Composition and Properties of Pearled and Fines Fractions from Hulled and Hull-less Barley

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ABSTRACT

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The effect of pearling on the properties of fractions from hulled nonwaxy and waxy barley and hull-less nonwaxy barley was evaluated. Barley pearled for short, moderate, and long periods produced correspondingly high, moderate, and low extraction rates (yields) of pearled barley grain together with hulls and fines fractions. The extraction rate had a marked effect on yield, color, composition, and pasting properties but less effect on functional properties. As extraction rate decreased, the starch content of pearled grain increased. There was a corresponding increase in the protein, oil, ash, and crude fiber content of the fines fractions. Moderate extraction rates increased the level of lysine, the first limiting essential amino acid, and the chemical score of protein in the fines fractions. Hot and cold pasting viscosities were highest for the pearled grain and lowest for the high protein fines fractions with their higher amylase and lower starch contents. Low extraction pearled grain from hulled waxy barley had the highest peak viscosity with characteristic retrogradation behavior on cooling. Most pastes exhibited little syneresis. Selection of pearling conditions and barley variety can produce fractions with widely varying properties for food systems.

Expanding world requirements for food can only be met by increased use of existing grains such as barley. In North America and Europe, barley is used mainly for brewing and as livestock feed (Kent 1975). Other consumption in food includes flour for flat bread, pearled barley for soup and barley water, ground and flaked grain for porridge, and malt enrichment for various food products (Matthews and Douglass 1978). Large quantities of barley have been used in Korea during periods of rice shortages (Han 1979).

Research has been done to develop new uses for barley in foods such as breakfast cereals, baked goods, noodles, and snacks (Prentice et al 1979, Moore 1980). The results were promising. In general, the nutritional properties compare favorably with other cereals. Sensory and other properties are usually judged to be acceptable and in some cases superior to other cereals.

More research is required on increasing the acceptability and consumption of barley in food to expand its market potential. An important area for study is pearling various types of barley for varying periods to determine the effect on extraction rate or yield of pearled grain and on the properties of the fractions (Han 1979, Reddick 1979). Pearling removes the hull, aleurone, and outer endosperm by abrasion to produce pearled grain, hull, and fines fractions with varying compositions. Previous research has shown that barley flavor is associated most strongly with the outer layers of the kernel (Sumner, *unpublished data*). Study of the composition and functional properties of these fractions should indicate new food uses (Matthews and Douglass 1978).

This research was undertaken to evaluate the properties of hulled nonwaxy and waxy barley and hull-less nonwaxy barley fractions produced by pearling for increasing periods to produce high, moderate, and low extraction pearled grain. The fractions were

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analyzed and compared on the basis of proximate analysis, amino acid content, and functional properties.

MATERIALS AND METHODS

Samples

Three varieties of barley (*Hordeum vulgare* L.)—Betzes, a hulled nonwaxy cultivar; a hulled waxy isoline of Betzes; and Scout, a hull-less nonwaxy cultivar—were grown and provided by the Crop Development Centre, University of Saskatchewan, Saskatoon, Canada.

Properties of Barley Fractions

Five-kilogram barley samples were pearled to high, medium, and low extraction rates in a mini dehuller designed by the National Research Council of Canada, Saskatoon, Canada (Reichert et al 1984). The dehuller consisted of four Carborundum stones rotating at 2,025 rpm in a semicircular trough. High extractions of dehulled grain involved pearling hulled samples for 1.5 min and removing the hull in a Palyi-Hanson air separator. This dehulled, high extraction barley then corresponded to the unpearled hull-less variety. Medium extraction pearled grain required an additional 3.5-min pearling of the hulled varieties and 2.5-min pearling of the hull-less variety with the fines (first fines) being removed with a 12-mesh screen in a Sweco separator. Low extraction pearled grain was obtained by additional pearling of the hulled regular, hulled waxy, and hull-less regular barleys for 4.5, 6.5, and 3.0 min, respectively, and removing the fines (second fines) in the Sweco separator. Pearled barley was ground for analysis in a hammer mill with 0.4-mm openings.

Methods of Analysis

The color of the barley fractions was measured with a Hunterlab Color and Color Difference Meter model D25D2M, using Hunterlab white tile standard no. C2-5470 ($L = +94.70$; $a = -0.9$; $b = +0.5$).

Proximate components were determined in duplicate by approved AACC (1982) methods. A nitrogen to protein conversion factor of 6.25 was used.

Starch was analyzed by the dual enzyme method of Banks et al (1970) except for the substitution of 0.2*M* for 0.1*M* acetate buffer as the medium for enzymatic starch hydrolysis and substitution of 2,2′-azino-di-(3-ethylbenzthiazolene sulfonic acid) for *o*-dianisidine as the chromagen in the glucose assay. α-Amylase and amyloglucosidase (Tenase and Diazyme L-100, respectively) were obtained from Miles Laboratories Inc., Elkhart, IN, and 2,2′-azino-di-(3-ethylbenzthiazolene sulfonic acid), glucose oxidase, and peroxidase from Sigma Chemical Co., St. Louis, MO.

Amino acids were analyzed on a Beckman model 119BL analyzer using the procedure described by Sosulski and Sarwar (1973). Results were corrected to 100% nitrogen recovery and expressed as grams of amino acid per 16 g of nitrogen. The chemical score was calculated using the FAO/WHO (1973) provisional pattern of essential amino acids as the reference protein.

Functional properties of the barley samples were determined on two or more replicates that were ground in a water-cooled Micro Analytical Mill to pass a 100-mesh Tyler screen. Sample weights were calculated on a dry weight basis and analyses were made at the natural pH. An untreated clears flour fraction from hard spring wheat was used as a reference.

The nitrogen solubility index was determined by the AOCS (1974) method except for the extraction, which was done in a Blue M Magni-Whirl constant temperature bath at 30° C with shaking at 120 rpm for 2 hr.

Water hydration capacity was analyzed by AACC method 88-04 (1982).

Fat absorption was measured by the method of Lin and Humbert (1974) and emulsification capacity by the procedure of Inklaar and Fortuin (1969). Canola (rapeseed) oil was used in these analyses.

Foaming capacity and foam stability were analyzed by dispersing a 6-g sample in 100 ml of water in a Kitchen Aid model 45A mixer with a wire whip operating first at slow speed 1 for 0.5 min, then at speed 6 for 8 min. After transfer to a 500-ml graduate cylinder, the volumes of foam and liquid were measured. Foam stability and leak were determined over a 20-min period.

Pasting properties were evaluated in a Brabender Visco-amylograph with a 700 cm-g sensitivity cartridge at 75 rpm using 10% (w/w) flour slurries in deionized water. AACC (1982) method 22-10 was used, with a heating and cooling rate of 1.5° C/min. Syneresis of these pastes was determined by storing 50-g samples in 120-ml sealed containers at 6° C for 16 hr. After free liquid was removed by decanting and blotting, the sample was reweighed and percent liquid loss reported as percent syneresis.

RESULTS AND DISCUSSION

The effects of pearling time on the yield and color of fractions from hulled and hull-less barley are shown in Table I.

A pearling time of 1.5 min was used to produce dehulled barley. About 15–16% by weight of the original kernel was removed, consisting of the hull and some of the other outer layers. Dehulled grain was recovered at a high extraction yield of 84–85% compared to 100% for the unprocessed dehulled barley.

A medium extraction yield of 71–73% pearled grain was obtained by pearling the dehulled grain for an additional 3.5 min. The resulting fines amounted to 12–13% of the original kernel weight and contained much of the pericarp, testa, and aleurone layers together with some of the embryo and endosperm. Pearling hull-less barley for 2.5 min produced similar products consisting of 83% pearled grain and 17% fines.

Low extraction yields were achieved by an additional 3.0–6.5 min pearling of the medium extraction pearled grain to remove most of the remaining outer layers as a second fines fraction amounting to 11–16% of the original weight. The resulting yields of

TABLE I
Extraction Time, Yield, and Color of Pearled Barley Fractions

Barley Fraction	Hulled Nonwaxy Barley					Hulled Waxy Barley					Hull-less Nonwaxy Barley				
	Time (min)	Yield (%)	Color[a] *L*	Color[a] *a*	Color[a] *b*	Time (min)	Yield (%)	Color[a] *L*	Color[a] *a*	Color[a] *b*	Time (min)	Yield (%)	Color[a] *L*	Color[a] *a*	Color[a] *b*
High extraction															
Hull fraction	1.5	16	69.0	3.6	17.6	1.5	15	62.0	4.7	15.5	…	…	…	…	…
Dehulled grain	1.5	84	86.2	0.6	10.8	1.5	85	86.2	0.3	9.0	0	100	80.3	1.0	9.0
Medium extraction															
Hull fraction	1.5	16	69.1	3.6	17.5	1.5	15	62.1	4.7	15.4	…	…	…	…	…
Fines	3.5	13	81.1	1.3	13.8	3.5	12	77.6	1.6	12.0	2.5	17	65.5	3.4	12.3
Pearled grain	5.0	71	89.1	−0.1	8.8	5.0	73	88.7	−1.0	7.8	2.5	83	85.9	0.6	8.2
Low extraction															
Hull fraction	1.5	15	69.0	3.7	17.6	1.5	15	62.0	4.6	15.4	…	…	…	…	…
Fines 1	3.5	14	81.2	1.5	13.4	3.5	13	76.8	1.8	12.2	2.5	17	65.3	3.4	12.4
Fines 2	4.5	15	86.5	0.3	10.9	6.5	16	84.7	0.5	9.3	3.0	11	76.4	1.8	11.2
Pearled grain	9.5	56	89.7	−0.2	7.4	11.5	56	90.2	−0.2	6.8	5.5	72	88.4	0.1	6.8

[a] *L* (100 white, 0 black), *a* (+ red, − green), *b* (+ yellow, − blue).

low extraction pearled grain were 56% for the hulled varieties and 72% for the hull-less variety. The higher yield of pearled grain from hull-less barley could be of economic benefit.

Hunterlab values indicated that removal of the outer kernel layers by pearling resulted in an increase in the *L* value (whiteness) of the pearled grain as the endosperm was exposed. This was accompanied by a reduction in the red and yellow values.

Compositions of the barley grains and fractions are provided in Table II. Hulled nonwaxy whole grain barley contained only 10.5% protein, which was somewhat lower than the hulled waxy and hull-less nonwaxy varieties at 15.5 and 19.9%, respectively. Hull-less barley usually has a higher protein content than hulled barleys because of the absence of low protein hulls (Robbins and Pomeranz 1972), but this sample was unusually high. The apparently high protein contents of the hull fractions were attributed to inclusion of some of the high protein outer layers and germ. Protein concentrated in the first fines to a maximum of 27% in the hull-less nonwaxy barley fines due to inclusion of high protein aleurone layer and germ. Second fines contained a lower concentration of protein. The lowest protein content was in the pearled grain fraction, which consisted mainly of the starchy endosperm. Normand et al (1965) found a similar distribution of protein in pearled barley fractions.

The oil content was highest in the hull and first fines fractions

TABLE II
Composition[a] of Barley Grain and Fractions

Barley Fraction	Hulled Nonwaxy Barley					Hulled Waxy Barley					Hull-less Nonwaxy Barley				
	Protein	Oil	Ash	Fiber	Starch	Protein	Oil	Ash	Fiber	Starch	Protein	Oil	Ash	Fiber	Starch
Whole grain	10.5	3.0	2.7	4.5	68.0	15.5	3.3	2.7	3.3	56.7	19.9	2.0	2.2	2.2	60.4
High extraction															
Hull fraction	12.3	5.5	8.1	20.9	···	16.0	6.0	7.1	20.8	···	···	···	···	···	···
Dehulled grain	10.2	1.9	1.7	1.5	72.4	15.2	2.3	1.5	3.7	63.0	19.9	2.0	2.2	2.2	60.4
Medium extraction															
Hull fraction	12.8	5.4	8.2	21.9	···	16.4	7.0	7.4	19.9	···	···	···	···	···	···
Fines	16.7	6.0	4.2	3.8	47.0	24.2	7.8	4.2	1.0	37.1	27.0	8.7	5.5	6.2	24.3
Pearled grain	9.2	1.1	1.2	0.7	74.8	13.8	1.9	1.2	0.9	67.2	18.3	2.5	1.6	1.6	67.4
Low extraction															
Hull fraction	12.8	5.4	8.0	20.8	···	16.5	6.4	7.3	20.0	···	···	···	···	···	···
Fines 1	16.6	5.6	4.0	4.1	47.3	24.2	7.8	7.4	3.9	34.1	26.3	7.6	5.6	7.5	25.8
Fines 2	13.5	2.7	2.4	1.5	70.8	21.2	3.7	2.4	1.6	53.8	24.9	6.0	3.9	2.6	46.0
Pearled grain	7.9	0.7	1.0	0.4	78.7	12.9	1.1	0.9	1.0	72.4	17.4	1.9	1.3	0.5	70.6

[a] Percent, dry basis.

TABLE III
Essential Amino Acid Distribution and Chemical Score in Barley Whole Grain and Fines

Essential Amino Acid[a]	Reference Protein[b]	Hulled Nonwaxy Barley			Hulled Waxy Barley			Hull-less Nonwaxy Barley			C.V.[c] (%)
		Whole Grain	Fines Extraction Medium	Fines Extraction Low	Whole Grain	Fines Extraction Medium	Fines Extraction Low	Whole Grain	Fines Extraction Medium	Fines Extraction Low	
Lysine	5.5	*4.0*	*4.3*	*3.7*	*3.3*	*3.5*	*3.1*	*3.2*	*4.4*	*4.0*	1.9
Methionine + cystine	3.5	4.0	3.9	3.7	3.5	3.3	3.2	3.4	3.3	3.4	···
Threonine	4.0	3.6	3.6	3.3	3.2	3.2	3.1	3.0	3.6	3.2	1.5
Isoleucine	4.0	3.7	3.7	4.0	3.8	3.4	3.5	3.5	3.5	3.5	1.3
Leucine	7.0	7.4	7.1	7.0	6.9	6.5	6.6	6.6	6.8	6.7	1.6
Tyrosine + phenylalanine	6.0	7.7	7.7	8.0	8.1	8.2	8.5	9.0	8.3	8.5	1.7
Valine	5.0	6.2	5.3	5.5	5.0	4.9	4.8	4.7	5.2	5.2	1.3
Chemical score	100	73	78	67	60	64	56	58	80	73	

[a] Amino acids in g/16 g of N. First limiting essential amino acid is in italic type. With the exception of methionine + cystine, values are the average of two replicates.
[b] FAO/WHO (1973).
[c] Average coefficient of variation for nine amino acid samples.

TABLE IV
Functional Properties[a] of Barley Grain and Fractions

Barley Fraction	Hulled Nonwaxy Barley					Hulled Waxy Barley					Hull-less Nonwaxy Barley				
	pH[b]	NSI (%)	WH (%)	FAb (%)	Emul (%)	pH	NSI (%)	WH (%)	FAb (%)	Emul (%)	pH	NSI (%)	WH (%)	FAb (%)	Emul (%)
High extraction															
Dehulled grain	6.0	15	110	113	18	5.9	10	117	127	11	6.0	13	102	133	10
Medium extraction															
Fines	6.6	29	117	130	15	6.4	25	111	133	23	6.3	29	132	133	12
Pearled grain	5.9	16	117	110	14	5.5	11	110	123	11	5.8	13	111	133	8
Low extraction															
Fines 1	6.6	29	111	130	19	6.6	25	110	120	15	6.3	31	122	150	14
Fines 2	6.5	15	110	133	14	6.4	17	111	127	17	6.3	20	102	132	9
Pearled grain	5.8	19	130	167	13	5.2	13	117	116	18	5.9	11	106	106	9
Reference															
Wheat flour	6.0	20	74	113	11	6.0	20	74	113	11	6.0	20	74	113	11

[a] NSI = nitrogen solubility index, WH = water hydration capacity, FAb = fat absorption, Emul = emulsification capacity.
[b] 10% (w/v) dispersion in distilled water.

largely because of the inclusion of separated germ.

Ash and fiber in the whole grain were highest for hulled nonwaxy barley and lowest for the hull-less variety. Both components were concentrated in the hull fractions of the hulled varieties and the first fines fraction of the hull-less sample and decreased in the pearled grain with progressive pearling.

As the outer layers of the grain were removed by pearling, the starch concentration in the pearled grain increased. The highest starch content of 78.7% was obtained with the hulled nonwaxy pearled grain compared to 72.4% in pearled grain from hulled waxy and 70.6% from hull-less nonwaxy barley. Starch concentration in the fines increased with longer pearling.

Table III compares the essential amino acid profile for the whole grain, medium extraction fines, and low extraction combined first and second fines. The FAO/WHO (1973) reference protein and chemical scores are also provided. Hulled nonwaxy whole grain barley contained the highest level of lysine and other limiting essential amino acids. A shift in the amino acid composition of the fines was most noticeable for the nonwaxy varieties. Compared to protein in whole grain, the protein in medium extraction fines contained more lysine, the first limiting essential amino acid. This had the beneficial effect of improving the chemical score. Similar observations were reported by Robbins and Pomeranz (1972).

A comparison of the functional properties of the dehulled barley fractions and the wheat flour reference is shown in Table IV. The natural pH of the samples was within the range of 5.2–6.6. Each sample exhibited a relatively low nitrogen solubility index (10–31%) due to the low protein solubility of the protein near the isoelectric point of about 5.5. Wu et al (1979) reported that barley protein concentrates are insoluble in aqueous solutions between pH 5.0 and 6.5. No large varietal differences in nitrogen solubility were observed, but the first fines always provided the highest nitrogen solubility index.

Water hydration capacity (102–132%) was higher for all of the barley fractions than the value (74%) for the wheat flour reference. The three barley varieties were similar in water hydration capacity, and there were no consistent differences between the fines and pearled grain.

Fat absorptions for all barley fines fractions ranged from 120 to 150%, which exceeded the wheat flour value of 113%. The fat absorption properties of pearled barley grain equaled or surpassed that of wheat flour. One factor affecting fat absorption is reported to be lipid-protein interaction (Kinsella 1979). Emulsification values for all barley fractions and the wheat control were quite poor (8–23%). The values were lowest for the hull-less barley fractions. Wu et al (1979) found that barley protein concentrate has good water hydration capacity but poor emulsification characteristics.

Foaming percent and foam stability were both very low for the hull, fines, and pearled grain fractions from the three barley varieties and would be of little practical value. Most fractions provided a foaming percent of less than 50% and a stability of less than 5 min. The small foaming capacity probably resulted in part from the low level of protein, which was largely insoluble.

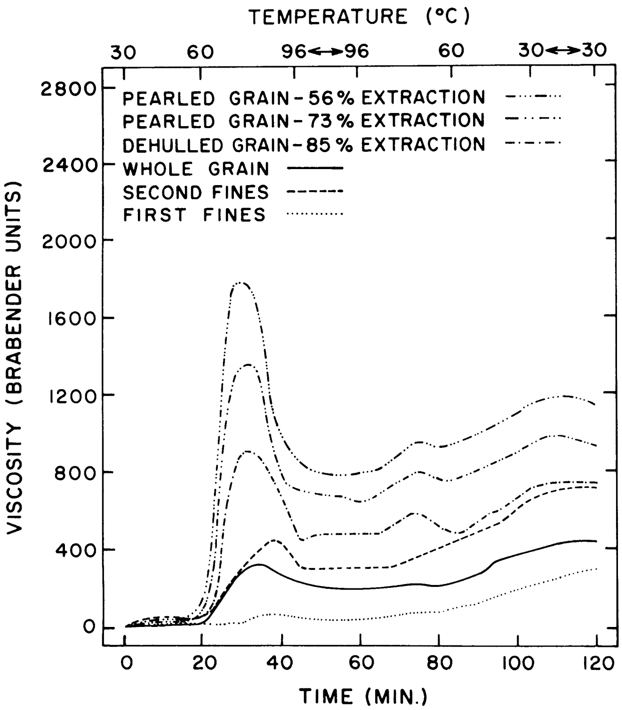

Fig. 2. Viscoamylograms of hulled waxy barley grain and fractions.

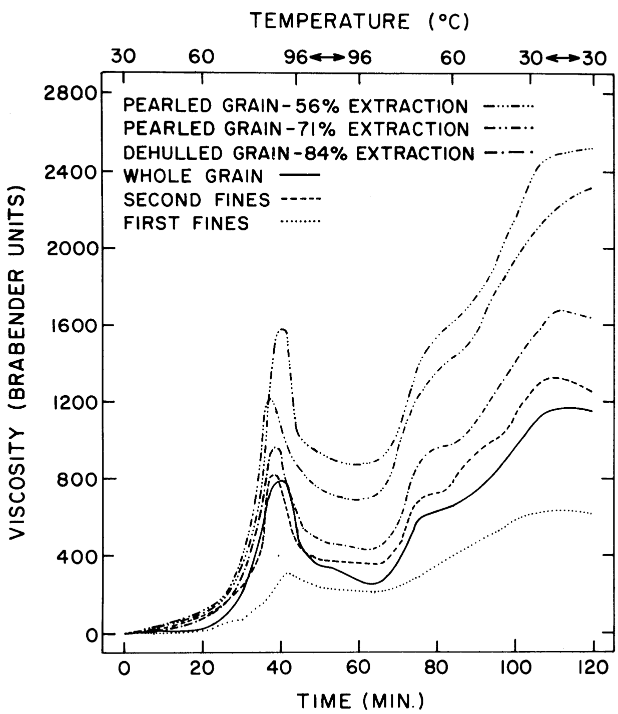

Fig. 1. Viscoamylograms of hulled nonwaxy barley grain and fractions.

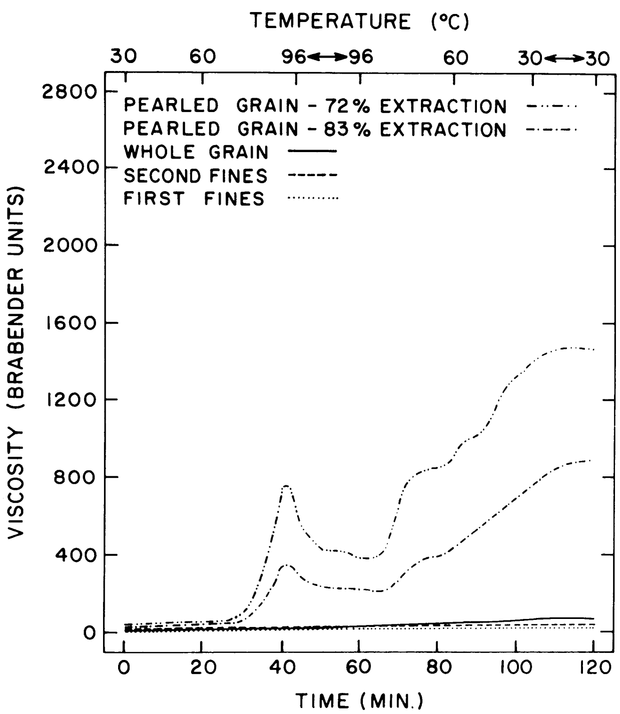

Fig. 3. Viscoamylograms of hull-less nonwaxy barley grain and fractions.

Viscoamylograms for the three barley varieties and their products are shown in Figures 1, 2, and 3. The highest peak viscosities for all varieties were shown by the pearled grain. Viscosities of these fractions increased with decreasing extraction rate because the resulting pearled grain contained more starch and less protein with associated amylase. Peak viscosity was highest for the low extraction hulled waxy barley pearled grain (1,780 B.U.). Hulled waxy barley also had the lowest temperature at peak viscosity of 72° C compared to about 90° C for the two nonwaxy varieties. Furthermore, the hulled waxy pearled barley showed characteristic lower stability and retrogradation on cooling than the nonwaxy varieties, which was in agreement with the observations of Vose and Youngs (1979). Fines from the hulled samples showed much lower viscosities than the corresponding pearled fractions. The decreased viscosities are attributed in part to a higher amylase content in these high protein fractions. This is particularly apparent in the very low viscosities of the whole grain and fines flours for hull-less barley (Fig. 3). These values are unusually low for this variety of hull-less barley compared to values for the same variety grown at various locations in 1978–1981 (R. T. Tyler, *unpublished data*). Low values could result from sprouting and an increase in amylase content when the grain was in swath. Syneresis of these pastes was determined. In general, the liquid loss was low and varied from 0.1 to 0.4%. Exceptions were some hull-less barley fractions, where syneresis values ranged from 15.1% for whole grain to 33.8% for one of the fines fractions, again probably due to the high amylase activity.

CONCLUSIONS

Pearling barley at various extraction rates can produce fractions that vary widely in their physical, chemical, and functional characteristics. These variations can be modified further by selection of the barley variety on the basis of such factors as hulled or hull-less and nonwaxy or waxy starch. Preselection of individual lots within a variety can also be important. By producing fractions with desired properties, their potential is enhanced for various foods and beverages. Pearled grain fractions with high starch content may be suitable as a brewing adjunct and bland thickener for food systems. The higher protein fines might be suitable for high protein snacks and other foods.

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