants vegetation. The average yield of hybrids over 6 years (2012-2017) was 6.03 t/ha and

Table 1: Falling number of Chulpan 7 and Winter rye hybrids (Educational and research center of Bashkir State Agrarian University)

Variety, hybrid	Average for 2012-2017 (sec)	Deviation from control (±s)
Chulpan 7 (control)	217	0
Picasso	246	+29
Visello	262	+45
Brasetto	251	+34
Palazzo	277	+60
Guttino	293	+76

Table 2: Content of water-soluble pentosans in Chulpan 7 grain and Winter rye hybrids (Educational and Research Center of Bashkir State Agrarian University)

Variety, hybrid	Average for 2012-2017 (sec)	Deviation from control (±s)
Chulpan 7 (control)	2.63	0.00
Picasso	2.61	-0.02
Visello	2.72	+0.09
Brasetto	2.54	-0.09
Palazzo	2.71	+0.08
Guttino	2.85	+0.22

of the population variety Chulpan 7 5.16 t/ha. The yield of Picasso, Visello and Brasetto was higher than the yield of Chulpan 7 by 0.27-0.70 t/ha.

The falling number of Winter rye hybrids in conditions of the continental climate of the forest-steppe of the Republic of Bashkortostan during the years of research was very high (217-341 sec). In 2012 and 2016 with dry weather, the falling number in hybrids was higher than in the cool and humid year 2017.

On average, for 6 years (2012-2017), the falling number of hybrids was 246-293 and of Chulpan 7 variety 217 sec. The falling number of hybrids grain exceeded the value of this index of the studied variety by 29-76 sec. The highest value of the falling number was in Guttino hybrid (293 sec) in Picasso hybrid, the value of this index was 246 sec which is by 29 sec higher than in Chulpan 7 (Table 1). The higher falling number in the grain of hybrids developed in the humid climate (Western Europe) is probably due to the continental climate in the study area. With the increasing temperature and decreasing humidity, the falling number naturally increases due to a decrease in the activity of the alpha-amylase enzyme in grain (Ismagilov *et al.*, 2001). Least significant difference₀₅ in 2012 is 15 sec in 2013 18 sec in 2014 14 sec in 2015 11 sec in 2016 17 sec in 2017 19 sec.

The content of water-soluble pentosans in the grain of Winter rye hybrids as a whole was at the level of this index of the population variety Chulpan 7 (Table 2). Among the hybrids, Guttino stood apart with the highest content of water-soluble pentosans (2.85%) and Brasetto (2.54%) with the lowest. The content of water-soluble pentosans in Picasso grain (2.61%) did not differ significantly from the value of this index of the population variety Chulpan 7 (2.63%). In 2012 and 2016 hybrids had

grain with a high content of pentosans (2.81-3.17%) as compared with other years: Visello 3.17%, Palazzo 3.14%, Picasso 3.11% and Chulpan 7 2.70%.

In 2013 the content of water-soluble pentosans in the grain of some hybrids was lower than that of Chulpan 7, Palazzo and Guttino hybrids did not differ significantly from Chulpan 7 (the statistic difference was 0.25 and 0.02%, respectively).

The correlation analysis of the experimental data showed that the content of water-soluble pentosans in the grain of hybrids as well as of varieties, decreases with the increase in the mass of 1000 grains ($r = -0.546$). The dependence of the content of water-soluble pentosans on the mass of 1000 grains is described by the following regression Eq. 1:

$$Y = -0.0445x + 4.2091 \quad (1)$$

Where:

Y = Content of water-soluble pentosans in grain (%)

x = Mass of 1000 grains (g)

According to the Eq. 1 with the increase in the mass of 1000 grains per one gram, the content of water-soluble pentosans decreases by 0.0445%.

The kinematic viscosity of the water extract of the Winter rye hybrids grain ranged from 40.2-73.5 cCt in the years of research. In 2017, the viscosity of the water extract of grain in most hybrids was lower compared with other years. Among the hybrids, Guttino had the highest viscosity of the water extract of grain (59.4 cCt) and Brasetto had the lowest (43.6 cCt). In dry years (2012 and 2016), the viscosity of the water extract of hybrids was higher compared to 2017 (43.7-71.4 cCt). Guttino (73.5 cCt), Visello (69.4 cCt) and Palazzo (60.4 cCt) showed higher viscosity of the water extract of grain as compared with Chulpan 7 (53.5 cCt).

In 2013 the viscosity of the water extract of Guttino grain was higher by 14.35 cCt and of Brasetto was lower by 18.13 cCt than that of Chulpan 7. Picasso, Visello and Palazzo hybrids did not differ significantly from Chulpan 7.

On average, for 2012-2017 the studied hybrids were characterized by a relatively high viscosity of the water extract of grain and inter-branch variability, the value of this index ranging from 49.9-67.2 cCt. Guttino (67.2 cCt) and Visello (60.1 cCt) had a relatively high viscosity of the water extract of grain and the index of Brasetto was low (47, 4 cCt).

The form of the relationship between the content of water-soluble pentosans and the viscosity of the water

Table 3: Quality of Chulpan 7 grain and Winter rye hybrids and shape stability of bread (on average for 2012-2017)

Variety, hybrid	Kinematic viscosity of water extract of grain (cCt)	Bread shape stability
Chulpan 7 (control)	49.9	0.71
Picasso	52.2	0.75
Visello	60.1	0.72
Brasetto	47.4	0.66
Palazzo	55.8	0.77
Guttino	67.2	0.75

extract of Winter rye hybrids grain within the limits studied is rectilinear. The regression equation is as follows:

$$Y = 14.06x + 19.19 \tag{2}$$

Where:

Y = The kinematic viscosity of the water extract (cCt)
 x = Content of water-soluble pentosans (%)

According to the regression Eq. 2 when the content of water-soluble pentosans increases by 1%, the kinematic viscosity of the water extract increases by 14.06 cCt.

As regards shape stability (0.63-0.84), bread quality from the grain of all hybrids of Winter rye was excellent, although, it varied from year to year and differed among hybrids. In 2017, bread shape stability fluctuated in the range from 0.70-0.82. When compared by year, a higher value of this index was in 2012 (0.79-0.84). This is due to the fact that dry weather conditions positively affected the synthesis of water-soluble pentosans in the grain. Compared with Chulpan 7, the shape stability of Picasso hybrid was slightly higher and that of Brasetto was the lowest among the hybrids.

On average, for 6 years (2012-2017) shape stability of Chulpan 7 bread amounted to 0.71. Palazzo (0.77) manifested the greatest shape stability that index of Picasso was 0.75 slightly higher than that of Visello, Brasetto, Guttino and Chulpan 7 (Table 3).

Correlation analysis confirmed the significant effect of the content of water-soluble pentosans in the grain of Winter rye hybrids on the shape stability of bread ($r = 0.671$). With the increase of water-soluble pentosans in grain, the shape stability of bread naturally increases. This correlation in the studied limits of water-soluble pentosans is rectilinear and is described by the following regression Eq. 3:

$$Y = 0.102x + 0.478 \tag{3}$$

Where

Y = Bread shape stability
 x = Content of water-soluble pentosans in grain (%)

From the regression Eq. 3 it follows that when the content of water-soluble pentosans in grain increases by 1%, the shape stability of the bread increases by 0.102 units. This is due to the fact that water-soluble pentosans in grain bind water at an early stage of dough formation and strengthen the spatial structure of the dough.

The correlation analysis also confirmed the presence of a rectilinear positive relationship between the viscosity of the water extract and the shape stability of bread from the grain of Winter rye hybrids ($r = 0.598$).

This correlation in the studied limits of the viscosity of the water extract is rectilinear and is described by the following regression Eq. 4:

$$Y = 0.0015x + 0.6587 \tag{4}$$

Where:

Y = Bread shape stability
 x = Kinematic viscosity of the water grain extract (cCt)

Consequently, increase in the viscosity of the water extract of hybrids grain by 1 cCt is accompanied by the increase in shape stability of bread from this grain by 0.0015 units.

Bread volume from the grain of Winter rye hybrids was different during the years of study and varied among hybrids (154-185 cm³). The volume of bread from the grain of Visello, Brasetto, Palazzo and Guttino slightly exceeded the value of that index of Chulpan 7. A certain negative effect of the content of water-soluble pentosans in the grain of hybrids on the bread volume was revealed.

The correlation coefficient among those indices was -0.344. No significant relations between the falling number of hybrids grain and the volume of bread were found. The tightness of the relations according to the correlation coefficient ($r = 0.122$) is very weak. This is probably due to the high value of the falling number of grain in all studied hybrids under conditions of the continental climate which ensures good bread baking qualities.

Breads of experimental baking from the grain of hybrids differed in organoleptic characteristics among themselves and from Chulpan 7. The photo of the experimental breads is shown in Fig. 1.

The bread from the grain of Picasso hybrid had a smooth crust surface without large cracks as in the case of Chulpan 7. The color of Picasso hybrid bread crust was dark brown and in Chulpan 7 and other hybrids varied from light brown to dark brown. Breads from all hybrids and varieties were of correct shape, round and well-structured. Breads from the grain of all hybrids were well baked not sticky and not wet to the touch without traces of impenetrable lumps.



Fig. 1: Breads of experimental baking from grain Chulpan 7 and hybrids (2013); 1) Population variety Chulpan 7; 2) Visello hybrid; 3) Brasetto hybrid; 4) Palazzo hybrid; 5) Guttino hybrid and 6) Picasso hybrid

Bread from Picasso grain was uniformly porous with small voids and seals. Porosity of bread from Visello and Brasetto was uniform with voids; Porosity of breads from Palazzo and Guttino was fairly uniform but with voids. Visello, Brasetto, Palazzo and Guttino demonstrated good bread crumb elasticity without permanent residual deformation.

From the results of the research it follows that under the conditions of the forest-steppe of the Republic of Bashkortostan, Winter rye hybrids form grain with a high falling number meeting the requirements of the 1st commodity class (GOST 16990-88 rye. Requirements for procurement and deliveries) and also the requirements for the quality of rye grain supplied for export (GOST 27850-88). The falling number of hybrids as well as of population varieties is a variable quality index. A significant change in the falling number is due to the influence of weather conditions on growth and development of the mother plant.

The content of water-soluble pentosans is subject to intervarietal inconsistency (Goncharenko *et al.*, 2005; Ismagilov and Wanueschina, 2007; Rodehutsord *et al.*, 2016). At the same time, dispersion analysis showed that the share of the effect of external conditions (year) on the content of water-soluble pentosans is much higher than the effect of the genotype (hybrid). The variance of this index about the genotype (hybrid) was 15.6% and the variance about external conditions (year) was 79.2%.

One of the factors affecting the content of water-soluble pentosans in the grain of Winter rye is grain size. Winter rye hybrids with large grains contain less water-soluble pentosans than hybrids with small grain.

There is no significant relationship between the falling number and the content of water-soluble pentosans in the grain of Winter rye hybrids ($r = 0.160$).

Based on regression analysis Kucerova (2009) came to the conclusion that there was a connection between these parameters of the baking qualities of Picasso grain.

A number of researchers (Goncharenko *et al.*, 2005; Kucerova, 2015) have shown that viscosity of the water extract is a fairly reliable index of the content of water-soluble pentosans in grain. The dependence of the water extract viscosity on the content of water-soluble pentosans is incomplete ($r = 0.481$). This can be explained by the influence of other factors on this relationship, the weather conditions of plants vegetation in particular. The studies have shown that when the influence of the year (weather conditions) is excluded the tightness of the relationship is increased. For example, in 2013 correlation coefficient between these characteristics was 0.718.

Bread shape stability is substantially determined by the content of water-soluble pentosans in the grain of Winter rye hybrids ($r = 0.671$). With the increase of water-soluble pentosans content, the bread shape stability naturally increases. However, according to the results of the study by Lavrentieva *et al.* (2016), the quality of bread from the grain of population varieties with a low content of water-soluble pentosans was no worse than from that with a high content of pentosans.

CONCLUSION

In conditions of the forest-steppe of the Republic of Bashkortostan, Picasso, Visello and Brasetto F1 hybrids of Winter rye are able to form a relatively high yield of grain.

Winter rye hybrids form grain with a high falling number (246-293 sec). The falling number of hybrids as well as of the population variety is an inconsistent index of grain quality which is due mainly to the influence of weather conditions during the formation of grain.

The content of water-soluble pentosans in the grain of the hybrids studied differs somewhat (by -0.09, ..., + 0.22%) from the value of this index of the population variety Chulpan 7. Guttino grain has got the highest content of water-soluble pentosans (2.85%). The content of water-soluble pentosans in the grain of hybrids depends significantly on the external conditions of vegetation of plants and decreases as the weight of 1000 grains increases ($r = -0.546$).

The kinematic viscosity of the water extract of Winter rye hybrids grain is quite high (47.4-67.2 cCt) and is not lower than that of Chulpan 7. Guttino (67.2 cCt) and Visello hybrids (60.1 cCt) have got a comparatively high viscosity of the water extract of grain. The content of water-soluble pentosans in the grain of Winter rye hybrids is characterized by the viscosity of the water extract upon average ($r = 0.481$) and within the period of one year (with elimination of weather conditions) to a great extent ($r = 0.718$). When the content of water-soluble pentosans changes by 1%, the viscosity of the water extract of the hybrid grain increases by 14.06 cCt.

Bread quality of the experimental baking from the grain of the studied rye hybrids is high and differs from the population variety Chulpan 7 by a number of indices. Shape stability of bread from the grain of hybrids is evaluated as excellent (0.66-0.75) and depends significantly on the content of water-soluble pentosans ($r = 0.671$) and the viscosity of the water grain extract ($r = 0.598$). With the increase in the content of water-soluble pentosans in the grain of hybrids by 1% and the viscosity of the water extract of grain by 1 cCt, the shape stability of the bread increases, respectively by 0.102 and 0.0015 units.

Bread volume of experimental baking (154-185 cm³ per 100 g of flour) from the grain of Winter rye hybrids is at or above Chulpan's 7 (158 cm³). Vizello has got the highest value of this index (185 cm³). The volume of bread is somewhat negatively affected by grain water-soluble pentosans. There was no significant correlation between the falling number and bread volume ($r = 0.122$) which is probably due to the high falling number of all hybrids in the conditions of the continental climate, providing a good volume of bread.

By a number of organoleptic indices the quality of bread from the grain of Winter rye hybrid and Chulpan 7 variety is somewhat different. The porosity of bread from Visello and Brasetto hybrids is uniform with voids from Palazzo and Guttino hybrids fairly uniform but with voids. Visello, Brasetto, Palazzo and Guttino demonstrated good bread crumb elasticity without permanent residual deformation while Picasso and Chulpan 7 had medium elasticity due to a slight residual deformation.

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