POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 33(1): 89–99, Y. 2018

EVALUATION OF TECHNOLOGICAL QUALITY IN GRAIN AND FLOUR OF WINTER TRITICALE (*TRITICOSECALE* WITTM.) FROM CONTROLLED CULTIVATION CONDITIONS

Katarzyna Panasiewicz, Wiesław Koziara, Hanna Sulewska

Department of Agronomy
Poznań University of Life Sciences in Poznań, Poland

Key words: winter triticale, irrigation, nitrogen fertilisation, flour, dough, bread.

Abstract

The paper presents results of studies from the years 2009–2010, aiming at the determination of quality attributes and technological properties of grain as well as produced bread, depending on sprinkling irrigation and nitrogen fertilisation of winter triticale cv. Gniewko. The first order factor was the water variant (non-irrigated, irrigated by sprinkling), while the second order factor was nitrogen fertilisation (0, 60, 90, 120 kg N ha^{-1}). It was found that despite improvement in certain indexes for grain, flour and dough under the influence of sprinkling irrigation and nitrogen fertilisation faults were found in the produced bread, which did not meet requirements for bread for human consumption. A primary cause for poor bread quality was connected with high amylolytic activity of flour.

OCENA JAKOŚCI TECHNOLOGICZNEJ ZIARNA I MĄKI PSZENŻYTA OZIMEGO (*TRITICOSECALE* WITTM.) Z KONTROLOWANYCH WARUNKÓW UPRAWY

Katarzyna Panasiewicz, Wiesław Koziara, Hanna Sulewska

Katedra Agronomii
Uniwersytet Przyrodniczy w Poznaniu, Polska

Słowa kluczowe: pszenżyto ozime, deszczowanie, nawożenie azotem, mąka, ciasto, chleb.

Address: Katarzyna Panasiewicz, Poznań University of Life Sciences, ul. Dojazd 11, 60-632 Poznań, Poland, phone: +48 (61) 848 73 95, e-mail: panas@up.poznan.pl

Abstrakt

W pracy przedstawiono wyniki badań z lat 2009–2010 mające na celu określenie cech jakościowych i technologicznych ziarna oraz uzyskanego pieczywa w zależności od deszczowania i nawożenia azotem pszenżyta ozimego odmiany Gniewko. Czynnikiem pierwszego rzędu był wariant wodny (niedeszczowany, deszczowany), a czynnikiem drugiego rzędu było nawożenie azotem (0, 60, 90, 120 kg N ha^{-1}). Stwierdzono, że pomimo poprawy niektórych wskaźników ziarna, mąki i ciasta pod wpływem deszczowania i nawożenia azotem uzyskany chleb był wadliwy i nie spełniał wymogów stawianych pieczywu konsumpcyjnemu. Stwierdzona niska liczba opadania w ziarnie oraz mała zawartość glutenu i niska liczba opadania w mące przyczyniły się do wytworzenia ciasta o słabych cechach farinograficznych, a w dalszej kolejności uzyskania niskiej wydajności i objętości chleba.

Introduction

Cereals constitute the basic food source worldwide and in terms of energy requirement they cover over 30% requirement of the world human population. The dominant species still include rice, maize and wheat; however, their production is frequently limited by climatic and soil conditions. Poland is a country with a considerable share of light soils, which results from the predominance of soils originating from sand, loamy sand and sandy clays. For this reason an alternative for these soils may be provided by cultivation of cereals in terms of their quality exhibiting comparative traits to wheat, at the same time showing greater adaptability to inferior soil conditions and greater tolerance to stress induced by drought and pathogens (LONBANI and ARZANI, 2011). According to MARCINIAK et al. (2008 a, b), triticale – thanks to its high productivity and stability obtained in recent years – might constitute a regional contribution of Poland to the world food market. In literature many authors indicates the potential use in human nutrition for triticale grain and its composition, resulting in increased interest in this synthetic species among breeders and processing companies (MC GOVERIN et al. 2011, PATTISON and TRETHOWAN 2013). To be used for flour and baking bread triticale grain should be of adequate quality, both in terms of general properties and specific requirements of the milling and baking industries. Many studies (TOHVER et al. 2004, SABOVIC 2014) indicate that it is possible to produce bread of satisfactory quality from triticale flour, but it requires certain modifications of bread production methods. Baking quality of cereals is determined first of all by the amount and composition of gluten reserve proteins (WIESER 2007, MARTINEK et al. 2008). According to VARUGHESE et al. (1996), triticale grain in comparison to wheat grain exhibits lower contents and lesser strength of gluten. For many years breeding work on triticale has aimed at the generation of new cultivars exhibiting properties comparable to wheat, i.e. good baking value, an increased number of glutelin units (TOHVER et al. 2005). Next to genetic characters, quality attributes are also modified by climatic, soil and cultivation conditions (PATTISON and TRETHOWAN 2013, JANKOWSKI et al. 2014). Among cultivation factors the application rate and date of nitrogen fertilisation have the greatest effect on properties and technological value of grain. Nitrogen is a nutrient having the most marked effect on yield and protein content (DELOGU et al. 1998). However, effects of nitrogen application are very often modified by variable weather conditions (RUITER et al. 1999), particularly availability of water. Many authors indicate that this factor has a stabilising effect on the yield of grain, while it also has an advantageous effect on grain quality (ALBRIZIO et al. 2010).

The aim of this study was to determine the effect of sprinkling irrigation and nitrogen fertilisation on selected quality parameters of grain, flour, dough and bread produced from triticale cv. Gniewko.

Materials and Methods

The field experiment using winter triticale cv. Gniewko were conducted in the years 2009–2010 at the Department of Agronomy, the Poznań University of Life Sciences on soils at the Department Experimental Teaching Station in Złotniki near Poznań (N: 52°29'0" E: 16°49'53") Poland. Triticale was grown on lessivè soils, formed from light loamy sands, of quality classes IVa and IVb, very good and good rye complex. According to the international WRB classification (2006) these soils are classified as Albic Luvisols, while according to Soil Taxonomy (1999) they are Typic Hapludalfs, while in terms of grain size they are loamy sands underlined by loam. The arable layer has a slightly acid reaction, pH from 5 to 6 (pH measured in 1 M KCl). This soil is abundant in phosphorus (0.78 mg P kg^{-1} soil) and potassium (1.35 mg K kg^{-1} soil), while it is poor in magnesium (0.45 mg Mg kg^{-1} soil). The groundwater table is deposited at a depth from 2.9 to 5.5 m and it is located outside the range of triticale roots, which in years with lower precipitation totals may cause periodical water deficits for crops. The trial was established as a two-factorial experiment in the split–plot design in four replications. The area of plots for crop harvest was 24 m^2. Investigated factors included the water variant (non-irrigated and irrigated by sprinkling) and nitrogen fertilisation applied at 0, 60, 120 and 180 kg ha^{-1}. Fields were irrigated at a decrease of soil moisture content in the 0-30 cm layer to 70% field capacity at the period of greatest sensitivity of plants to water deficit. Water application rates in the years of analyses were 120 mm in the first year and 80 mm in the following year (a single dose was 40 mm). Nitrogen fertilisation was applied as ammonium nitrate at 60 kg N ha^{-1} before sowing and in respective treatments at 60 kg N ha^{-1} at the tillering phase (BBCH 21) and 60 kg N ha^{-1} the heading phase (BBCH 51). Phosphorus and potassium fertilisation as 46% superphosphate was applied before sowing at 80 kg ha^{-1} P_2O_5 (35 kg P ha^{-1}) and as 60% potassium salt at 100 kg ha^{-1} K_2O (83 kg K ha^{-1}). Moreover, weed infestation was regulated by autumn spraying with a preparation containing active substances chlorotoluron 80% at 1.0 kg ha^{-1} and fluroxypyr + 2.4-D at 1.2 l ha^{-1}. The other cultivation measures were performed in accordance with the recommendations for this species.

Samples of grain produced in a given year were ground in a Quadrumat Senior mill, simultaneously determining flour extraction rates (JAKUBCZYK and HABER, 1983).

Analysis of the basic chemical composition included determinations of contents of dry matter (*Ziarno zbóż…* PN-EN ISO 712: 2012), crude ash (ICC method 104/1), crude fat (ICC-Standard No. 136. 1984), protein according to Kjeldahl (AOAC, 1990) and fibre (VAN SOEST, 1963). Nitrogen-free extractives were denoted as 100% (contents of protein + fat + ash + crude fibre). Results of all assays were converted into dry mass.

Grain quality was evaluated based on determinations of grain moisture content (by the oven dry method), bulk density of grain (PN-ISO 797-2:1998) and grain vitreousness (ICC-Standard No. 129. 1980).

Quality of flour was assessed based on flour colour (PN-A-74029: 1999P), the amount of gluten, sedimentation properties (SDS test) and amylolytic properties (falling number) (PN-ISO 3093: 1996/ AZ1:2000).

Rheological properties of dough were assessed using a Brabender farinograph in accordance with the ICC-Standard No. 115/72. Farinograph analyses determined water absorption of flour (%), dough stability (min.), dough development (min.), dough softening (BU) and Brabender quality number.

Experimental bread was baked using a single phase process in order to determine the yield and bread volume per 100 g bread based on the method developed by KLOCKIEWICZ-KAMIŃSKA and BRZEZIŃSKI (1997).

Recorded results were analyzed statistically using the analysis of variance for orthogonal factorial experiments and the analysis of variance in the split-plot design (ANOVA). The means of treatment were compared by means of Tukey's Multiple Range test and least significant difference (LSD) was declared at $P < 0.01$ and $P < 0.05$.

Results and Discussion

In the period of analyses mean air temperature ranged from 9.4 to 10.2°C, at the multiannual mean of 8.8°C, while in the vegetation period for April it was 14.2 and 10.5 °C, May 15.1 and 12.0°C, June 16.7 and 19.2°C, whereas for July it was 21.7 and 23.0°C, respectively. Precipitation totals in these years ranged from 605.8 mm to 707.3 mm, while for the above mentioned months they amounted to 16.0 and 38.5 mm, 92.3 and 134.6 mm, 129.1 and 26.6 mm, 104.6 and 100.9 mm, respectively (Table 1).

Table 1

Weather conditions at Meteorological Station at Złotniki in 2008–2010

Months	Years				Average of the multi-year 1951–2006	
	2008/2009		2009/2010			
	rainfalls [mm]	temperature [°C]	rainfalls [mm]	temperature [°C]	rainfalls [mm]	temperature [°C]
IX	16.8	14.4	53.9	17.0	45.8	13.8
X	69.4	9.9	59.4	7.9	34.8	9.1
XI	20.5	5.4	38.2	6.6	34.7	3.7
XII	25.0	1.5	31.8	-0.3	39.0	0.1
I	16.3	-2.4	34.4	-6.5	28.9	-1.4
II	32.9	0.0	22.8	-0.5	27.2	-0.4
III	56.8	4.5	33.8	4.2	30.0	3.3
IV	16.0	14.2	38.5	10.5	31.3	8.5
V	92.3	15.1	134.6	12.0	48.0	14.2
VI	129.1	16.7	26.6	19.2	57.8	17.4
VII	104.6	21.7	100.9	23.0	74.5	19.1
VIII	26.1	21.4	132.4	19.6	54.2	18.4
Total – Average	605.8	10.2	707.3	9.4	506.2	8.8

Chemical analyses showed that grain of winter triticale cv. Gniewko varied slightly in terms of its composition depending on the experimental factors (Table 2). Sprinkling irrigation caused a reduction of contents of crude protein and ash, as well as an increase in crude fat contents in grain. A decrease in protein contents under the influence of irrigation in wheat was also reported by ERECUL et al. (2012).

Table 2

Chemical composition in grain of winter triticale (in % dry matter)

Factor	Level	Crude protein	Crude fiber	Crude lipides	N – free extract	Ash
WV	T0	11.6	4.50	1.35	72.0	1.82
	T1	10.9	4.56	1.54	72.4	1.68
LSD		0,33**	n.s.	0.15*	n.s.	0.12*
NF [kg N ha^{-1}]	0	9.70	4.64	1.38	73.5	1.78
	60	9.96	4.53	1.48	73.5	1.73
	120	11.7	4.49	1.44	71.7	1.72
	180	13.5	4.47	1.48	70.0	1.70
LSD		0.47**	0.12*	n.s.	0.88**	0.07*

WV – water variant; T0 – non-irrigation; T1 – sprinkling irrigation; NF – nitrogen fertilization; n.s. – not significant; *$P < 0.05$ and **$P < 0.01$.

Nitrogen fertilisation applied in this experiment significantly modified analysed components. With an increase in nitrogen application rates a significant increase was observed in crude protein contents, but reduced contents of crude fibre, nitrogen-free extractives and ash. KIRCHEV (2014) in the experiments on triticale conducted in southern Bulgaria showed a positive effect of high nitrogen application rates on the content of protein in triticale grain.

Technological quality of triticale grain assessed based on moisture content, grain bulk density, vitreousness and falling number depending on sprinkling irrigation showed not significant effect of this factor (Table 3).

Table 3

Technological quality of winter triticale grain cv. Gniewko depending on sprinkling irrigation and nitrogen fertilization

Factor	Level	Falling number [s]	Grain vitreousness [%]	Bulk density of grain [kg hl^{-1}]	Grain moisture content [%]
WV	T0	62.0	1.37	64.1	11.9
	T1	63.1	1.62	65.1	11.7
LSD		n.s.	n.s.	n.s.	n.s.
NF [kg N ha^{-1}]	0	62.7	1.0	63.4	11.6
	60	63.0	0.0	64.8	12.1
	120	62.5	1.25	64.2	11.8
	180	62.0	3.75	65.9	11.7
LSD		n.s.	n.s.	n.s.	n.s.

WV – water variant; T0 – non-irrigation; T1 – sprinkling irrigation; NF – nitrogen fertilization; n.s. – not significant; *$P < 0.05$ and **$P < 0.01$.

A trend could also be observed for an increase in values of these parameters in treatments irrigated by sprinkling. In turn, the assessment of the effect of nitrogen fertilisation on these parameters showed a significant effect of nitrogen dose on grain vitreousness. An increase in grain vitreousness was recorded under the influence of increasing nitrogen doses. The greatest value of this parameter was observed following the application of the highest of the applied doses, i.e. 180 kg N ha^{-1}. KIRCHEV (2014) showed that increasing of nitrogen doses within the range of 0–180 kg N ha^{-1} contributed to the highest value of this parameter at the highest tested variant.

Analysis of technological quality of flour showed that sprinkling irrigation significantly differentiated only parameters in the sedimentation test, i.e. swelling power and sedimentation of large molecules of gluten proteins and the amount of gluten (Table 4). Irrigation caused a deterioration of flour strength determined based on the sedimentation test and the amount of gluten contained in flour. Presented analyses indicate low contents of gluten proteins, determining dough elasticity, gas retention and as a result of the formation of a spongy crumb structure. A negative effect of irrigation on the value in the sedimentation test and the amount of gluten in wheat was also shown by ERECUL et al. (2012). Those authors recorded the highest values of these parameters in treatments with no sprinkling irrigation applied, while a considerable reduction of their values was observed between water application variants of 0 mm and 40 mm.

Table 4

Technological quality of winter triticale flour cv. Gniewko depending on sprinkling irrigation and nitrogen fertilization

Factor	Level	Flour yield [%]	Flour colour [% of standard]	Falling number [s]	SDS test [ml]	Amount of gluten in flour (elution manual) [%]	Water absorption of flour [%]
WV	T0	66.0	77.3	67.7	34.1	5.69	51.3
	T1	66.5	77.8	76.4	28.1	2.52	51.2
LSD		n.s.	n.s.	n.s.	4.05**	2.99*	n.s.
NF [kg N ha^{-1}]	0	66.9	77.4	74.0	24.5	0.38	50.4
	60	66.3	78.0	74.5	27.2	0.35	50.5
	120	66.3	77.6	71.7	33.0	5.04	51.3
	180	65.4	77.1	68.0	39.5	10.6	52.7
LSD		n.s.	n.s.	n.s.	5.72**	4.22**	n.s.

WV – water variant; T0 – non-irrigation; T1 – sprinkling irrigation; NF – nitrogen fertilization; n.s. – not significant; *P < 0.05 and **P < 0.01.

In the presented experiment sprinkling irrigation did not significantly differentiate flour yield, flour colour, falling number.

Nitrogen doses significantly modified results of the sedimentation test and wet gluten content. The greatest values of both parameters were recorded for the highest tested application rate of this nutrient, i.e. 180 kg N ha^{-1}. ZECEVIC et al. (2010) showed positive effect of increasing nitrogen doses in the cultivation of two winter triticale cultivars, the greatest sedimentation values and washed gluten amounts were recorded at the fertilisation with 120 kg N ha^{-1}.

The falling number determined in these tests for flour from triticale cv. Gniewko indicates a high activity of α-amylase, which has a negative effect on the enzyme-protein complex of flour. High amylolytic activity of triticale flour was reported by CEGLIŃSKA et al. (2005).

The yield of flour from triticale grain was 65.4–66.9%, while both sprinkling irrigation and increasing nitrogen doses had no significant effect on this parameter.

Water absorption of flour is an important parameter characterising material for baking of bread and other cereal products. CEGLIŃSKA et al. (2005) reported that an increase in nitrogen doses caused decrease of triticale flour yield.

Table 5

Technology assessment of dough and bread obtained from grain triticale cv. Gniewko depending on sprinkling irrigation and nitrogen fertilisation

Factor	Level	Farinograph test				Properties of bread	
		dough development [min]	dough stability [min]	dough softening [BU]	Brabender quality [number]	bread yield [%]	bread volume for 100 g of bread [cm^3]
WV	T0	0.99	0.94	221	16.7	139	442
	T1	0.91	0.72	234	13.2	137	452
LSD		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
NF [kg N ha^{-1}]	0	0.85	0.42	228	10.2	135	438
	60	0.80	0.50	214	10.0	137	460
	120	0.97	0.77	231	15.0	139	450
	180	1.17	1.62	237	24.7	140	442
LSD		n.s.	0.71*	n.s.	9.95*	2.93**	21.4*

WV – water variant; T0 – non-irrigation; T1 – sprinkling irrigation; NF – nitrogen fertilization;; n.s. – not significant; $^*P < 0.05$ and $^{**}P < 0.01$.

In the presented experiment sprinkling irrigation did not significantly differentiate rheological properties of dough (Table 5). Still certain trends may be observed towards a reduction of such parameters as dough development, dough stability and quality number, and an improvement of dough softening. Similar changes in the technological value of dough produced from wheat grain grown using irrigation were shown by SELEIMAN et al. (2011). In turn, nitrogen fertilisation significantly modified such parameters as dough stability and Brabender quality numbers. Increasing nitrogen doses caused a significant increase in values of both parameters. The greatest dough stability and quality number were recorded for the highest analysed nitrogen dose (180 kg ha^{-1}), which is also confirmed by an earlier study by CEGLIŃSKA et al. (2005). The recorded values were low for both traits and formed triticale dough produced from grain of cv. Gniewko both after kneading, fermentation and re-kneading was stiff and non-elastic, which shows that it exhibits poor properties and thus limited applicability in baking.

The baking test showed faults of the produced bread, which was of inadequate quality and very limited potential use for human consumption. An excessive amylolytic activity (low falling number) in grain and flour caused obtaining dough with poor farinographic characteristics, as a result of which the produced bread had extent lacked crumb and low yield and bread volume. Sprinkling irrigation did not significantly differentiate yield and volume of bread. Values of both these parameters were determined by nitrogen fertilisation. Bread yield was 135–140% and it increased with an increase in nitrogen application rates, while significant differences were recorded between the treatment with no nitrogen fertilisation and two greatest doses of this nutrient, which was confirmed in a study by BIELSKI et al. (2015). In turn, the greatest bread volume was found from the treatment fertilised with 60 kg N ha^{-1}. In the opinion of ZECEVIC et al. (2010), due to the low quality of triticale, a potential improvement in properties of baked bread could be provided by an addition of wheat flour.

Conclusions

Collected observations showed that flour of winter triticale cv. Gniewko, irrespective of the water and nitrogen fertilisation variants, exhibits low applicability for the baking industry. This results from the fact that despite improvement in certain parameters of grain, flour and dough under the influence of sprinkling irrigation and nitrogen fertilisation, faults were found in the produced bread and it did not meet requirements for bread for human consumption. The low falling number in the analyzed grain, low gluten content and falling number in the flour contributed to the formation of dough with poor farinographic characteristics, followed by low yield and bread volume.

Translated by Anna Binczarowska

Accepted for print 13.07.2017

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