Int. Agrophysics, 2003, 17, 111–116

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Characteristics of grain quality and the endosperm microstructure of some Czech and Polish winter wheats

J. Sadowska[1], T. Jeliński[1], M. Hruškova[2], J. Přihoda[2], and E. Klockiewicz-Kamińska[3]*

[1]Institute of Animal Reproduction and Food Research, Polish Academy of Sciences, Tuwima 10, 10-748 Olsztyn, Poland
[2]Institute of Chemical Technology, Praha, Czech Republic
[3]Research Centre for Cultivar Testing, Słupia Wielka, Poland

Received January 6, 2003; accepted April 24, 2003

A b s t r a c t. The grain and flour of two Czech and two Polish winter wheats of the same classification were examined. The quality of the grain (evaluated with standard methods), the endosperm microstructure and the size distribution of the starch granules numerically studied with digital image analysis (DIA) methods were determined. The endosperm microstructure was found to be typical for soft (Leguan and Flair), medium (Line 2038), and hard (Begra) wheats. Stronger wheats (Line 2038 and Begra) showed a higher percentage of small B-type starch granules, compared to soft wheats (Leguan and Flair). Direct comparison of the data obtained for Czech and Polish wheats showed only approximate DIA results because of different agricultural and climatic conditions, which strongly influenced the grain properties examined but the same tendency in the variability of endosperm microstructure and starch granule size distribution for hard and soft wheats from both countries was confirmed.

K e y w o r d s: grain quality, microstructure, starch, wheat

INTRODUCTION

The known inter-relationships between some physical properties and the quality of wheat grain are used in practice for the prediction of its technological suitability. A close relationship between physical and physico-chemical properties and microstructure has been also found, thus the existence of a relationship between wheat endosperm (or its particular compounds) microstructure and grain quality is expected. The development of modern digital image analysis (DIA) techniques has made it possible to be objective in the methods for evaluating microscopic images and expressing numerically the variability of the wheat kernel's microstructure (Sadowska *et al.*, 1999). Characteristic differences in the distribution of the granule size of starch in hard and soft wheats were found and the number of large starch granules (type A) in wheats was proposed by Zayas (1994) as a distinguishing feature of hard and soft wheats. Peterson and Fulcher (2001), who examined starch granule distribution in Minnesota hard red spring (HRS) wheats, concluded that variation in wheat performance is in part related to differences in the properties of the varieties such as the distribution of starch granules. These modern methods could supplement or even replace traditional time-consuming methods of evaluating grain quality. However, environmental and agrotechnical factors do influence endosperm microstructure and starch geometry characteristics. Therefore, studies on Czech and Polish wheats growing in different conditions have been carried out for testing the DIA methods developed for evaluating wheat grain varieties.

MATERIAL AND METHODS

The grain and flour of two Czech winter wheats: line 2038 (class A) and Leguan (class B) were examined. Two Polish winter wheats: Begra (standard winter wheat – class A) and Flair (class B), from the same locality were selected as the grains to be compared.

The characteristics of grain quality of the Czech wheats was done according to the Czech standards which are equivalent to the ISO standards (Přihoda,1998; Hruškova and Brzicová, 2001). The characteristics of grain quality of the Polish wheats were investigated according to the methods accepted in the Polish Classification System (Klockiewicz-Kamińska and Brzeziński, 1998).

*Corresponding author's e-mail: jaga@pan.olsztyn.pl

The specimens of cross-sectioned wheat kernels coated with gold were examined in a JSM 5200 microscope. Endosperm micro-pictures were collected, transformed and presented using the digital image analysis method (DIA) according to Sadowska *et al.* (1999).

Starch granules were isolated according to the method described by Bechtel *et al*. (1993) and examined with an Olympus light microscope (Olympus, Japan). Size distribution was determined using the DIA method (Sadowska *et al*., 1998) - the number of starch granules counted per sample varying from 10 000 to 20 000. Detailed characteristics of geometry of all measured objects was done (area, maximum and minimum and mean equivalent diameters, perimeter and roundness of image objects) but only equivalent diameter of objects, i.e., $d_e = 2(\text{area}/\ )^{1/2}$ was accepted as granule size index (Zayas *et al*., 1994; Peterson and Fulcher, 2001).

RESULTS

DIA methods for determining the variability of endosperm microstructure and starch granule size were developed using Polish wheat; thus for comparison, the characteristics of two Polish winter wheats were investigated. Corresponding or similar methods for determining quality parameters (except for extensigraph energy) allowed the results obtained to be compared. Although requirements for estimating grain quality in the Czech Republic and Poland are not the same, the basic parameters are determined in both countries. Equivalent quality parameters for Czech and Polish winter wheats are presented in Table 1. Differences in the values of these parameters for Czech wheats of various qualities did not suggest such a large difference in the basic quality index, i.e., the bread volume - 418.6 and 222.8 cm^3 100 g^{-1} of flour for line 2038 and Leguan, respectively. Undoubtedly, the low protein and high strong gluten content of the Leguan cultivar (Table 2) was the reason for the low bread volume and the reduction of the technological susceptibility of this cultivar. It was confirmed that soft wheat flours with strong gluten produce cookies, sponge cakes and noodles of poor quality compared with soft wheat flour with weak gluten (Mikhalylenko *et al.,* 2000). The protein content in Czech wheats was lower and the gluten content was higher than in Polish wheats of a similar classification. Although the protein content and gluten quality of both Polish cultivars are similar (Table 2), the difference in other basic quality parameters are more distinct, resulting in a different classification for them (Table 1).This could probably be explained by the different protein composition. In hard wheats generally the glutenin composition influenced many quality attributes (Anjum *et al.*, 2000). Tronsmo *et al.,* (2002) showed even detailed relationships, for example, the HMW

T a b l e 1. Characteristics of grain quality

Parameter	Line 2038	Leguan	Begra	Flair
Bulk density (kg hl^{-1})	79.6	78.3	80.4	76.7
Falling number (s)	284	362	367	277
Zeleny test (ml)	48	47	–	–
SDS test (ml)	–	–	74.0	57.5
Yield of flour (%)	–	–	74.4	72.8
Water absorption (%)	61.3	61.3	62.8	63.3
Dough softening (j.Br.)	30	50	40	75
Energy (ext.) (cm^2)	142[a]	158[a]	94.0[b]	75.2[b]
Bread volume (cm^{3}100 g^{-1} flour)	418.6	222.8	618.0	576.0
Classification	Class E-A	Class B	Class A	Class B

[a] – energy after 90 min fermentation, [b] – energy after 3   45 min fermentation.

T a b l e 2. Characteristics of protein quality

Parameter	Line 2038	Leguan	Begra	Flair
Protein content (% d.m.)	13.1	11.3	14.9	14.2
Wet gluten content (%)	36.3	29.0	25.8	24.7
Gluten index	97	99	94	77

glutenin sub-unit pair 7+8 was not significant enough to predict loaf characteristics whereas the pair 7+9 was positively associated with loaf form ratio (height/width). Huebner *et al.* (1999) presented relationships between protein composition and dough functional properties also for soft wheats.

The endosperm microstructure of both Czech wheats is characterized by large (lens-shaped) and small (spherical) starch granules loosely packed in the protein matrix but the endosperm of line 2038 wheat, in which single starch granules are covered with protein, seems to be denser and more compact (Fig. 1 A, B). The microstructure of the Flair endosperm was similar to the Leguan (Fig. 1C) while the Begra endosperm microstructure was characterized by the strong adhesion of protein covering the starch granules (Fig. 1D). The endosperm microstructure of Leguan and Flair are typical for soft wheat, while the microstructure of Line 2038 is typical for the medium and Begra for the hard wheats (Sadowska *et al.* 1999). The results of the DIA analysis confirmed the different endosperm character of the wheats examined. Numerical indices presented in Table 3 for Begra and Flair (first of all, area and number of objects: 367.67 and 427.1 pixels and 259 and 214, respectively) presented distinct differences in their endosperm microstructure. The calculated difference between the indices mentioned, i.e., 59.5 pixels and 45 was similar to the respective values (59.2 pixels and 32) obtained for hard Sigma and soft Alba wheats (Sadowska *et al.*, 1999). Digital image analysis also confirmed the difference between line 2038 and Leguan wheats (Table 2). The difference in values of the DIA indices mentioned, i.e., object area and number of transformed picture (321.9 and 378.6 pixels and 272 and 244, respectively) were 56.7 pixels and 28, respectively. The differences between endosperm microstructure of Czech wheats were also significant. It is worth noting that the maximum area value of the minimum number of objects was determined for Flair, whose vitreosity was low, i.e., 40.5%.

Typically wheat starch is recognized as having two different granule populations of distinct size and shape (Peterson and Fulcher, 2000; Reaker *et al.*, 1889) and perhaps three (Bechtel *et al.*, 1993; Zayas *et al.*, 1994). SEM pictures of starch isolated from Czech wheats showed

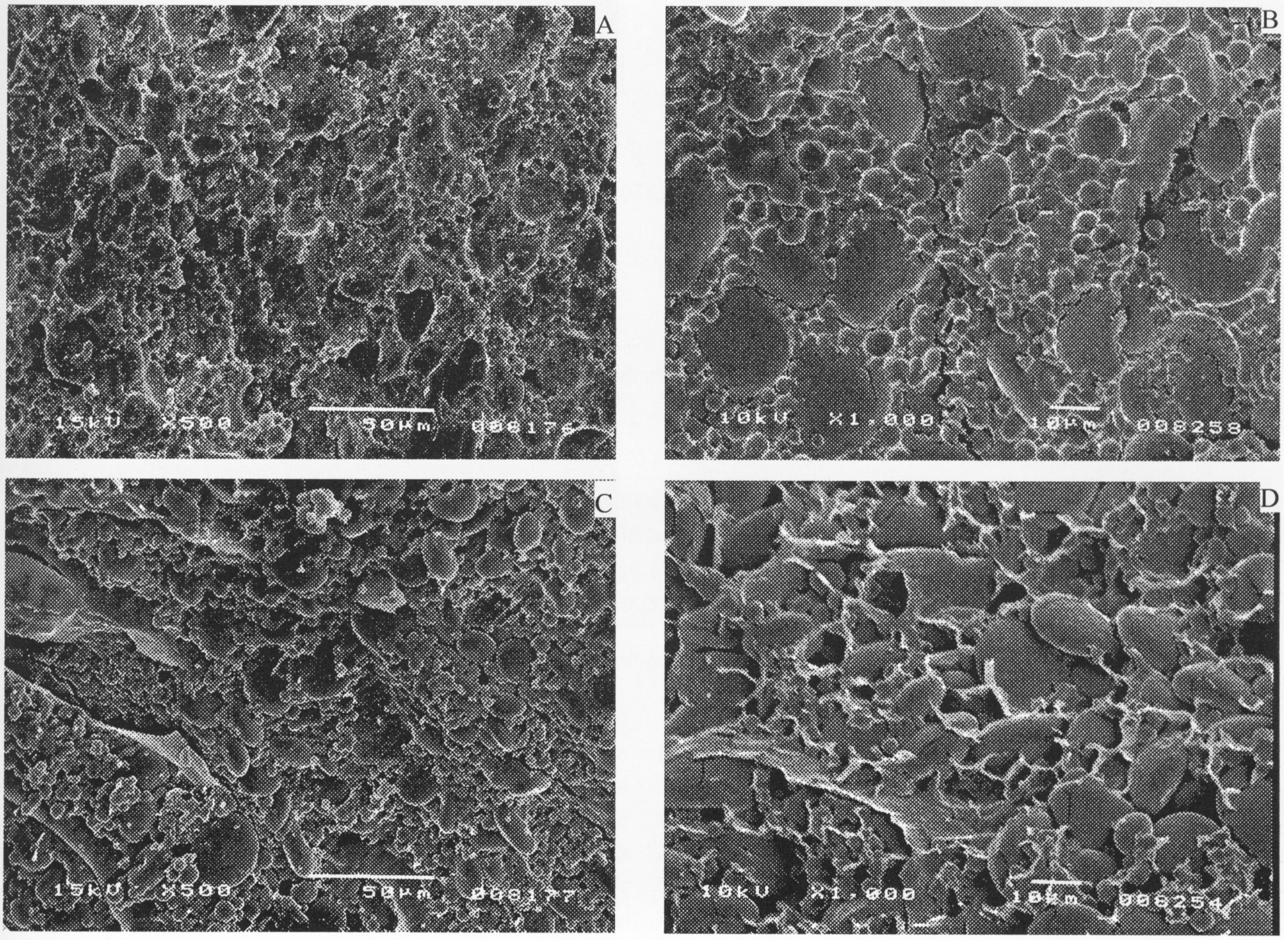

Fig. 1. SEM micrographs of wheat endosperm: A) Begra, B) Line 2038, C) Flair, and D) Leguan.

Table 3. Characteristics of endosperm microstructure

Winter wheat	Characteristics of transformed image object (pixels)				
	Area	Diameter	Perimeter	Roundness	Number
Line 2038	321.9	11.20	64.63	2.90	272
Leguan	378.6	11.32	64.61	2.75	244
Begra	367.6	10.72	59.17	2.45	259
Flair	427.1	11.73	67.10	2.66	214

typically small and large granules (Fig. 2). During microscopic examination a low number of mechanically damaged or slightly deformed starch granules was found in all wheats. However, in Leguan wheat (Fig. 2D) a slightly higher number of damaged (not only mechanically) granules was noted. This could suggest their weaker structure which could be its native feature. Starch damage is consistently lower in the softer than in the harder wheat flours but Lin and Czuchajowska (1996) found the strong influence of starch damage in soft wheats in all varieties wherever this occurred. Variations in starch functionality have been linked to differences in starch granule distribution (Peterson and Fulcher, 2001). Thus, the distribution of different sizes of starch granules should be connected with the hardness and even the technological quality of the wheat grain. The distribution of starch granule size is presented in Fig. 3 and the factors of the detailed characteristics of granule size are shown in Table 4. Irrespective of the manner of

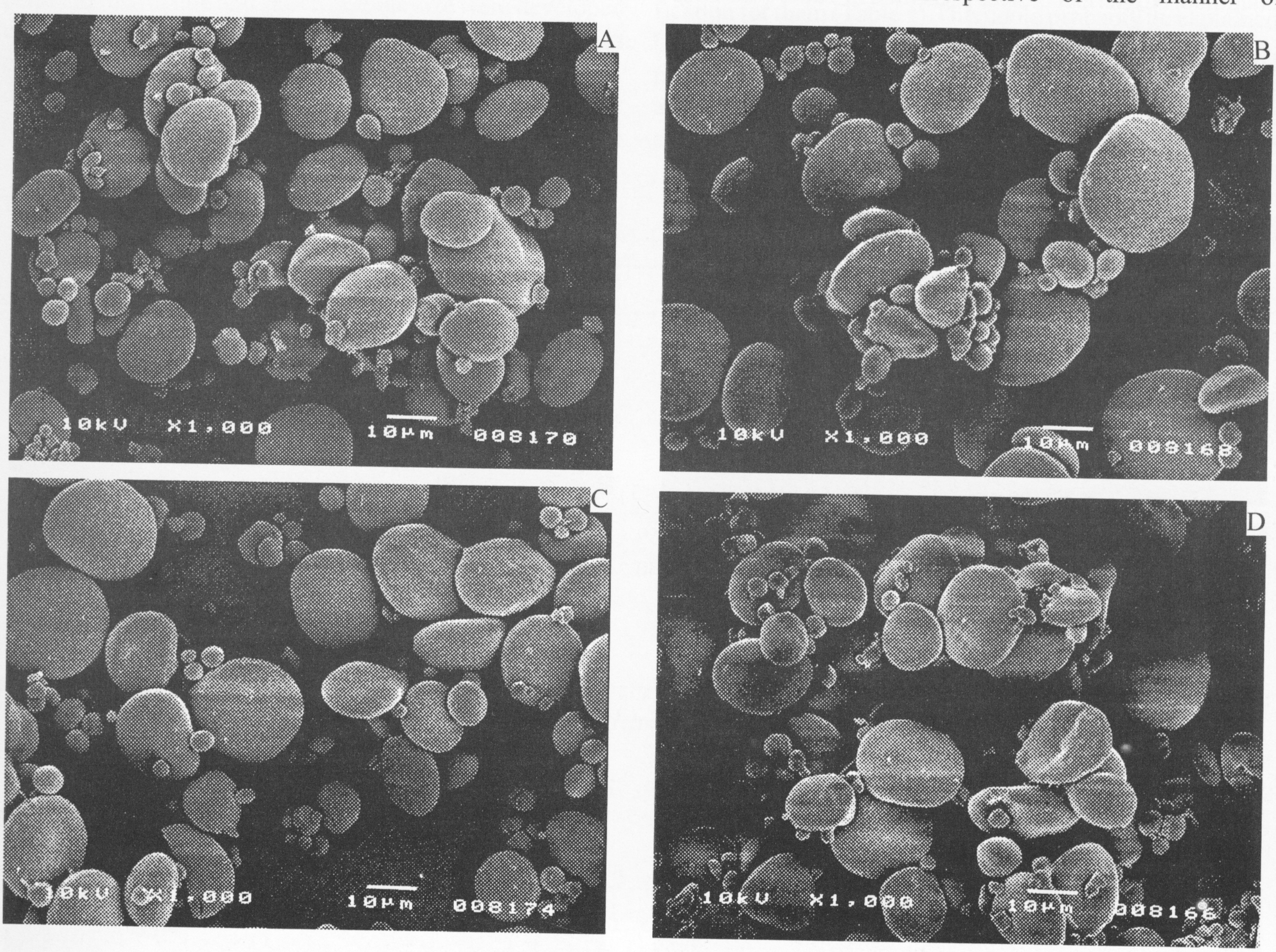

Fig. 2. SEM micrographs of isolated starch: A) Begra, B) Line 2038, C) Flair, and D) Leguan.

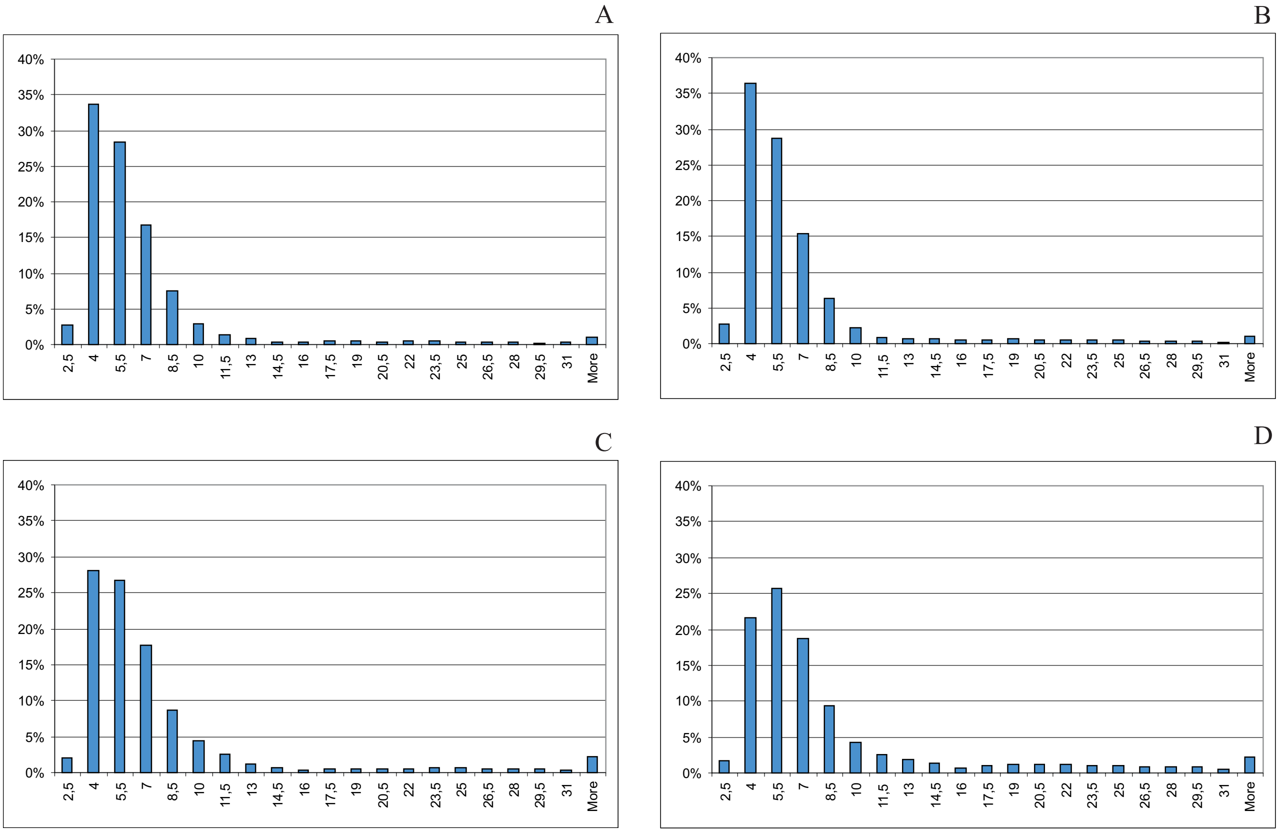

Fig. 3. Size distribution of starch granules: A) Begra, B) Line 2038, C) Flair,and D) Leguan.

T a b l e 4. Characteristics of starch granule size distribution

Winter wheat	Percentage of starch granules					Mean d_e (m)
	B’ d_e<10 m	A’ d_e> 10 m	C* d_e<5 m	B* d_e<16 m	A* d_e>16 m	
Line 2038	91.62	8.38	59.47	35.10	5.42	5.96
Leguan	81.52	18.48	40.24	47.92	11.84	8.07
Begra	91.88	8.12	56.11	38.80	5.09	6.05
Flair	87.60	12.40	48.53	43.91	7.56	7.04

’ – classification according to Raeker *et al*. (1998), * – classification according to Zayas *et al.* (1994).

classification, stronger wheats (Line 2038 and Begra) showed a higher percentage of B type (small) granules than did the soft wheats (Leguan and Flair). According to indices proposed by Zayas *et al.* (1994) only Leguan can be classified as a soft wheat (share of A type granules was 11.84%). The percentage of A type granules of other cultivars examined ranged from 5.09 to 7.56%, characteristic of hard wheats. It is noteworthy that the 5.09% share of A type granules in the hard wheat Begra did not differ significantly from the respective shares (5.94 and 4.85% for 1993 and 1996) obtained in previous years (Sadowska *et al.,* 1998).

A direct comparison of data obtained for the Czech and Polish wheats showed only approximate DIA results because of the different agricultural and climatic conditions which strongly influence the properties of the grain examined (Gaines *et al*., 1996). However, the same tendency was found in the variability of the microstructure of the endosperm and starch granule size distribution for hard and soft wheats.

CONCLUSION

Comparison of the data obtained for Czech and Polish wheats showed only approximate DIA results because of different agricultural and climatic conditions, which strongly influenced the grain properties examined but the same tendency in the variability of endosperm microstructure and starch granule size distribution for hard and soft wheats from both countries was confirmed.

REFERENCES

Anjum F.M., Lookhart G.L., and Walker C.E., 2000. High molecular glutenin subunit composition on Pakistani hard white spring wheats grown at three locations for 2 years and its relationship with end-use quality characteristics. J. Sci. Agric., 80, 219–225.

Bechtel D.B., Zayas I.Y., Dempster R.E., and Wilson J.D., 1993. Size distribution of starch isolated from hard and soft winter wheats. Cereal Chem., 70, 238–240.

Gaines C.S., Finney P.L., and Rubenthaler G., 1996. Milling and baking qualities of some developed for eastern and northwestern regions of the United States and grown at both locations. Cereal Chem., 73, 521–525.

Hrušková M. and Brzicová P., 2001. Assessment of saccharides-amylose complex in wheat flour (in Czech). Pekar a Cukrár, 9, 13–15.

Huebner F.R., Bietz J.A., Nelsen T., Bains G.S., and Finney P.L., 1999. Soft wheat quality as related to protein composition. Cereal Chem., 76, 650–655.

Klockiewicz-Kamińska E. and Brzeziński J.W., 1998. Method of quality evaluation and classification of wheat cultivars (in Polish). Przegląd Zbożowo-Młynarski, XLII(1), 2–6.

Lin P.-Y. and Czuchajowska Z., 1996. Starch damage in soft wheats on the Pacific Northwest. Cereal Chem., 73, 551–555.

Mikhaylenko G.G., Czuchajowska Z., Baik B.-K., and Kidwell K.K., 2000. Environmental influences on flour composition, dough rheology, and baking quality of spring wheat. Cereal Chem., 77, 507–511.

Peterson D.G. and Fulcher R.G., 2001. Variation in Minnesota HRS wheats: starch granule size distribution. Food Research Int., 34, 357–363.

Raeker M.O., Gaines C.S., Finney P.L., and Donelson T., 1998. Granule size distribution and chemical composition of starches from 12 soft wheat cultivars. Cereal Chem., 75, 721–728.

Přihoda J., 1998. Assessment of quality of cereal grain and products (in Czech). Mlynárské Noviny, 26–81.

Sadowska J., Fornal J., and Jeliński T., 1998. Effect of fertilization on size of starch granules in wheat. Polish J. Food and Nutr. Sci., 7/48, 2(S), 125–130.

Sadowska J., Jeliński T., and Fornal J., 1999. Comparison of microstructure of vitreous and mealy kernels of hard and soft wheat. Polish J. Food Nutr. Sci., 8/49, 3–15.

Tronmo K.M., Fargestad E.M., Longva A., Schofield J.D., and Magnus E.M., 2002. A study how size distribution of gluten proteins, surface properties of gluten and dough mixing properties relate baking properties of wheat flours. J. Cereal Sci., 35, 201–214.

Zayas I.Y., Bechtel D.B., Wilson J.D., and Dempster R.E., 1994. Distinguishing selected hard and soft red winter wheats by image analysis of starch granules. Cereal Chem., 11, 82–86.