Production of Food Malt from Hull-less Barley[1]

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Cereal Chem. 73(1):75–80

ABSTRACT

Four cultivars of hull-less barley and, for comparison, two cultivars of malting barley and one cultivar of soft wheat, all having germination capacity >95%, were steeped to about 42% moisture and malted in an automatic micromalting system. Hull-less barleys had a 16-hr shorter steep time than the malting barleys or wheat and produced malts that were comparable in composition and enzyme activities (α-amylase, diastatic power, β-glucanase, and proteolytic) to the malting barley malts but superior to the wheat malt. One cultivar each of hull-less barley, malting barley, and wheat, steeped to about 43% moisture, were malted in a pilot plant. Again, hull-less barley malt was, except for cultivar differences, more like malting barley malt than wheat malt in composition and enzyme activities. Nondiastatic malts having reduced enzyme activities were prepared by heating the green malt at 85°C; the heating temperature may be adjusted to prepare malts of desired color, flavor, and enzyme activities. Hull-less barley malt was milled in a flour mill to produce malted bran and flour. Hull-less barley malt and its products can be added directly to a variety of foods without the need to prepare extracts and syrups, as is the case with most brewer's and distiller's malts. However, malt extracts and syrups may be prepared from hull-less barley malt without the problem of residual hull disposal. It is proposed that hull-less barley malt be called "food malt" to distinguish it from brewer's and distiller's malts, which are prepared from select grades of malting (hulled) barleys.

Several malted barley products such as extracts, syrups, and solid and liquid diastatic and nondiastatic malts are commercially available and are added to a variety of fermented and nonfermented foods to enhance color, enzyme activity, flavor, sweetness, and nutritional quality (Bamforth and Barclay 1993). Malt extracts added to wheat flour enhance α-amylase, soluble sugars, and protein in the dough and promote yeast activity, bread texture, and loaf volume. Malt products varying widely in color, composition, and flavor can be prepared to meet market demands. A more recent commercial product is malted barley bran, a source of insoluble fiber, prepared by combining malt extract and ground malted barley, which are vacuum dried and ground to size for use in breads and nonbread cereal products. Extracts and syrups are prepared by extracting brewer's or distiller's malts with water under various conditions and evaporating the extract under vacuum to obtain desired color, flavor, and diastatic activity. Dry diastatic malts are prepared by blending finely ground malted barley, wheat flour, and dextrose having enzyme activity of 20–60° L (Hickenbottom 1993). Green malts may be dried under elevated temperatures or subjected to other treatments to obtain nondiastatic malts containing little or no enzyme activities.

Malt extracts and syrups are prepared essentially to eliminate hull, which limits the addition of brewer's and distiller's malts directly to foods. In contrast, malt prepared from hull-less barleys has no such limitation and can be directly processed into a variety of products, after milling, without the cost and inconvenience of preparing malt extracts and syrups and disposing of hull. Hull-less barley malt may be used to produce flakes, grits, or cracked grain or it may be ground and sifted or milled to obtain malt flour and malt bran; these products have many food applications. It is proposed that hull-less barley malt be called "food malt" to distinguish it from brewer's and distiller's malts, which are prepared from select grades of malting (hulled) barleys.

Some earlier studies have reported malting of hull-less or naked cereals such as wheat (Pomeranz et al 1975, Sethi and Bains 1978, Singh et al 1983), corn (Singh and Bains 1984), and sorghum (Morrall et al 1986); only a few studies have reported malting of hull-less barleys (Rennecke and Sommer 1979, Singh and Sosulski 1985). Hull-less barley is an ideal cereal for malting because of its inherent capacity, like that of hulled barley, to rapidly synthesize β-glucanases and amylolytic enzymes.

This article reports malting of hull-less barleys and, for comparison, malting barleys and wheat under comparable conditions and compares their compositions and enzyme activities. The objective was to promote the use of hull-less barley, now commercially available in Canada and the United States, in food and industrial applications.

MATERIALS AND METHODS

Materials

Four registered cultivars of hull-less barley (CDC Buck, CDC Richard, Condor, and Falcon), two registered cultivars of malting barley (Harrington and Stein), and two registered cultivars of wheat (AC Fielder and AC Reed) were obtained from B. G. Rossnagel and P. Hucl of the Crop Development Centre, University of Saskatchewan, Saskatoon. They were of the 1992 harvest grown at the Kernen Crop Research Farm of the university. All the barley cultivars were two-rowed, except Falcon and CDC Buck, which were six-rowed. AC Fielder and AC Reed were Canadian soft white spring wheats. Commercial malted barley flour (120–180°L) and nondiastatic dry malt extract were obtained from Malt Products, Maywood, NJ.

For analytical purposes, subsamples of unmalted and malted grains were ground in a Udy cyclone mill to pass a 0.5-mm screen and were stored in airtight jars.

Laboratory Malting

Twenty-gram samples (two samples per malting container) were steeped and malted in the laboratory using an automatic micromalting system (Phoenix Systems, Kingswood, South Australia). The steeping and germination cycle for the hull-less barleys was 9-(4)-9-(76) hr; the numbers outside the brackets indicate steep time and those inside, air rest times. The germinated grain was kilned for 9 hr at 30–50°C, 4 hr at 50–65°C, 2 hr at 65–75°C, 4 hr at 75–85°C, and 0.5 hr at 25°C. Harrington and Stein malting barleys and AC Fielder wheat were steeped for 30 hr with a steeping and germination cycle of 10-(4)-10-(4)-10-(76) hr; the kilning cycle was similar to that used for the hull-less

[1]Partly included in a final report to Alberta Barley Commission, Calgary, AB.

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Publication no. C-1996-0109-07R.

barleys. For the preparation of nondiastatic (low enzyme activity) malts, the steeped and germinated grains were removed from the automatic micromalting system and heated at 85°C for 20 hr in a forced-air oven. The rootlets were removed by gentle rubbing and screening of the malts. The moisture content of kilned and heated malts varied from 4 to 6%.

Pilot Plant Malting

Twenty-five kilograms of CDC Richard and Harrington barleys and of AC Reed wheat were malted in a pilot plant at the Canada Malting Co., Calgary, Alberta. The steeping and germination cycle was 8-(8)-8-(8)-8-(96) hr; again the numbers outside the brackets indicate steep time and those inside air rest time in hours. The kilning cycle was 10 hr at 65°C, 7 hr at 75°C, and 6 hr at 85°C. Malt moisture varied from 4 to 5%.

Malt Extract

Malt extracts were prepared by extracting 10 g of laboratory-prepared CDC Richard malt with 100 ml of distilled water for 1 hr at 70 or 85°C in a shaking water bath. The extracts were filtered and the clear filtrates freeze-dried.

Malt Bran and Flour

CDC Richard malt was dry-milled in a Brabender Quadrumat Jr. mill and sifted in a Ro-Tap shaker (C.E. Tyler Engineering Inc., Bessemer, NC) using a no. 60 (250-µm) sieve. The material that passed through the sieve was taken as flour and that which remained on the sieve as bran. Sifting time was adjusted to obtain yields of 90, 80, and 70% flour and the balance of 10, 20, and 30% bran, respectively. Total and soluble dietary fiber of 30% bran was determined by the procedure of Prosky et al (1988).

Analyses of Laboratory Malts

Whole seed and ground seed (meal) color was measured with a Hunterlab ColorQuest spectrocolorimeter (Hunter Associates Laboratory, Reston, VA), standardized with a white tile. Seed hardness was measured with a micro hardness tester (C.W. Brabender Inc., South Hackensack, NJ). Germination energy and water sensitivity were determined on ungerminated grain as described by LaBerge and Tipples (1992); the latter is defined as the difference between the number of kernels germinated with 4.0 ml of water (germination energy) and 8.0 ml of water. Germination capacity was determined as described in ASBC (1992).

Moisture, ash, and protein were determined by the AACC procedures (AACC 1983), except that the catalyst used for protein determination was copper sulfate. Starch was determined by the method of Holm et al (1986) on samples boiled with 80% ethanol and centrifuged at 2,000 × *g* for 10 min. β-Glucan was analyzed by the method of McCleary and Glennie-Holmes (1985), using an assay kit (Megazyme, Sydney, Australia). Soluble sugars were extracted from the meals with 70% ethanol at room temperature for 30 min; the extracts were centrifuged at 10,000 × *g* for 10 min. Aliquots of the supernatant were used for the determination of total carbohydrates (Dubois et al 1956); raffinose was used as a standard. The same extracts were used for the determination of soluble protein (AACC 1983). Acid extract (pH 1.5) viscosity was measured using a digital viscometer (Brookfield Engineering Laboratories Inc., Stoughton, MA) at 20°C. For amino acid analysis, CDC Richard barley and malt were refluxed with 5.7*N* HCl for 24 hr; the hydrolysates were dried under vacuum and dissolved in citrate (pH 2.2) buffer. Aliquots were injected onto an ion-exchange column of a Perkin Elmer high-performance liquid chromatograph equipped with an Omega 2.5 data handling system.

Enzyme Assays

α-Amylase was determined with the Megazyme kit (Sydney, Australia), which was based on the procedure of McCleary and Sheehan (1987). One unit of enzyme activity was defined as the amount of enzyme required to release 1 µmol of *p*-nitrophenol from *p*-nitrophenyl maltoheptaoside in 1 min under the assay conditions; this is termed a Ceralpha unit. Diastatic power (DP) was determined using the ASBC (1992) procedure; enzymatic activity was defined as °ASBC, calculated from the regression equation, where the reducing sugars were obtained by analyzing malts of known DP supplied by Canada Malting (Calgary). Reducing sugars were determined using ρ-hydroxybenzoic acid hydrazide as a reducing agent according to Henry (1984). Proteolytic activity was determined using the AACC procedure (1983). β-Glucanase activity was also determined using a Megazyme kit, which uses azo-barley β-glucan substrate (McCleary and Shameer 1987). Enzyme activity was reported as international units (U) per kilogram of malt, where 1 U was equal to 1 µm of glucose reducing-sugar equivalent released per minute at 30°C and pH 4.6.

Analysis of Pilot Plant Malts

ASBC (1992) methods were used for the determination of moisture, total protein, soluble protein, DP, viscosity, and α-amylase. In this case, an α-amylase unit (20°C dextrinizing unit) was defined as the quantity of enzyme that dextrinized soluble starch in the presence of excess β-amylase at the rate of 1 g/hr at 20°C. Proteolytic and β-glucanase activities were determined using methods described above for the analyses of laboratory malts.

RESULTS AND DISCUSSION

Steeping

The hull-less barley cultivars were slightly darker than the malting cultivars and wheat; the hull of malting barleys was responsible for their lighter color. Hull-less barleys, especially CDC Buck and Falcon, were also harder than the malting barleys, as was wheat. Malting barley cultivar Stein was the softest, with a grind time of 131 sec (Table I). In our laboratory, grind times smaller or greater than 45–50 sec, as determined with the Brabender microhardness tester, are taken to indicate hard and soft grains, respectively. On this basis, the hull-less barleys and the wheat were hard and the two malting barleys soft. Malting barleys are selected for a softer or mealy endosperm, which absorbs water at a faster rate and facilitates intercellular water diffusion during steeping more easily than a steely endosperm. In

TABLE I
Description of Barley and Wheat Cultivars Used for Malting[a]

Measurement	Hull-less Barley				Malting Barley		Wheat
	CDC Buck	Condor	Falcon	CDC Richard	Harrington	Stein	AC Fielder
Seed color, *L*	46.5	42.4	43.7	41.9	53.5	56.3	50.6
Hardness, sec	46.0	52.0	44.0	54.5	78.5	131.0	46.8
Germination energy, %	99.0	98.0	93.5	97.0	98.0	99.0	93.0
Water sensitivity, %	2.0	-0.5	1.0	2.0	-1.0	-1.0	-4.0
Germination capacity, %	97.5	100.0	96.0	99.5	100.0	100.0	100.0

[a] Means of duplicate determinations.

a mealy endosperm, the starch granules are relatively loosely packed in the protein matrix, unlike those in a steely endosperm, which has tight protein-starch packing (Bamforth and Barclay 1993).

All the cultivars showed little or no water sensitivity, or low dormancy potential. The water sensitivity test measures the ability of barley to grow in excess of water such as during steeping. All the cultivars also had high germination capacity (96–100%), measured by the hydrogen peroxide test (ASBC 1992). Barleys for malting preferably have germination capacity and germination energy greater than 95%, which was the case in the hull-less and malting barleys and wheat used in this study.

Barleys and wheat were steeped to an average moisture of 42–43% after steeping conditions were determined in a number of preliminary experiments. The range in steep moisture was 41–43% for the hull-less barleys with a mean of 42% and 43–44% for the two malting barleys with a mean of 43.5%, which was similar to the steep moisture in wheat. The total steeping and rest time to reach this moisture was 22 hr (9-4-9) in hull-less barleys and 38 hr (10-4-10-4-10) in malting barleys and wheat. Thus, hull-less barleys required 16 hr less to reach the desired steep moisture than the malting barleys and wheat. The shorter steep time in hull-less barleys was due to lack of hulls, which retard water uptake in malting barleys. However, in wheat, the slower water absorption may be due to endosperm structure, even though AC Fielder wheat had grain hardness similar to two of the four hull-less barleys (Table I). It may thus be possible to have structural differences in barley and wheat endosperms with nearly similar grind times. Rate of water uptake in grain is influenced by several factors (Bamforth and Barclay 1993). Uniform hydration of the endosperm plays an essential role in malt modification, inducing the embryo to germinate and the aleurone to synthesize the hydrolytic enzymes. A shorter steep time in Scout hull-less barley than in Harrington malting barley and a Glenlea hard wheat was also reported by Singh and Sosulski (1985).

Diastatic Malts

The chemical compositions and enzyme activities of unmalted and malted barleys and wheat are given in Table II. Also included in the table are data of similar determinations on a commercial sample of diastatic malt. Enzyme activities showed large differences. Unmalted malting barleys, hull-less barleys, and wheat contained no α-amylase or β-glucanase activities but considerable DP and proteolytic activities. On malting, α-amylase activity increased 258-fold in hull-less barleys, 288-fold in the malting barleys, and 112-fold in wheat, taking enzyme activities present in the unmalted grains as zero. The range in α-amylase activity was 216–301 Ceralpha units per gram for the four hull-less barley malts (Falcon hull-less barley malt had the lowest α-amylase activity) and 277–300 Ceralpha units per gram for the two malting barley malts. Thus, some cultivars of hull-less barley can develop, on malting, α-amylase activity similar to that of malting barleys, which are selected for high enzyme activity. β-Glucanase activity increased, on malting, 500- to 600-fold in hull-less and malting barleys and 79-fold in wheat. Again, there were cultivar differences in β-glucanase activity among the hull-less barley malts; the range was 491–727 U/kg; Condor malt had the highest β-glucanase activity (727 U/kg), which was about one and one-half times higher than in the malting barleys. The increases in DP, on malting, were less than threefold in the hull-less and malting barleys and none in wheat. Proteolytic activity increased two- to threefold in barley and wheat malts.

The composition of the malts reported in Table II partly reflects development of the enzyme activities on malting of the grain. The malts were generally similar in color, with an *L* value varying only from 80 to 83. Hull-less barley malts had higher total protein than malting barley malts, starch content similar to that of malting barley malts but lower than wheat malt, and about 2% β-glucan, which was about 10 times higher than in wheat malt. Increases in soluble carbohydrates, soluble protein, and reducing sugars and decreases in β-glucan and viscosity showed the extent of hydrolysis of starch, protein, and β-glucan, respectively, on malting. The lower β-glucan content of the malts was largely responsible for their greatly reduced viscosity. Although extensive hydrolysis of protein and starch takes place on malting, their absolute values do not change substantially due to the measurement of total nitrogen and glucose for their determinations, respectively. The soluble/total protein (*S/T*) ratio, called the Kolbach index, was 28% in hull-less barley malts, 32% in malting barley malts, and 36% in wheat malt. This ratio is sometimes used as an index of modification on malting. A higher soluble nitrogen or *S/T* ratio indicates more extensive breakdown of the protein by proteolytic enzymes. However, several indices are involved in barley modification. These include the rate at which water distributes through the endosperm, synthesis of the hydrolytic enzymes, their diffusion into the endosperm and interactions with substrates, and structural features of the endosperm that promote or resist its dissolution (Bamforth and Barclay 1993).

TABLE II
Composition and Enzymatic Activities of Unmalted and Laboratory-Malted Barleys and Wheat[a]

	Hull-less Barley[b]		Malting Barley[c]		Commercial[d] Malted Barley	Wheat	
Component, dry basis	Unmalted	Malted	Unmalted	Malted	Flour	Unmalted	Malted
Steep moisture, %	...	42.1 ± 0.8	...	43.3 ± 0.8	...	...	43.4 ± 0.5
Color, *L*	84.5 ± 0.8	80.9 ± 1.0	83.1 ± 0.5	80.0 ± 0.1	79.4 ± 0.0	84.0 ± 0.2	82.8 ± 0.2
Ash, %	1.8 ± 0.1	1.4 ± 0.3	2.4 ± 0.2	2.2 ± 0.1	2.3 ± 0.0	1.4 ± 0.0	1.2 ± 0.0
Total protein (*T*), %	16.0 ± 1.3	15.7 ± 1.2	15.3 ± 0.9	13.7 ± 0.5	12.0 ± 0.2	13.0 ± 0.1	11.5 ± 0.0
Starch, %	64.4 ± 1.4	62.9 ± 2.7	61.4 ± 0.8	62.8 ± 2.5	58.6 ± 1.0	70.4 ± 3.0	72.0 ± 2.2
β-Glucan, %	4.9 ± 0.5	1.8 ± 0.5	4.4 ± 0.5	1.2 ± 0.2	0.7 ± 0.0	0.8 ± 0.0	0.2 ± 0.0
Soluble carbohydrates, %	4.0 ± 0.3	10.4 ± 1.5	2.9 ± 0.6	10.1 ± 0.2	15.3 ± 0.3	3.1 ± 0.2	5.8 ± 0.0
Soluble protein (*S*), %	2.9 ± 1.5	4.3 ± 0.5	3.6 ± 0.4	4.4 ± 0.7	3.8 ± 0.1	3.5 ± 0.1	4.2 ± 0.1
S/T, % (Kolbach index)	...	27.5		32.3	31.6	...	36.3
Viscosity, cps	33.3 ± 7.8	1.7 ± 0.1	20.2 ± 1.3	1.6 ± 0.1	1.5 ± 0.0	1.8 ± 0.0	1.8 ± 0.1
Reducing sugars, %	0.2 ± 0.1	2.9 ± 0.2	0.3 ± 0.1	3.2 ± 0.1	6.6 ± 0.1	0.2 ± 0.0	1.5 ± 0.1
α-Amylase, Ceralpha units g^{-1}	0.1 ± 0.0	258.4 ± 36.6	0.1 ± 0.0	288.0 ± 15.1	344.3 ± 2.1	0.2 ± 0.0	112.4 ± 0.6
Diastatic power, °ASBC	113.2 ± 56.8	147.5 ± 43.6	71.0 ± 20.0	189.5 ± 23.7	243.5 ± 0.5	86.7 ± 4.4	85.2 ± 1.6
β-Glucanase, U/kg	0	583.0 ± 101.0	0	502.0 ± 17.0	697.0 ± 6.0	0	79.0 ± 5.0
Proteolytic activity, mg npn 100 g^{-1}	42.0 ± 6.0	112.0 ± 13.0	46.0 ± 2.0	105.0 ± 9.0	107.0 ± 0.0	62.0 ± 4.0	137.0 ± 5.0

[a] Mean and standard deviation of duplicate determinations.
[b] Mean of four hull-less cultivars (CDC Buck, Condor, Falcon, and CDC Richard).
[c] Mean of two hulled cultivars (Harrington and Stein).
[d] Malted barley flour obtained from Malt Products Corporation (Maywood, NJ) and analyzed in our laboratory.

TABLE III
Composition and Enzyme Activities of Pilot Plant Prepared Malts[a]

Measurement, dry basis	CDC Richard	Harrington	AC Reed
Steep moisture, %	44.8	43.1	42.6
Total protein (*T*), %	13.9	14.1	11.8
Soluble protein (*S*), %	4.8	6.1	4.0
S/T, % (Kolbach index)	34.7	43.2	33.8
Viscosity, cPs	1.7	1.5	1.8
Wort β-glucan, ppm	176	151	34
α-Amylase, 20°DU	39.1	68.5	23.0
Diastatic power, °ASBC	157.0	175.0	106.0
β-Glucanase, U/kg	407.1	525.5	73.8
Proteolytic activity, mg npn/100 g	86.9	75.6	129.6

[a] Single determinations except for β-glucanase and proteolytic activities, which are means of duplicate determinations.

TABLE IV
Amino Acid Composition of Unmalted and Laboratory-Malted CDC Richard Hull-less Barley[a]

Amino acid (g/100 g protein, dry basis)	Unmalted	Malted
Aspartate	5.0 ± 0.1	6.0 ± 0.0
Threonine	3.1 ± 0.0	3.1 ± 0.1
Serine	4.1 ± 0.1	4.0 ± 0.0
Glutamate	26.6 ± 0.0	24.6 ± 0.1
Proline	11.5 ± 0.2	12.1 ± 0.0
Glycine	4.1 ± 0.1	4.0 ± 0.0
Alanine	4.0 ± 0.1	4.2 ± 0.0
Valine	4.5 ± 0.1	4.4 ± 0.0
Methionine	0.7 ± 0.1	0.7 ± 0.2
Isoleucine	3.1 ± 0.0	3.3 ± 0.0
Leucine	6.4 ± 0.0	6.6 ± 0.0
Tyrosine	2.7 ± 0.0	2.8 ± 0.0
Phenylalanine	5.1 ± 0.0	5.3 ± 0.1
Histidine	2.3 ± 0.0	2.3 ± 0.0
Lysine	3.4 ± 0.0	3.7 ± 0.0
Arginine	4.5 ± 0.0	4.7 ± 0.1
Total	91.1	91.8

[a] Means of duplicate determinations.

Their cumulative effect is not completely understood. A number of procedures have been described to measure barley modification on malting (Fretzdorff et al 1982; Henry 1989).

The data for the commercial malt sample may be compared with those of the laboratory malted barleys, as it was prepared from finely ground malting barley. Commercial malt contained lower total protein and starch, similar soluble protein, but higher soluble carbohydrates than the laboratory malted barleys. It also had higher amylolytic and β-glucanase activities. These differences were due to the method of commercial dry diastatic malt preparation, where finely ground malted barley is blended with wheat flour and dextrose to obtain enzyme activities of 20–60° L (Hickenbottom 1993).

One cultivar each of hull-less barley (CDC Richard), malting barley (Harrington), and wheat (AC Reed) were malted in 25-kg quantities in a pilot plant and the malts analyzed for composition and enzyme activities. In the pilot plant malting, the steep and germination cycle was the same (136 hr) for each cultivar; the steep moisture was nearly similar (43–45%). Composition and enzyme activities of the pilot plant malts are given in Table III. Due to different malting conditions used in the pilot plant, the data given in Table III are not comparable to those given in Table II for laboratory-prepared malts of the same cultivars. However, this is not of concern as malting conditions in a commercial plant may be adjusted to prepare malts of a desired quality. Comparisons can, however, be made between the malts prepared in the pilot plant. The data show that malt with composition and enzyme activities comparable to that obtained from the malting barley can be prepared from hull-less barley. The differences in enzyme activities between CDC Richard hull-less barley and Harrington malting barley were varietal; Harrington has been selected for high amylolytic activities. Of greater interest was the comparison of CDC Richard and wheat malts. Both the malts had similar *S/T* ratios in spite of the higher proteolytic activity of the wheat malt. CDC Richard malt had much higher wort β-glucan; its amylolytic and β-glucanase activities were also much higher than those of the wheat malt.

The amino acid compositions of unmalted and laboratory-malted CDC Richard are given in Table IV. The sums of total amino acids for unmalted and malted barleys were almost identical. There were only minor differences in individual amino acids. The amino acid composition of hull-less barley malt is expected to be similar to that of brewer's malt, which has not been commonly reported. Free amino nitrogen of wort is of greater importance for yeast nutrition during the brewing process and is more commonly reported than the amino acid composition of malt.

TABLE V
Composition and Enzymatic Activities of Non-Diastatic Barley and Wheat Malts[a]

Measurement (dry basis)	Hull-less Barley[b]	Malting Barley[c]	Wheat
Color, *L*	77.7 ± 1.3	77.6 ± 0.6	80.7 ± 0.3
Ash, %	1.5 ± 0.1	2.0 ± 0.1	1.3 ± 0.0
Total protein (*T*), %	14.6 ± 0.7	14.6 ± 0.8	12.4 ± 0.1
Starch, %	62.8 ± 2.2	64.2 ± 0.0	76.3 ± 0.8
β-Glucan, %	3.0 ± 0.4	1.7 ± 0.2	0.2 ± 0.0
Soluble carbohydrates, %	7.0 ± 1.0	10.7 ± 0.2	8.0 ± 0.2
Soluble protein (*S*), %	3.1 ± 0.9	4.9 ± 0.7	4.7 ± 0.1
S/T, %	21.4	33.3	37.9
Viscosity, cps	2.1 ± 0.2	2.0 ± 0.1	2.2 ± 0.0
Reducing sugars, %	2.2 ± 0.1	3.5 ± 0.2	1.8 ± 0.1
α-Amylase, Ceralpha units/g	82.8 ± 13.3	134.7 ± 0.0	95.8 ± 0.3
Diastatic power, °ASBC	50.9 ± 12.0	78.3 ± 11.0	53.2 ± 0.5
β-Glucanase, U/kg	71.0 ± 9.0	80.0 ± 10.0	60.0 ± 2.0
Proteolytic activity, mg npn/100 g	45.0 ± 9.0	62.0 ± 6.0	124.0 ± 0.0

[a] Mean and standard deviation of duplicate determinations.
[b] Mean of four hull-less barley cultivars (CDC Buck, Condor, Falcon, and CDC Richard).
[c] Mean of two malting barley cultivars (Harrington and Stein).

TABLE VI
Composition and Enzyme Activities of Commercial and Laboratory-Prepared Nondiastatic Malt Extracts

Measurement	Commercial Malt Extract[a]	Laboratory Malt Extracts 70°C	Laboratory Malt Extracts 85°C
Ash, %	1.1 ± 0.1	2.6± 0.1	3.4 ± 0.3
Total protein, %	2.9 ± 0.2	6.2 ± 0.0	5.9 ± 0.0
Starch, %	17.0 ± 2.4	10.0 ± 0.8	15.8 ± 0.3
β-Glucan, %	0.1 ± 0.0	2.4 ± 0.1	1.6 ± 0.1
Soluble carbohydrates, %	92.1 ± 0.5	85.3 ± 0.5	76.6 ± 2.4
Soluble protein, %	2.0 ± 0.1	2.3 ± 0.0	2.0 ± 0.0
Reducing sugars, %	35.9 ± 0.5	33.2 ± 0.2	28.1 ± 0.2
α-Amylase, Ceralpha units/g	1.6 ± 0.0	33.6 ± 1.1	0
Diastatic power °ASBC	5.6 ± 3.1	2.4 ± 0.8	0
β-Glucanase, U/kg	88.0 ± 2.0	62.0 ± 1.0	0
Proteolytic activity, mg npn/100 g	5.0 ± 0.0	0	0

[a] Obtained from Malt Products Corporation (Maywood, NJ) and analyzed in our laboratory.

Nondiastatic Malts

In a preliminary experiment, green malt of CDC Richard was heated for 20 hr at 65, 75, and 85°C, and the color and enzyme activities of the malts were compared. The color of the dried malt became darker as the heating temperature increased. Amylolytic

TABLE VII
Composition and Enzyme Activities of Bran and Flour of CDC Richard Malt Milled in a Quadrumat Junior Mill[a]

Measurement, dry basis	Fraction 1		Fraction 2		Fraction 3	
	Flour	Bran	Flour	Bran	Flour	Bran
Yield, %	90	10	80	20	70	30
Color, *L*	80.6	70.3	80.7	71.1	81.1	73.3
Ash, %	1.5	2.8	1.4	2.3	1.5	2.2
Protein, %	14.4	17.6	14.0	16.7	12.9	16.2
Starch, %	72.5	53.2	71.5	51.6	69.7	51.9
Reducing sugars, %	2.3	1.5	2.4	1.7	2.4	1.5
α-Amylase, Ceralpha units/g	271.2	166.5	282.0	163.0	293.3	172.0
Diastatic power, °ASBC	211.5	143.1	214.2	152.6	225.6	162.3
β-Glucanase, U/kg	556.2	346.5	572.3	351.5	568.7	346.2
Proteolytic activity, mg npn/100 g	81.0	90.6	96.0	82.9	114.6	84.4

[a] Duplicate determinations except yields of bran and flour.

and β-glucanase enzyme activities decreased by about two-thirds and proteolytic activity by about one-half on drying from 65 to 85°C (data not given). Subsequently, nondiastatic malts were prepared by heating green malts of all the cultivars at 85°C to inactivate most of the enzymes. The analytical data for the nondiastatic malts are given in Table V and may be compared with data of diastatic malts for the same cultivars dried in a kilning cycle (see Materials and Methods section) given in Table II. There were only minor differences in color and compositions of the diastatic and nondiastatic malts, with the exception of soluble carbohydrates in hull-less barley and wheat nondiastatic malts. The major differences between the two kinds of malt were, as expected, in enzyme activities, which were reduced to 12–40% of the diastatic hull-less malt activities and 16–59% of the malting barley malt activities given in Table II; β-glucanase activity was the most heat-labile both in hull-less and malting barley malts. The enzyme activities in nondiastatic wheat malt were more stable, being 62–91% those of the diastatic wheat malt reported in Table II. Why enzyme activities were more stable at 85°C in wheat malt than in malting and hull-less barley malts is not known. Nevertheless, nondiastatic malts containing different levels of enzyme activities may be prepared by adjusting the temperature and rate of kilning, taking into account its effect on malt color. Nondiastatic malts are used to improve the flavor, sweetness, and nutritional quality of food products.

Malt Extract

Liquid or solid commercial malt extracts containing 78–80% solids are prepared from malted barley under various conditions of extraction and wort drying and may be diastatic or nondiastatic. Nondiastatic malt extracts are used as a natural flavoring and coloring ingredient. A commercial nondiastatic malt extract contained 17% starch, 92% of which was 70% ethanol-soluble carbohydrates, 36% reducing sugars, and mostly ethanol-soluble proteins (Table VI). It contained little amylolytic and proteolytic activities but some β-glucanase activity.

In one experiment, a nondiastatic malt extract was prepared from CDC Richard at 70 and 85°C and was freeze-dried. The solid yield was about 52% at 70°C and 49% at 85°C, which were lower than yields of commercial malt extracts. The 70°C malt extract contained 6% protein, one-third of which was ethanol-soluble; 10% starch, which was 85% soluble; and 33% reducing sugars (Table VI). It contained some α-amylase and β-glucanase activities but little or no DP or proteolytic activity. All of the enzyme activities were abolished when the extraction was done at 85°C. At this temperature, starch yield increased to 16%, 77% of which was ethanol-soluble.

Malted Bran and Flour

In another experiment, CDC Richard malt was milled in a Brabender Quadrumat Jr. Mill, commonly used for milling wheat. This mill does not separate bran and flour, which were obtained by sifting the milled malt. Malt flour yields of 90, 80, and 70% were obtained; the balance 10, 20, and 30%, respectively, were bran (Table VII). The three flour fractions had essentially the same color, ash, and reducing sugar contents. Protein and starch were lower in the 70% flour fraction. Enzyme activities, especially the proteolytic activity, increased as the flour yield decreased from 90 to 70%. Amylolytic activities were also higher in the 30% bran fraction, while there was little or no change in β-glucanase and proteolytic activities. The 30% bran was analyzed for dietary fiber fractions. As expected, it contained mostly insoluble fiber (17.9%) but also some soluble fiber (2.5%). Hull-less barley malt, bran, and flour will have different applications in foods, due to differences in their particle size, composition, and enzyme activities.

CONCLUSIONS

Hull-less barley now commercially available in Canada and the United States can be used to prepare diastatic malts having composition and enzyme activities comparable to those of brewer's and distiller's malts but superior to that of wheat malt prepared under identical conditions. A shorter steep time in hull-less barley than in malting barley or wheat is a first benefit of such a malt. Another benefit of hull-less barley malt is that it can be used directly in food applications without the necessity of preparing malt extracts and syrups, as is the case with brewer's and distiller's malt. However, liquid or solid extracts can be prepared from hull-less barley malt without the problem of hull disposal. Nondiastatic hull-less barley malts of desired color, composition, and enzyme activities may be prepared by kilning the green hull-less barley malt at higher temperature for shorter times or by other methods, such as infrared processing. Samples of CDC Richard and Harrington barleys tempered to 12% moisture and infralyzed at 130–140°C for 60 sec were completely devoid of enzyme activities (data not given). Hull-less barley malt may be ground and sieved or milled in equipment routinely used for wheat milling to produce malted bran and flour of various extractions. Malted bran and flour contain largely insoluble fiber and have multiple food applications. A hull-less barley malt may be called a "food malt" to distinguish it from brewer's and distiller's malts, which are made from select grades of malting (hulled) barleys.

ACKNOWLEDGMENTS

The author is indebted to: The Alberta Barley Commission, Calgary, for financial support; Brian Rossnagel for providing barley cultivars; Bryan Harvey for use of the automatic micromalting system; Peter Freeman for pilot plant facilities; and Lori Jackson for excellent technical assistance.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. Method 08-03, approved April 1961, revised October 1976; Method 46-13, approved 1976, reviewed October 1982; Method 22-61, approved 1961; Method 44-19, approved April 1961, revised October 1975, reviewed October 1982. The Association: St. Paul, MN.

AMERICAN SOCIETY OF BREWING CHEMISTS. 1992. Methods of Analysis, 8th ed. Method Barley 3B, 1978, revised 1981; Method Malt 2C, 1958, revised 1976; Method Malt 3, 1958, revised 1976; Method Malt 4, 1958, revised 1976, 1991; Method Malt 5, 1975, revised 1976; Method Malt 6, 1958, revised 1976, 1991; Method Malt 6B, 1991; Method Malt 7, 1958, revised 1976, 1991; Method Malt 8, 1958; Method Wort 9, 1969, revised 1976; Method Wort 13, 1975, revised 1976. The Society: St. Paul, MN.

BAMFORTH, C. W., and BARCLAY, A. H. P. 1993. Malting technology and the uses of malt. Pages 297-354 in: Barley: Chemistry and Technology. A. W. MacGregor and R. S. Bhatty, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.

DUBOIS, M., GILLES, K. A., HAMILTON, J. K., REBERS, P. A., and SMITH, F. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350.

FRETZDORFF, B., POMERANZ, Y., and BECHTEL, D. B. 1982. Malt modification assessed by histochemistry, light microscopy and transmission and scanning electron microscopy. J. Food. Sci. 47:786.

HENRY, R. 1984. A rapid method for the determination of diastatic power. J. Inst. Brew. 90:37.

HENRY, R. J. 1989. Factors influencing the rate of modification of barleys during malting. J. Cereal Sci. 10:51.

HICKENBOTTOM, J. W. 1993. Malts in bakery foods. Tech. Bull. vol. 5, issue 3. American Institute of Baking: Manhattan, KS.

HOLM, J., BJOREK, F., DREWS, A., and ASP, N. G. 1986. A rapid method for the analysis of starch. Starch/Staerke 38:224.

LaBERGE, D. E., and TIPPLES, K. H. 1992. Quality of Western Canadian Malting Barley. Crop Bull. 200. Canadian Grain Commission: Winnipeg.

McCLEARY, B. V., and SHAMEER, I. 1987. Assay of malt β-glucanase using azo barley glucan: An improved precipitant. J. Inst. Brew. 93:87.

McCLEARY, B. V., and GLENNIE-HOLMES, M. 1985. Enzymatic quantification of (1→3),(1→4)-β-D-glucan in barley and malt. J. Inst. Brew. 91:285-295.

McCLEARY, B. V., and SHEEHAN, H. 1987. Measurement of cereal α-amylase: A new assay procedure. J. Cereal Sci. 6:237-251.

MORRALL, P., BOYD, H. K., TAYLOR, J. R. N., and van der WALT, W. H. 1986. Effect of germination time, temperature and moisture on malting of sorghum. J. Inst. Brew. 92:439.

POMERANZ, Y., STANDRIDGE, N. N., ROBBINS, G. S., and GOPLIN, E. D. 1975. Malting of new wheat cultivars. Cereal Chem. 52:485.

PROSKY, L., ASP, N. G., SCHWEIZER, T. F., DEVRIES, J. W., and FURDA, I. 1988. Determination of insoluble and total dietary fiber in food products: Interlaboratory study. J. Assoc. Off. Anal. Chem. 71:10.

RENNECKE, D., and SOMMER, W. 1979. Use of naked barley in malting and brewing. Labensm. Ind. 26:66.

SETHI, V. B., and BAINS, G. S. 1978. Factors influencing the malting quality of Indian wheats. J. Food Sci. Technol. 15:62.

SINGH, T., and BAINS, G. S. 1984. Malting of corn: Effect of variety, germination, gibberellic acid and alkali pretreatment. J. Agric. Food Chem. 32:346.

SINGH, T., and SOSULSKI, F. W. 1985. Malting of hull-less barley cultivars and Glenlea (*Triticum aestivum*) utility wheat. J. Food. Sci. 50:342.

SINGH, T., MANNINDER, K., and BAINS, G. S. 1983. Malting of *Triticum diococcum* (Khapli wheat): Response to gibberellic acid and use in baking. J. Food. Sci. 48:1135.

[Received May 30, 1995. Accepted October 13, 1995.]