Chemical Composition of Barley Cultivars Fractionated by Weighing, Pneumatic Classification, Sieving, and Sorting on a Specific Gravity Table

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ABSTRACT

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Five different barley cultivars, including covered and naked samples containing low, normal, or high-amylose starches were fractionated by weighing, pneumatic classification, sieving, or sorting on a specific gravity table, and analyzed for content of starch, protein, ash, and β-glucan. For ash content, almost no variation could be found between different fractions. Protein content was minimum in the intermediate fractions for all cultivars when sorted by weighing. For the other fractionation methods, the differences in protein content were small. A tendency for decreasing content of starch with increasing grain mass and size could be seen when fractionating grains by weighing and sieving, respectively. The clearest trend was seen in differences in β-glucan content for all cultivars and all methods used. The main interpretation of our results is, however, that the chemical composition within the cultivars studied is very similar for all fractions, and that the differences between the unfractionated barley samples are larger.

The interest in fractionation of cereal grains has grown in recent years. Two reasons for this are an increased demand for grains of different qualities for specific uses and the development of new methods to analyze single grains.

Barley is the most commonly grown cereal in Scandinavia (FAO 1998). It is mainly used as feed, but it is also used in malt production and as human food. The major components of barley are starch, dietary fiber, and protein, constituting ≈60, 20, and 10% of dry matter, respectively (Åman et al 1985, Åman and Newman 1986, Oscarsson et al 1996). β-Glucan is an important dietary fiber constituent, and the content has been reported at 3–7%. Fat, ash, and low molecular weight sugars are minor constituents, constituting ≈3, 2, and 4% of dry matter, respectively.

In a previous study by Andersson et al (*in press*), the mass of individual barley grains varied between ≈10 and 80 mg, with an average mass of 30.5–52.4 mg for eight different barley cultivars. Dahlstedt (1991) and Regnér (1995) reported that the mass of individual grains in samples of spring wheat varied between 1 and 70 mg. The variation in grain size depends on the ability of each grain to compete for nutrients but also on the period of development (Kent and Evers 1994). In barley, the spikelets located at the center of the ear develop earlier and reach higher sizes than upper and basal ones (Kirby 1977).

Cereal grains can be separated on their mass, that is, by weighing individual kernels and sorting them into fractions. Spring wheat grains with higher mass contain more protein and ash than grains with lower mass (Regnér 1995). Separation can also be performed by sieving. Henry (1986) showed that smaller grains of sieved barley contained more pentosan and had a higher pentosan-to-β-glucan ratio than larger grains. This was taken as an indication that pentosan content may correlate with husk content.

The malting industry prefers plump, well-filled, large barley kernels. Therefore, sieving is often used when selecting barley for malting. According to Palmer (1989) high husk content and small grain size can reduce starch extract potential. The yield of malt extract is directly related to starch content if the grains are ripe, free from fungal infestation, and intact (Kent and Evers 1994). Another quality criterion of malting barley is low content of β-glucan, since a high content may lead to poor quality of the beer because of low rate of wort filtration, haze formation, and possibly reduced extraction efficiency (Bamforth 1985). A low content of soluble proteins is also important since they too lead to haze formation and may provide nutrients for bacteria that can impair the keeping quality of the beer (Kent and Evers 1994).

Separation of cereal grains depends not only upon discrimination by size or mass, but also by shape, specific gravity, composition, and texture. To remove freely assorted material before storage and processing of cereals, different separation procedures are often performed (Kent and Evers 1994). Fractionation by specific gravity tables is based on two conditions: the ability of a grain to flow down an incline plane and the lifting or floating effect produced by the upward motion of air (Henderson and Perry 1976). These authors also state that the lifting effect is a function of size, shape, and weight, and perhaps also of degree of surface roughness. Tkachuk et al (1991) showed that it is possible to remove sprouted, shrunken, and broken wheat grains, and improving milling performance of the remaining wheat, by use of a specific gravity table.

Little is known about the relationships between physical and chemical characteristics of cereals. In a previous study by Andersson et al (*in press*), barley cultivars with a high content of hull components showed low bulk densities, while cultivars with a high content of starchy endosperm components showed a high mean grain mass. Furthermore, cultivars with low starch content had a high proportion of grains remaining on the sieve with the largest openings (>2.8 mm). These findings may indicate a possibility of separating barley grains into fractions with different chemical composition.

The main objective of the current work was to study the chemical composition of barley cultivars fractionated by weighing, pneumatic classification, sieving, and sorting on a specific gravity table.

MATERIALS AND METHODS

Materials

The study included samples of five barley cultivars (*Hordeum vulgare* L.) with different characteristics as shown in Table I. The chemical and physical characteristics of the samples are further described by Andersson et al (*in press*). They were all obtained from Svalöf Weibulls AB, Sweden, and were grown in 1995 in the same experimental field in Landskrona in the south of Sweden.

Fractionation of Cultivars

A representative sample of each cultivar was separated into five fractions of ≈20% each, using a pneumatic classifier. The classifier, in which velocity of the air stream could be adjusted, was constructed and built at the Department of Agricultural Engieering, Swedish University of Agricultural Sciences, Uppsala. The fraction of the sample, which had lower terminal velocity than the actual velocity of the air stream, was carried by the air stream to a cyclone where the grains were separated from the air and passed

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to a settling container. The fraction was collected and the procedure was then repeated at an increased air velocity.

Five fractions of grains of each cultivar with the mass of the individual grains differing between 1 and 3 mg in each fraction were obtained by use of an automatic mass sorter (Regnér 1993) that weighed each grain individually (0.5 mg resolution setting of the balance). A personal computer controlled the process, recorded the mass of the grains, and distributed grains of the selected mass into different small containers. Grains with a mass other than that selected were diverted to a waste container. The masses of the grains in the fractions were chosen to make up a good representation of the distributions of mass of the individual grains of each cultivar. The grain masses of the fractions differed between the cultivars as they had different 1,000-kernel weight.

Representative samples of each cultivar were sieved on a Delta Type Super 101 fine cleaner (Cimbria Unigrain Ltd. A/S, Thisted, Denmark) with three different changeable sieves. Sieves with oblong openings of 2.5, 2.6, 2.7, 2.8, 3.0, and 3.25 mm were used to produce seven fractions.

A representative sample of each cultivar was separated into four fractions of ≈25% each with a Delta Type 150 specific gravity table (Cimbria Unigrain).

The sieve and the specific gravity table were also combined to produce fractions from each cultivar. After sieving of a representative sample (sieves with oblong openings 2.2, 2.5, and 2.8 mm were used), the sieve fractions $2.5 < x < 2.8$ mm and $x > 2.8$ mm were used, except for cultivar Bz 489-30 for which the fractions $2.2 < x < 2.5$ mm and $2.5 < x < 2.8$ mm were used. The sieve fractions were further fractionated on the specific gravity table to produce four new subfractions of about equal size from each fraction.

The different fractions of each method were numbered so that the fraction with the highest number for each method contains what we have referred to as the largest grains. That is, the grains that had the highest terminal velocity when sorted in a vertical air stream, the highest individual grain mass when sorted by weighing, the largest least dimension when sorted by sieves, and those that had, as it is usually regarded, the highest density when sorted on the specific gravity table.

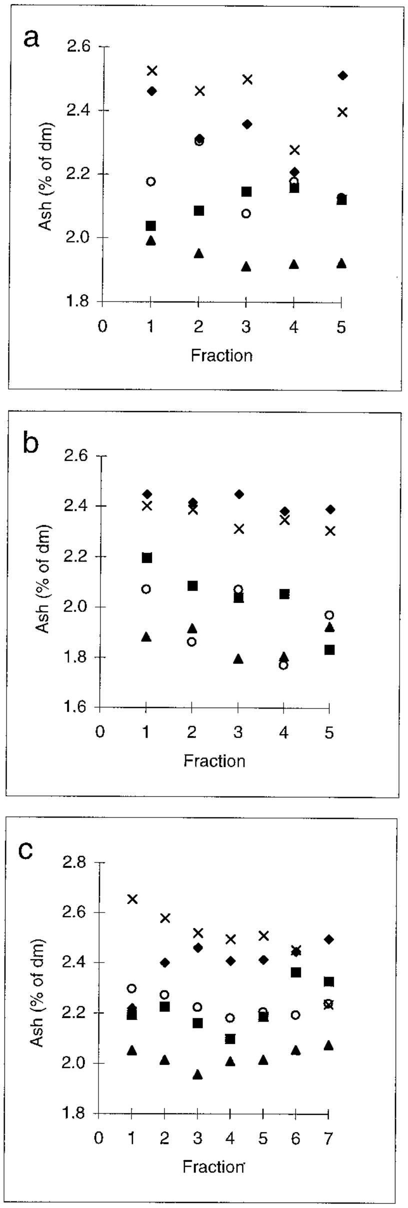

Fig. 1. Content of ash (% of dry matter) in fractions of High amylose Glacier (◆), SW 906129 (×), SW 8775 (■), Golf (○), and Bz 489-30 (▲) produced by a) weighing of individual grains, b) pneumatic classification, and c) sieving.

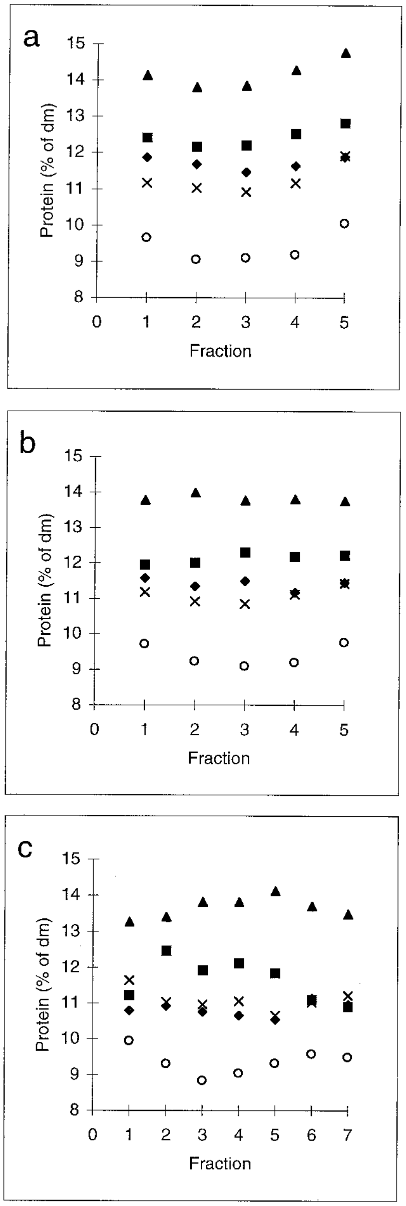

Fig. 2. Content of protein (% of dry matter) in fractions of High amylose Glacier (◆), SW 906129 (×), SW 8775 (■), Golf (○), and Bz 489-30 (▲) produced by a) weighing of individual grains, b) pneumatic classification, and c) sieving.

Chemical Analyses

Before analysis, representative samples (50–100 g) of all barley cultivars and all barley fractions were ground in a Tecator cyclone mill to pass a 0.5-mm screen. Dry matter content was determined by oven-drying at 105°C for 5 hr. Starch was determined enzymically (Åman et al 1994). Ash and crude protein (N × 6.25) were analyzed according to standard methods (AOAC 1984). Total β-glucan was determined enzymically according to Åman and Graham (1987). For cereals, the coefficient of variation for the starch analysis method is 0.5–1.5% (Åman et al 1994) and for the analysis of total β-glucan 1.9–2.6% (Åman and Graham 1987). All chemical analyses are reported on a dry matter basis as an average of at least duplicate analyses.

RESULTS AND DISCUSSION

The content of starch in the unfractionated barley cultivars varied between 50.1 and 61.8%, and the content of protein varied between 9.3 and 14.1% (Table I). The highest content of both starch and protein was found in naked barley samples, which is in agreement with earlier reports (Oscarsson et al 1996, Andersson et al, *in press*). The content of ash varied between 2.0 and 2.5%, with the highest content generally in covered cultivars. The β-glucan content was higher in the waxy and high-amylose cultivars (5.6–6.9%) than in the cultivars with normal starch (4.6–4.7%), which is also in agreement with previous studies (Oscarsson et al 1996; Andersson et al, *in press*).

To simplify the reading, only the results from the fractionation by weighing, pneumatic classification, and sieving are presented as graphs (Figs. 1–4). Weighing and sieving were chosen because these methods use only one physical property each as a separating factor. Pneumatic classification was chosen as an example of a method where the fractionation criterion is multifactorial. The results from the other methods are presented in Table II.

For ash content, only a small variation could be detected between different fractions in each “cult-fract” group (i.e., all the subsamples of one cultivar that are produced with the same fractionation method) (Fig. 1 and Table II). The similar ash content in

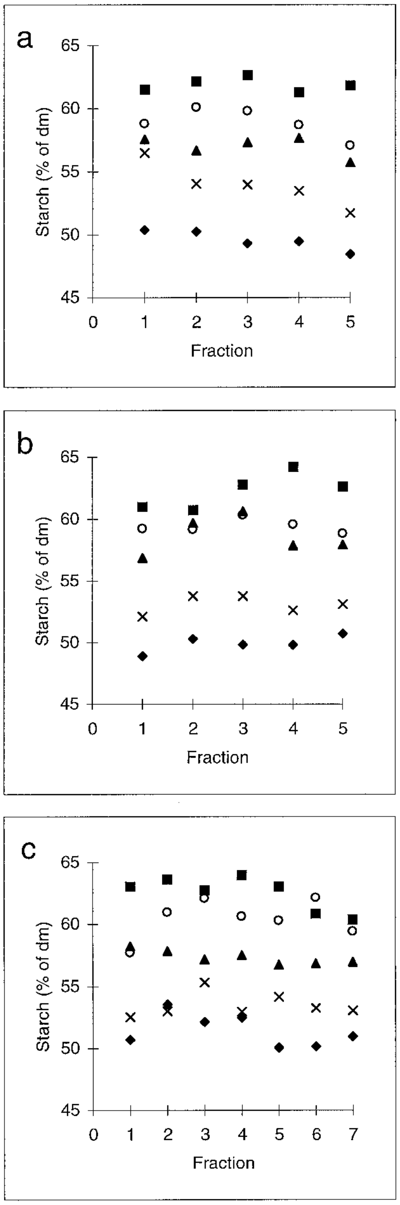

Fig. 3. Content of starch (% of dry matter) in fractions of High amylose Glacier (◆), SW 906129 (×), SW 8775 (■), Golf (○), and Bz 489-30 (▲) produced by a) weighing of individual grains, b) pneumatic classification, and c) sieving.

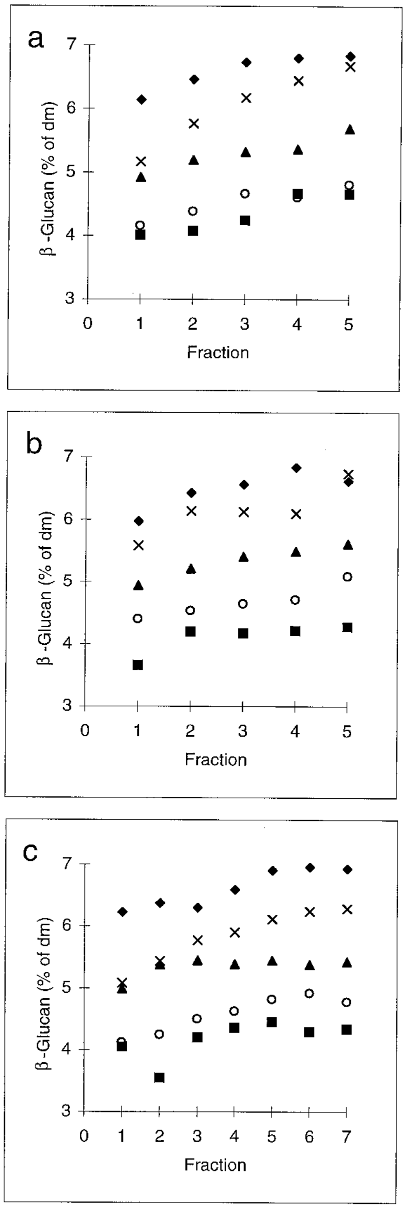

Fig. 4. Content of β-glucan (% of dry matter) in fractions of High amylose Glacier (◆), SW 906129 (×), SW 8775 (■), Golf (○), and Bz 489-30 (▲) produced by a) weighing of individual grains, b) pneumatic classification, and c) sieving.

different fractions indicates that the amount of ash-rich outer layers including hull was fairly independent of grain size. On a geometrical basis, small grains are expected to have more hull and therefore a higher ash content than the large grains. Kent and Evers (1994) stated that large and heavy barley grains have proportionately less hull than small, lightweight grains. Regnér (1995) reported, however, a contradictory relationship in spring wheat, with higher ash content in grains with higher mass. In winter wheat cultivars, there was no consistent relationship between ash content and grain mass. Porceddu et al (1983) concluded that even if size, shape, and chemical composition of cereal grains vary, the relative proportions of the different parts of the grains are rather stable. Ash content could thereby be expected to be fairly independent of grain size. In another study (Evers et al 1990), the content of endosperm in well-filled plump grains was independent of their mass in dissected wheat grains. Endosperm content of shriveled grains (defined as grains with concave areas on the surface) increased with grain mass, but was only slightly lower than that of plump grains. Our results are in agreement with the studies reporting only small differences.

The protein content in the fractions sorted by weighing showed a minimum in the intermediate fractions in all cultivars (Fig. 2a). For the other cult-fract groups, the differences between the fractions were small (Fig. 2 and Table II). The larger differences found for weighing were probably caused by the more narrow fractions produced by the automatic mass sorter than by the other methods. In studies of fractionated wheat (Evans and Bhatt 1977, Dintzis et al 1992, Regnér 1995), both increasing and decreasing protein content with increasing grain size were found for different samples in all studies. For some samples, no differences were found at all. In the literature, no results from studies on fractionated barley were found that either confirm or reject our results.

TABLE I
Characteristics and Chemical Composition (% of dry matter) of Barley Cultivars

Cultivar	Characteristics	Ash	Starch	Protein	β-Glucan
Covered					
Golf	Normal starch, 2-rowed	2.3	60.7	9.3	4.7
High amylose Glacier	High amylose starch, 6-rowed	2.5	50.1	11.3	6.9
SW 906129	High amylopectin (waxy) starch, 2-rowed	2.5	53.7	11.4	6.1
Naked					
SW 8775	Normal starch, 2-rowed	2.3	61.8	12.0	4.6
Bz 489-30	High amylopectin (waxy) starch, 2-rowed	2.0	58.7	14.1	5.6

There were no large differences in starch content between different fractions in the cult-fract groups (Fig. 3 and Table II). A tendency of decreasing content of starch with increasing grain size could generally be seen when fractionating grains with weighing and sieving (Fig. 3a and c). The small differences found are in accordance with results reported by Porceddu et al (1983) and Evers et al (1990).

The clearest trend was seen for β-glucan content in the different fractions. In almost all cult-fract groups, the β-glucan content increased with increasing grain size (Fig. 4 and Table II). The largest increase was found in SW 906129, with a relative increase of >20% from the smallest to the largest kernels for weighing, pneumatic classification, and sieving (Fig. 4a–c). The automatic mass sorter was generally the most effective method for separating kernels on β-glucan content. This was probably because fractions used for this method were narrower than for the other methods. Sieving was effective only in separating grains of covered barley. The higher β-glucan content in the larger grains might indicate thicker cell walls in these grains. A microscopy study of fractionated grains could probably answer that question.

Sieving is commonly used before malting to discard the smallest grains. A high starch content is important for the yield, and a high β-glucan content is harmful for the process and may lead to poorer quality of the beer (Bamforth 1985). Our results indicate that the largest grains, which have a high β-glucan and, in some cases, a low starch content, should be omitted instead to produce the best malt. However, to maximize extraction yield, it is important that the kernels are of uniform size because the time required for the physical modification is size-dependent, and partially modified kernels are not desirable.

Some studies of wheat have shown rather large differences in chemical composition between different fractions of grains (Evans and Bhatt 1977, Tkachuk et al 1991, Dintzis et al 1992, Regnér 1995). The variation within the barley cultivars in our study was much smaller than the differences between the unfractionated samples. The reason for the differences between barley and wheat could be related to how the spikelets and heads of wheat and barley develop. The spikelet in barley contains only one floret, while wheat contains up to six florets per spikelet (Kent and Evers 1994). Growing conditions are also of great importance for grain quality (Oscars-

TABLE II
Variation in Content of Ash, Protein, Starch, and β-Glucan (% of dry matter) Between Four Fractions Produced with the Specific Gravity Table and a Combination of Sieving and the Specific Gravity Table

	Golf	High amylose Glacier	SW 906129	SW 8775	Bz 489-30
Specific gravity table					
Ash	2.1–2.4	2.3–2.5	2.2–2.5	2.0–2.1	1.9–2.0
Protein	9.0–9.3	10.8–11.3	10.9–11.3	11.3–11.9	13.0–13.7
Starch	60.0–62.6	49.9–52.0	54.1–55.2	63.4–64.9	58.5–60.9
β-glucan	4.4–4.9	6.9–7.3	5.8–6.3	3.8–4.6	5.2–5.6
Sieving 2.2–2.5 mm and specific gravity table					
Ash	· · ·	· · ·	· · ·	· · ·	2.0–2.0
Protein	· · ·	· · ·	· · ·	· · ·	13.9–14.1
Starch	· · ·	· · ·	· · ·	· · ·	56.5–57.9
β-glucan	· · ·	· · ·	· · ·	· · ·	4.8–5.1
Sieving 2.5–2.8 mm and specific gravity table					
Ash	2.1–2.2	2.3–2.5	2.4–2.6	2.1–2.1	1.9–2.0
Protein	9.0–9.3	10.8–11.3	10.9–11.3	12.3–12.6	14.1–14.5
Starch	58.6–60.0	50.5–52.5	52.6–54.3	62.4–65.0	57.8–59.4
β-glucan	4.1–4.4	5.8–6.4	5.5–5.7	3.9–4.4	5.2–5.4
Sieving >2.8 mm and specific gravity table					
Ash	2.1–2.2	2.4–2.6	2.4–2.5	2.1–2.4	· · ·
Protein	9.5–9.7	11.2–11.6	11.3–11.4	11.3–12.8	· · ·
Starch	58.1–60.4	48.2–49.9	51.2–52.9	57.6–64.7	· · ·
β-glucan	4.5–4.7	6.5–6.9	6.0–6.4	3.9–4.4	· · ·

son et al, *in press*). The results in our study indicate that fractionation of a bulk of grains of normal quality is not effective in producing fractions of grains with specific chemical compositions.

CONCLUSIONS

The differences in chemical composition between the different fractions within a cult-fract group were generally small. The similarity in ash content indicates that the amount of ash-rich outer layers was fairly independent of grain size. The protein content in the fractions sorted by weighing showed a minimum in the intermediate fractions in all cultivars. The clearest trend was seen in β-glucan content, which generally increased with increasing grain size. Our results indicate that to produce the best malt, the largest grains, which have a high β-glucan and, in at least some cases a low starch content, should be omitted instead of the smallest.

The main interpretation of our results is that the chemical composition within cultivar in this study was very similar for all fractions and that the differences between the unfractionated barley samples were larger. Homogeneity of a bulk sample is of great importance to most users, and if our findings are true for all barley, all grains can be kept without risking a varying content.

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