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Characteristics of spelt wheat products and nutritional value of spelt wheat-based bread

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Abstract

Spelt wheat cultivars (cv.) Hercule, Rouquin and Ostro, grown in the Alpine region of Italy, were compared to the common wheat cv. Manital and durum wheat Grazia for protein, ash and dietary fibre contents. The spelt wheat cultivars studied had higher contents of soluble dietary fibre and protein than the standard wheat or the durum wheat. In the bread of spelt wheat (cv. Hercule), there was more rapidly digested starch (RDS) and a higher starch digestion index (SDI) in comparison to wheat bread. The bread made of whole spelt wheat flour (cv. Hercule) had less total starch, more resistant starch and less rapidly digested proteins in comparison to bread made of white spelt wheat flour and white wheat flour (cv. Manital). In pasta and extruded products of whole spelt flours, more protein, ash and dietary fibre was found in comparison to the same products made of white spelt wheat flour.

1. Introduction

Spelt wheat (*Triticum aestivum* subsp. *spelta*) is an old European crop, grown for centuries, including the first half of this century, in several countries of central Europe (e.g. Belgium, Germany, Austria, Slovenia, and northern parts of Italy). For many years, cultivation of spelt declined, but recent interest in use of spelt for ecologically grown foods has led to resurgence in its cultivation. Spelt wheat is a low-input plant, suitable for growing without the use of pesticides, in harsh ecological conditions and in marginal areas of cultivation. Hercule is one of the spelt varieties which shows promising yield potential and other agronomic characteristics for growth, both in northern Italy and possibly in neighbouring countries. Little information is known about the nutritional quality of spelt wheat (Abdel-Aal, Hucl, Sosulshi & Bhirud, 1997; Grela, 1996; Ranhotra, Gelroth, Glaser & Stallknecht, 1996). The aim of this study was to review the protein, ash and dietary fibre content, in spelt wheat cultivars grown in the Alpine region of Italy and to discover whether it is feasible to make pasta and extruded products from spelt wheat. The extent of starch digestion and changes in other specific nutritional properties during the production of quality bread from spelt wheat were also estimated and compared to commercial wheat bread.

2. Materials and methods

2.1. Wheat samples

Spelt wheat cultivars: Hercule, Rouquin and Ostro grown in the years 1992–1994 in Alto Adige, Italy; a commercial sample of spelt wheat, obtained from the USA, a sample of white flour from wheat, cv. Manital from Italy, and a sample of durum wheat cv. Grazia from Emilia Romagna, Italy, were used.

2.2. Preparation of the bread, pasta and extruded product

The milling process and the production of bread, pasta and extruded products were performed according to a previous study (Bonafaccia & Kreft, 1994), with

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adaptations described here. White spelt flour (cv. Hercule, extraction rate 71%) and whole spelt (extraction rate 100%) flours were obtained by milling dehusked spelt grains with a laboratory mill (Bühler ML 202). White wheat flour (cv. Manital) and durum wheat flour (cv. Grazia), used for comparison purposes, were milled in the same mill. Flour blends (whole spelt combined with white Manital, and white spelt combined with white Manital) were formulated in the ratio 1:1.

The bread-making test was done using the standard procedure outlined in the National Institute of Nutrition, Rome (Bonafaccia & Kreft, 1994): 500 g flour, 7.5 g salt, 20.0 g yeast and 200 ml water. The bread volume was determined by colza seed displacement. The hardness of crumb was determined by a Universal Testing Machine. With this method (AACC, 1995), a 25 mm thick slice of bread is compressed up to 25% using a piston, 36 mm in diameter, at a speed of 100 mm/min. The results, expressed in Newton, indicate the power required for compression of crumb.

A Pavan Mapimpianti TT58W bi-screw extruder with 58 mm diameter screws (temperature of extrusion 160/190°C) was used to produce extruded rings for the study, with the initial water content of 21%. Rings were made of 80% spelt or whole spelt flour and 20% sugar. Pasta was produced according to the method of Bonafaccia and Kreft (1994), from flour and water, with initial water content of 36% for whole spelt pasta, and of 30% for white spelt and durum pasta, dried to final moisture of 12.5%. Slender noodles (spaghetti) of 1 mm thickness were made using a PAT press (Pavan s.p.a., Padova, Italy; water temperature 50°C, head temperature 45°C, cylinder temperature 25°C, water 36%) with a capacity of 50 kg/h. For production of pasta white spelt, whole spelt and durum flours were used.

2.3. Chemical analyses

Amino acid analyses were performed using Beckman System Gold (Moore, Spachman & Stern, 1958). AACC (1995) methods were used to determine ash (0803) and moisture (44-19). Protein was determined by the Kjeldahl method (979.09) (AOAC, 1990), using a nitrogen to protein conversion factor of 5.75. Dietary fibre was determined according to Prosky, Asp, Schweizer, Devries and Furda (1988). All analyses were performed in quadruplicates.

2.4. Protein and starch digestibility

Protein digestibility was determined following the method of Gauthier, Vachon and Savoie (1986), that requires an *in vitro* digestion with pepsin and pancreatin in a dialysis bag. The dialysed amino acids and peptides were withdrawn every hour for a duration of 6 h. The nitrogen content was determined according to the Kjeldahl method (AOAC, 1990). The contents of total starch (TS), rapidly digested starch (RDS), slowly digested starch (SDS), and resistant starch (RS) were determined according to the procedure of Englyst, Kingman and Cummings (1992); the method is based on an enzymatic hydrolysis with porcine pancreas enzymes and amyloglucosidase. The starch digestion index (SDI) was calculated as RDS/TS (%).

2.5. Statistical analysis

The data were statistically analysed by analysis of variance to determine significant differences among samples using STATG (Statgraphics 5.0, Statistical Graphics Corporation, USA). Significance was accepted at $p < 0.05$.

3. Results and discussion

A comparison of the protein, ash and dietary fibre contents of spelt wheat varieties is presented in Table 1. Ostro had the highest protein content in comparison to other spelt wheat samples (Rouquin and Hercule). The spelt wheat cultivars studied had a higher protein content than the standard cultivars of wheat and durum wheat. They also had a higher content of soluble dietary fibre in comparison to the common wheat, while no difference in the ash content has been observed when comparing spelt and common wheat flours.

Hercule is a widely-grown cultivar in the Bolzano area, since the yield was higher than Rouquin and Ostro. Thus, for the detailed study of bread, pasta and extruded product, cv. Hercule was used.

Amino acid analysis showed that Hercule had a very similar amount of lysine and threonine, somewhat less cysteine but more methionine than the representative wheat sample from the same area (Table 2). The two spelt wheat tested (Hercule and the USA sample) may contain more of a specific protein (or group of proteins) rich in methionine. In a study of amino acid composition of three spelt wheat cultivars, it was found by Belitz, Seilmeier and Weiser (1989) that lysine and methionine content were in the range of comparable cultivars of wheat, but the cisteine content was higher in spelt wheat than in wheat.

Spelt wheat flour has a much higher water absorption capacity giving a somewhat smaller loaf volume than common wheat flour (Table 3). Further, the greater proportion of RDS and higher SDI in spelt wheat bread samples compared to wheat bread (Table 4) may be related to the higher water absorption ability. When more water is accessible in the system, starch granules can swell and gelatinise to a greater extent, and thus, be more readily digested than when a lower amount of water is present. While, in the literature, spelt wheat is studied mainly from the technological point of view,

Table 1
Average chemical composition of milled spelt wheat, wheat and durum wheat seeds, cultivated in the years 1992–1994

Cultivar	Protein (% dmb ± SD)	Ash (% dmb ± SD)	Dietary fibre (% dmb)			
			Total	Soluble	Insoluble	% Soluble
Hercule (spelt wheat)	15.9 ± 0.3	1.76 ± 0.02	13.8	1.7	12.1	12.3
Rouquin (spelt wheat)	16.2 ± 0.3	1.82 ± 0.02	13.0	1.8	11.2	13.8
Ostro (spelt wheat)	17.1 ± 0.4	1.85 ± 0.01	12.9	1.7	11.2	13.2
Manital (wheat)	13.8 ± 0.3	1.83 ± 0.01	12.8	1.4	11.4	10.9
Grazia (durum wheat)	12.4 ± 0.3	1.86 ± 0.01	12.3	1.6	11.7	13.0

Table 2
Amino acid composition of wholemeal spelt wheat and wheat flours (g/100 g protein)

	Spelt wheat (Hercule)	Spelt wheat (USA)	Wheat[a]
Asp	5.2	5.3	4.9
Thr	2.7	2.9	2.9
Ser	4.7	4.7	4.9
Glu	36.0	30.9	29.9
Pro	11.9	8.9	9.9
Gly	3.8	4.4	13.9
Ala	3.4	3.6	3.6
Cys	2.1	2.4	2.5
Val	4.7	4.7	4.4
Met	1.7	2.0	1.5
Ile	3.8	3.8	3.3
Leu	7.1	7.0	6.7
Tyr	2.7	2.3	3.0
Phe	5.1	5.4	4.5
Lys	2.7	2.8	2.9
His	2.4	2.3	2.3
Arg	4.5	4.5	4.6

[a] Literature data (Carnovale & Miuccio, 1989).

related to its applicability in some food products, there is still a lack of data about specific characteristics of major components, e.g. starch. Knowing the molecular characteristics of starch granules would probably help to explain the behaviour of spelt wheat starch during exposure to the amylolytic enzymes. With common wheat it was suggested (Eliasson & Larsson, 1993), that strong adhesion between starch and protein may result in breakage of the starch granules when milling the grain. Damaged starch could be therefore more accessible to the enzymes. As spelt wheat contains more protein than common wheat, it might be possible that proteins are firmly bound in starch granules, in the matrix. During milling, a greater extent of breakage of starch granules and thus higher SDI is expected in the case of spelt wheat. Bread from whole spelt wheat flour had less total starch but more resistant starch compared to bread from white wheat flour and white spelt flour. The difference might be due to the fact, that the material used for wholemeal spelt bread contained significantly more dietary fibre than that for white spelt wheat bread. The RS content obtained for spelt wheat breads (1.5–2.5%, dmb) showed that these particular products are relatively poor sources of RS. From this point of view, the present results are in accordance with those reported for other flour-based breads which on average contain up to 2% RS (Englyst et al., 1992; Liljeberg, 1995). By contrast, as shown in Table 5, protein in bread from whole spelt and white spelt wheat, cv. Hercule, was less rapidly digested and, after 6 h, more undigested residue was retained in comparison to bread from common wheat. From the spelt wheat studied, it was possible to produce bread with a higher (but less rapidly digested) protein content compared to bread made from common wheat flour.

Table 3
Results of technological bread-making test of spelt wheat and wheat flours, 1994 yield[a]

	Moisture (%)	Protein (% dmb)	Ash (% dmb)	Water absorption (%)	Loaf volume (cm^3)	Bread hardness (Newton ± SD)	Dietary fibre (% dmb)			
							Total	Sol.	Ins.	% Sol.
Manital, wheat[b]	29.0	11.8	1.86	53.5	459	14.3 ± 0.5	3.2	1.5	1.7	47
Hercule, spelt wheat[c]	28.7	12.8	1.75	58.0	454	13.5 ± 1.7	4.4	1.5	2.8	34
Hercule (whole)[d], spelt wheat	36.5	14.1	2.01	60.0	446	13.9 ± 1.9	12.4	4.0	8.4	32
Hercule[c] + Manital[b] (1:1)	28.8	12.2	1.80	58.0	431	13.9 ± 2.1	3.9	1.5	2.4	38
Hercule(whole)[d] + Manital[b] (1:1)	32.7	13.0	1.97	60.0	449	14.1 ± 2.0	7.4	2.7	4.7	36

[a] Values are means of four independent determinations.
[b] Flour extraction rate: 72%.
[c] Flour extraction rate: 71%.
[d] Flour extraction rate: 100%.

Table 4
Total starch, free glucose, and starch digestibility of bread (in % dmb), and starch digestion index (in % of total starch)[a,b]

Bread sample	Total starch	Free glucose	RDS	SDS	RS	SDI%
Manital, wheat[c]	81.6 ± 0.6a	0.9 ± 0.1a	55.8 ± 1.5c	24.0 ± 1.3a	1.8 ± 0.1c	68 ± 1.6c
Hercule, spelt wheat[d]	80.7 ± 0.4a	1.2 ± 0.2a	64.2 ± 0.9a	14.7 ± 1.0c	1.8 ± 0.1c	80 ± 2.8a
Hercule (whole)[e], spelt wheat	68.0 ± 1.0c	1.0 ± 0.3a	57.3 ± 0.7b	8.2 ± 0.9d	2.5 ± 0.3a	84 ± 2.0a
Hercule[d] + Manital[c] (1:1)	81.3 ± 1.0a	1.0 ± 0.1a	60.4 ± 0.9b	19.4 ± 0.5b	1.5 ± 0.2d	74 ± 1.3b
Hercule (whole)[e] + Manital[c] (1:1)	75.6 ± 0.8b	1.0 ± 0.2a	56.9 ± 0.5c	16.6 ± 1.1c	2.1 ± 0.1b	75 ± 1.5b

Numbers in the same column followed by the same letter are not significantly different at $p < 0.05$.
[a] Values are means of quadruple determinations ± SD.
[b] RDS, rapidly digestible starch; SDS, slowly digestible starch; RS, resistant starch; SDI, starch digestion index (in % of total starch).
[c] Flour extraction rate: 72%.
[d] Flour extraction rate: 71%.
[e] Flour extraction rate: 100%.

Table 5
Protein digestibility of bread from wheat and spelt wheat (in % dmb)[a]

	Hours of digestion						
Cultivar	1	2	3	4	5	6	Residue
Manital, wheat[b]	18 ± 2.7a	31 ± 1.5a	36 ± 1.9a	45 ± 1.8a	53 ± 2.0a	59 ± 1.7a	41 ± 2.0d
Hercule, spelt wheat[c]	11 ± 1.9b	21 ± 1.4c	29 ± 2.0b	36 ± 1.9b	43 ± 1.6b	48 ± 1.9b	52 ± 1.6b
Hercule (whole)[d], spelt wheat	9 ± 0.9b	17 ± 0.8d	25 ± 2.1b	31 ± 0.8c	36 ± 1.5c	41 ± 0.9c	59 ± 1.5a
Hercule[c] + Manital[b] (1:1)	15 ± 1.3a	26 ± 1.3b	32 ± 1.7b	40 ± 0.9b	48 ± 1.8b	54 ± 1.5b	46 ± 1.8c
Hercule (whole)[d] + Manital[b] (1:1)	13 ± 1.5a	24 ± 0.9b	31 ± 0.8b	38 ± 2.1b	45 ± 2.0b	50 ± 2.1b	50 ± 1.8b

Numbers in the same column followed by the same letter are not significantly different at $p < 0.05$.
[a] Values are means of quadruple determinations ± SD.
[b] Flour extraction rate: 72%.
[c] Flour extraction rate: 71%.
[d] Flour extraction rate: 100%.

Table 6
Moisture, protein, ash and dietary fibre contents of spaghetti and extruded rings from spelt wheat cv. Hercule and of spaghetti from durum wheat cv. Grazia

Sample	Moisture (%)	Protein (% dmb)	Ash (% dmb)	Dietary fibre (% dmb)			
				Total	Soluble	Insoluble	% Soluble
Spaghetti Hercule[a]	10.66	11.7	0.82	2.3	1.2	1.1	52.1
Spaghetti Hercule (whole)[b]	11.25	14.3	1.84	7.5	1.9	5.6	25.3
Spaghetti Grazia[c]	10.80	10.9	1.45	2.7	1.1	1.6	40.7
Rings Hercule[a]	5.16	9.35	1.90	1.6	0.6	1.0	37.5
Rings Hercule (whole)[b]	5.58	10.6	2.29	6.2	0.9	5.3	14.5

[a] Flour extraction rate: 71%.
[b] Flour extraction rate: 100%.
[c] Flour extraction rate: 69%.

White spelt wheat breads, and especially breads produced from wholemeal spelt wheat, contain more dietary fibre in comparison to wheat bread (Table 3). Results for dietary fibre include RS according to the method applied (Prosky et al., 1988).

From a nutritional point of view, spaghetti and extruded products made from white spelt wheat flour do not offer substantial amounts of ash and dietary fibre to the diet. However, the extent of the enrichment of food products with these two components, when using the wholemeal spelt wheat alternative, is evident from Table 6. The soluble/insoluble fibre ratio was higher in white spelt wheat products in comparison to the corresponding ratio in wholemeal spelt wheat products. The increased percentage of the soluble fibre depended on the process used (pasta production or extrusion), though it was generally more pronounced in the case of white spelt wheat products.

It is feasible to produce a range of spelt wheat products (as shown for bread, pasta and extruded products, respectively) with some specific characteristics rendering these products unique. The starch in spelt wheat undergoes hydrolysis more rapidly in the first period; thus products could be used in diets where readily digested carbohydrates are preferred. Further, spelt wheat and its products could serve as an abundant source of protein and, lastly, a great proportion of soluble fibre emerges in the final spelt wheat product.

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