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Influence of starch, gluten proteins and extraction rate on bread and pasta quality

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Wholemeal products and white products of bread and pasta were made of the same material consisting of a set of bread wheat varieties. The protein content varied little, whereas the protein quality varied significantly among the varieties. The composition of the high molecular weight glutenin subunits and a set of gliadins could explain most of the variations in Zeleny sedimentation volume, farinogram data and bread quality. Total amylose content in white flour varied significantly among the wheat varieties. All varieties with good protein quality gave good bread quality. Among those with poor protein quality, one had higher and one had lower total amylose content than average, and both gave poor baking results. Small differences in gelatinization temperature and gelatinization enthalpy were observed among the wheat varieties. The gelatinization temperature was slightly higher in wholemeal flour than in white flour, whereas the gelatinization enthalpy was lower in the former. White flour from bread wheat gave pasta of unacceptable quality, whereas the quality of pasta made from wholemeal flour was close to that of commercial pasta made from wholemeal durum wheat. The poor pasta quality of the white bread flours may be attributed to the fine granulometry of the flours. Variations in pasta quality and bread quality between different varieties were not correlated. T-8020 and Bastian with the same protein quality characteristics and the same bread quality gave pasta of different qualities.

INTRODUCTION

The chemical composition and physical properties of wheat affect milling properties, dough properties, quality of the fresh end product, and staling properties. It is well documented that the content and the quality of gluten proteins have significant effects on dough properties and end product qualities, such as loaf volume (Finney & Barmore, 1948; Wall, 1979; Payne *et al.*, 1984) and pasta texture (Geddes, 1935; Feillet, 1984). There are considerable variations in gluten protein content and quality due to environmental and genetic factors, respectively, making gluten proteins important as quality criteria. Starch properties are also important in baked goods. Starch dilutes the gluten to an appropriate consistency, furnishes maltose by amylase action for fermentation, provides a suitable surface for strong gluten bonding, provides flexibility for loaf expansion during partial gelatinization while baking, and sets the loaf structure by providing a rigid network to prevent loaf collapse upon cooling (Shelton & D'Appolonia, 1985). These functions can be lost by enzymatic starch degradation which is a major quality problem in certain areas in some years. However, little knowledge is available on variation in starch in non-sprouted wheat and the impact that this might have for the end-product quality.

The aim of the present study was to investigate the

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importance of starch as well as proteins, for determining the quality of bread and pasta products. Pasta is usually made from semolina of durum wheat. To investigate differences in wheat quality requirements between pasta and bread, both products were made of the same material consisting of flours of different breadwheat varieties. Both white flour products and wholemeal products were made.

MATERIALS

Seven different Norwegian spring wheat (*Triticum aestivum* L.) varieties were used: T-8020, Bastian, Reno, Tjalve, T-7043, Snøgg and T-7034. The wheat was grown in experimental field trials in the south east of Norway in 1991. The trials were selected to achieve as little variation as possible in total protein content.

METHODS

Laboratory milling

T-8020, Bastian, Reno, Tjalve, T-7043 and Snøgg were milled at 15% moisture content on a Brabender Automat Mill Quadrumat Senior (Brabender OHG, Duisburg, Germany) to white flour and wholemeal flour, respectively. Wholemeal flour of Bastian and T-7034 were also prepared on an Akron Cyclone hammer mill, fitted with a 1 mm sieve for preliminary tests. All flours except wholemeal flour made from Bastian and T-7034 milled on the hammer mill were supplemented with 30 ppm ascorbic acid and used 50 days after milling. Hammer-milled wholemeal flours made of Bastian and T-7034 were stored for 100 days before use and therefore no ascorbic acid was added to the flour. All flours were mixed well and stored in tight containers at 7°C.

Chemical and physical analysis

Extraction rate was measured using a Sartorius analytical balance (Sartorius GmbH, Goettingen, Germany). Kernel hardness was kindly analysed by Gunnar Svensson (Weibullsholm Plant Breeding Institute, Landskrona, Sweden), using NIR (Near Infrared Reflection) calibrated against Pearling Resistance. The moisture contents of wheat grains were determined according to ICC Standard no. 110, at 130°C for 16 h. Moisture contents of the flours were determined by using a Sartorius Thermo Control Infrared dryer, YTC 01 L (Sartorius GmbH, Goettingen, Germany). The ash content was determined by ICC Standard no. 104, at 650°C for 16 h in the ash oven, type Carbolite CFS 11/7 (Eurotherm, Sheffield, UK). The results are presented on a dry weight basis.

Protein content was determined by Kjeldahl analysis, ICC Standard no. 105, distilled in a Kjeltec Auto 1030 Analyzer (Tecator, Höganäs, Sweden). The results are presented on a dry weight basis (N × 5·75). The compositions of the HMW glutenin subunits were examined using sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE, 10%) as described by Uhlen (1990). The SDS-PAGE electrophoresis was carried out in a Protean II XI Slab Cell (Bio Rad Laboratories GmbH, München, Germany) connected to a 2303 Multidrive XL (Pharmacia/LKB, Uppsala, Sweden). Gliadins were separated by acid polyacrylamide gel electrophoresis at pH 3·1 (APAGE) as described by Mosleth and Uhlen (1990). The Zeleny sedimentation test was carried out according to AACC method no. 56–14A, 1983. The volume of the sediment of the flour suspended in water and treated with lactic acid was read after a 5 min resting period.

Total dietary fibre was measured according to AOAC (1984, 1990).

The starch was isolated from wheat grains by the steeping method described by Meredith *et al.* (1978), except for exclusion of the fractionation by successive sedimentation. The extracted starch fraction was collected after 2 h of sedimentation in 2 litres of water. The extracted starch was washed with water, ethanol and acetone. Between each wash the A-starch was concentrated on a filter paper, Schleicher & Schull No. 597, with vacuum filtration. Finally the washed extracted starch was vacuum dried until the smell of acetone or ethanol was not detectable. Lipids were extracted at ambient temperature, 25–27°C, with chloroform-methanol 2:1 v/v (Vasanthan & Hoover, 1992), using 10 ml solvent per 5 g extracted starch during 15 h in a rotating device. The defatted extracted starch was collected with vacuum filtration as described above and vacuum dried until the smell of solvent could no longer be detected. Total starch was measured in wholemeal flour and white flour using the method of Holm *et al.* (1986). Falling Number values were determined with a type 1800 Falling Number apparatus (Falling Number AB, Huddinge, Sweden), using AACC method 56-81B, 1983. Damaged starch was analysed according to AACC method 76-30A, 1984.

The thermal properties of wholemeal flour, white flour and extracted starch were studied by differential scanning calorimetry. The studies were carried out on a Mettler DSC 30S (Mettler Instrument AG, Volketswil, Switzerland), at a scanning rate of 5°C/min. The water content of the samples was 65% w/w. About 100 mg of each sample was heated in a steel cell from 10°C to 150°C, with water as reference. The calibration of the DSC and the calculation of the enthalpies were carried out according to the instrument manual.

Total amylose content in defatted extracted starch (10–20 mg) was determined according to Morrison and Laignelet (1983). Total amylose content in white flour was determined using a modified method of Morrison and Laignelet (1983).

Rheological analyses of the dough

Measurements of water absorption, dough development time and dough stability were carried out according to ICC Standard no. 115 on a Brabender Farinograph, model no. 8 101 (Brabender OHG, Duisburg, Germany).

Baking test

Bread was made from white flour and wholemeal flour. Three hundred grams of flour with 14% moisture content was mixed (Farinograph mixer, Model no. 8205) with the optimum amount of water according to the farinogram, plus 2% yeast, 2% fat (marine oil), and 0·75% salt. Each flour was mixed to the optimum dough development time defined by the farinograph development time. The temperature of the added water was adjusted to give a final dough temperature of 30°C. After mixing the dough rested for 30 min. Three loaves each of 125 g were formed and baked in iron pans (bottom: 60 × 60 mm, top: 80 × 80 mm, height: 70 mm). Proving time was 45 min at 35°C and 85% relative humidity (RH). The loaves were baked in a rotating fan oven, type BEX 1·0 (Bago line, Faaborg, Denmark). Steam was added during baking (220°C in 20 min) for the first 30 s.

Technological analysis of bread

Loaf weight was measured using an Ohaus analytical balance GT 2100 +/− 0·01 g (Heigar & Co. A/S, Oslo, Norway). Loaf volume was measured by rape seed displacement according to AACC method 72-10, 1983. Loaf height was measured using a slide caliper. The crumb texture was measured according to AACC method 74-09, 1983, using an Instron 1140 (Instron Ltd, High Wycombe, UK). The cell structure of the crumb was assessed according to Dallmann's Porentabelle on a scale from 1 to 8 (Dallmann, 1958).

Pasta test

Five kilograms of flour were mixed for 5 min with water to obtain a final moisture content of 32%. The mix was rested for 15 min. Pasta was extruded on a Pressquick extruder at 15·6 kg/h. After extrusion the pasta was dried for 12 h at 55°C.

Technological analysis of pasta

Pasta firmness and stickiness were recorded on an Instron instrument equipped with a Kramer cell. The method used was developed in the Nestlé Research Centre (G. Fayard, to be published).

RESULTS AND DISCUSSION

There was limited variation in protein content between the different varieties (Table 2), whereas protein quality as evaluated by composition of HMW glutenin subunits and gliadins and Zeleny sedimentation volume varied significantly (Table 1). In general, the Zeleny sedimentation volume agreed well with the Glu-1 score, and the presence or absence of the quality-related gliadins identified by Mosleth and Uhlen (1990). However, even though Snøgg and T-7043 have similar Glu-1 scores and both lack the quality-related gliadins, they differ significantly in sedimentation volume. Similar results were observed for Tjalve and Reno, with Tjalve having higher sedimentation volume than Reno. This might be due to other gluten proteins than those analysed.

As expected, protein content, ash content and total dietary fibre were higher in wholemeal flour (100% extraction rate) than in white flour (68–73% extraction rate), whereas total starch content was lower (Table 2). For white flour ash content of the different varieties was significantly correlated with extraction rate ($r = 0·82$, $p = 4·4\%$). There was also a significant variation in total dietary fibre among the varieties (Table 2). This variation was not correlated with the variation in extraction rate and ash content ($p > 30\%$).

Kernel hardness varied from 6·4 to 7·7 for the six bread wheat varieties (Table 2). In comparison, durum wheat has a kernel hardness of 9 using Pearling Resistance.

The percentage of damaged starch in flour correlated well with kernel hardness ($r = 0·85$, $p = 3·3\%$). Thus, when protein content and milling conditions are aimed to vary as little as possible, as in the present study, starch damage appears first of all to be determined by kernel hardness.

Total amylose content in white flour varied significantly between the varieties, $p < 0·1\%$. Snøgg had the highest value and Tjalve and T-7043 the lowest (Table 3). The magnitude of the differences between the varieties were higher when calculated as percentage of total starch than as percentage of white flour. Defatted extracted wheat starch contains mainly the large starch granules which have a higher total amylose content than white flour. The values observed in the present study were generally slightly higher than the total amylose content observed for large starch granules (A-starch) by Morrison and Laignelet (1983).

The average gelatinization temperature was 67·2°C for wholemeal flour, 66·4°C for white flour and 64·5°C for defatted extracted starch. The different varieties varied from 66·2 to 68·5°C for wholemeal flour, from

Table 1. The composition of HMW glutenin subunits, Glu-1 score, the presence (+) or absence (−) of quality-related gliadins and Zeleny sedimentation volume in the Norwegian spring wheat

Variety	HMW	Glutenin	subunits[a]	Glu-1 score[b]	Gliadins[c]	Zeleny sed. vol.[d]
T-8020	2*	13 + 16	5 + 10	10	+	69
Bastian	2*	7 + 9	5 + 10	9	+	69·5
Reno	1	7 + 9	5 + 10	9	−	55·5
Tjalve	2*	7 + 9	5 + 10	9	−	61
T-7043	2*	7	2 + 12	6	−	42·5
Snøgg	0	7 + 8	2 + 12	6	−	25
Level of significance						$p < 0{\cdot}1\%$

[a]Nomenclature of Payne and Lawrence (1983).
[b]Glu-1 score calculated on the basis of the HMW glutenin subunits as described by Payne *et al.* (1984, 1987). Bands 13 + 16 are given a value of 3 according to Uhlen (1990).
[c]Quality-related gliadin bands identified by Mosleth and Uhlen (1990).
[d]Zeleny sedimentation volume.

Table 2. Chemical composition of the flours produced with the Brabender Quadrumat Senior Mill

Property[a]	T-8020		Bastian		Reno		Tjalve		T-7043		Snøgg	
Extraction rate (% of total weight)	72	100	70	100	71	100	73	100	71	100	68	100
Protein (%)	11·6	11·9	11·6	12·1	10·8	11·3	10·9	11·5	10·2	10·9	11·5	13·2
Water content (%)	12·9	10·6	13·0	10·9	13·6	11·9	12·0	11·3	13·7	10·7	13·0	11·0
Ash content (%)	0·60	1·88	0·60	1·86	0·60	1·76	0·66	1·83	0·64	1·83	0·56	1·83
Total dietary fibre (%)	3·8	13·1	3·6	12·8	3·6	12·4	3·0	13·5	3·9	12·5	3·7	14·7
Kernel hardness	6·4		6·4		7·6		7·7		7·0		6·5	
Damaged starch	4·5	5·3	4·5	5·3	5·5	6·1	7·0	7·1	6·2	7·1	4·4	5·5
Total starch (%)	84·8	68·4	86·2	68·4	86·5	70·5	86·2	71·4	85·1	73·1	83·7	64·9
Falling Number	480	439	483	435	425	424	400	373	467	442	321	275

[a]Kernel hardness and Falling Number are given in seconds and extraction rate as percentage of total milling streams. The other values are given as percent of dry matter.
Differences between varieties and between white flour and wholemeal flour were significant ($p < 0{\cdot}1\%$) for all analyses.

Table 3. Total amylose content in white flour and defatted extracted starch

Variety	Amylose content in white flour[a]	Percent of total starch[b]	Amylose content in defatted extracted starch[a]
T-8020	20·2	23·8	34·9
Bastian	20·6	23·9	34·7
Reno	20·6	23·8	33·6
Tjalve	15·3	17·7	32·4
T-7043	15·3	16·8	34·5
Snøgg	22·8	27·2	35·9

[a]Percent of dry matter.
[b]Amylose content in white flour calculated as percent of total starch in white flour.

65·4 to 67·7°C for white flour, and from 63·7 to 64·8° for defatted extracted starch. For isolated wheat starch Eliasson (1983) found that addition of gluten increased the gelatinization temperature. The material investigated in this study is too small to confirm whether such relationships exist for intact flours of different varieties.

The average gelatinization enthalpy was 5·4 J/g for wholemeal flour, 6·2 J/g for white flour, and 13·1 J/g for defatted extracted starch. The different varieties varied from 5·0 to 6·3 J/g for wholemeal flour, from 5·2 to 6·8 J/g for white flour, and from 12·0 to 14·6 J/g for defatted extracted starch. Gelatinization enthalpies have been related to the degree of crystallinity in starch granules (Zobel *et al.*, 1988). As crystallinity is mainly a property of the amylopectin molecule, a starch with high amylopectin content would be expected to have a high gelatinization enthalpy. Such a relationship could not be confirmed in the present material.

Rheological properties

Water absorption was higher in wholemeal flour than in white flour. Water absorption is influenced by extraction rate, gluten proteins, damaged starch and pentosans (Orth & Mander, 1975; Mailhot & Patton, 1988). All these factors were higher in wholemeal flour than in white flour (Table 4). Differences in water absorption among varieties within white flour and wholemeal flour were also observed (Table 4).

The dough development time and dough stability

Table 4. Farinograph parameters for the flours

Variety	Extraction rate (% of total weight)	Water absorption (%)	Dough dev. time (min.)	Stability (min.)
T-8020	72	58·5	11	27
	100	71·5	8	9
Bastian	70	59·3	11	25
	100	71·0	8	9
Reno	71	57·5	7	13
	100	68·3	7·5	8
Tjalve	73	58·2	7	17
	100	70·0	7·5	7·5
T-7043	71	60·6	3	14
	100	71·0	6	6
Snøgg	68	60·3	3	3
	100	70·0	3·5	3

(Table 4) agreed well with Zeleny sedimentation volume (Table 1). White flour of T-7043, Snøgg and wholemeal flour of Snøgg has a very short farinogram dough developing time, about 3 min; Snøgg also had a dough stability of only 3 min. White flour of T-8020 and Bastian had long dough developing times and extremely long dough stability times. By increasing the extraction rate to 100% the dough stability was reduced for all varieties.

Bread and pasta quality

Loaf volume of white bread and wholemeal bread was significantly higher for T-8020, Bastian, Reno and Tjalve than for T-7043 and Snøgg (Fig. 1). Observations of loaf height, crumb firmness and subjective evaluation correlated well with the loaf volume values (data not shown).

Differences in baking performance among the varieties agreed well with differences in protein quality evaluated by gluten protein composition, Zeleny sedimentation volume (Table 1) and Farinogram data (Table 4). The correlation coefficients (r) between Zeleny sedimentation volume and loaf volume were 0·95 and 0·96 ($p < 5{\cdot}0\%$) for white flour and wholemeal flour, respectively. Among the two varieties with poor protein quality, Snøgg had high and T-7043 low total amylose content. The amylose fraction is claimed to influence setting of the crumb structure of the loaf (Hoseney *et al.*, 1971). Hoseney *et al.* (1983) found that too high and too low levels of barley amylose made the loaves collapse. Normal levels of amylose:amylopectin found in wheat starch granules were required to produce adequate loaf volume. It is possible that the total amylose content in Snøgg and T-7043 also contribute to their poor bread quality.

Two different wholemeal flours of Bastian were produced. The wholemeal flour produced on a hammer mill gave very low loaf volume compared to the wholemeal flour from Brabender Quadrumat Senior, Fig. 1. The hammer mill produces a very coarse wholemeal flour where the flour constituents are not exposed properly and normal dough development is prevented.

Pasta made from white flours of T-8020, Bastian and T-7043 milled on the Brabender Quadrumat Senior mill were of poor quality, being very soft and sticky. The instrumental firmness was in the range of 300–400 N (Table 5) whereas 800–900 N is the normal range for commercial spaghetti made from durum wheat semolina (Table 6). The cooked spaghetti from white bread flours had a very bad surface state causing the spaghetti strands to stick together and to the plate. Stickiness

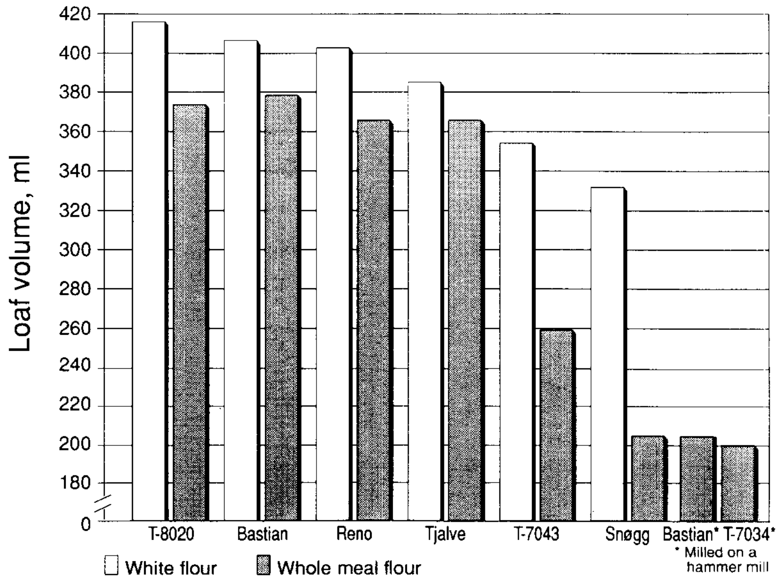

Fig. 1. Loaf volume. Technological analysis of bread baked from wholemeal flour and white flour of Norwegian bread wheat. Level of significance for difference between varieties and between white flour and wholemeal flour, $p < 0{\cdot}1\%$.

depends on substances, prevalently starch, escaping from the protein network and adhering to the surface of the cooked spaghetti (Cubbada, 1988). The poor pasta quality of the white bread flours may therefore be attributed to the fine granulometry of the white flours, which is in the range of 0–150 μm (Mailhot & Patton, 1988). Pasta is usually made from semolina having a coarser granulation, 200–400 μm (Landi & Guarneri, 1992).

The quality of pasta made from wholemeal flour (T-8020, Bastian and T-7043) was fairly acceptable, with Bastian giving the best quality (Table 5). The firmness of Bastian spaghetti, 747·5 N, was close to that of commercial fibre-rich durum spaghetti, 749–1020 N (Table 6). The wholemeal flour spaghetti strands were, however, slightly more sticky than the durum wheat spaghetti.

When comparing Bastian and T-7034 milled on a

Table 5. Rheological properties of pasta produced from wholemeal flours and white flours of bread wheat

Variety	Moisture content (%)		Firmness[a] (N)	Stickiness[a] (%)	Diameter (mm)	T.D.F.[e] (%)	Protein (%)
	After drying	After 10 min cooking					
Bastian[b]	11·5	63·3	665	67·3	1·6	13·2	15·1
T-7034[b]	11·2	63·8	622	71·3	1·6	15·2	11·9
T-8020[c]	—	63·9	665·6	55·2	—	13·1	12·9
Bastian[c]	—	61·7	747·5	52·6	—	12·8	13·2
T-7043[c]	—	64·1	645·2	55·5	—	12·5	11·8
T-8020[d]	—	71·8	386·8	59·0	—	3·8	12·6
Bastian[d]	—	73·1	316·5	59·2	—	3·6	12·6
T-7043[d]	—	71·6	386·9	61·2	—	3·9	11·1

[a]According to Nestlé Research Centre technique.
[b]Wholemeal flour prepared on an Akron cyclone hammer mill.
[c]Wholemeal flour prepared on a Brabender Automat Mill Quadrumat Senior.
[d]White flour prepared on a Brabender Automat Mill Quadrumat Senior.
[e]Total Dietary Fibre.

Table 6. Rheological properties of pasta produced from commercial durum wholemeal flours

Commercial pasta	Moisture content (%)		Firmness[a] (N)	Stickiness[a] (%)	Diameter (mm)	T.D.F.[e] (%)	Protein (%)
	After drying	After 10 min cooking					
Spaghettini Tipo Integrale Buitoni[b]	9·9	64·6	928	49·1	1·6	7·5	13·6
Matriciane Integrale Rustichella[c]	10·3	63·4	781	47·8	2·4	—	—
Spaghetti semi-integrale Tota Munda[c]	10·4	63·6	843	44·8	1·6	—	—
Spaghetti Integrale Alce Nero[c]	11·5	60·3	1 020	50·4	1·9	—	—
Dietofibra Spaghetti Euvita[d]	10·5	63·9	749	48·4	1·5	9·7	13·0
Spaghetti Tipo Integrale Misura[d]	11·1	65·0	801	57·3	1·7	—	13·0

[a]According to Nestlé Research Centre technique.
[b]Durum wheat + bran.
[c]Whole durum wheat.
[d]Durum wheat + bran + cellulose.
[e]Total Dietary Fibre, according to package information.

hammer mill (Table 5) Bastian performed again slightly better. However, the hammer mill gave flour of poorer pasta quality than the Brabender Quadrumat Senior mill, being less firm and more sticky (Table 5). The water absorption after 10 min cooking of wholemeal flour spaghetti (Table 5) was similar to the water absorption of durum wheat fibre-rich spaghetti (Table 6). For the different varieties variation in moisture content after 10 min cooking correlated well with variation in pasta firmness and stickiness, Bastian having the lowest moisture content after 10 min cooking and the highest firmness and lowest stickiness.

Although Bastian and T-8020 had similar protein characteristics (Tables 1 and 4) and exhibited similar bread quality (Fig. 1), they performed differently in pasta processing (Table 5). Differences in pasta quality between these two varieties are therefore likely to be related to other factors than protein composition.

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