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Heredity of the fractional composition of wheat grain proteins in the F_1 generation

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Abstract

Wheat maternal male-sterile forms and paternal ones possesing a fertility-restoring ability were used for obtaining series of F_1 hybrids and in this material total N, protein fractional composition and total extractability, as well as the compactness of molecules contained in the particular fractions, were determined. It was found, that the above mentioned properties in the F_1 generation were influenced to a significant extent by the maternal forms. Particularly important for wheat breeding in the direction of improving the baking quality is the influence of maternal forms on the content of proteins soluble in NaOH, which contain high molecular weight glutenin, as well as on the compactness of the molecules contained in it. The data presented in this paper indicate, that selection of maternal forms for crosses should be performed with great care.

INTRODUCTION

In a previous study (Bernacka and others, 1977), preliminary results were presented, concerning the fractional composition of proteins isolated from some selected F_1 hybrids. The data obtained in those experiments showed, that the total N content and that of protein fractions soluble in acetic acid and in NaOH seems to be influenced rather by maternal forms. Such investigations are of importance for breeding of bread cereals (particularly wheat), as their baking quality depends on the content and character of some protein fractions. It should be suggested, therefore, that in the crossing programmes of breeding in the direction of improving the wheat baking quality, maternal forms should be

carefully selected from the aspect of the content and properties of the protein fractions known to be most important in formation of the gluten complex.

As the preliminary experiments had been carried out with rather poor material, this paper presents data obtained on a much more differentiated material harvested in 1975, in order to confirm the previous suggestions.

MATERIAL AND METHODS

Material. For heredity experiments wheat samples harvested in 1975 in the Institute of Plant Genetics and Breeding, were used. They consisted of six maternal MS forms: Manella — 1, Splendeur — 2, Somme — 3, Luna — 4, Ursynów — 5 and Norin 10 X Brevor — 7 and six paternal RS forms of high fertility-restoring ability: Nadzieja — A, Grana — B, Mironowskaja 808 — E, Bezostaja 1B — F, Prinepi — G and Palomares — H, as well as their fourteen hybrids in three blocks. The hybrid seeds were obtained by means of free pollination of parental forms sown in rows on isolated experimental plots. The seeds of the maternal forms were obtained from free pollination of MS forms and fertile analogues, cultivated on isolated plots. In all cases of MS forms the cms gene was introduced by using the American variety Nebrasca and at least five backcrosses. All MS, RS and F_1 forms were obtained by J. Jakubiec and his coworkers.

Methods. In the grains described above total N was determined in ground material and flour of 60% milling by the Reifer and Tarnowska (1950) method, and fractionation of flour proteins was performed by the method of Coates and Simmonds (1961), based on successive extraction with 0.005 M pyrophosphate buffer, 0.05 M acetic acid and 0.1 M sodium hydroxide. The coefficient of extinction at 280 nm for total N (E_{280}/total N) was calculated according to Jankiewicz and Jankowski (1969) with the use of Zeiss VSU-2 spectrophotometer.

RESULTS

The results of total N determination in whole ground grain and flour are given in Table 1 and average data, calculated separately for MS, RS and F_1 forms — in Table 2. The data presented indicate, that maternal forms had mearly always much higher protein contents. Most of the F_1 hybrids showed values rather similar to maternal ones and some of them, particularly those concerning flour were even transgressive to MS ones. The calculated recombinational values as percent of contribu-

tion of MS and RS forms in the formation of the particular feature, as related to the total difference between both parental forms, which are not cited here, indicate the particularly high ability of varieties MS Luna and RS Grana of transferring this feature. The total tendency to an overwhelming influence of the maternal form on protein contents are confirmed by the average data presented in Table 2. They show, that over 75% in the case of flour and 81% in the case of whole grain of this feature originates from the maternal forms in direct crosses.

Table 1*

Protein contents (N × 5,7) in ground whole grains and in flour in percents

		A	12.44 11.51	B	13.06 13.20
1	17.59 16.76	1A	18.16 15.89	1B	15.57 15.23
2	16.46 14.42	2A	15.57 14.53	2B	15.79 13.57
3	18.62 16.61	3A	17.66 14.56	3B	15.19 13.97

		E	14,17 12,08	F	13,57 12,82	G	14,87 13,73
4	17,58 15,93	4E	16,56 16,22	4F	15.74 17.30	4G	18.14 17.10
5	18,13 15,73	5E	17,49 14,78	5F	17.51 15.62	5G	17.17 14.53

		B	13,06 13,20	H	12,13 11,09
7	19.76 17.97	7B	18.89 15.10	7H	18.86 15.76

Upper figures concern protein contents in whole grain, the lower ones—protein contents in flour

Table 2

The average contents of total protein in %% in MS, RS and F_1 forms

	in flour	in whole grain
MS	16.18	18.00
RS	12.55	12.75
F_1	15.30	17.05

* Tables 1, 3, 4, and 5: The figures and letters concern the wheat varieties as indicated in "Material and methods", the mixed indications 1A, 1B, etc. concern the hybrids thereof.

The fractional composition of flour proteins and total extractability are presented in Table 3, and the averages calculated separately for MS, RS and F_1 forms — in Table 6. The data indicate, that the level of the pyrophosphate fraction in MS forms was relatively stable and in the case of RS — much more dispersed. The values obtained for F_1 hybrids showed no regular influence of any parental forms, which could be confirmed by the averages given in Table 6, which are almost uniform for all three forms.

Table 3

Fractional composition of flour proteins in percent of total protein and the total extractability in %

			A	21,98 42,5 30.1	94.6	B	13.7 54.7 24.2	92.6
1	18.0 68.2 11.9	98.1	1A	16.5 58.9 14.0	89.3	1B	14.5 63.7 12.2	90.4
2	16.9 60.0 22.4	99.2	2A	16.3 57.7 19.5	93.5	2B	16.5 61.8 16.2	94.5
3	15.8 63.3 12.2	91.3	3A	19.8 65.9 13.0	98.7	3B	15.0 72.6 12.1	99.7

			E	14.4 48.6 28.5	91.5	F	13.6 47.7 25.7	87.1	G	12.6 60.2 14.9	87.2
4	16.1 60.9 13.2	90.2	4E	16.7 58.6 11.4	86.7	4F	15.3 64.0 13.5	92.8	4G	14.0 63.0 12.3	89.3
5	16.5 61.7 14.7	92.9	5E	15.0 60.3 14.2	89.5	5F	15.3 57.6 14.5	87.4	5G	13.7 70.8 11.7	96.2

			B	13.7 54.7 24.2	92.6	H	15.1 50.6 19.3	85.0
7	14.8 57.9 20.1	92.8	7B	14.6 65.7 13.8	94.2	7H	14.4 67.7 11.5	93.5

The upper figures concern the pyrophosphate fraction, the medium ones—the acetic acid fraction, and the lower — the NaOH fraction. Right figures concern the total extractability of flour

Much more regular were found to be the relations as regards protein fractions soluble in acetic acid, which contain gliadin and soluble glutenin. Maternal forms showed on the average a 20% higher level of this fraction, than the RS ones. F_1 hybrids had a percentual content of this fraction rather similar to that, obtained for MS forms and even transgressive values could be observed in most cases; this was also confirmed by average data, where transgressive values were also obtained. It can be concluded therefore, that the influence of paternal forms on the level of the acetic acid fraction seems to be rather limited, and that of MS forms amounted in most cases to over 70%.

Of particular interest is the fraction of residual proteins extracted with 0,1 M NaOH, which contains high molecular weight glutenin insoluble in acetic acid. The content of this fraction, shown in Tables 3 and 6 was in RS forms on the average by about 58% higher, than for the MS forms. Those values observed for F_1 hybrids were on the average even lower than those for MS forms and in almost all cases very similar to the latter. Also in this case the influence of RS forms seems to be very weak. The total extractability of flour, which seems to be a good index of flour quality, is also influenced to a higher extent by the maternal MS forms than by the RS ones.

The ratio of acetic acid/NaOH fractions was also calculated, because it was observed earlier that this value could be of significance as a quality index of flour. The data concerning it are presented in Table 4.

Table 4

The ratio between protein contents soluble in acetic acid to those soluble in NaOH

		A	1.41	B	2.26
1	5.72	1A	4.21	1B	5.22
2	2.67	2A	2.96	2B	3.81
3	5.18	3A	5.08	3B	6.00

		E	1.71	F	1.85	G	4.05
4	4.60	4E	5.14	4F	4.75	4G	5.13
5	4.18	5E	5.24	5F	3.97	5G	6.05

		B	2.26	H	2.62
7	2.87	7B	4.75	7H	5.91

Averages for MS forms—4.20, for RS forms—2.30, for F_1 crossings—4.80

It is seen from those data, that most RS forms except Prinepi showed low values of this ratio, whereas mearly all maternal forms exhibited much higher values. Most F_1 hydrids showed transgressive values as related to maternal forms, as confirmed by average data, about 15% higher in the case of F_1, than for MS forms.

Table 5

The E_{280}/total N ratios of particular protein fractions extracted from flour

		A	0.110 0.068 0.155	B	0.129 0.066 0.162
1	0.133 0.074 0.225	1A	0.129 0.077 0.195	1B	0.139 0.077 0.179
2	0.152 0.065 0.172	2A	0.134 0.079 0.161	2B	0.152 0.072 0.185
3	0.172 0.073 0.233	3A	0.155 0.073 0.240	3B	0.139 0.070 0.225

		E	0.152 0.064 0.164	F	0.135 0.065 0.145	G	0.136 0.076 0.198
4	0.142 0.082 0.225	4E	0.149 0.079 0.239	4F	0.151 0.082 0.231	4G	0.150 0.086 0.217
5	0.170 0.087 0.235	5E	0.167 0.086 0.262	5F	0.148 0.086 0.213	5G	0.138 0.074 0.253

		B	0.129 0.066 0.162	H	0.133 0.081 0.195
7	0.136 0.065 0.176	7B	0.163 0.081 0.235	7H	0.138 0.071 0.210

The upper figures concern pyrophosphate fraction, the medium ones—acetic acid fraction, the lower ones—NaOH raction

The baking quality of wheat flour depends not only on the protein content and fractional composition, but also on the compactness of molecules contained in at least some particular fractions. One of the simplest

measures of this property should be the ratio E_{280}/total N. The data concerning those values for particular samples and fractions are given in Tables 5 and 6. Those values calculated for the pyrophosphate fraction, acetic acid fraction and particularly for the basic one showed a very strong influence of the maternal form on the compactness of the corresponding molecules in F_1 hybrids. In the latter case, which seems to be most important for the baking quality, the E_{280}/total N values for F_1 hybrids are in most cases transgressive to MS forms, showing in almost all cases higher values, than the RS ones (average) for about 29%. In this case particularly high recombination ability of the MS form Luna and RS Grana could be observed.

Table 6

Average data concerning fraction composition of wheat proteins and the total extractability of flour — a and the E_{280}/total N ratios — b

Form		Fraction			Total extractability
		pyrophosphate	acetic acid	NaOH	
MS	a	16.35	61.87	15.33	93.98
	b	0.152	0.076	0.214	
RS	a	15.45	51.50	24.61	90.64
	b	0.130	0.069	0.166	
F_1	a	15.55	63.50	13.56	92.57
	b	0.147	0.078	0.218	

DISCUSSION

The samples used in the experiments described above were collected into blocks so, that each MS or RS form took part in more crossings. Therefore, in some cases the calculation of recombinational value for particular varieties was possible. The material was selected so, that maternal components contained as a rule more protein and had a lower baking quality, than the paternal ones. This made possible observation of the influence of those components in the formation of the investigated features in F_1 hybrids.

On the basis of result obtained in this work one can conclude, that, in general, the maternal form is much more important as the determinant of protein content and composition in the F_1 generation. The very similar and even transgressive values of total protein content in hybrids, as related to maternal forms indicate the significance of careful selection of the latter for breeding. As concerns the fractional composi-

tion, most important for baking quality should be the fraction soluble in NaOH, which contains high molecular weight glutenin. This type of protein should be responsible for the formation of stretching and strong dough structure (Orth, Bushuk, 1972). The content of this fraction is on the average about 60% higher in paternal forms, than in the MS ones and this remains in accord with the analysis the rheological properties of gluten, the results of which are not cited here. Unfortunately in the case of examples presented in this paper, the content of particularly this fraction is highly influenced by the maternal form and therefore, similarly to some other properties, in the selection of crossing components, this feature should be taken into account. The results concerning this fraction are also quite similar to those obtained in the first series of experiments (Bernacka et al., 1977).

As observed earlier, in the evaluation of the flour baking quality, the ratio of the fraction content soluble in acetic acid/soluble in NaOH, should be of interest. This suggestion is confirmed by all maternal forms of poor quality showing high values of this ratio, and RS forms Mironowskaja 808 and Bezostaja 1B of good quality, showing a low value. The only exception in this regularity is the RS sample Nadzieja of medium quality, and the lowest value of the mentioned ratio; however in this case a particularly high content of the pyrophosphate fraction (22%) was observed, which caused the lowering of the acid fraction content as well as of the baking quality. Another well known quality index mentioned for example by Pomeranz (1965), should be the total extractability of flour proteins in the three-step procedure of Coates and Simmonds (1961). The results cited in the present work also show, that samples of higher quality exhibited in most cases lower total extractability (about 90%), than those of low quality (over 93%).

As suggested in some earlier papers (Jankiewicz & Jankowski, 1969; Liss & Kączkowski, 1975; Kączkowski et al., 1968) not only the contents of protein particular fractions, but also of their properties are of significance as components of flour baking potentialities. The most important of them seems to be the compactness of protein molecules, which could be expressed by some coefficients calculated on the basis of viscosity measurements (Shorina, Vakar, Kretovich, 1965; Kączkowski et al., 1968), or as the ratio E_{280}/total N (Jankiewicz & Jankowski, 1969). The latter values were calculated in this paper and also showed in this case the influence of the maternal component on those values in F_1 hybrids. This observation was particularly striking in the case of the basic fraction containing high molecular weight glutenin. Since in this fraction proteins are contained, which are suggested to be most important for the baking quality of flour, this observation should be treated with the highest attention by breeders selecting wheats in the direction of quality improvement.

CONCLUSIONS

1. Total protein content in wheat, its fractional composition and total extractability in F_1 hybrids are influenced mainly by the maternal components of the crosses.

2. The content of the protein fraction soluble in NaOH is strictly bound with the flour baking quality.

3. In the evaluation of the flour baking quality of interest is the ratio of protein soluble in acetic acid to those soluble in NoOH; its value in F_1 hybrids is influenced by the maternal component.

4. The compactness of molecules contained in the particular protein fractions is also influenced by maternal components, the most striking case being the basic fraction containing high molecular weight glutenin.

5. The observations mentioned above should be of importance for breeders intending to improve the baking quality of wheat.

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Dziedziczenie składu białek ziarna pszenicy w mieszańcach F_1

STRESZCZENIE

Na próbach pszenicy form matecznych męskosterylnych i ojcowskich o zdolności przywracania płodności wykonano serię krzyżówek F_1 i oznaczono we wszystkich azot ogólny, skład frakcyjny białek i ogólną ekstraktywność oraz zwartość cząsteczek zawartych w poszczególnych frakcjach. Wykazano, że wymienione wskaźniki w pokoleniu F_1 były w znacznym stopniu kształtowane przez formy mateczne. Szczególnie ważny dla hodowli pszenicy, w kierunku poprawiania wartości wypiekowej, jest wpływ form matecznych na zawartość frakcji rozpuszczalnej w NaOH, zawierającej wysokocząsteczkową gluteninę oraz na zwartość cząsteczek w niej zawartych. Uzyskane wyniki wskazują na konieczność szczególnie starannego doboru form matecznych w programach prac krzyżówkowych.