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EFFECT OF GENOTYPE AND WEATHER CONDITIONS ON WHEAT GRAIN HARDNESS AND THE DEGREE OF STARCH DAMAGE

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Abstract. The effect of genotype and weather conditions on the grain hardness of eight spring and winter wheat cultivars and relations between grain hardness and starch damage in the obtained flour were analyzed. Grain hardness, total content of nitrogen compounds and raw protein, and the degree of starch damage in flour were studied. The obtained results were verified using statistical analysis. It was shown that the degree of starch damage shows a high positive correlation with grain hardness (r = 0.7), which depends mostly on wheat genotype. Weather conditions during wheat growth in central Poland did not have a significant effect on grain hardness, although the grain of spring wheat cultivars was more sensitive to changeable weather conditions than the grain of winter wheat cultivars.

Key words: flour, spring wheat, starch, wheat cultivars, winter wheat

INTRODUCTION

Hardness is a general indicator of the technological usefulness of wheat grain, as it determines the directions of its use and affects the functional qualities of flour [Soszyńska and Cacak-Pietrzak 1992, Dziki and Laskowski 2005]. Flour from soft wheat is used for starch production and biscuit and cake baking. It is also suitable for the production of all sorts of bakery products that require rising, for example bread. Flour from hard wheat is used mostly for the production of pasta [Gąsiorowski 2004]. Relation was repeatedly shown between wheat grain hardness and grinding easiness, as well as the degree of starch damage. Experiments confirm that wheat flour for starch production should not contain damaged starch grains, and flour for baking, on the other hand, should contain a certain amount of damaged starch, since it affects volume increase in bakery products [Martin et al. 2007, Miller et al. 2008].

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Studies by many authors indicate that grain hardness, and therefore properties of the obtained flour and the degree of the contained starch damage, are connected with wheat genotype [Baker 1977] and with the soil and weather conditions of growth [Anjum and Walker 1991, Soszyńska and Cacak-Pietrzak 1992, Dziki and Laskowski 2005]. Correlation degree of those factors is not precisely described in literature. Good insolation and moderate temperatures are conducive to starch synthesis during wheat growth [Gąsiorowski 2004]. Moderate temperatures in May, June, and July are more favourable than high ones, which are usually accompanied by drought [Rudnicki 1996]. Wheat demand for water changes depending on plant development phase and cultivar. Usually spring wheat shows a higher demand for water than does winter wheat [Gąsiorowski 2004]. In the available literature, there is a lack of specific information to what extent in Poland weather conditions affect grain hardness in different wheat cultivars and the degree of starch damage during grinding. Clarification of the above issues was the main aim of the present studies.

MATERIAL AND METHODS

Grain of eight wheat cultivars grown at present in Poland were chosen for the studies, including three spring cultivars (Torka, Koksa, and Kontesa) and five winter cultivars (Sakwa, Symfonia, Zyta, Jawa, and Elena). Grain originated from plants grown at the Plant Breeding Institute in Strzelce (52°18' N; 19°24' E). Wheat was grown in constant soil conditions. In the three years of the experiment, namely in 2007, 2008, and 2009, the following fertilisation doses were applied: nitrogen 120-200 $kg \cdot ha^{-1}$, phosphorus 17-44 $kg \cdot ha^{-1}$ P, and potassium 33-100 $kg \cdot ha^{-1}$ K. Directly after grain harvest and its drying in constant humidity (12%), grain hardness was analysed, as well as total protein content in the grain and the degree of the damage of starch isolated from flour obtained in constant laboratory conditions.

Grain was ground in laboratory mill WŻ-1. The obtained flour was sieved through sieves with mesh size Ř = 250 μm at the last stage of sieving. The aim of the task was to unify flour extracts so that the obtained results were comparable for the studied cultivars.

Grain hardness measurement

Wheat grain hardness was set as the result of a compression resistance test carried out with the use of texture analyser TA.XT Plus produced by Stable Microsystems (Great Britain). Single grains were compressed in the position of furrow down. Force value (F_{max}) at which the studied grain cracked was the measure of its hardness. Measurements were repeated ten times for the grains of all the wheat cultivars in the particular years of growth.

Nitrogen compound and raw protein marking

Marking total nitrogen compound content (as nitrogen N) and raw protein (N x 5.7) was carried out using the micro-Kjeldahl method [Krełowska-Kułas 1993]. Analyses were repeated three times. Analysis result was expressed in %, recalculated into dry substance (d.s.) present in starch isolated from the studied grain.

Starch damage marking

Flour was obtained in laboratory conditions from the studied grain, and subsequently dough was prepared from it. Starch was isolated from dough through wash out with water, according to the classic procedure by Martin [Kerr 1950]. Gluten was thrown aside, whereas starch milk was purified (through slime and hemicellulose removal), and then it was spun and dried in standard conditions. Degree of isolated starch damage was established according to the method by Hoover and Sosulski, and Englyst and Cummings, with the use of α-amylase EC. 3.2.1.1., produced by A 6255 Sigma Chemical Co., St. Louis, MO, USA [Farhat et al. 2001]. Conditions of starch hydrolysis: pH 6.9; t = 37°C, time 1 hour. Amount of liberated glucose was established using the phenol method and expressed in percents, in relation to the dry substance contained in the isolated starch. Analyses were conducted in three repetitions.

Results were statistically evaluated using one- and two-factor analysis of variance and the significance of differences test LSD, at the significance level of 0.05, using computer program Statistica 7.1.

RESULTS AND DISCUSSION

Average monthly temperatures in June and July fell within the range of 17-19°C. In 2007, temperatures were very even, whereas in years 2008 and 2009, temperature diversification of about 2°C took place in those months (Fig. 1). No torrid heat was noted. In years 2007 and 2009, much more precipitation was noted (in 2007 – 334 mm; in 2009 – 354 mm) than in 2008 (148 mm). Various precipitation amounts (Fig. 2), did not have a clear cut effect on the diversification of the grain properties of the compared wheat cultivars, including hardness (Table 1). According to some authors [Pomeranz and Wiliams 1985], hardness is determined genetically. Others say, in addition, that also environment interaction has an effect on this qualitative trait of grain [Pomeranz et al. 1990]. Comparing the variability of the grain hardness of wheat grown in years 2007--2009, it can be stated that it depended on both the genotype and the weather conditions during growth period. Average hardness of the studied wheat cultivars was the highest in 2008 and amounted to 138 N. In that particular year, May and June were much drier than in the remaining years. This confirms a significant effect of the meteorological factor on wheat grain hardness.

Regardless of the precipitation amount, the greatest hardness was characteristic for spring wheat grain cultivar Koksa (158.6 N), and the lowest one for spring wheat grain cultivar Kontesa (109.4 N). In the driest year 2008, the lowest hardness was also characteristic for spring wheat grain cultivar Kontesa (107.2 ± 21.7 N), whereas the hardest was winter wheat grain cultivar Sakwa (163 ± 31 N) and spring wheat cultivar Koksa (162 ± 30 N). Generally speaking, grain of spring wheat cultivars proved to be more sensitive to changeable weather conditions than did the grain of winter wheat cultivars.

Among the studied cultivars, the greatest hardness was characteristic for spring wheat grain cultivar Koksa (on average 158 N). Regardless of the harvest year, the most even hardness (109-113 N) was reached by wheat grain cultivar Jawa. This means that, among the evaluated cultivars, Jawa is the least sensitive to changeable weather conditions.

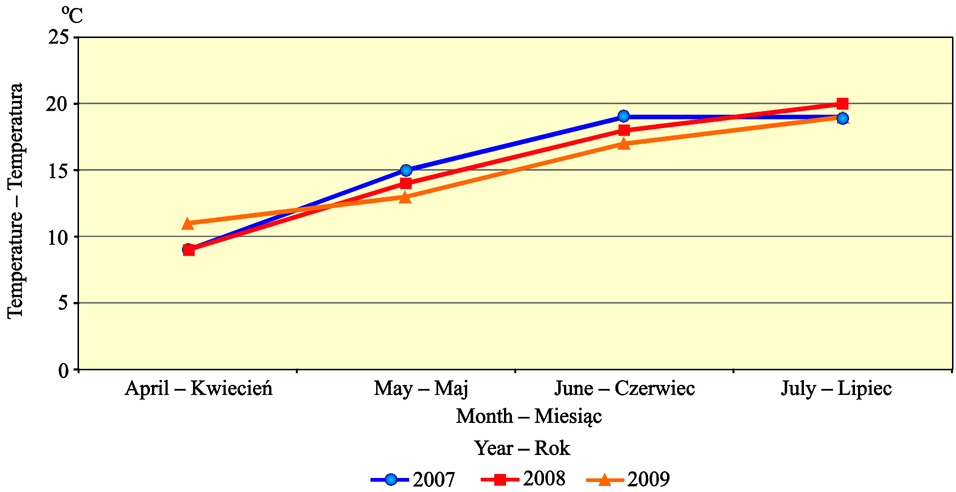

Fig. 1. Mean monthly temperatures during wheat growth
Rys. 1. Średnie miesięczne temperatury w okresie wzrostu pszenicy

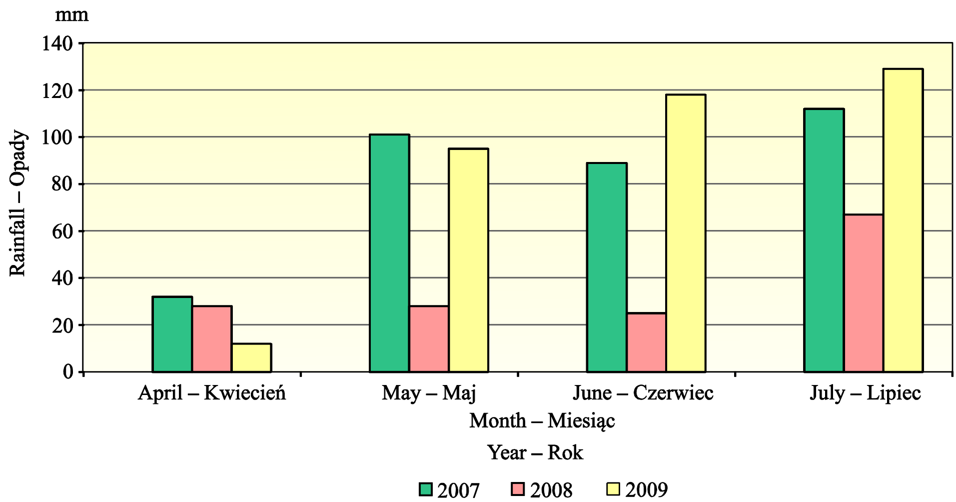

Fig. 2. Mean monthly precipitation during wheat growth
Rys. 2. Średnie miesięczne opady w okresie wzrostu pszenicy

Average protein content in the grain of wheat cultivars did not display any relations with the weather conditions of growth, rather with the genotype (Fig. 3). For example, the highest average protein content in grain was noted in 2009 (15.6), and the lowest in 2007 (12.2). Those years were characterised by similar precipitation amounts and temperatures in the summer months. The obtained results connected to protein content agreed with the ones presented by other authors [Rothkaehl 2003, 2004, Różyło et al. 2003]. Probably, protein content also depended on diversified nitrogen fertilisation (120-200 $kg \cdot ha^{-1}$).

Protein content in wheat is connected with its hardness, and both parameters are important qualitative features of wheat [Soszyńska and Cacak-Pietrzak 1992]. Comparing the measurement results of the grain hardness of the particular cultivars and protein content in grain, positive correlation may be found for wheat cultivars Koksa and Symfonia (r = 0.6), which means that the more protein was present in wheat grain, the harder it was. Study results by Różyło et al. [2003] and Miś and Klockiewicz-Kamińska [2002] confirm the existence of the relation between wheat grain hardness and protein content.

Table 1. Grain hardness of wheat cultivars
Tabela 1. Twardość ziaren odmian pszenicy

Wheat cultivar Odmiana pszenicy	Force F needed for grain crashing – Siła F potrzebna do zgniecenia ziarna, N			
	Year of wheat growth – Rok uprawy pszenicy			
	2007	2008	2009	mean – średnia 2007-2009
Koksa	146^{a}_{B} ± 29.9	162^{a}_{B} ± 31.8	167^{b}_{B} ± 30.3	158
Symfonia	100^{a}_{AC} ± 19.1	$157^{b}_{A\text{-}D}$ ± 19.4	162^{b}_{BD} ± 31.7	139
Zyta	140^{a}_{AB} ± 35.6	146^{a}_{ABD} ± 20.8	117^{a}_{AC} ± 25.7	135
Elena	92^{a}_{AC} ± 20.7	160^{b}_{ABD} ± 22.3	148^{b}_{ABC} ± 22.2	134
Sakwa	115^{a}_{AC} ± 18.4	163^{a}_{B} ± 30.8	108^{a}_{C} ± 25.4	128
Torka	102^{a}_{A} ± 26.4	114^{a}_{A} ± 22.6	131^{b}_{A} ± 28.6	116
Jawa	110^{a}_{AC} ± 24.8	113^{a}_{AB} ± 24.7	109^{a}_{C} ± 16.3	111
Kontesa	87^{a}_{AC} ± 20.2	93^{a}_{C} ± 21.7	147^{b}_{B} ± 14.7	109

values within each column marked with capital letter indexes differ significantly (P = 0.05) – wartości w obrębie każdej kolumny oznaczone różnymi dużymi indeksami literowymi różnią się istotnie (P = 0,05)
values within each row marked with small letter indexes differ significantly (P = 0.05) – wartości w obrębie każdego wiersza oznaczone różnymi małymi indeksami literowymi różnią się istotnie (P = 0,05)
±SD – standard deviation – odchylenie standardowe

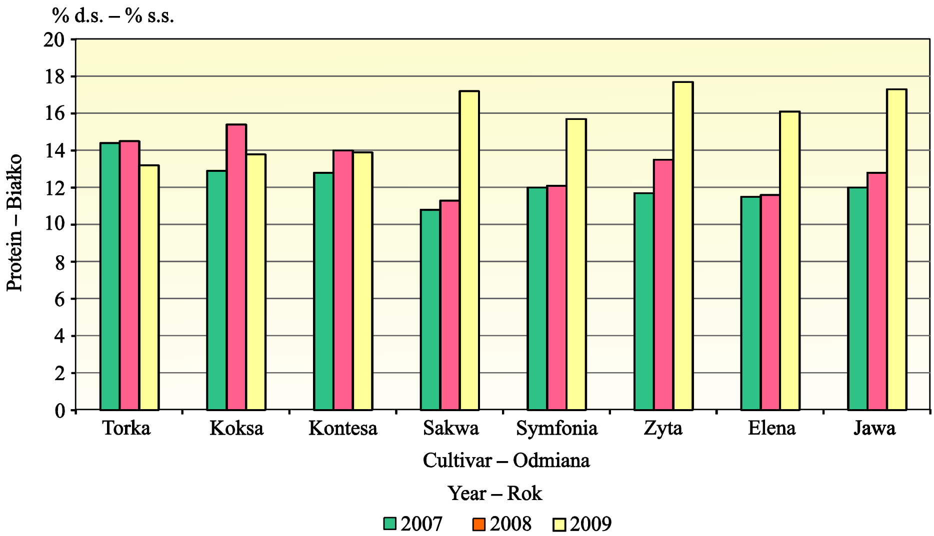

Fig. 3. Protein content in the grain of wheat cultivars
Rys. 3. Zawartość białka w ziarnie odmian pszenicy

It results from the data presented in Figure 4 that the degree of starch damage in various wheat cultivars was rather diversified but did not show a significant relation with the weather conditions of the growth. In the flour from wheat grain collected in 2007, the degree of starch damage reached from 16.1% (cultivar Zyta) to 25.6% (cultivar Symfonia), in the flour from grain collected in 2008 from 15.9% (cultivar Kontesa) to 27.1% (cultivar Symfonia), and in the flour from wheat grain collected in 2009 from 17.3% (cultivar Elena) to 26.7% (cultivar Symfonia). Therefore, in all the compared years of growth, relatively the highest degree of starch damage was noted in flour obtained from wheat cultivar Symfonia (26.4%), and subsequently from Koksa and Elena (over 22%). The conducted measurements and analyses documented how in the flour obtained from wheat cultivar Symfonia, the degree of starch damage showed a lower changeability, regardless of the weather (25.6-27.1%). Therefore, flour from wheat grain of that cultivar may be recommended for bread baking, although it should not be used for obtaining starch.

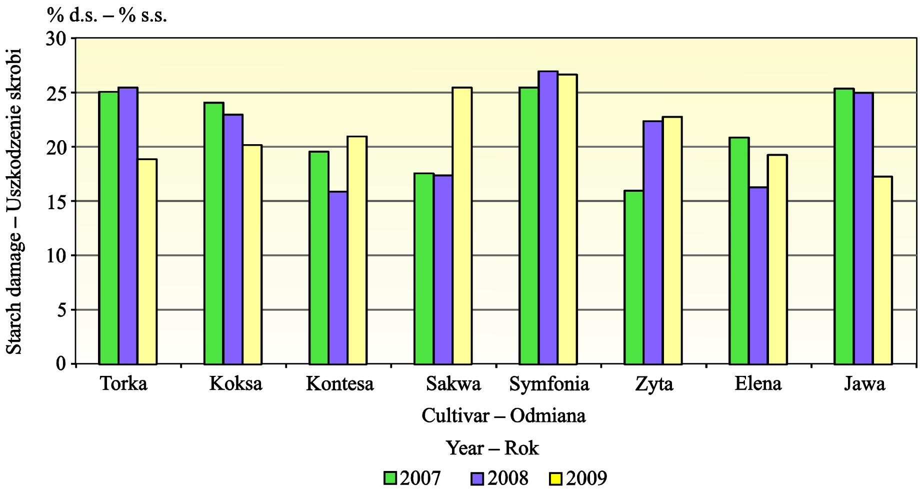

Fig. 4. Damage of starch isolated from grain of wheat cultivars
Rys. 4. Uszkodzenie skrobi wyizolowanych z ziarna odmian pszenicy

No unambiguous relation between the weather conditions of the growth of eight wheat cultivars and the degree of starch damage in the flour obtained from them was found.

Comparing the results of starch damage analysis and grain hardness measurements of different wheat cultivars, depending on the harvest year, quite high correlation was found. In 2008, it amounted to r = 0.7. The highest values of the coefficient of correlation appeared between the degree of starch damage and the grain hardness of wheat cultivars Kontesa (r = 0.85) and Symfonia (r = 0.94). Existence of a relation between grain hardness and the degree of starch damage was presented, among others, in the studies by Gąsiorowski et al. [1999].

Taking into consideration all the studied years of growth, it can be stated that the lowest hardness was characteristic for wheat grain cultivars Kontesa and Jawa (average hardness from the three years of the experiment 109.5 N). Flour obtained from the grain of those cultivars was characterised also by the lowest degree of starch damage (on average around 18%).

Statistical analysis of all the obtained results did not show an unambiguous effect of the weather conditions of the growth on grain hardness and the degree of starch damage in the obtained flour. In the driest year 2008, grain hardness, protein content in grain, and the degree of starch damage did not differ significantly, however, from the properties of wheat grain obtained in years 2007 and 2009. Therefore, it may be finally stated that in the weather conditions of central Poland, namely with average temperatures in the summer months significantly lower than 20^{o}C, precipitation amount did not have a significant effect on the properties of wheat grain, and in result also on the methods of its use.

CONCLUSIONS

Grain of eight winter and spring wheat cultivars differed significantly in regard to hardness and the degree of the damage of starch isolated from the obtained flour. Weather conditions in central Poland, especially in May, June, and July had a smaller effect on the physiochemical properties of grain than did the genotype. However, the grain of spring wheat cultivars was more sensitive to changeable weather conditions than the grain of winter wheat cultivars. The degree of starch damage showed high positive correlation with grain hardness.

Statistically significant correlation was found between grain hardness and the degree of the damage of starch isolated from it from the 2008 growth. Coefficient of correlation value r = 0.7. Also, the existence of a correlation was found between those parameters for wheat cultivars Kontesa (r = 0.85) and Symfonia (r = 0.94), taking into account the values of grain hardness and starch damage from the three years of growth.

Flour from wheat cultivar Koksa may be a good material for pasta production, but it should not be used for obtaining starch. Flour from the grain of wheat cultivar Symfonia, on the other hand, may be particularly recommended for bread baking.

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WPŁYW GENOTYPU I WARUNKÓW POGODOWYCH NA TWARDOŚĆ ZIARNA PSZENICY I STOPIEŃ USZKODZENIA SKROBI

Streszczenie. Analizowano wpływ genotypu i warunków pogodowych na twardość ziarna 8 odmian pszenicy jarej i ozimej oraz związek między twardością ziarna a uszkodzeniem skrobi w otrzymanej mące. Badano twardość ziarna, ogólną zawartość związków azotowych i białka surowego oraz stopień uszkodzenia skrobi w mące. Wyniki zweryfikowano metodami statystycznymi. Wykazano, że stopień uszkodzenia skrobi wykazuje wysoką korelację dodatnią z twardością ziarna (r = 0,7), zależną głównie od genotypu pszenicy. Warunki pogodowe w czasie uprawy pszenicy w środkowej Polsce nie miały znaczącego wpływu na twardość ziarna, przy czym ziarno odmian pszenicy jarej było bardziej wrażliwe na zmienne warunki pogodowe niż ziarno odmian pszenicy ozimej.

Słowa kluczowe: mąka, odmiany uprawne pszenicy, pszenica jara, pszenica ozima, skrobia

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