Characteristics of Meal from Hulled Wheats (*Triticum dicoccon* Schrank and *T. spelta* L.): An Evaluation of Selected Accessions

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ABSTRACT

Fifty accessions of *Triticum dicoccon* (emmer) and 37 accessions of *T. spelta* (spelt) selected from a germplasm collection were evaluated and compared with cultivars of *T. durum*. For each sample, the chemical composition of the whole meal was determined. The carotene and gluten content, the hydration capacity of gluten were determined, and the sodium dodecyl sulfate (SDS) test was also performed. A wide variability of all tested traits was observed for both species. Emmer and spelt were found to differ mainly for gluten, bran, and SDS value. Higher contents of bran were typical of emmer, while spelt was characterized by higher values of gluten, and SDS test values. The experimental data were also submitted to principal component analysis. A satisfactory separation between the two species was obtained.

The hulled wheats *Triticum monococcum* L. (einkorn), *T. dicoccon* Schrank (emmer), and *T. spelta* L. (spelt) were extensively grown in the past and they represented a staple in the everyday diet. Their diffusion has progressively diminished though the centuries. Yet during the late Roman Empire, hulled wheats were largely replaced by the modern unhulled wheats, which provided higher yields and were easier to process. As a consequence of their decline, the growing of einkorn, emmer, and spelt was restricted to less favorable sites (Kuckyuck 1970, D'Antuono 1994). Currently, they survive in marginal farming areas of Italy, the Balkan peninsula, and Turkey, where they are mainly used for feeding livestock (Pavicevic 1975, Hammer and Perrino 1984, D'Antuono 1989). Nevertheless, the interest toward hulled wheats has been increasing again over the last few years. This increased interest is due to the low-input techniques used for their management (D'Antuono 1989), the increasing demand for unconventional foods, the therapeutic properties attributed to their derivatives (Auricchio et al 1982, Strehlow et al 1991), and their potential as source of genes for breeding unhulled wheats (Sharma et al 1981).

To set out the best strategy for the utilization of hulled wheats, it is essential to safeguard and evaluate the available germplasm. Although a sufficient level of knowledge has been reached on the agronomic performances of hulled wheats (Hakim et al 1992, Vallega 1992, Ruegger and Winzeler 1993), a systematic screening of the technologically relevant characteristics of these grains is still lacking. Data available in literature on this topic for emmer and spelt are sparse and controversial (Luft et al 1991, Cubadda and Marconi 1994, Galterio et al 1994, Abdel-Aal et al 1995).

The aim of this study was to evaluate the grain composition of 87 accessions of both *T. dicoccon* and *T. spelta* selected from the collection of hulled wheats held at Germplasm Institute of Bari (IdG). The selection was made from 1990 to 1992 in the hilly environments of Southern Italy, on the basis of several agronomical traits (yield, resistance to diseases, etc.) (Perrino et al 1991, 1993).

MATERIALS AND METHODS

The examined hulled wheat accessions (50 of *T. dicoccon* Schrank and 37 of *T. spelta* L.) (Table I) were grown, together with control durum wheats, in an experimental field in Southern Italy (Gaudiano di Lavello 41° 05′ N latitude, 15° 53′ E longitude, 140 m elevation) in 10 m^2 plots during the 1992–93 growing season. The durum wheat cultivars selected as the control were those more widely grown in the Southern Italy environments used to grow the material tested in this study. After harvesting, *T. dicoccon* and *T. spelta* accessions were dehulled with a wheat thresher. The apparatus rpm was set to cause only very slight abrasions on the grain surface. About 50 g per accession were cleaned and successively ground with a 1.0-mm sieve Cyclotec mill 1093 (Tecator). Only whole meal was used for all the analyses.

Ash, fat, and moisture contents were determined according to standard methods (AOAC 1970). Protein content was determined by the Kjeldhal method (N × 5.7). Wet and dry gluten were determined by hand-washing the meal according to the standard method (AACC 1995). The hydration capacity of gluten was calculated as the weight ratio: (wet gluten – dry gluten)/wet gluten. Bran was collected during gluten test, washed until starch was not detected in the washing water, then dried and weighed. Pigment content (expressed as ppm of carotene) was measured spectrophotometrically (AACC 1995). Sodium dodecyl sulfate (SDS) sedimentation assays were performed with a 2% SDS solution (Dick and Quick 1983). The quality index was equal to the ratio between SDS test value and protein content. This removes the influence of the protein content on the SDS value and, consequently, allows a correct comparison among accessions with different protein level (Halverson and Zeleny 1988).

Statistical analysis of experimental data was made using the SAS system package (1987).

RESULTS

Data relative to the grain composition of hulled and unhulled wheats are summarized in Table II. An appreciable variability among accessions, relative to all tested parameters, was observed in both emmer and spelt.

The protein content was not significantly different between *T. dicoccon* and *T. Spelta*. The highest values were found in three spelt accessions showing 19.4% (MG 15451/1) and 19.0% (MG 5285/3 and MG 5285/8). The mean protein level relative to emmer and spelt (16.7 vs. 17.1%) exceeded the values observed for the controls. Whole meal of both hulled wheat species was also very similar for ash and fat contents (Table II).

A distinctive trait between the two species ($P < 0.01$) was the bran content; higher values were observed for emmer (mean 15.3% vs. 11.6%). The highest value among *T. dicoccon* lines was 26.4% (MG 5400/2A), while 18.0% (MG 5285/2) was the maximum for *T. spelta* accessions. Some technological perform-

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ance parameters of the whole meal were also tested (Table II). Significant differences between the two species were observed for the dry gluten content ($P < 0.01$); 80% of the emmer lines had values ranging from 9 to 13%, while 85% of spelt accessions fell between 11 and 13%. The maximum (17.2%) was recorded for the spelt accession MG 5285/3, one which had shown the highest protein content. The anomalous value (only 4.2%) relative to the emmer line MG 5400/2A, which also showed the highest bran value, was confirmed by repeated analyses. The gluten content of this accession was remarkably lower than the minimum (≈8%) recorded for this species. As expected, both species showed a positive correlation between protein and dry gluten contents (emmer, $r = 0.638$ $P < 0.01$; spelt, $r = 0.765$ $P < 0.01$), while a negative correlation between gluten and bran was significant only for emmer ($r = -0.591$ $P < 0.01$). The gluten content observed in the whole flours of the controls was lower than the value of the hulled wheats (Table II).

Ratios between dry gluten and protein content were also significantly different ($P < 0.01$) between the two species; higher values were typical of spelt, with 87.5% (MG 5285/3) as maximum. The lowest value observed for emmer (only 29.8%) is relative to the accession MG 5400/2A, which has also shown very low value for gluten. The next lowest value was 50.8% (MG 5281/1), which should be regarded as the true minimum of this species. Quite similar was the water retention capacity of gluten relative to the three tested species.

The SDS test significantly differentiated between spelt and emmer ($P < 0.01$). *T. spelta* was characterized by a very broad range of values, whereas emmer SDS results fell into a more narrow range (Fig. 1). In fact, the maximum relative to *T. dicoccon* (53 ml, MG 5320/1) was slightly lower than the mean value (56 ml) of spelt lines. The highest SDS value (95 ml) was recorded for the accession MG 15398/1. SDS values of controls appeared, as expected, to be more similar to those of emmer. The calculation of the quality index confirmed this trend. However, the highest values were found for different accessions. Finally, the ranges of carotene content relative to emmer and spelt were widely overlapping (Table II). The maximum (5.0 ppm) was found in the spelt accession MG 27225/1.

Protein, ash, fats, bran, gluten, carotene, and SDS value were submitted to the principal component analysis (PCA) to better perceive the distinctive features of the two hulled wheat species. The analysis of the obtained eigenvalues shows that the components PRIN 1 and PRIN 2 account for 54.5% of the standardized variance, the addition of a third component (PRIN 3) increases this value to 67.8%. The first eigenvector has similar loadings on proteins, ash, bran, gluten, and SDS values (0.407, 0.402, –0.427, 0.494, and 0.410, respectively). The second eigenvector mainly evaluates proteins, fats, carotene, and SDS values (–0.535, 0.419, 0.425, and 0.453, respectively). If PRIN 1 and PRIN 2 are used to diagram the tested accessions, a polarization of emmer from spelt can be observed (Fig. 2). Spelt accessions fall on the right of the diagram, emmer accessions fall on the left. The appreciable dispersion of both species denotes the high genetic variability of this part of the hulled wheat germplasm collection.

DISCUSSION

Because whole grains of emmer or spelt are traditionally used in the preparation of soups as are, sometimes, whole grains of durum wheat, it is important to evaluate the total grain composition of these species. As shown in Table II, hulled and unhulled wheat grains differed mainly in the protein content (Table II). The high levels observed in this study for *T. dicoccon* and *T. spelta* agree with data reported in literature. Cubadda and Marconi (1994) found protein levels of 18.5 and 21.9% in two hulled wheat populations, while values ranging from 14.9 to 16.0% were found by Abdel-Aal et al (1995) in five spelt accessions. High protein contents were reported also for 12 accessions of *T. monococcum* (from 12.9 to 18.7%) (D'Egidio et al 1993) suggesting this as a common trait of hulled wheats. However, these evidences do not justify the classification of these primitive wheats as protein-rich crops since their high protein levels are a consequence of low

TABLE I
Identification Code (MG number) of Analyzed Accessions

T. spelta					
4451/1	5268/2	5281/3	5285/2	5285/3	5285/8
5320/2	5321/2	15347/1	15355/1	15366/1	15387/1
15398/1	15400/1	15418/1	15440/1	15451/1	15464/1
15469/1	15477/1	15490/1	15492/1	15559/1	15577/1
15586/1	15612/1	26716/1	26716/2	26716/3	27182/4
27186/1	27201/1	27201/3	27216/2	27219/4	27224/2
27225/1					
T. dicoccon					
3521/1	4375/1	4378/1	4387/1	5281/1	5281/1A
5282/1	5282/2	5282/3A	5282/3B	5285/1	5285/7
5292/1	5293/2	5293/3	5297/1	5297/2	5300/3
5302/1	5302/4	5303/1	5308/2A	5308/2B	5320/1
5324/3	5331/1	5333/1	5334/1	5334/2	5335/2
5338/1	5350/2	5357/2	5357/4	5379/4Bi	5379/4S
5380/1	5381/1	5399/3	5399/4C	5399/4S	5399/7
5400/2A	5400/2M	5400/5	5539/1	27201/4	30832/1
30833/2	30835/1				

TABLE II
Grain and Flour Characteristics[a] of the Examined Accessions (% dry basis)

Type	Protein	Ash	Fat	Bran	Dry Gluten	DG/P (%)	IC (%)	SDS (ml)	QI	Car (ppm)
Emmer										
Mean	16.7	2.00	2.0	15.3	10.9	65.4	73.3	34	2.02	2.9
Min	13.7	1.75	1.4	7.6	4.2	29.8	68.9	26	1.53	2.0
Max	18.8	2.33	2.8	26.4	14.1	78.1	77.4	53	3.01	4.2
SE	0.16	0.02	0.05	0.47	0.24	1.12	0.27	0.76	0.05	0.07
CV	6.62	5.75	17.36	21.84	15.28	12.06	2.58	16.01	16.95	18.19
Spelt										
Mean	17.1	2.09	2.1	11.6	12.8	74.8	73.3	56	3.32	3.4
Min	15.0	1.91	1.7	9.0	10.2	62.5	68.3	29	1.71	2.2
Max	19.4	2.46	2.5	18.0	17.2	87.5	76.7	95	5.52	5.0
SE	0.16	0.02	0.03	0.36	0.24	0.92	0.40	2.16	0.13	0.11
CV	5.68	5.29	8.78	18.62	11.62	7.50	3.30	23.22	24.27	20.34
Durum wheats										
Norba	14.1	1.89	1.4	16.1	7.0	50.0	67.4	35	2.48	4.7
Simeto	16.1	2.34	1.1	16.3	7.4	46.0	70.5	32	1.99	4.1
Venusia	15.6	1.84	2.1	18.2	8.1	52.0	72.0	30	1.92	5.2

[a] DG/P = dry gluten/protein; IC = hydration capacity of gluten; SDS = sodium dodecyl sulfate; QI = quality index; Car = carotene. SE = standard error; CV = coefficient of variation.

grain yields. This is manifested by comparing the protein yields of the three tested species. The maximum value of emmer (450 Kg/ha) and spelt (460 Kg/ha) only accounts for the 75% of protein yield of the control wheats (mean 550 Kg/ha).

From a nutritional point of view, high protein contents are effective only when coupled with high protein quality. Sparse and controversial data are available for hulled wheats on this topic. Galterio et al (1994) reported high lysine levels (3.1%) for emmer populations. Ranhotra et al (1995) found an opposite result for one spelt accession (2.0% of lysine) but described a higher digestibility of spelt proteins as compared to wheat. The different size of grains between the two species could explain the difference observed in bran content. In fact, spelt grains, due to the larger volume have a lower surface-to-volume ratio, and consequently, less bran per meal weight unit. The bran, as well as other nonnutritional grain components of hulled wheats, needs further investigation. One recent study has associated interesting therapeutic properties of spelt to high levels of noncellulose polysaccharides in its fiber (Italiano and De Pasquale 1994).

For the minor grain components, both emmer and spelt showed higher ash contents than did the durum wheats. Similar results have been reported also for einkorn (D'Egidio et al 1993, Abdel-Aal et al 1995). The low ash content of present-day wheat cultivars is the result of a selection to increase the milling yield (Rasmusson et al 1971). Therefore, this parameter could be an indicator of the primitiveness of hulled wheats. Breeding for low mineral contents might be possible for hulled wheats since a broad range of ash contents has been observed in this study, however, this will be associated with a decrease of microelement supply to the diet.

The increasing consumer interest toward hulled wheats is stimulating investigations to evaluate the use of hulled wheat meal in the industrial production of common wheat derivatives (bread, pasta, biscuits, etc.). Similar utilization requires specific standards of protein quality and gluten performance (Matweef 1966, D'Egidio et al 1979, Grzybowski and Donnelly 1979, Dexter et al 1981). Both species show a higher dry gluten content relative to the whole meal of controls. The divergence between *T. dicoccon* and *T. spelta* increases when analyzing the gluten-to-protein ratio. In fact, 81% of the spelt accessions showed values higher than 70%, while only 28% of the emmer lines exceeded this threshold. High gluten levels, as well as high gluten-to-protein ratio, have been described also for einkorn (D'Egidio et al 1993), suggesting these as additional distinctive traits of the hulled wheat species. Probably gluten of hulled and unhulled wheats differ also from a qualitative point of view. Low glutenin-to-gliadin ratio have been described recently for emmer genotypes (Galterio et al 1994).

The gluten properties of emmer and spelt have been only partially evaluated in this study because of the scarcity of material, which is typical of germplasm accessions where there is not enough to carry out the alveographic assays. The water retention capacity of gluten, not a species-specific trait, was found similar to the control wheats, in contrast to what has been reported for einkorn (D'Egidio et al 1993). Conversely, the gluten strength, as estimated by the SDS test, became a distinctive trait between emmer and spelt. The quality index calculation confirmed the strong divergence of the two species relative to this parameter (Table II). The range observed for spelt SDS is surprisingly broad; it is greater than that observed by Blanco et al (1990) analyzing 200 accessions of *T. monococcum* (subsp. *monococcum*, 26–61 ml; subsp. *boeoticum* 29–63 ml).

CONCLUSIONS

The biochemical evaluation of a selected part of the hulled wheats germplasm stored at IdG has shown the existence of a wide variability for several traits. The screening of the whole collection could add further interesting information. Familiarity with the characteristics of this germplasm is fundamental for its utilization in breeding programs aimed at improving the performances of these primitive crops, as well as to using them as source of useful genes.

Though the tested parameters did not allow a complete differentiation between emmer and spelt, they are sufficient to assess some peculiarities of each species. Spelt meal appears to be more appropriate for the production of bread or similar products. Recent studies have shown that the performance of spelt bread is inferior to that of common bread (Ranhotra et al 1995), but it is comparable to that of durum wheat bread, which is very much appreciated in several Mediterranean regions (Spada et al, *in press*). It is important to remember that the potential of *T. dicoccon* and *T. spelta* does not reside in their capacity to mimic attributes that are already present in the commercial cultivars of wheat, but in their genetic potential to code for very specific characteristics such as high digestibility and nontoxicity in coeliac disease, etc.

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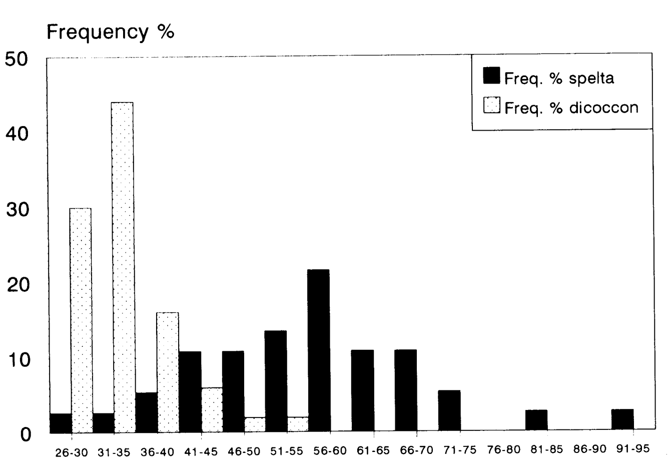

Fig. 1. Distribution frequency of sodium dodecyl sulfate (SDS) test values.

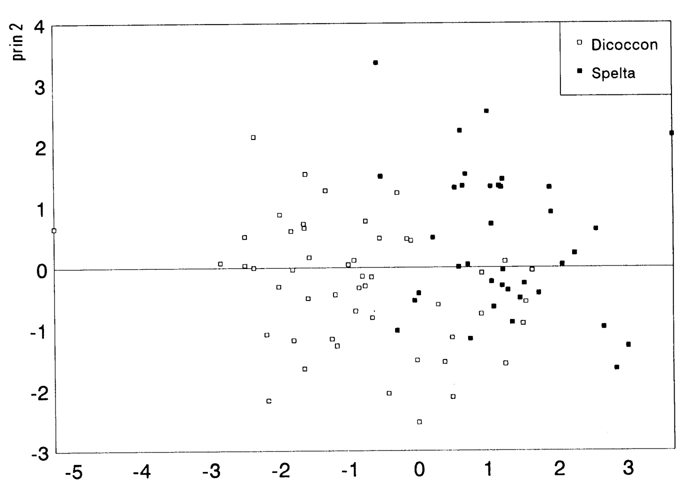

Fig. 2. Principal component analysis plot.

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