ACTA Acta Sci. Pol., Technol. Aliment. 5(1) 2006, 87-96

CHARACTERISTICS OF CARBOHYDRATE FRACTION OF RYE VARIETIES

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Abstract. 4 Austrian varieties of rye ('Walstaudenroggen', 'Echo', 'Schlager' and 'Esprit') and one Polish variety ('Dańkowskie Złote') were investigated. There were differences in grains composition as well as in starch properties. Among all varieties, the best one 'Waldstaudenroggen' was distinguished due to a high content of soluble carbohydrates, low level of amylose and high molecular mass of starch. Basing on those permises it was found, that the mentioned above properties, influenced high quality of rye variety. Despite growing in different climatical conditions, the Polish variety 'Dańkowskie Złote' did not differ in the analysed features from the Austrian ones.

Key words: carbohydrate fractions, starch, rye varieties

INTRODUCTION

Rye grains and also fractions of their milling are characterized by lower content of proteins and fat and higher enzymatic activity in comparison to wheat [Rye. Production, Chemistry and Technology 1976, Żyto. Chemia i technologia 1994].

Rye starch is characterized by lower pasting temperature in comparison to wheat one [Gudmundsson and Eliasson 1991, Schierbaum and Kettlitz 1994, Żyto. Chemia i technologia 1994, Gambuś et al. 1997], that in conjunction with high enzymatic activity may lead to creation of dextrins at the beginning of bread baking, which causes dough to be sticky. In order to limit it, dough for rye bread is developed on sourdough.

Starch content with high water binding capacity is responsible for rye bread quality. Water released, during hydrolysis [Greaber 1999] of proteins and pentosans at early stage of bread baking will be bounded by starch, and unbounded water contributes to dough moisture.

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In bread crumb creation a capacity of rye starch towards swelling and pasting plays a significant role. Partially pasted starch consolidates or fortifies the crumb, and during bread ageing contributes to its hardness [Rye. Production, Chemistry and Technology 1976].

Rye starch exhibits lower retrogradation tendency, and according to Gudmudsson and Eliasson [Gudmundsson and Eliasson 1991] responsibility for this is attributed to different amylopectin structure in comparison to wheat starch. Schierbaum and co-workers [Schierbaum et al. 1991, Radosta et al. 1992] reported that rye starch exhibited somewhat smaller crystallinity. But others authors [Żyto. Chemia i technologia 1994] slower retrogradation of rye starch attributed to presence of pentosans in rye flour, that leads to slower rye bread ageing.

Some of scientists reported also about similar viscosity of rye starch pastes in comparison to wheat starch gels [Rye. Production, Chemistry and Technology 1976, Schierbaum and Kettlitz 1994, Gambuś et al. 1997].

Rye protein contains considerable amount of exogenous amino acids [Rye. Production, Chemistry and Technology 1976] in comparison to wheat. It also characterized by supremacy of soluble fractions, that are able to create foam. Rye is considered as a perfect raw material for “crispbread” production [Zawadzki 2002].

Moreover, rye grain is characterized (in comparison to wheat one) by a higher amount of dietary fiber, including fructans and β-glucans, and by the highest pentosans content among all cereals [Żyto. Chemia i technologia 1994]. The presence of these carbohydrates contributes also to water binding capacity and viscosity of rye dough [Rye. Production, Chemistry and Technology 1976, Michniewicz et al. 1998]. Soluble pentosans, especially with high molecular weight cause favourable properties of bread crumb and volume [Vandhamel et al. 1993, Żyto. Chemia i technologia 1994].

Basing on registered rye varieties studied it may be concluded, that there are no significant differences in agricultural and functional properties and only small in technological value, when comparing to large differences as in case of wheat varieties [Żyto. Chemia i technologia 1994].

Knowing that rye technological values depends on carbohydrate-amylolitical system [Piekarstwo i ciastkarstwo 1988, Żyto. Chemia i technologia 1994], the aim of this work was to determine the differences among Austrian varieties of rye and one Polish variety in respect to content of different carbohydrate fractions, with special emphasis on physico-chemical properties of starch and to indicate to those properties, which influenced high quality of rye varieties.

MATERIAL AND METHODS

Four rye varieties, cultivated in Gerasdorf (near to Vienna), were used in studies: ‘Waldstaudenroggen’ – very good old variety (according to Agriculture University in Vienna), ‘Echo’ and ‘Schlagler’ – very good (not better than ‘Waldsstaudenroggen’), ‘Esprit’ – medium (hybrid-variety). The oldest registered Polish variety ‘Dańkowskie Złote’ cultivated in Śrem-Wójtostwo was also used.

In these cereals were estimated: falling number using Falling Number – 1800 Perten [ICC – Standard Methods... No. 107/1], total protein content (N x 5.7) using NIR method in Infratec 1255 Testator, total pentosans content [Douglas 1981] and crude fiber [ICC – Standard Methods... No. 113]. In those samples were measured water soluble carbohydrates by shaking 0.1 g sample with 50 cm^3 of distilled water for 0.5 h. Then after centrifugation for 5 min using 1250 x g, soluble carbohydrates in supernatant were measured by anthrone method using 540 nm [Morris 1948]. Carbohydrates soluble in ethanol were measured by shaking 0.1 g sample in 10 g of this solvent for 1h. Next it was centrifuged for 5 min using 1250 x g and soluble carbohydrates were estimated in supernatant using a previous method. Sums of carbohydrate [Fortuna et al. 1985] and starch [ICC – Standard Methods... No. 122/1] contents were also measured.

From flour obtained from a laboratory mill, the starch was isolated using Richter and co-authors method [Richter et al. 1968]. Starch was next subjected to following analyses: total protein in apparatus KJELDEC Auto II Plus Tecator (N x 5.7) [Richter et al. 1968], total phosphorus content [Marsh 1959], apparent amylose content [Morrison and Laignelet 1983] as well as swelling [Richter et al. 1968] and pasting characteristics [Gambuś and Nowotna 1992]. To obtained molecular masses high pressure SEC was performed with a series of TSK columns (PWM + 6--- + 5--- + 4000 + 3000; 30 + 30 + 30 + 30 × 0.75 cm, Toyo Soda) connected to dual detection of mass DRI: Optilab 903, Wyatt Tech./US) and scattering intensity (LALLA: KMX-6, TSP/US). Absolute molecular weight was calculated according to:

$$M = [K \cdot c/R_0 - 2\,A_2 \cdot c]$$

Analyses for all samples (five rye varieties) were performed in double. For those data LSD coefficient was calculated et df = 9, $\alpha = 0.05$.

RESULTS AND DISCUSSION

Investigated rye varieties differed in amylolitic activity (Table 1), measured as falling number, which exhibited much lower number than wheat (164-300 s) [Nowotna et al. 2003]. Besides varieties 'Esprit' and 'Dańkowskie Złote', remaining varieties fulfil the normatic specifications [PN-A-74032, 2002]. The lowest amylolitic activity was discovered in variety Echo.

Table 1. Amylolytic activity of grains of rye varieties
Tabela 1. Aktywność enzymatyczna ziarna odmian żyta

Variety Odmiana	Falling number, s Liczba opadania, s
Waldstaudenroggen	98
Echo	154
Schlagler	103
Esprit	85
Dańkowskie Złote	84

All rye varieties contain 1.63-1.92% ash (Table 2). Differences were stated in total protein content between rye varieties, and lower content than it is measured in wheat varieties 12.1-13.2% [Nowotna et al. 2003], what is commonly known [Żyto. Chemia i technologia 1994]. Among all rye varieties 'Schlaegler' showed highest protein content, comparable to wheat grain. Protein content in rye, has a limited importance, due to lack of the gluten complex in dough, in comparison to wheat dough.

Table 2. Total ash and total protein content in grains of rye varieties
Tabela 2. Całkowita zawartość popiołu i białka w ziarnie odmian żyta

Variety Odmiana	Content of, % Zawartość, %	
	total ash popiół całkowity	total protein białko ogółem
Waldstaudenroggen	1.65	10.4
Echo	1.63	8.3
Schlagler	1.86	11.7
Esprit	1.56	7.9
Dańkowskie Złote	1.92	9.9

Statistical analysis (LSD) showed, that investigated rye varieties did not exhibit any difference among them in total carbohydrates content (Fig. 1), but there were differences in starch content. The highest values were noted for 'Esprit', 'Echo' and 'Waldstaudenroggen' varieties. Varieties with higher starch content were characterized by lower protein content (Fig. 1, Table 1). Average starch content in rye varieties was slightly lower as compared to wheat ones [Nowotna et al. 2003].

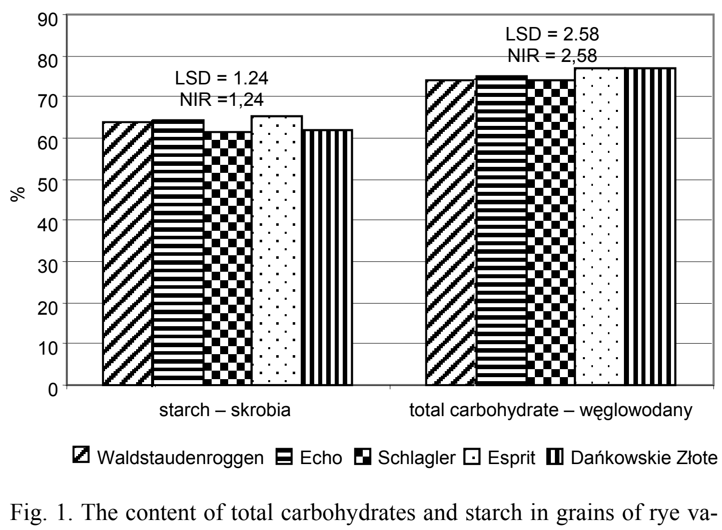

Fig. 1. The content of total carbohydrates and starch in grains of rye varieties
Rys. 1. Całkowita zawartość węglowodanów w ziarnie odmian żyta

Content of carbohydrates fractions in rye varieties was depicted on Figure 2. The highest content of crude fiber (mostly cellulose) was observed in rye varieties 'Schlagler' and 'Esprit', still lower than in wheat varieties (2.39-3.11%) [Nowotna et al. 2003].

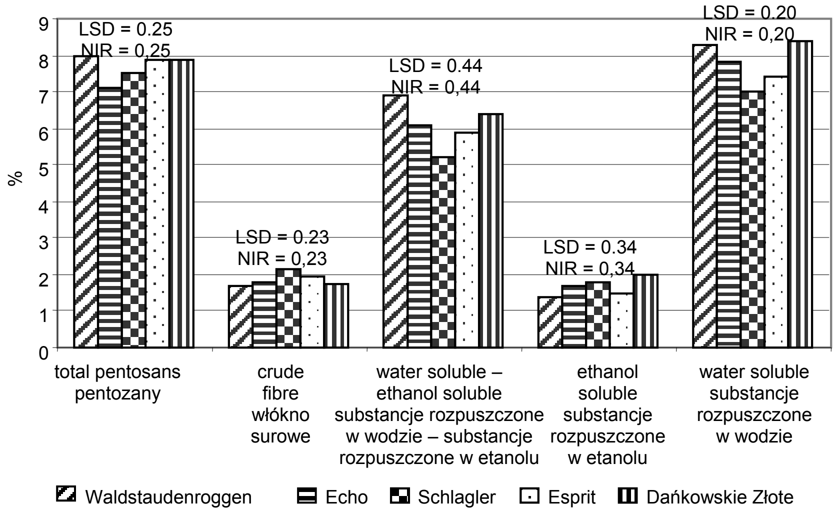

Fig. 2. The content of carbohydrates in grains of rye varieties
Rys. 2. Zawartość węglowodanów w ziarnie odmian żyta

Statistical analysis (LSD) exhibited, rye varieties 'Waldstaudenroggen', 'Esprit' and 'Dańkowskie Złote' showed the highest value of total pentosans content. This fraction, that in greatest extent contributed to high viscosity of rye dough, was observed in rye in greater amount than in wheat (6.4-6.9%) [Żyto. Chemia i technologia 1994, Nowotna et al. 2003].

Differences among rye varieties were proved by statistical analysis (LSD), also in respect of water soluble carbohydrate content, low molecular mass fraction (ethanol soluble) and high molecular mass fraction (calculated as difference between mentioned above fractions). The obtained results showed, the highest soluble carbohydrate content, at different share of low and high molecular mass fractions, was observed in the following varieties: 'Waldstaudenroggen', 'Echo' and 'Dańkowskie Złote'. Soluble carbohydrates (including also soluble pentosans) contributed to increased water binding capacity and dough yield. Moreover, low molecular mass carbohydrates are used as nutrient for bacteria and yeasts.

It should be mentioned that the amount of soluble polysaccharides and pentosans in rye varieties is higher as compared to wheat, that is genetically conditioned and connected to higher enzymatic activity of rye.

Reassuming all obtained results of grain analysis, it may be stated from technological point of view, due to important role of carbohydrate-amylolitic complex, variety 'Waldstaudenroggen' is characterized by the best properties, i.e. the proper enzymatic activity, high water soluble substances and pentosans content.

In Figure 3-5 and Table 3 are presented physico-chemical properties of starch. The amount and differences in phosphorus content (LSD = 0.001), that is an indicator of phospholipids content, are lower in starches from rye varieties in contrast to wheat starches (0.056-0.033%) [Nowotna et al. 2003] is caused by lower level of lipids in rye than in wheat. The lowest amount of phosphorus content was measured in 'Echo'. Protein content (LSD = 0.005) in starch differs with varieties but are close to wheat starch (0.12-0.20%) [Nowotna et al. 2003].

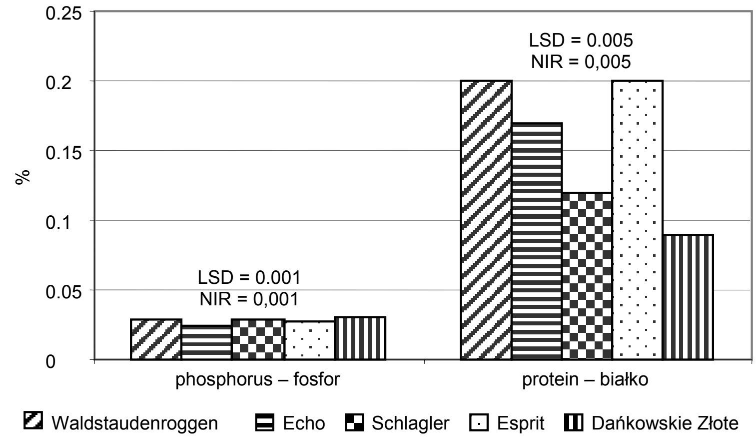

Fig. 3. The content of phosphorus and protein in starch isolated from rye varieties
Rys. 3. Zawartość fosforu i białka w skrobi wyizolowanej z mąki odmian żyta

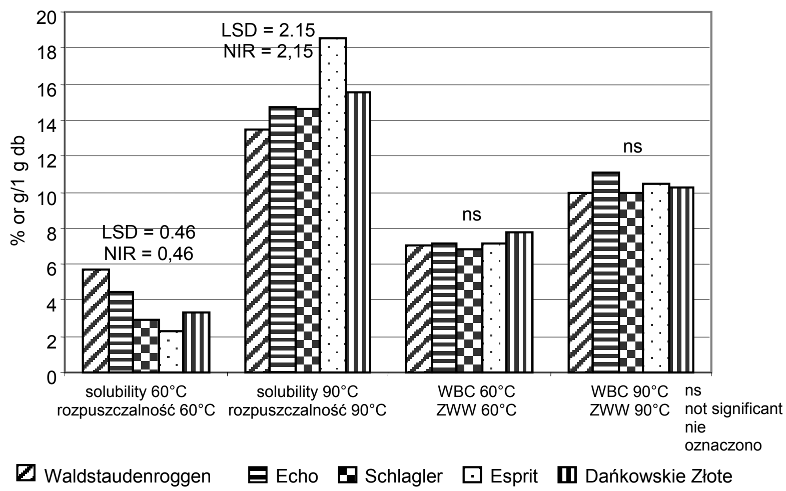

Fig. 4. Solubility, %, and water binding capacity (WBC), g/1 g db, of starch isolated from rye varieties
Rys. 4. Rozpuszczalność, %, i zdolność wiązania wody (ZWW), g/1 g s.m., skrobi wyizolowanej z odmian żyta

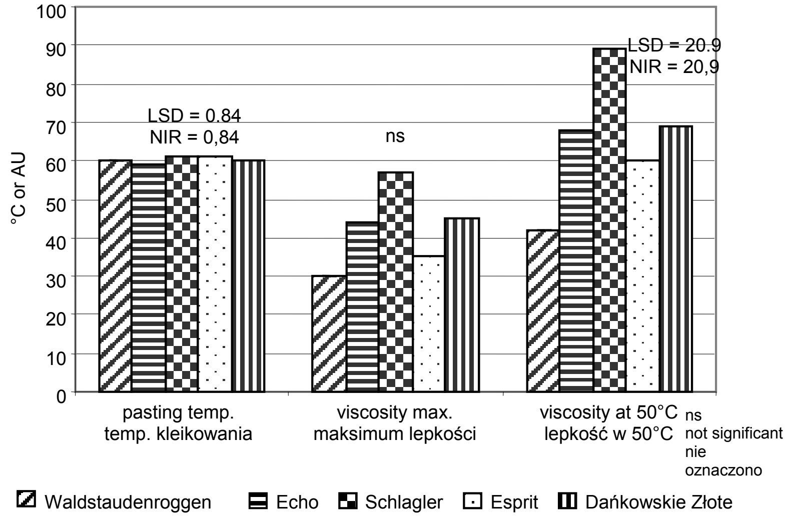

Fig. 5. Pasting characteristics parameters of starch isolated from rye varieties
Rys. 5. Parametry charakterystyki kleikowania skrobi wyizolowanej z odmian żyta

Table 3. Molecular weight of starch and amylose content
Tabela 3. Masa cząsteczkowa skrobi i pozorna zawartość amylozy

Variety Odmiana	Content of apparent amylose, % Pozorna zawartość amylozy, %	Molecular weight of starch 10^6 g/mol Masa cząsteczkowa skrobi 10^6 g/mol
Waldstaudenroggen	13.1	41.2
Echo	22.9	3.2
Schlagler	23.8	18.4
Esprit	22.8	23.3
Dańkowskie Złote	22.9	19.3

Swelling and pasting properties of rye starches are shown in Figures 4 and 5. According to statistical analysis the highest solubility in 60°C (LSD = 0.46) characterized starch isolated from 'Waldstaudenroggen' variety (Fig. 4). Rye starches exhibited greater values of solubility in comparison to wheat ones [Nowotna et al. 2003], that is genetically influenced and connected to higher enzymatic activity of rye as compared to wheat. Starches from all rye varieties were characterized by the same water binding capacity, but higher than it was measured in wheat starches [Nowotna et al. 2003]. High water binding capacity has a great importance, because starch is binding water released during hydrolysis at the beginning of baking.

High solubility of starch extracted form rye variety 'Waldstaudenroggen' could suggest the highest enzymatic activity of this one, because at 60°C hydrolysis of starch occurred, mostly in amorphous regions. But this variety is characterized with normative enzymatic activity (FN = 98 s), and starch isolated from this variety has the highest molecular mass (Table 3). Moreover, the differences in starch solubility from this variety are not caused by enzymatic activity is supported by very similar water binding capacity at 60°C [Gambuś et al. 1987].

The starch from rye varieties differs only about 2 grades among each other in respect of pasting temperature (Fig. 5), but are lower in comparison to starches from wheat varieties (71-79°C) [Nowotna et al. 2003]. The lower pasting temperature of rye starch in comparison to wheat one is known from previous research [Gudmundsson and Eliasson 1991, Schierbaum and Kettlitz 1994, Żyto. Chemia i technologia 1994, Gambuś et al. 1997], that is genetically conditioned and connected to enzymatic activity. It may be caused by different crystallinity of wheat and rye starch granules, because starch behaviour in water depends mostly on internal structure of starch granules, and so the character of intermolecular net [Zobel 1988, Jane 1996].

Rye starches were also different in respect of the viscosity value at 50°C. The lowest value of viscosity after cooling to 50°C was obtained for rye starch var. 'Waldstaudenroggen', that may testify about slowest retrogradation tendency, that was confirmed by the lowest amylose content in this starch (Table 3) [Gambuś 1997], because linear fraction is responsible for this phenomenon.

All rye starches exhibited average amount of apparent amylose – about 23% (LSD value = 0.91). Only variety 'Waldstaudenroggen' is characterized by much lower amount of linear starch fraction (Table 3). Therefore this variety exhibited the highest molecular mass.

Summing up it can be concluded that properties of starches isolated from different rye varieties are different. Starch extracted from rye variety 'Waldstaudenroggen' was characterized by high solubility at 60°C, low content of amylose, and the highest molecular mass.

Basing on obtained results it may be concluded, that there are differences among the investigated rye varieties. Taking into account high soluble carbohydrate content and low amylose content and the highest molecular mass, the old variety 'Waldstaudenroggen' is still satisfactorily good.

CONCLUSION

1. Investigated 4 varieties of rye of Austrian origin differed in the respect of the majority of the analysed features, both grains and starches.

2. Rye varietie 'Waldstaudenroggen', recognized as the best in Austria, was distinguished due to a high content of soluble carbohydrates, low amylose content and high molecular mass, so these features of cereal carbohydrates would be recognized as important factors of rye varieties evaluation.

3. Despite cultivation in different climatical conditions, Polish variety 'Dańkowskie Złote', did differ in respect of the analysed properties from Austrian rye varieties.

REFERENCES

Douglas S.G., 1981. A rapid method for the determination of pentosans in wheat flour. Food Chem. 1, 139-143.

Fortuna T., Gambuś H., Nowotna A., 1985. Oznaczanie czystości skrobi [Estimation of starch purity]. Zesz. Nauk. AR Krak. 193, 5-11 [in Polish].

Gambuś H., 1997. Wpływ fizyczno-chemicznych właściwości skrobi na jakość i starzenie się pieczywa (badania modelowe) [Influence of physico-chemical starch properties on quality and bread staling (model investigation)]. Zesz. Nauk. AR Krak. 226 [in Polish].

Gambuś H., Fortuna T., Nowotna A., Pałasiński M., 1987. Physical properties of triticale starch. Part II. Water binding capacity and solubility of starch. Acta Aliment. Pol. 13, 99-106.

Gambuś H., Nowotna A., 1992. Physicochemical properties of defatted triticale starch. Pol. J. Food Nutr. Sci. 1/42, 101-107.

Gambuś H., Zamroźniak-Rys I., Achremowicz B., 1997. Porównanie wybranych fizyczno-chemicznych właściwości skrobi zbożowych poddanych działaniu promieniowania jonizującego w stanie wyizolowanym lub w mące [Comparison of the selected physico-chemical properties of cereal starches subjected to ionization radiation in flour or as separated from flour]. Zesz. Nauk. AR Krak. 324, 55-66 [in Polish].

Graeber S., 1999. Influence of enzyme treatment on the rheology of rye doughs. Nahrung 43, 249-252.

Gudmundsson M., Eliasson A.C., 1991. Thermal and viscous properties of rye starch extracted from different varieties. Cereal Chem. 68, 172-177.

ICC – Standard Methods. Determination of crude fibre value. No. 113, 1995, Vienna.

ICC – Standard Methods. Determination of starch content by calcium chloride dissolution. No. 122/1, 1995, Vienna.

ICC – Standard Methods. Determination of the “Falling Number” according to Hagberg-Perten as a measure of the degree of alpha-amylase activity in grain and flour. No. 107/1, 1995, Vienna

Jane J., 1996. Struktura gałeczek skrobiowych [Structure of starch granules]. In: Mater. VII Międzynarodowej Konferencji Skrobiowej. Kraków, 207-216 [in Polish].

Marsh B.B., 1959. The estimation of inorganic phosphate in the presence of adenosine triphosphate. Biochem. Biophys. Acta 32, 357-359.

Michniewicz J., Kołodziejczyk P., Nadolnicka J., Anioła J., Ulichnowska A., 1998. Ocena zawartości różnych form nieskrobiowych polisacharydów [Evaluation of different forms of non starch polysacharides]. Prz. Zboż.-Młyn. 62, 14-17 [in Polish].

Morris D.L., 1948. Quantitative determination of carbohydrates with Dreywoods anthrone reagent. Science 107, 254-255.

Morrison W.R., Laignelet B., 1983. An improved colorimetric procedure for determinig apparent and total amylose in cereal and other starches. J. Cereal Sci. 1, 9-20.

Nowotna A., Gambuś H., Liebhard P., Praznik W., Ziobro R., Berski W., Cygankiewicz A., 2003. The importance of main components of grains on baking quality wheat. EJPAU, Ser. Food Sci. Technol. www.ejpau.media.pl/series/volume6/issue1/food

Piekarstwo i ciastkarstwo [Bakery and pastry]. 1988. Ed. Z. Ambroziak. WNT Warszawa [in Polish].

PN-A-74032. 2002. Przetwory zbożowe. Mąka żytnia [Cereal products. Rye flour] [in Polish].

Radosta S., Kettlitz B., Schierbaum F., Gernat Ch., 1992. Studies on rye starch properties and modification. Part II. Swelling and solubility behaviour of rye starch granules. Staerke 44, 8--14.

Richter M., Augustat S., Schierbaum F., 1968. Ausgewaehlte Methoden der Staerke-chemie. VEB Fachbuch Verlag Leipzig [in German].

Rye. Production, Chemistry and Technology. 1976. Ed. W. Bushuka. AA of CC, St. Paul, Minnesota.

Schierbaum F., Kettlitz B., 1994. Studies on rye starch properties and modification. Part III. Viscograph pasting characteristics of rye starches. Staerke 46, 2-8.
Schierbaum F., Radosta S., Richter M., Kettlitz B., Gernat Ch., 1991. Studies on rye starch properties and modification. Part I: Composition and properties of rye starch granules. Staerke 43, 331-339.
Vanthamel S., Cleemput G., Delcour J.A., Nys M., Darius P.I., 1993. Physicochemical and functional properties of rye nonstarch polisacharides. IV. The effect of high molecular weight water-soluble pentosans on wheat-bread quality in a straight-dough procedure. Cereal Chem. 70, 306-311.
Zawadzki K., 2002. Żyto – europejskie zboże wymagające wsparcia [Rye – european cereal requiring suport]. Prz. Zboż.-Młyn. 10, 26-27 [in Polish].
Zobel H.F., 1988. Molecules to granules: A comprehensive starch review. Staerke 40, 44-50.
Żyto. Chemia i technologia [Rye. Chemistry and Technology]. 1994. Ed. H. Gąsiorowski. PWRiL Poznań [in Polish].

CHARAKTERYSTYKA WĘGLOWODANOWYCH FRAKCJI ODMIAN ŻYTA

Streszczenie. Przebadane odmiany żyta – cztery austriackie (‘Walstaudenroggen’, ‘Echo’, ‘Schlager’ i ‘Esprit’) i jedna polska (‘Dańkowskie Złote’) – różniły się zawartościami składników ziarna, jak również właściwościami skrobi. Wśród badanych odmian wyróżnia się ‘Walstaudenroggen’ pod względem dużej zawartości węglowodanów rozpuszczalnych, małej zawartości amylozy i wysokiej masy cząsteczkowej skrobi. Pomimo uprawy w innych warunkach klimatycznych, polska odmiana „Dańkowskie Złote’ nie odbiega od odmian austriackich pod względem analizowanych cech.

Słowa kluczowe: frakcje węglowodanowe, skrobia, odmiany żyta

Accepted for print – Zaakceptowano do druku: 9.02.2006

For citation – Do cytowania: Nowotna A., Gambuś H., Liebhard P., Praznik W., Ziobro R., Berski W., Krawontka J., 2006. Characteristics of carbohydrate fraction of rye varieties. Acta Sci. Pol., Technol. Aliment. 5(1), 87-96.