FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin. 2009, Agric., Aliment., Pisc., Zootech. 274 (12), 75–90

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QUALITY OF BREAD MADE FROM RYE GROWN WITH CONVENTIONAL AND ECOLOGICAL METHODS

JAKOŚĆ PIECZYWA Z ŻYTA POCHODZĄCEGO Z UPRAW KONWENCJONALNYCH I EKOLOGICZNYCH

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Abstract. There were checked the baking proprieties of six rye cultivars coming from conventional and ecological tillages. Bread made from rye grown with conventional method characterized with higher volume and imperceptibly lower baking loss. The way of tillage had no essential influence on porosity. Bread made from cultivar Conduct grown with ecological way received the highest notes in the sensory assessment (31.5 points). The addition of 1-moll lactic acid to the dough enlarged bread volume, bread porosity and the total baking loss, not influencing on the sensory assessment of breads. In dependence of analyzed feature of texture the factor of changeability (the way of tillage, cultivar and the method of baking) influenced on the reological properties of breads from rye flour in different degree. The hardness, gumminess and chewiness of crumb depended on way of tillage, then on cultivar as well as the addition of souring agent. The cohesiveness of crumb depended on the way of tillage mainly. However there was affirmed no influence of the studied variables on bread springiness.

Słowa kluczowe: chleb, mąka, tekstura, TPA, uprawa konwencjonalna i ekologiczna, żyto.
Key words: bread, ecological and conventional tillage, flour, rye, texture, TPA.

INTRODUCTION

The principal component of rye bread is the sourdough produced by fermentation of rye flour (so called the bakery leaven), so the rye bread contains more components of correct diet in organism nutrition than other breads (Dewettinck et al. 2008). It is the source of plant proteins, unsaturated fats, minerals, some vitamins as well as ballast substances.

Rye is a cereal grown in Europe mainly. The countries of former Soviet Union, Poland and Germany are the largest rye producers. Tillage of rye (as cereal plant) occupies the largest surface in Poland, however its participation in crops places it on the third position really. The interest in rye tillage diminishes gradually in our country. The reason of this phenomenon is the crossing on more remunerative tillages (triticale, barley) and the elimination of some kinds of soils. In spite of low soil quality requirements, the interest in rye as a bread cereal falls too. The main reason of such state is the compliance to the standards of Western Europe countries and the USA as well as the more difficult technology of production of rye bread.

Aiming to enlarge the meaning of rye as a bread cereal there are introduced to tillage the new rye cultivars of high yield and there are propagated ecological tillages. There is the opinion that in ecological agriculture some material expenditures can be replaced by the knowledge, but it requires the enlarged expenditure of work. In some farms such way of tillage requires about 30% larger expenditure of work per 1 hectare of agricultural areas than traditional way of tillage, but the earnings of ecological farm can be approximately 7% higher (Runowski 1996). This is result of higher prices of ecological products (Siebeneicher 1993). Searching of the new cereals cultivars of good technological values becomes the basic question of agriculture. Their tillage is the attempt to obtain a good raw material of desired qualitative values. One of the more important questions is the assessment of commodities and technological quality of flours as well as final products, with regard on economic meaning. Technological value, called also processing value, depends on grain specific proprieties, what are defining the cereal processing potential usefulness. The essential influence on technological value of grain has also soil quality, genetic features of grown cultivars as well as agrotechnical factors, among which the largest meaning has the way of tillage. The aim of present work is characteristic and the comparison of influence of conventional and ecological tillages of rye on the baking values of received flours.

MATERIAL

There were investigated the samples of rye flours received from grain from research conducted in year 2006 at State Research Institute for Agriculture and Fisheries Mecklenburg-Western Pomerania in Gülzow (Germany) – Table 1.

Table 1. The sign of flour samples
Tabela 1. Oznaczenia prób mąki

Cultivar Odmiana	The system of tillage System uprawy	
	conventional tillage system uprawa konwencjonalna	ecological tillage system uprawa ekologiczna
Pollino	301	302
Recrut	303	304
Conduct	305	306
Askari	307	308
Carotop	309	310
Carodss	311	312

In the conventional tillage there was applied nitrogen fertilization in quantity of 130 kg N · ha^{-1}, meanwhile in the ecological tillage the source of nitrogen was the mixture of clover and grass as a forecrop. The samples of grain were milled on flour on the dimension apparatus Quadrumat Senior in Division of Cereal Technology of SGGW (Warsaw University of Life Sciences) in Warsaw. There was got the average flour yield of 51%.

METHODS

Control baking

The control baking was carried out according to the direct method by Horubałowa and Haber (1989) and ICC Standard No.131.

Dough was prepared in mixer Hobart Kitchen Aid (USA). There was weighed out 250 g of flour with moisture of 15%. In case of appointed moisture different than 15% there was applied an equation:

$$X = (S \times 100) / (100 - w)$$

where:

X – the searching mass of investigated flour of appointed moisture,

S – the content of dry substance in 250 g of flour with moisture of 15%, in g (212.5 g),

w – the moisture of investigated flour, in %.

There was measured the amount of water necessary to obtain the dough yield of 165% (162.5 cm^3). In case of rye bread and wheat-rye bread with lactic acid addition there was applied the addition of water in quantity of 154.5 cm^3, and 8 cm^3 of the 1-moll lactic acid. The accounted quantity of water was suitably reduced or enlarged of so many cm^3, how many grams of flour were used up more or less in relation to 250 g of flour with 15% of moisture. There was measured out the addition of yeast (3% in relation to quantity of flour) as a water suspension (water was taken from total amount of water). There was measured out the addition of salt (1.5% in relation to amount of flour) as a water solution (water was taken from total amount of water). Water has been dosing such a way to ensure the temperature of dough carrying out 32°C. Dough growth was led in temp. 32°C by 1 hour in the proofing chamber of Unox S.P.A. (Italy), type XL, model XL 091 in relative air moisture of 75 – 80%. Then there were formed dough of mass of 350 g. Formed bites were subjected the final fermentation in temperature of 35°C. The time of final dough fermentation to obtain its full maturity carried out 20 – 40 minutes. The process of bread baking was led in the electric baking Unox S.P.A. (Italy), type XF, in temp. of 230 – 240°C by 35 – 40 min. There was applied the baking evaporation by 3 seconds every 5 minutes for first 15 minutes of baking process.

Sensory evaluation

The sensory evaluation of bread was executed 6 – 8 hours after baking according to Polish Standard PN-A-74108 and ICC Standard No.131.

Bread porosity

The porosity of bread was estimated according to the porosity table by Dallman (Horubałowa and Haber 1989). The recording of the crumb appearance was conducted applying MultiScan imagine analysis equipment.

Bread volume

Bread volume was marked in Sa-Wy apparatus.

Dough yield

The dough yield was estimated according to equation:

$$X = (a \times 100)/ m \quad (\%)$$

where:

a – the mass of dough, in g,

m – the mass of used flour with moisture of 15%, in g.

Baking loss

The baking loss was counted according to equation:

$$X = ((a - b) \times 100) / a \quad (\%)$$

where:

a – the mass of dough formed to baking, in g,

b – the mass of hot bread after baking, in g.

Bread yield

The bread yield was counted according to equation:

$$X = (c \times w) / a \quad (\%)$$

where:

c – the mass of cooled bread, in g,

w – the dough yield, in %,

a – the mass of dough formed to baking, in g.

Total baking loss

The total baking loss was counted according to equation:

$$X = ((a - c) \times 100) / a \ (\%)$$

where:

a – the mass of dough formed to baking, in g,

c – the mass of cooled bread, in g.

Analysis of the texture profile

The analysis of profile of texture (TPA) was executed on bread crumb using the Texture Analyser apparatus TA – XT 2/25 (Stable Micro Systems®, Great Britain), coupling with computer by its own widening card. The steering was carried out by Texture Expert programme for Windows® v. 1.22. The speed of pin was 2 mm $\cdot$ s^{-1} before the beginning of test, and 5 mm $\cdot$ s^{-1} in time of test and after it. There was used the cylindrical pin with diameter of 0.5 inch (SMS P/0.5") and the twofold deformation of sample up to 50% of its height. The course of test was recorded as curves representing changes of strengths in time. Applying the calculating programme (tpafrac.mac) there were determined the following parameters of texture profile: hardness, cohesiveness, springiness, resilience, gumminess and chewiness.

Study of results

The received results were worked out statistically with utilization of Excel® and Statistica® 8.0 PL programmes. The significant differences were marked with Scheffe test with the level of significance $p \leq 0.05$.

RESULTS AND DISCUSSION

The summary results of test baking have been shown in Tables 2 and 3. The features of rye breads received by method of test baking depended on the kind of flour as well as the addition of 1-moll lactic acid to the dough. The properties of the sourdough in the bread texture forming process are widely known (De Vuyst and Neysens 2005, De Angelis et al. 2006, Arendt et al. 2007), there is also known its microflora, where some species of yeasts are present. Thus, the application of sourdough might cause disturbing of the proper aim of the experiment. Therefore, there had been decided to use the addition of 1-moll lactic acid. The volume of bread varied from 520 to 680 cm^3, and the average volume of bread with addition of 1-moll lactic acid was higher (642 cm^3) than in case of bread without it (565 cm^3). Simonson et al. (2003) have been examining the behaviour of sourdough in different temperatures, with different salt concentrations and the addition of enzymes. They affirmed that the low pH helped the activity of α-amylase, what translated directly on the structure of flour starch and its baking properties. This situation can be also affected by the presence of arabinoksylan and its gel formation properties (Dervilly-Pinel et al. 2001). The way of the rye tillage also influenced on the qualitative features of bread. Bread from rye grown with conventional methods characterized with higher volume (574 ± 21.5 cm^3) in comparison with bread got from rye grown with ecological methods (555 ± 25.7 cm^3). It can be explained with activity of native alpha-amylase. The optimum level of enzymes had a positive effect on the technological features of rye flour. In case of small doses of fertilization there was observed the increase of falling number, what was caused by the decrease of alpha-amylase activity. In case of high doses of fertilization there was observed decrease of activity of this enzyme in wheat (Mazurek 1987). According to Iwański et al. (2006) the content of enzymes in flour grows up with moisture of flour. However, the microbiological activity also grows up together with growth of water content, what is unfavourable phenomenon because of possibility of raw material spoilage.

Therefore there can be told about compromise between high content of own enzymes and the production of bread from flour with high moisture. Baking loss (14.2 – 19.7%) was comparable for both ways of tillage. Average value of this feature was imperceptibly lower (16.5 ± 1.6%) in case of bread received from rye grown with conventional method than in case of bread received from rye grown with ecological method (16.8 ± 1.6%). It might be caused by nitrogen fertilization, what is very essential agronomic factor, strongly influencing on the level of crop and the quality of grain. The kind of applied forecrop also influences on content of nitrogen in soil. The soil conditions formed by forecrop influence on size and quality of crops of different cereal species in larger degree than the genetic value of cultivars (Bojarczuk 1995). Applying of lactic acid during baking process had no significant influence on the baking loss size. The bread without addition of 1-moll lactic acid was characterized with imperceptibly higher baking loss (16.8 ± 1.5%) in comparison to bread with addition of 1-moll lactic acid (16.6 ± 1.7%). The total baking loss of bread from rye grown with conventional methods (20.8 ± 0.9%) was also imperceptibly lower in comparison to bread from rye grown by ecological way (21.2 ± 0.9%). The results of investigations of Piech et al. (1988) show the insignificant influence of the fertilization on the water absorption of flour, what can also explain the unimportant variations of mass in baking process. Haber et al. (1981) and Cacak-Pietrzak et al. (1999) affirmed the positive influence of enlarged fertilization on the water absorption of wheat flour. Applying of 1-moll lactic acid imperceptibly enlarged the total baking loss of bread at an average of about 0.4%. The porosity of bread estimated by the Dallman method (Horubałowa and Haber 1989) varied from 60 to 100 points.

Table 2. The mean results of control baking process
Tabela 2. Średnie wyniki wypieku kontrolnego

Trait Cecha	Tillage system Metoda uprawy											
	conventional tillage system uprawa konwencjonalna						ecological tillage system uprawa ekologiczna					
	Probe number Numer próby											
	301	303	305	307	309	311	302	304	306	308	310	312
The average moisture of flour [%] Średnia wilgotność mąki [%]	9.8	9.1	10.5	10.3	9.9	9.8	9.5	9.7	10.0	10.1	9.8	9.8
The addition of flour [g] Naważka mąki [g]	236	234	237	237	236	236	235	235	236	236	236	236
The addition of water [cm^3] Dodatek wody [cm^3]	177	179	175	176	177	177	178	177	177	176	177	177
The addition of water – The addition of lactic acid [cm^3] Dodatek wody – kwas mlekowy [cm^3]	169	171	167	168	169	169	170	169	169	168	169	169
The addition of lactic acid [cm^3] Dodatek kwasu mlekowego [cm^3]	8	8	8	8	8	8	8	8	8	8	8	8
The addition of yeasts [g] Dodatek drożdży [g]	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
The addition of salt [g] Dodatek soli [g]	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
The bread without the addition of 1M lactic acid in dough processing Pieczywo bez dodatku 1-molowego kwasu mlekowego w procesie produkcji ciasta												
Dough weight [g] Masa ciasta [g]	399	405	391	403	414	404	402	412	404	406	409	410
The bakery processing ready dough weight [g] Masa ciasta uformowanego do wypieku [g]	353	352	354	356	356	354	353	352	352	357	355	357
The weight of bread directly after bakery processing [g] Masa pieczywa gorącego [g]	286	293	290	301	302	301	288	291	287	297	301	303
The weight of consumption ready bread [g] Masa pieczywa ostudzonego [g]	277	280	279	283	285	286	276	276	276	279	285	287
The volume of bread [cm^3] Objętość chleba [cm^3]	585	595	585	555	585	540	570	555	540	595	520	550
Baking loss [%] Strata piecowa [%]	19.0	17.0	18.0	15.4	15.2	15.0	18.5	17.4	18.6	16.7	15.2	15.1
Total baking weight loss [%] Strata wypiekowa całkowita [%]	21.5	20.5	21.2	20.5	19.9	19.4	21.8	21.6	21.8	21.9	19.8	19.5
The bread with 1 M lactic acid addition in dough processing Pieczywo z ciasta ukwaszonego (z dodatkiem 1 M kwasu mlekowego)												
Dough weight [g] Masa ciasta [g]	410	413	396	408	414	405	406	413	411	409	413	407
The bakery processing ready dough weight [g] Masa ciasta uformowanego do wypieku [g]	352	353	352	355	355	355	352	352	355	355	357	35
The weight of bread directly after bakery processing [g] Masa pieczywa gorącego [g]	290	292	286	305	299	302	290	292	285	301	302	302
The weight of consumption ready bread [g] Masa pieczywa ostudzonego [g]	281	276	274	280	281	285	276	276	275	279	286	283
The volume of bread [cm^3] Objętość chleba [cm^3]	670	670	640	680	650	660	620	655	530	665	625	635
Baking loss [%] Strata piecowa [%]	17.7	17.2	18.9	14.2	15.7	15.0	17.7	17.2	19.7	15.2	15.2	15.6
Total baking weight loss [%] Strata wypiekowa całkowita [%]	20.4	21.7	22.4	21.3	21.0	19.7	21.5	21.7	22.4	21.5	19.9	21.0

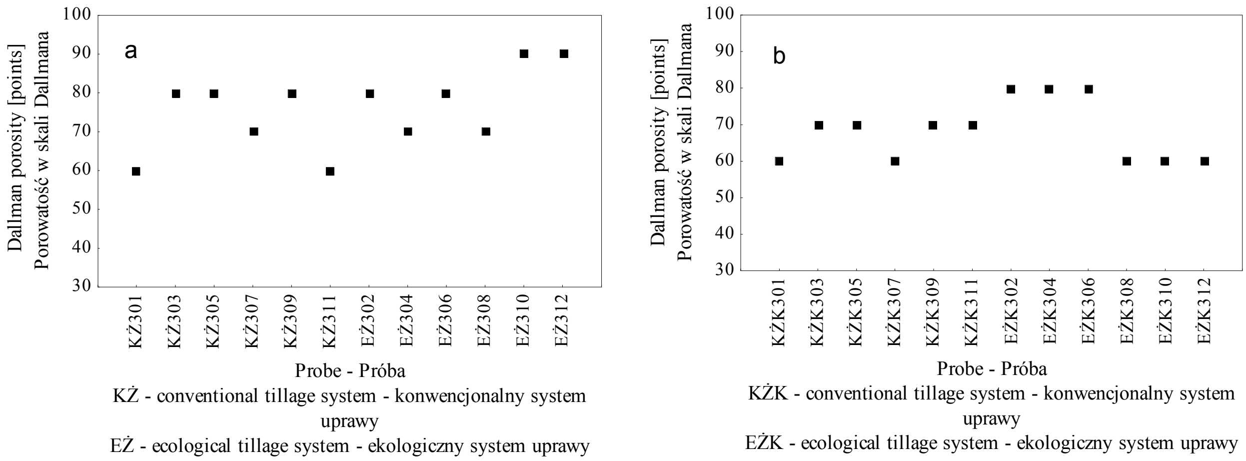


Fig. 1. Porosity of studied bread estimated by the Dallman method. The bread without (a) and with (b) the addition of 1-moll lactic acid in dough processing

Rys. 1. Porowatość badanego pieczywa oceniana metodą Dallmana. Próba bez (a) i z dodatkiem (b) 1-molowego kwasu mlekowego w procesie produkcji ciasta.

Bread from rye of cultivars Carodss, Carotop and Ascari characterized with the lowest porosity. Generally, bread with addition of 1-moll lactic acid showed porosity about 10 points higher than bread without it. The way of tillage had only insignificant influence on porosity. Bread from rye grown by conventional way characterized with higher porosity (68 ± 7.8 point) in comparison to bread from rye grown with ecological methods (71.3 ± 17.3 points). Thus, on porosity of rye bread there influenced, apart from rye cultivar, the way of dough processing at first (with or without 1-moll lactic acid) and the way of tillage in farther order. It should be also mentioned here about specific proteins of rye flour, what limit the regularity of forming of the crumb structure.

The results of sensory evaluation of received rye bread, executed by the Banecki method (PN-A-74108) (without physical and chemical properties), were rather diversified and they varied from 15 to 31.5. The highest notes (31.5 points) received breads from rye of cultivar Conduct grown with ecological way. However, breads obtained from cultivar Pollino grown with ecological way were disqualified because of crumb features which was uneven and it was separated from crust. There was affirmed no clear influence of lactic acid applying on results of sensory evaluation. In some cases the presence of 1-moll lactic acid enlarged the general opinion and it reduced it in other cases. The carbon-amylolitic complex forms the structure of rye dough. It seems, that peptidized proteins can show some protective influence by starch retrogradation preventing, because they create colloidal solution with dispersed grains of starch, swelled proteins and bran parts in it (Iwański et al. 2007).

Table 3. Mean results of control baking process. Sensory evaluation
Tabela 3. Średnie wyniki wypieku kontrolnego. Ocena sensoryczna

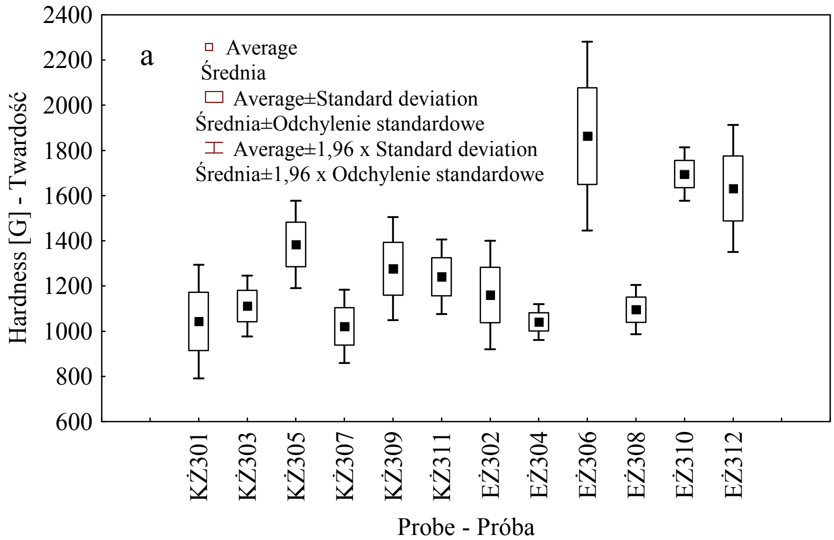
Trait Cecha	Probe number – Numer próby											
	301	301K	303	303K	305	305K	307	307K	309	309K	311	311K
External appearance Wygląd zewnętrzny	0	0	4	4	0	4	4	4	4	5	5	4
Crust / colour Skórka / barwa	3	3	3	3	2	3	2	2	2	2	3	2
Crust / thickness Skórka / grubość	3	3	4	3	3	3	4	0	3	3	3	4
Crust / others Skórka / pozostałe cechy	4	4	4	4	3	3	3	0	3	3	4	4
Crumb / resilience Miękisz / elastyczność	4	3	4	4	4	4	4	4	3	4	4	3
Crumb / porosity Miękisz / porowatość	3	3	3	3	0	0	2	2	2	3	0	2
Crumb / others Miękisz / pozostałe cechy	2	2	2	2	2	2	2	2	0	3	2	2
Taste and flavour Smak i zapach	5	5	5	5	5	6	5	5	6	5	5	5
	302	302K	304	304K	306	306K	308	308K	310	310K	312	312K
External appearance Wygląd zewnętrzny	0	0	4	0	5	5	4	0	4	4	4	4
Crust / colour Skórka / barwa	2	2	3	2	3	3	2	2	2	3	3	3
Crust / thickness Skórka / grubość	0	0	4	4	4	4	0	0	3	4	4	4
Crust / others Skórka / pozostałe cechy	4	4	4	3	4	4	3	3	4	4	4	3
Crumb / resilience Miękisz / elastyczność	4	4	4	4	4	4	4	4	4	4	4	4
Crumb / porosity Miękisz / porowatość	0	0	3	2	3	3	0	2	0	3	2	3
Crumb / others Miękisz / pozostałe cechy	-35	-35	3	3	2	2	2	3	0	2	2	2
Taste and flavour Smak i zapach	5	5	5	5	6	5	5	5	5	5	5	5

[1]K – dough with 1-moll lactic acid addition – ciasto z dodatkiem 1-molowego kwasu mlekowego.

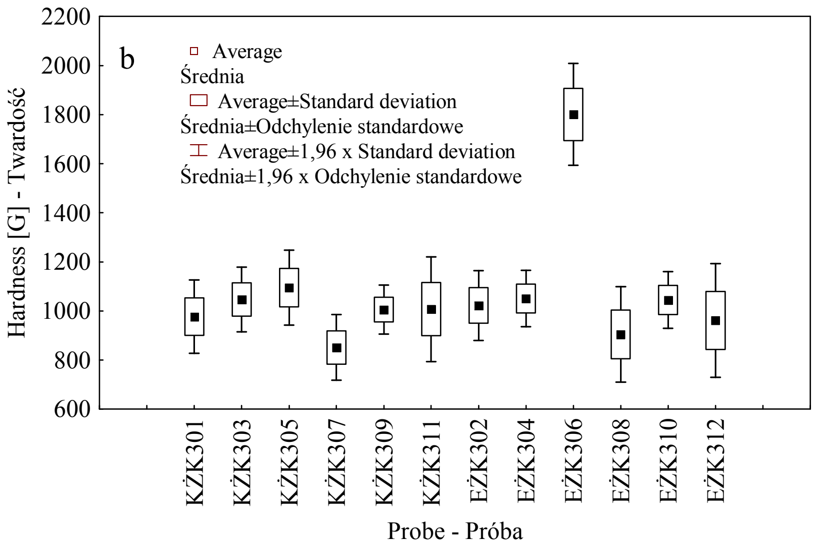
By Gąsiorowski and Kołodziejczyk (1994), the technological value of rye depends on environmental factors mainly, and less on soil conditions and agrotechnical parameters. Although the content of total protein in rye (9–11%) is lower than in wheat, it characterizes the higher rate of nonprotein nitrogen (amino acids, amides and other nitrogenous components) at the level of 6–12% of the total nitrogen. The quantity of water soluble nitrogen substances decides about quality of rye bread and it can come up to 30–50% of total proteins. The water soluble rye proteins influence on dough yield, its properties and first of all on crumb resilience and sourdough acidity, so in consequence they influence on porosity and flavour of bread. The significant influence on structure of rye bread has also the carbonate-amylolytic complex, especially pentosans and glukosides (Jarosz 1998). Therefore the properties of rye dough are defined by properties of sticky liquid phase, where there are swelled proteins, peptidized mucuses, soluble dextrins and other water soluble substances in (Ambroziak 1998). In comparison to wheat bread, the rye bread characterizes with lower specific volume (nearly twice) and the higher hardness of crumb (Pasqualone et al. 2004).

In dependence of analyzed feature of texture, the factor of changeability (the way of tillage, the cereal cultivar, and the way of baking process) had different influence on the reologic properties of breads from rye flour.

The hardness of crumb of studied samples depended on the way of tillage in first order, then on the rye cultivar and the addition of 1-moll lactic acid to dough before baking process.



KŻ - conventional tillage system - konwencjonalny system uprawy
EŻ - ecological tillage system - ekologiczny system uprawy



KŻK - conventional tillage system - konwencjonalny system uprawy
EŻK - ecological tillage system - ekologiczny system uprawy

Fig. 2. Hardness of studied bread estimated by the TPA method. The bread without (a) and with (b) the addition of 1-moll lactic acid in dough processing
Rys. 2. Twardość badanego pieczywa oceniana metodą TPA. Próba bez (a) i z dodatkiem (b) 1-molowego kwasu mlekowego w procesie produkcji ciasta

The bread from rye grown with ecological method characterized with about 16% higher value of the crumb hardness in reference to the bread from rye grown with conventional method. Differences of bread crumb hardness statistically essential at $p \leq 0.05$ were affirmed mainly among the rye cultivars grown with ecological method (Table 4).

Table 4. Values of profile texture parameters of bread crumb baked from different rye cultivars
Tabela 4. Wartości parametrów profilu tekstury miękiszów chleba wypieczonego z ziarna żyta różnych odmian

Cultivar Odmiana	The way of baking (with or without 1-moll lactic acid addition) Sposób wypieku (z dodatkiem lub bez dodatku 1-molowego kwasu mlekowego)	Probe number Numer próby	TPA test parameters Parametry tekstury											
			hardness twardość		gumminess gumiastość		chewiness zżuwalność		springiness springiness		cohesiveness cohesiveness		resilience resilience	
			$\bar{x}$	SD [1]	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
			Conventional tillage system Uprawa konwencjonalna											
Pollino	without acid bez kwasu	301	1043^{a} [2]	128	672^{a}	90.7	651^{a}	86.5	0.968^{a}	0.023	0.644^{a}	0.020	0.347^{a}	0.024
	with acid z kwasem	301K	977^{ef} [3]	76	603^{ef}	61.7	587^{ef}	60.9	0.973^{e}	0.012	0.616^{eg}	0.021	0.320^{e}	0.012
Recrut	without acid bez kwasu	303	1111^{ab}	69	704^{ab}	44.7	682^{ab}	44.5	0.970^{a}	0.012	0.633^{a}	0.008	0.342^{a}	0.003
	with acid z kwasem	303K	1047^{e}	67	614^{e}	50.9	592^{e}	48.7	0.964^{e}	0.009	0.586^{ef}	0.018	0.299^{ef}	0.023
Conduct	without acid bez kwasu	305	1384^{c}	99	805^{c}	57.8	773^{c}	60.7	0.960^{a}	0.011	0.582^{b}	0.021	0.295^{b}	0.020
	with acid z kwasem	305K	1095^{e}	78	637^{e}	47.5	622^{e}	46.6	0.976^{e}	0.017	0.582^{f}	0.014	0.289^{fg}	0.011
Askari	without acid bez kwasu	307	1021^{ad}	83	652^{ad}	47.5	624^{ad}	46.4	0.957^{a}	0.011	0.639^{a}	0.014	0.323^{ab}	0.014
	with acid z kwasem	307K	8518^{f}	68	545^{f}	50.7	518^{f}	44.8	0.952^{e}	0.013	0.639^{g}	0.013	0.322^{e}	0.009
Carotop	without acid bez kwasu	309	1276^{bc}	116	831^{bc}	93.7	809^{bc}	89.9	0.974^{a}	0.007	0.650^{a}	0.028	0.335^{a}	0.031
	with acid z kwasem	309K	1006^{e}	51	634^{e}	31.1	614^{e}	26.3	0.969^{e}	0.021	0.631^{g}	0.020	0.318^{eg}	0.020
Carodss	without acid bez kwasu	311	1241^{bc}	84	792^{bc}	68.9	773^{bc}	69.9	0.976^{a}	0.008	0.638^{a}	0.022	0.326^{ab}	0.018
	with acid z kwasem	311K	1008^{e}	109	626^{e}	66.9	612^{e}	69.1	0.977^{e}	0.010	0.622^{g}	0.015	0.307^{eg}	0.020

Cont. Table 4. – cd. tabela 4.

		Ecological tillage system Uprawa ekologiczna												
Pollino	without acid bez kwasu	302	1160 ^{a}	123	756 ^{a}	84.8	728 ^{a}	78.3	0.964 ^{a}	0.017	0.652 ^{a}	0.028	0.345 ^{a}	0.027
	with acid z kwasem	302K	1023 ^{e}	73	636 ^{e}	50.8	616 ^{e}	52.6	0.968 ^{e}	0.012	0.622 ^{e}	0.019	0.315 ^{e}	0.017
Recrut	without acid bez kwasu	304	1041 ^{a}	40	627 ^{a}	41.7	595 ^{a}	42.7	0.949 ^{a}	0.034	0.603 ^{ab}	0.037	0.316 ^{ab}	0.038
	with acid z kwasem	304K	1051 ^{e}	59	614 ^{e}	40.2	596 ^{e}	47.6	0.970 ^{e}	0.030	0.584 ^{fgh}	0.008	0.296 ^{e}	0.004
Conduct	without acid bez kwasu	306	1863 ^{b}	213	1035 ^{b}	114	974 ^{b}	112	0.940 ^{a}	0.020	0.557 ^{b}	0.040	0.237 ^{c}	0.028
	with acid z kwasem	306K	1801 ^{f}	106	973 ^{f}	68.5	913 ^{f}	67.4	0.938 ^{e}	0.017	0.540 ^{i}	0.013	0.229 ^{f}	0.006
Askari	without acid bez kwasu	308	1095 ^{a}	55	673 ^{a}	36.2	644 ^{a}	36.4	0.957 ^{a}	0.012	0.614 ^{a}	0.012	0.303 ^{ad}	0.013
	with acid z kwasem	308K	905 ^{e}	99	540 ^{e}	62.3	509 ^{e}	61.7	0.942 ^{e}	0.019	0.597 ^{ef}	0.016	0.289 ^{e}	0.018
Carotop	without acid bez kwasu	310	1695 ^{bc}	60	1003 ^{bc}	35.3	945 ^{bc}	43.7	0.943 ^{a}	0.016	0.592 ^{b}	0.011	0.275 ^{bcd}	0.013
	with acid z kwasem	310K	1045 ^{e}	59	624 ^{e}	50.5	593 ^{e}	52.8	0.950 ^{e}	0.012	0.596 ^{eg}	0.019	0.292 ^{e}	0.017
Carodss	without acid bez kwasu	312	1631 ^{c}	143	972 ^{c}	64.9	946.9 ^{c}	54.7	0.975 ^{a}	0.013	0.597 ^{b}	0.022	0.283 ^{bd}	0.026
	with acid z kwasem	312K	962 ^{e}	118	574 ^{e}	71.8	539.8 ^{e}	63.6	0.942 ^{e}	0.020	0.597 ^{eh}	0.021	0.295 ^{e}	0.019

[1] standard deviation – odchylenie standardowe.

[2] Means followed by different letters (for each cultivation system) are significantly different according to Scheffe test at p=0.05 in group of breads without 1-moll lactic acid addition in dough processing.

Średnie oznaczone różnymi literami (dla każdego systemu upraw) różnią się istotnie przy p = 0,05 wg testu Scheffego, w grupie wypieku bez dodatku 1-molowego kwasu mlekowego do ciasta.

[3] Means followed by different letters (for each cultivation system) are significantly different according to Scheffe test at p=0.05 in group of breads with 1-moll lactic acid addition in dough processing.

Średnie oznaczone różnymi literami (dla każdego systemu upraw) różnią się istotnie przy p = 0,05 wg testu Scheffego, w grupie wypieku z dodatkiem 1-molowego kwasu mlekowego do ciasta.

The hardest crumb among analyzed breads characterized cultivar Conduct. As it was mentioned already, the higher values of hardness were noted down in case of ecological tillage (1862.9 [G]) than conventional (1383.9 [G]). Equally hard crumb was present in breads baked from flour from cultivars Carotop (1694.9[G] and 1276.4 [G]) and Carodss (1631.4 [G] and 1240 [G]). The least hard crumb marked the bread from cultivars Askari (1021.3 [G] and 1095.4 [G]), Pollino (1043.4 [G] and 1160.3 [G]) and Recrut (1111.3 [G] and 1040.9 [G]). The statistically essential differences ($p \le 0.5$) of crumb hardness of bread baked without 1-moll lactic acid addition were found between cultivars Conduct, Carotop, Carodss and other cultivars used in test, grown in ecological tillage (Table 4). In majority of cases the addition of 1-moll lactic acid contributed to decrease of crumb hardness of studied samples of about 15% in case of conventional tillage and about 23% in ecological tillage. However, it was found no essential ($p \le 0.05$) influence of 1-moll lactic acid addition on changes of crumb hardness in case of all studied rye cultivars except the Conduct cultivar (the statistically essential differences on the same significant level in relation to other cultivars) (Table 4).

The changes of gumminess and chewiness of bread crumb were the reflection of the hardness changes. There were observed similar dependences of these texture parameters on cultivar, way of tillage or 1-moll lactic acid addition as in case of hardness. The highest values of gumminess (ca. 1000) and chewiness (ca. 900) were noted during the investigation of crumb of bread baked from flour coming from cultivars Conduct, Carotop and Carodss (Table 4). The average value of gumminess and chewiness of crumb of other breads was ca. 600. The kind of tillage had considerable influence on the values of these parameters. Breads from flour coming from rye with ecological tillage characterized with more gummy (ca. 10%) and harder chewable (ca. 8%) crumb than that coming from conventional tillage, independently on the fact whether they had been baked with or without addition of 1-moll lactic acid (Table 4). The largest influence on the decrease of values of gumminess and chewiness had the addition of lactic acid to dough prepared from cultivar Carotop and Carodss which was about 23% in conventional tillage and about 40% in ecological tillage. Statistically essential differences at $p \le 0.05$ referred to the same dependences which was affirmed during analysis of hardness of studied samples (Table 4).

There were no statistically essential differences ($p \le 0.05$) of bread crumb springiness among analyzed rye cultivars, among way of baking or among way of tillage, though more springy (ca. 1.5%) there was the crumb of bread made from corn grown with conventional method (Table 4). The most springy crumb (ca. 0.976) characterized the bread from flour got from cultivar Carodss grown conventionally, baked both with and without 1-moll lactic acid. The least springy crumb (0.939) was affirmed in case of cultivar Conduct grown by ecological way (the largest hardness).

There was noticed no considerable influence of kind of tillage on value of crumb cohesiveness of studied breads, though the conventional tillage contributed to small increase of its cohesiveness of about 4.5% in relation to ecological tillage (Table 4). The smallest cohesiveness of crumb was marked for the cultivar Conduct (ca. 0.582 in conventional tillage and ca. 0.549 in ecological tillage), regardless of way of baking. Other samples characterized with cohesiveness on level of about 0.641 (conventional tillage) or about 0.611 (ecological tillage). The addition of 1-moll lactic acid to the dough caused the decrease of crumb cohesiveness of the studied breads in average about 3%, regardless of cultivar and the way of tillage (Table 4). The statistically essential differences of cohesiveness ($p \le 0.05$) were affirmed between the Conduct cultivar and other cultivars mainly and they were for both comparisons, the influence of way of tillage as well as the addition of 1-moll lactic acid to dough.

The way of rye tillage influenced on differentiation of resilience of studied samples. Bread baked from flour coming from conventional tillage characterized with greater resilience in average of about 11% than the one from flour got from rye with ecological tillage. The addition of 1-moll lactic acid influenced on decrease of crumb resilience in average of about 6%, regardless of rye cultivar and the way of tillage. Only in case of cultivars Carotop and Carodss grown by ecological way there was affirmed the increase of crumb resilience after addition of 1-moll lactic acid to the dough, of about 6% and 4% respectively. The least resilient crumb (ca. 0.237) characterized bread baked from rye of cultivar Conduct, coming from the ecological tillage (resilience about 20% smaller than from the conventional tillage). The most resilient crumb (ca. 0.332) characterized bread from cultivar Pollino, prepared with 1-moll lactic acid as well as without it (Table 4). The differences of crumb resilience, statististically essential at $p \le 0.05$ where marked between the cultivar Conduct and the other rye cultivars, independently on way of tillage, as well as the addition of 1-moll lactic acid to the dough (Table 4).

REFERENCES

Ambroziak Z. 1998. Piekarstwo i ciastkarstwo [Bakery and Confectionary Products]. Warszawa, WNT, 189–190 [in Polish].

Arendt E.K., Ryan L.A.M., Dal Bello F. 2007. Impact of sourdough on the texture of bread. Food Microbiology 24, 165–174.

Bojarczuk J. 1995. Reakcja heksaploidalnego pszenżyta ozimego na niekorzystne warunki fitosanitarne gleby. Część I. Ocena fitosanitarna wartości przedplonów [The reaction of the winter heksaploidal triticale on unfavourable fitosanitary conditions of the soil. Part I. The fitosanitary assessment of the forecrop value]. Hod. Roś. Aklim. Nasienn. 39 (1/2), 3–17 [in Polish].

Cacak-Pietrzak G., Cieglińska A., Haber T. 1999. Wartość technologiczna wybranych odmian pszenicy ozimej w zależności od zróżnicowanego nawożenia azotowego [The technological value of chosen cultivars of winter wheat in dependence on diverse nitrogen fertilization]. Pamięt. Puł. 118, 45–55 [in Polish].

De Angelis M., Coda R., Silano M., Minervini F., Rizzello C.G., Di Cagno R., Vincentini O., De Vincenzi M., Gobbetti M. 2006. Fermentation by selected sourdough lactic acid bacteria to decrease coeliac intolerance to rye flour. J. Cereal Sci. 43, 301–314.

Dervilly-Pinel G., Rimsten L., Saulnier L., Andersson R., Åman P. 2001. Water-extractable arabinoxylan from pearled flours of wheat, barley, rye and triticale. Evidence for the presence of ferulic acid dimmers and their involvement in gel formation. J. Cereal Sci. 34, 207–214.

De Vuyst L., Neysens P. 2005. The sourdough microflora: biodiversity and metabolic interactions. Trends Food Sci. Technol. 16, 43–56.

Dewettinck K., Van Bockstaele F., Kühne B., Van de Walle D., Courtens T.M., Gellynck X. 2008. Nutritional value of bread: influence of processing, food interaction and consumer perception. J. Cereal Sci. 48, 243–257.

Gąsiorowski H., Kołodziejczyk P. 1994. Wartość technologiczna żyta i metody jej oceny [w: Żyto. Chemia i technologia] [Technological value of rye and methods of its assessment (in: Rye. Chemistry and technology)]. Ed. H. Gąsiorowski. Poznań, PWRiL, 170–184 [in Polish].

Haber T., Pątek J., Czuchaj D., Dziewulska T. 1981. Wpływ poziomu i terminu nawożenia azotowego na wartość technologiczną pszenicy „Alfa" i „Kolibri" [The influence of level and date of nitrogen fertilisation on the technological value of wheat "Alpha" and "Kolibri"]. Zesz. Nauk. SGGW-AR 14, 67–79 [in Polish].

Horubałowa A. Haber T. 1989. Analiza techniczna w piekarstwie [Technical analysis in bakery industry]. Warszawa, WSiP [in Polish].

ICC Standard No. 131. Procedura wypieku kontrolnego [The procedure of control baking] [in Polish].

Iwański R., Wianecki M., Cebulska J., Adamkiewicz M., Rumińska A. 2006. Wpływ modyfikacji enzymatycznej na jakość pieczywa pszennego i pszenno-żytniego [Influence of the enzymatic modification on the wheat and wheat-rye bread quality]. Folia Univ. Agric. Stetin., Ser. Scientia Aliment. 251, 23–32 [in Polish].

Iwański R., Wianecki M., Mierzwa M., Szymczak M., Zieliński K., Stanisz P., Klinkosz D., Kłosowska E., Księżak E., Tubacka M. 2007. Wpływ temperatury przechowywania na teksturę i strukturę pieczywa [The influence of storage temperature on the texture and the structure of bread]. Folia Univ. Agric. Stetin., Ser. Agric., Aliment., Pisc., Zootech. 262, 37–48 [in Polish].

Mazurek J., Biskubski A., Maj L. 1987. Wpływ nawożenia azotowego i ilości wysiewu na plonowanie i wartość technologiczną pszenicy jarej [The influence of nitrogen fertilisation and sowing quantity on the crop and technological value of the spring wheat]. *Biul. IHAR* 164, 215–228 [in Polish].

Pasqualone A., Caprio F., Summo C., Arapi V. 2004. Characterization of traditional Albanian breads derived from different cereals. Eur. Food Res. Technol. 219 (1), 48–51.

Piech M., Stankowski S. 1988. Wpływ dawek i terminów nawożenia azotem na ilość wysiewu, na plonowanie i jakość ziarna pszenicy ozimej. Cz. II. Jakość ziarna [The influence of doses and date of fertilisation with nitrogen on the quantity of sowing, on crop and quality of the winter wheat grain. Part II. Quality of grain]. *Biul. IHAR* 166, 17–26 [in Polish].

Polish Standard PN-A-74108. Ocena organoleptyczna pieczywa [Sensory assesment of bread] [in Polish].

Runowski H. 1996. Ograniczenia i szanse rolnictwa ekologicznego [The limitation and the chances of ecological agriculture]. SGGW, Warszawa [in Polish].

Siebeneicher G. 1993. Podręcznik rolnictwa ekologicznego [Handbook of ecological agriculture]. Warszawa, PWN [in Polish].

Simonson L., Salovaara H., Korkola M. 2003. Response of wheat sourdough parameters to temperature, NaCl and sucrose variations. Food Microbiol. 20, 193–199.

Streszczenie. Sprawdzono właściwości wypiekowe sześciu odmian żyta pochodzących z upraw konwencjonalnych i ekologicznych. Pieczywo z żyta uprawianego metodami konwencjonalnymi charakteryzowało się wyższą objętością i nieznacznie niższą stratą piecową. Sposób uprawy nie miał istotnego wpływu na porowatość. Pieczywo z odmiany Conduct uprawianego ekologicznie otrzymało najwyższe noty w ocenie sensorycznej (31,5 pkt.). Zastosowanie dodatku kwasu mlekowego do ciasta zwiększyło objętość pieczywa, jego porowatość i stratę piecową całkowitą, nie wpływając na ocenę sensoryczną wypieków. W zależności od analizowanej cechy tekstury czynnik zmienności (sposób uprawy, odmiana oraz metoda wypieku) wpływał w różnym stopniu na właściwości reologiczne wypieków z mąki żytniej. Twardość, gumiastość, zżuwalność, miękiszu zależała od sposobu uprawy, następnie od odmiany oraz dodatku zakwaszacza. Spoistość miękiszu zależała głównie od sposobu uprawy. Nie stwierdzono natomiast wpływu badanych zmiennych na sprężystość pieczywa.