Compositional and Nutritional Characteristics of Spring Einkorn and Spelt Wheats

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ABSTRACT

One einkorn and five spring spelt accessions were grown at five and four locations in 1992 and 1993, respectively, and evaluated for their compositional and nutritional properties compared to common hard red spring (HRS) and durum wheats. Einkorn and two spelt accessions, SK0021 and PGR8801, were higher in soluble sugars, protein, and ash, whereas spelt accessions SK0505, SK0263, and RL5407 were higher in starch and fat. The accessions contained less total and insoluble dietary fiber than did common HRS, while soluble fiber was similar among the wheat species. Einkorn was significantly higher in phosphorus level, and all accessions exceeded the HRS wheat in potassium level. Einkorn tended to be high in riboflavin and pyridoxine compared with other wheats, whereas einkorn and spelt SK0263 and RL5407 were richer in β-carotene and retinol equivalent than was common HRS wheat. Einkorn and spelt SK0021 and PGR8801 flours had higher protein contents than did common HRS flour. The gluten content of all wheat species was similar and constituted about 77% of total flour protein. The gliadin to glutenin ratios were 2:1 for einkorn; 1:1 for spelt SK0021 and PGR8801 and common HRS; and 0.8:1 for durum and spelt SK0505, SK0263, and RL5407 wheat flour proteins.

Wheat is the principal source of energy, protein, and dietary fiber for a major portion of the world's population. While most of the world wheat crop arises from production of common (*Triticum aestivum* subsp. *vulgare* [Vill. Host] Mackey) and durum (*T. durum* Desf.) cultivars, there is increasing interest in ancient wheat species. These currently have limited uses, except as animal feeds, because of the retention of hulls on the grain after threshing. Among species of interest are einkorn (*T. monococcum* L.) and spelt (*T. aestivum* subsp. *spelta* [L.] Thell). After dehulling, the grains are promoted as being more nutritious than current commercial species and potentially nonallergenic. Spelt wheat is reported to have a unique flavor and high vitamin content (Jacquot et al 1960, Winzeler and Ruegger 1990). Much of the interest in einkorn arises from the findings of Auricchio et al (1982) and Favret et al (1984, 1987) that einkorn proteins were not a factor in the induction of celiac disease or in subsequent toxicity.

Recently, einkorn was found to be not only a good source of new and useful genes but also as a crop that has good agri-biological properties (Waines 1983; Vallega 1992, 1994). It is a small-seeded wheat with high flour protein and yellow pigment contents (D'Egidio et al 1993, D'Egidio and Vallega 1994). Doughs prepared from einkorn flour exhibited lower mixograph characteristics and were sticky, difficult to handle, and produced low bread loaf volumes. A sample of spelt wheat was also investigated for its baking and nutritional qualities by Ranhotra et al (1995). They found that there are no significant differences between spelt and HRW wheat in nutritional constituents such as protein, fiber, minerals, and vitamins. Furthermore, the spelt gluten proteins tested positive to a gluten immunoassay.

The objective of the present study was to evaluate the nutritional composition of selected accessions of einkorn, durum, spelt, and common hard red spring (HRS) wheats, which were grown in replicated tests at five locations in 1992 and four locations in 1993. The hulled accessions were dehulled before analysis so that comparisons could be made on a whole-grain basis. Because of the interest in vitamin and essential mineral contents, the study was restricted to the analysis of whole wheat grains and not milled flours. The latter would be depleted in these nutrients in proportion to the degrees of bran and germ removal. The wheat flours were used for an evaluation of gluten, gliadin, and glutenin contents of the endosperm proteins.

MATERIALS AND METHODS

Materials

The accessions evaluated in this study were TM23 einkorn (*T. monococcum*) and SK0021, PGR8801, SK0505, SK0263, and RL5407 spelt (*T. aestivum* subsp. *spelta*). The spelt accessions are representative of about 200 lines based on their agronomic properties, quality attributes, and their gliadin composition relative to six commercial winter spelt samples using A-PAGE. Kyle durum (*T. durum*) and Katepwa (*T. aestivum* subsp. *vulgare*), a common hard red spring cultivar, were included as controls. The wheats were grown in a three-replicate randomized complete block experiment at five locations including Saskatoon, Kernen, Elrose, Goodale, and Wakaw in central Saskatchewan in 1992 and four locations in 1993. Only two replicates from each trial were analyzed in the present study. The data were analyzed by analysis of variance using Minitab Statistical Software (Minitab 1989). Because the main aim of the present study was to study differences among wheat genotypes, the data are averaged over replications and experiments (n = 18). Mineral and vitamin data were analyzed on only one location in each year and thus are means of four replicates.

The samples were dehulled by passing the grain between rubber-coated rolls and aspiration to remove the hulls. The hull-free grain was then ground to pass a 1-mm screen on a Udy Cyclone sample mill (Udy Co., Fort Collins, CO). The wheat flours were obtained by tempering the grains for 18 hr to 13, 14, 15, and 16% moisture for einkorn, spelt, common, and durum wheats, respectively, based on the results of preliminary experiments. One hundred gram samples were milled on a Brabender Quadrumat Jr. Flour Mill (Brabender Co., South Hackensack, NJ) equipped with a 6xx (233 μ) steel screen. Additional sifting of the bran fraction was done on a 64-mesh sieve using a Ro-Tap sieve shaker (Tyler Co., Mentor, OH) for 3 min.

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Analytical Tests

Meal samples were analyzed by standard AACC procedures (1990) for moisture (Method 44-15A), crude protein (Method 46-13), crude fat (Method 44-15A), and total ash (Method 08-03). For crude protein in wheat, the specific nitrogen (N)-to-protein conversion factor is 5.7 (AACC 1990 Method 46-11) but N × 6.25 is commonly used in nutritional studies for all protein sources (Bender 1988). Starch was measured as glucose on the YSI model 27 industrial analyzer (Yellow Springs Instrument Co., Yellow Springs, CO) after hydrolysis with α-amylase and amyloglucosidase. The 80% ethanol-soluble sugars were measured as glucose using the same instrument. Insoluble and soluble dietary fiber were quantified by the enzymatic gravimetric procedure of AACC (1990) Method 32-21. Energy was calculated as the sum of caloric values of protein, starch, sugars, and fat in each wheat species. Wet and dry gluten were determined by the machine washing Method 38-11 of AACC (1990). Gliadin was determined in 70% ethanol extracts, following extraction with 0.5*N* NaCl solution, by the Kjeldahl method, while glutenin was determined in the residue by the Kjeldahl method. β-Carotene was determined by the spectrophotometric Method 43.014-43.017 of the AOAC (1984). Analysis for thiamine and riboflavin (Sims and Shoemaker 1993), niacin (Chase et al 1993), and vitamin D (Agarwal 1992) were based on liquid chromatographic procedures. Vitamin A was quantified colorimetrically by Method 974.29 of the AOAC (1990) and vitamin E was measured by gas chromatography Method 988.14 of the AOAC (1990). Pyridoxine was determined microbiologically according to Method 961.15 of the AOAC (1990). Minerals were measured in an ash solution using an inductively coupled plasma/atomic emission spectrometry (ICP/AES) technique.

RESULTS AND DISCUSSION

Major Constituents

Durum and three spelt accessions, SK0505, SK0263 and RL5407, contained the highest starch contents, about 65%, as compared to only 61–62% starch in the other wheats (Table I). Soluble sugar concentrations, while not high, occurred in inverse proportion to starch levels. Similarly, the protein levels in einkorn and SK0021 and PGR8801 spelt accessions were high, 16.0–16.5%, as compared to 14.9–15.3% in the more starchy wheats. Acquistucci et al (1995) reported very close protein content at mean level of 16.7% when they investigated 15 einkorn strains for their amino acid and protein composition. On the other hand, a higher protein level of 18.6% in einkorn flour was reported by Waines (1983). Einkorn and spelt SK0505, SK0263, and RL5407 accessions contained significantly more crude fat than other wheats, suggesting that there may also be significant differences in proportion of germ in the kernels. Einkorn and spelt SK0021 and PGR8801 accessions were high in ash as compared with wheat controls, whereas spelt SK0505, SK0263, and RL5407 accessions were intermediate. Similar results were obtained by Vallega (1991) in 15 strains of diploid, two strains of tetraploid, and two strains of hexaploid wheats.

Insoluble dietary fiber was the major fiber component in the wheat species, soluble fiber representing only 17% of total dietary fiber (Table II). While there were no significant differences among species and subspecies in soluble fiber content, the HRS wheat was highest in insoluble and total dietary fiber, followed by durum wheat. There were no significant differences among the spelt accessions, which averaged 10% of total dietary fiber. Einkorn was significantly lower in insoluble and total dietary fiber, the latter being 8.7%, of which soluble fiber was nearly 20%.

The total constituents accounted for by the analyses reported in Tables I and II varied from 93.5 to 97.4%. Components also present in wheat include polar lipids, phytate, volatile ash constituents, and oligosaccharides.

The digestible energy contents of the wheats were calculated using conversion factors for the digestible constituents in Table I (Table II). These data confirmed the low levels of high energy components in spelt SK0021 and PGR8801 and the higher levels in the other spelt accessions. Wheat grains contained from 338 to

TABLE I
Chemical Composition of Meals from Wheat Species and Subspecies Grown in Nine Trials Over Two Years (% dry basis)[a]

Wheat Species or Subspecies	Name or Designation	Cultivar or Accession	Digestible Carbohydrates		Crude Protein		Crude Fat	Total Ash
			Starch	Sugars	N × 5.7	N × 6.25		
monococcum	Einkorn	TM23	61.8 a–c	2.67 ab	16.5 a	18.1 a	2.48 a	1.86 a
durum	Durum	Kyle	64.9 a–c	1.98 b–d	15.1 b	16.6 b	2.10 d	1.63 d
spelta	Spelt	SK0021	60.9 c	2.51 bc	16.0 a	17.5 a	2.21 bc	1.84 ab
spelta	Spelt	PGR8801	61.6 bc	2.48 bc	16.0 a	17.5 a	2.30 b	1.77 a–c
spelta	Spelt	SK0505	65.6 ab	1.98 b–d	15.2 b	16.7 b	2.48 a	1.69 c
spelta	Spelt	SK0263	65.3 ab	1.69 d	14.9 b	16.3 b	2.45 a	1.68 c
spelta	Spelt	RL5407	65.8 a	1.80 cd	15.1 b	16.6 b	2.47 a	1.69 c
vulgare	Common HRS	Katepwa	62.4 a–c	3.29 a	15.3 b	16.8 b	2.14 cd	1.73 bc
...	...	Pooled SE	1.38	0.26	0.20	0.23	0.04	0.05

[a] Means with the same letters are not significantly different at $P \leq 0.05$.

TABLE II
Dietary Fiber and Energy of Meals from Wheat Species and Subspecies Grown in Nine Trials Over Two Years (% dry basis)[a]

Wheat Species	Dietary Fiber			Total Constituents[b]	Energy (cal/100 g)
	Insoluble	Soluble	Total		
Einkorn	6.9 d	1.7 a	8.7 d	94.0	346.2
Durum	9.5 b	1.6 a	11.1 b	96.8	346.8
Spelt SK0021	8.3 c	1.7 a	10.0 c	93.5	337.5
Spelt PGR8801	8.4 c	1.9 a	10.3 c	94.5	341.0
Spelt SK0505	8.3 c	1.7 a	10.0 c	97.0	353.4
Spelt SK0263	8.1 c	1.7 a	9.8 c	95.8	349.6
Spelt RL5407	8.0 c	1.8 a	9.8 c	96.7	353.0
Common HRS	10.8 a	1.7 a	12.5 a	97.4	343.2
Pooled SE	0.21	0.15	0.28	...	...

[a] Means with the same letters are not significantly different at $P \leq 0.05$.
[b] Using N × 5.7 protein values.

353 cal per 100 g sample with spelt SK0505, SK0263, and RL5407 accessions having the highest level.

Minerals and Vitamins

Phosphorus, potassium, sulfur, and magnesium were the major mineral components in the wheats (Table III). These analyses were not done on all accessions and locations; rather, a representative sample was selected. Einkorn, which contained the most ash (Table I), was significantly higher in phosphorus content (415 mg/100 g) and all accessions exceeded the HRS wheat in potassium level, averaging about 383 mg/100 g. Because phytate is the principal source of phosphorus in wheat (Bourdet and Feillet 1967), its levels in einkorn relative to other wheats were of interest. A spelt wheat sample was also found to be higher in phosphorus, copper, potassium, and zinc by 19, 20, 7, and 91%, respectively, as compared to HRW wheat (Ranhotra et al 1995). Spelt PGR8801 had a high level of sulfur (210 mg/100 g). Manganese showed few significant differences among wheat species and subspecies with spelt PGR8801 having the lowest concentration (3.7 mg/100 g). There were few significant differences among the wheats for the other minerals. For example, magnesium ranged from 140 to 150 mg/100 g, calcium from 30 to 35 mg/100 g, sodium from 8 to 12 mg/100 g, iron from 5.3 to 7.1 mg/100 g, zinc from 2.7 to 3.6 mg/100 g, and copper from 0.5 to 1.0 mg/100 g.

Differences in composition of B vitamins among the wheats were not large, especially for thiamine, which amounted to about 0.6 mg/100 g (Table III). Riboflavin was relatively high in einkorn and common wheat (about 0.5 mg/100 g) but was low (0.15 mg/100 g) in the spelt accessions. On the other hand, spelt PGR8801 and RL5407 had higher concentrations of niacin (5.5 mg/100 g) compared to einkorn, spelt SK0263, and common wheat (2.5 mg/100 g). Ranhotra et al (1995) analyzed three B vitamins, thiamine, riboflavin, and niacin, and found that only niacin was higher (5%) in spelt wheat compared with HRW. Einkorn appeared to be high in pyridoxine compared to the other wheats.

Among the fat-soluble vitamins, there were no significant differences among wheats in contents of vitamin A, E, and D. These vitamins ranged from 6 to 9, from 2.5 to 5.0, and from 0.4 to 0.5 IU/100 g, respectively. However, einkorn was rich in β-carotene and retinol equivalent, with spelt also being significantly higher in these vitamins than common HRS wheat (Table III). Several researchers reported that einkorn is rich in yellow pigments (D'Egidio et al 1993, D'Egidio and Vallega 1994).

Protein Composition

The allergenicity of bread wheats is associated with the gluten-forming proteins in the storage proteins of the endosperm, specifically gliadin proteins. However, *T. monococcum* was found to be nontoxic for individuals having celiac disease (Auricchio et al 1982). Therefore, the total gluten content and composition in the wheat, especially in the endosperm flour proteins, and the ratio of gliadin to glutenin (G/G) was of interest in the nutritional evaluation of the wheat accessions. In addition, gliadin proteins have quite different amino acid compositions from glutenin proteins in that they are relatively rich in glutamic acid and proline, whereas glutenins are rich in lysine. Consequently, the G/G ratio may reflect the concentrations of these amino acids in wheat proteins or their peptide digests.

Again, einkorn and spelt SK0021 and PGR8801 flours were significantly higher in protein content than was common HRS flour, whereas the durum and spelt SK0505, SK0263, and RL5407 were particularly low in total protein (Table IV). Wet and dry gluten yields from the flours were particularly high for the spelt SK0021 and PGR8801, whereas gluten yields from einkorn

TABLE III
Mineral and Vitamin Contents of Meals from Wheat Species and Subspecies Grown in Two Trials Over Two Years[a]

Component	Einkorn	Spelt PGR8801	Spelt SK0263	Spelt RL5407	Common HRS	Pooled SE
Minerals (mg/100g)						
Phosphorus	415 a	370 b	355 b	350 b	360 b	34.5
Potassium	390 a	375 a	375 a	390 a	305 b	36.5
Sulfur	190 b	210 a	190 b	190 b	185 b	5.0
Manganese	4.4 ab	3.7 b	5.9 a	5.8 a	5.1 ab	0.5
B vitamins (mg/100g)						
Thiamine	0.50 a	0.60 a	0.55 a	0.52 a	0.57 a	0.15
Riboflavin	0.45 a	0.15 b	0.17 b	0.14 b	0.55 a	0.13
Niacin	3.1 b	5.7 a	2.0 b	5.3 a	2.3 b	0.90
Pyridoxine	0.49 a	0.42 b	0.35 c	0.35 c	0.36 c	0.02
Fat-soluble vitamins (IU/100 g)						
β-carotene	914 a	286 c	782 ab	672 bc	408 c	89
Retinol equivalent[b]	93.8 a	30.7 e	80.9 b	69.9 c	42.6 d	1.7

[a] Means with the same letters are not significantly different at $P \leq 0.05$.
[b] 1 retinol equivalent = 3.33 IU vitamin A or 10 IU β-carotene.

TABLE IV
Protein Compositions of Flours from Wheat Species and Subspecies Grown in Nine Trials Over Two Years (% dry basis)[a]

Wheat Species	Flour Protein (N × 5.7)	Wet Gluten Yield	Dry Gluten Yield	Gliadin (% of total flour protein)	Glutenin (% of total flour protein)	G/G ratio[b]
Einkorn	14.6 a	25.9 d	9.7 d	51.3 a	26.5 d	1.94 a
Durum	12.7 c	34.8 c	12.0 c	34.9 c	41.4 ab	0.84 cd
Spelt SK0021	14.2 a	41.7 ab	14.0 ab	39.5 b	38.0 bc	1.04 b–d
Spelt PGR8801	14.1 a	42.7 a	14.0 ab	41.9 b	34.6 c	1.22 b
Spelt SK0505	13.2 bc	39.2 b	12.8 bc	33.4 c	42.3 a	0.79 d
Spelt SK0263	13.2 bc	39.9 ab	13.0 bc	33.1 c	40.9 ab	0.81 cd
Spelt RL5407	13.2 bc	40.1 ab	12.9 bc	34.7 c	42.8 a	0.81 cd
Common HRS	13.4 b	35.0 c	12.3 c	41.3 b	38.3 b	1.08 bc
Pooled SE	0.19	1.17	0.45	1.18	1.26	0.10

[a] Means with the same letters are not significantly different at $P \leq 0.05$.
[b] Gliadin to glutenin ratio.

were particularly low. However, the gluten content constitutes about 77% of total flour proteins and was similar in all wheat species. The gliadin to glutenin ratio for einkorn proteins was 2:1 as compared to 1:1 for spelt SK0021 and PGR8801 and common HRS proteins and 0.8:1 for durum and spelt SK0505, SK0263, and RL5407. Based on the current study, einkorn showed a distinct gluten composition and G/G ratio that was significantly different and higher than that of the other wheat species.

In general, the einkorn accession was more nutritious, having higher levels of protein, phosphorus, potassium, riboflavin, and pyridoxine. In addition, einkorn proteins showed a low gluten yield and 2:1 ratio of gliadin to glutenin. The spelt accessions SK0021 and PGR8801 were rich in protein, whereas spelt SK0505, SK0263, and RL5407 were high in starch, fat, and energy. Einkorn and the latter spelt wheats were also rich in β-carotene and retinol equivalent compared with common HRS wheat.

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