Unmalted Grains as Maltsters' Adjuvant and Brewers' Adjunct[1]

P. F. KOSZYK and M. J. LEWIS, *Dept. of Food Science and Technology, University of California, Davis, CA 95616*

ABSTRACT

Unmalted cereal grains are a potentially attractive material for brewing. A range of cereals was evaluated by chemical analysis, in pilot scale operations, and by sensory analysis of the beers produced. Some unmalted cereal grains can provide as much diastatic power and protease activity as malt, almost as much extract, roughly half as much amino nitrogen, and a variable low level of amino acids. When milled, wheat and triticale yielded a spectrum of particle size similar to malt, but barley was quite different. Pilot plant operations were minimally affected by cereal grains incorporated in the mash, and the only disadvantage was seen in boiling the grain. Some cereal beers were liked as much as a corn grits brew, others were less well liked, especially rye beer. Our main points are: 1) unmalted grains are a feasible material for brewing without added enzymes, and are worthy of study; 2) those grains need to be selected for desirable properties, including enzyme content and beer flavor; 3) this selection is logically a function of the malting industry; 4) for greatest efficiency the selected grains should be blended with malt, in which state they are a maltsters' adjuvant as well as a brewers' adjunct; and 5) barley is not necessarily the best grain to choose for this purpose—wheat and triticale offer alternatives worthy of investigation.

Key words: *Adjunct, Adjuvant, Brewing, Cereals, Unmalted.*

There is apparently only limited use of unmalted grains in U.S. brewing (15), though barley and sorghum are brewed in North America. Much work has been done on mashing with barley with added microbial enzymes (3,14), and the malting of unusual grains has been explored (12).

Traditional adjuncts dilute malt and have physical and chemical properties which differ from malt. However, unmalted grains may imitate malt to some extent and, if mashed with malt, could add desirable materials to the wort. Therefore, they are possible malt adjuvants. The maltster may need such adjuvants in the future to conserve the supply of malt or malting capacity, and to add flexibility to his product and process.

Standard tests (1) and pilot brews have been used to evaluate unmalted grains. The results suggest that unmalted grains can be mashed with malt without added microbial enzymes, and will contribute extract, enzymes, and some amino nitrogen to the wort. Unmalted grains should be selected for desirable properties, including their flavor. Some unmalted grains could be used blended with malt. Wheat and triticale may be preferred to barley.

EXPERIMENTAL

Grains

Malts were provided by a local malting company. Unmalted grains were provided by the Department of Agronomy and Range Science, University of California, Davis.

Barleys. Traill (CI 9538[2]), a malting variety; Compana (CI 5436), a two-row feed variety; Waxy Compana, an experimental variety containing 100% amylopectin (Montana State University); Glacier (CI 7243) a six-row feed variety; Glacier High Amylose, an experimental line containing about 47% amylose (Montana State University); and Wocus (CI 8058), a six-row feed variety.

Rye. Merced, a commercial variety grown in California.

Oats. Montezuma (CI 8419), a newly released variety (University of California, Davis); Curt (CI 7424), a commercial variety.

Triticales. Cinnamon, an experimental variety (University of California, Davis); UC 8825, a new variety (University of California, Davis).

Wheats. Yecora 70, a common wheat (*Triticum aestivum*) grown in Mexico; Leeds (CI 13768), a durum wheat (*T. durum*) grown in California; Anza (CI 15284), a common wheat grown in California; and ND 6655, an experimental durum wheat of North Dakota.

Other grains. Rough rice (unmilled, husked, whole-kernel rice) and brewer's rice grits were supplied by the Sacramento Rice Growers Association, Sacramento, Calif.; refined corn grits were purchased from Clinton Brand Company, Clinton, Iowa.

Pelletized hops were obtained from S. S. Steiner Inc., Yakima, Wash. Commercial brewer's yeast was obtained from a local brewery and stored at 0°C.

Analyses

The following analyses were conducted by standard methods (1): 1000-kernel weight, moisture, protein (a conversion factor of 5.7 was used for wheat and triticale), fermentable extract, and diastatic power (DP).

Total DP was determined by treatment with dithiothreitol (13). Protease activity was determined by extracting 12.5 g of grain, finely ground in a Wiley hammer mill with a No. 20 mesh screen, with 0.5% w/v saline at 20°C for 2.5 hr with occasional stirring. After filtration, the extract was diluted with 9 vol of saline and 10 ml was added to 50 mg of pulverized Fibrin Blue (Calbiochem, Los Angeles, Calif.). After exactly 30 min at 35°C, the suspension was filtered and the absorbance of the filtrate was measured at 620 nm. Precise timing was required.

Millability was determined in a Brabender Quad Mill®. Exactly 100 g of grain was milled at settings of 0.025 in. between the first rolls and 0.003 in. between the remaining rolls. The milled grain was shaken for exactly 5 min on a Tyler Ro-Tap shaker equipped with U.S. Standard Sieve Nos. 20, 40, 60, 70, 100, and pan. At least 96% of the grain was recovered.

Laboratory mashes were conducted in a standard eight-place laboratory mash vessel (Weber Bros. and White Metal Works, Hamilton, Mich.) according to the ASBC method Cereal Adjuncts-5 (1). For comparison, the unmalted grains were also mashed without boiling. All grains were finely ground in a Wiley hammer mill with a No. 20 mesh screen.

Wort viscosity was determined in a Brookfield Rotational Viscometer, Model RPT; a No. 1 spindle at 100 rpm was used. Amino nitrogen was measured on wort diluted with 99 vol of water (11). A glycine standard was used. Amino acid analyses were conducted in a fully automated apparatus consisting of a column (0.9 × 30 cm) containing Durrum A-6 resin, eluted with the Durrum *pico*-buffer system IV (Durrum Chemicals Inc., Palo Alto, Calif.).

Wort was produced in a 20-liter pilot brewhouse (Steriline Brewing Equipment, Milwaukee, Wis.) fitted with a modified lauter vessel. The ratio of traditional adjunct or unmalted grain was 40% extract basis. The refined corn grits adjunct was boiled; the unmalted grains were not boiled but were mashed in with the malt at 40°C. After 30 min, the mash temperature was raised 2°C/min to 70°C and held for 40 min. The mash temperature was then raised rapidly to 77°C and transferred to the preheated lauter and allowed to stand 30 min. Time of lautering was measured from the beginning of collection of clear wort to kettle full (22 liters). During fermentation at 13°C for 10 days, yeast dry weight in suspension, specific gravity, and pH were measured. The beer was lagered for 21 days at 0°C, filtered, carbonated, and bottled. Beer analyses were conducted by standard ASBC methods (1).

Sensory evaluation of the beers was conducted with a panel of 18 judges previously screened for high ability to correctly match beers. The multiple Comparison Difference Test was used (8). The data were analyzed by Duncan's Multiple Range Test. Each beer was evaluated five times by each judge in two sets. An unidentified control beer was included in each test set. On a scale 100 mm long,

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[2]Cereal Investigation number.

the judges were asked to mark "X" for the liking of each beer compared to an identified control (refined corn grits) beer. The liking of the control beer was fixed at the 50-mm point on the line. Thus, beers scored higher than 50 were preferred to the control while those below 50 were less liked than the control. A perceptive panel would score the unidentified control beer close to 50.

TABLE I
Kernel Weight, Moisture, and Protein Content of Malt and Some Unmalted Grains

Sample	1000-Kernel wt g[a]	Moisture %	Protein %[a]
Klages control malt	35.1	7.92	12.4
Larker malt	34.0	5.88	11.3
Piroline malt	32.2	5.62	11.6
Traill barley	37.6	9.54	12.0
Compana barley	42.2	8.18	16.5
Waxy Compana barley	49.7	8.54	16.6
Glacier barley	44.1	8.18	13.9
High Amylose barley	46.5	7.72	14.2
Wocus barley	52.2	8.02	12.5
Montezuma oats	36.1	7.47	12.3
Curt oats	33.8	9.13	12.8
Merced rye	20.4	8.40	13.3
Cinnamon triticale	42.0	8.71	16.2
UC 8825 triticale	41.3	8.67	13.8
Yecora wheat	44.9	8.85	16.7
Leeds wheat	44.4	8.78	16.2
Anza wheat	31.8	9.23	13.8
ND 6655 wheat	51.8	8.71	14.1
Brewer's rice	...	10.74	8.2
Rough rice	28.7	9.52	6.7
Refined corn grits	...	11.17	...

[a]Dry basis.

TABLE II
Diastatic Power (DP) and Protease Activity of Malt and Some Unmalted Grains (Values are Dry Basis)

	Free DP	Total DP	Latent DP (% of Total)	Relative Protease[a]
Klages control malt	97	130	25	141
Larker malt	132	149	11	163
Piroline malt	89	102	13	171
Traill barley	28	44	36	255
Compana barley	70	98	29	169
Waxy Compana barley	73	131	44	172
Glacier barley	15	40	63	143
High Amylose barley	9	40	78	158
Wocus barley	28	98	71	133
Montezuma oats	2	5	60	308
Curt oats	8	8	0	392
Merced rye	48	63	24	92
Cinnamon triticale	134	237	44	168
UC 8825 triticale	166	189	12	204
Yecora wheat	78	187	58	96
Leeds wheat	106	154	31	153
Anza wheat	96	127	24	102
ND 6655 wheat	217	229	5	167
Brewer's rice	0	0	0	185
Rough rice	0	0	0	335
Refined corn grits	0	0	0	14

[a]Value is $A_{620} \times 10^3$.

RESULTS

Laboratory Analyses

With some exceptions, the unmalted grains tested had a higher protein content, moisture, and 1000-kernel weight than the malts (Table I). The free DP of some barleys, triticales, and wheats approached or exceeded that of brewer's malt (Table II). However, the malts contained a smaller portion of their total DP in the latent form than did the unmalted grains. The high DP of wheat is interesting because wheat starch gelatinizes almost as easily as malt starch (5,6). The protease activity of unmalted grains was frequently as high as or higher than that of the malts (Table II), probably reflecting the reduction of protease activity by malt kilning. The protease content of the oats samples was particularly high.

Except for some wheats, unmalted grains yielded less extract (% dry basis) than the malts when mashed by the Cereal Adjuncts-5 method (1) (Fig. 1). Oats were especially poor in extract. Brewer's rice and refined grits yielded better than malt, especially when boiled, but for the unmalted grains extract yield was not always increased by boiling.

Barley, oats, and rye, when mashed by the method of Cereal Adjuncts-5 (1), yielded worts that were more viscous than an all-malt mash (Table III). Triticale and wheat worts were as viscous as the all-malt wort. Brewer's rice and refined grits reduced wort viscosity. Barley worts had a pH equal to that of all-malt wort, but the other unmalted grains produced worts of higher pH. Worts made with unmalted cereals, especially rye, had a higher haze than malt wort, but about the same fermentability. The color and odor of all worts were judged normal except for rye.

Unmalted grains, when present in the mash, reduced the amount

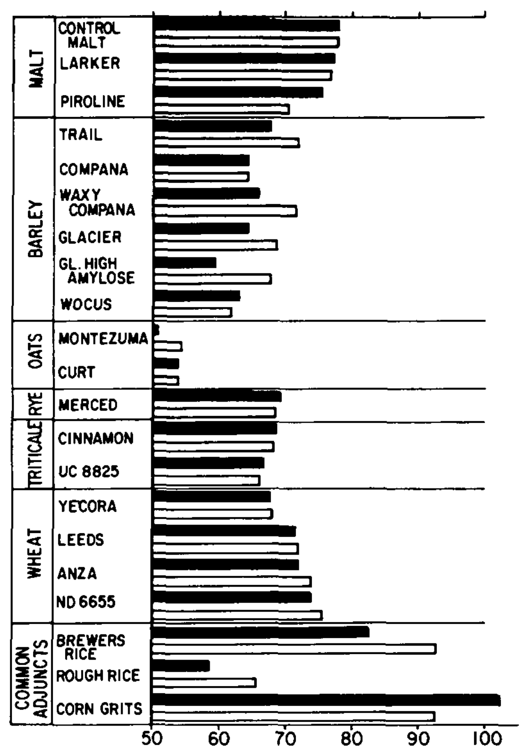

Fig. 1. The materials listed were used as the 'adjunct' in the method Cereal Adjuncts-5 (1) and were either boiled (open bars) or not boiled (closed bars) before use. The extract yield (% dry basis) shown by the bars is computed for each material when it is used as an 'adjunct.'

of amino nitrogen present in the wort (Fig. 2). It has previously been reported (4,9) that unmalted grains make no contribution to wort amino nitrogen. In the present study, this was the case for one wheat, but the other unmalted grains made a contribution of amino nitrogen to the wort which was about half as much as that of an equal weight of malt.

Amino acid analysis of the worts produced by the method of Cereal Adjuncts-5 (1) confirmed that, in general, the amino acids present in the worts made with unmalted grains were less in total, but were proportionate to the all-malt wort. Wheat produced less total amino acids than the other unmalted grains, and part of the total amino nitrogen reported in Fig. 2 could be peptide material rather than amino acids. Rye wort contained as much amino acid as the all-malt wort.

Milled malts separated into a characteristic distribution of particle sizes under the carefully controlled conditions of milling and sifting (Fig. 3). Barley, oats, and rye gave a distribution of particle sizes which differ from malt but, under the same conditions, triticale and wheat yielded a distribution of particle sizes remarkably similar to that of malt. Although averaged data are shown in Fig. 3, it was possible to identify the data from each grain.

Pilot Plant Analyses

Ten of the unmalted grains used for laboratory testing were brewed at the 40% level and compared with the 40% corn grits controls (Table IV). The unmalted grains were not boiled because, with barley, there was a dramatic increase in wort viscosity (10) and boiling the unmalted grain did not consistently increase extract yield (Fig. 1) or extraction of amino nitrogen (Fig. 2). Boiling was therefore omitted to preserve the enzyme content of the unmalted grain. Brewhouse yield was slightly less for the unmalted grains than for the malts, and substantially less than for the corn grits controls. Lautering times for the mashes containing unmalted grain were equal to or slightly faster than all-malt mashes (60 min) but slower than the 40% corn grits mashes (45 min). Rye lautered slowly (100 min). The wort fermented readily and reached end gravity within 10 days. Gravity change, pH change, yeast growth, and sedimentation were unexceptional in any of the worts. There was some interbrew variation among the beer analyses, as would be expected. However, none of the sensory data could be ascribed to analytical differences among the beers, except for the rye beer which had a persistent unfilterable haze. The beers containing unmalted grains were essentially as chill stable as the corn grits control beers, and wheat beers were slightly more chill stable. The persistent haze in the rye beer precluded chill haze evaluation.

TABLE III
Analyses of Laboratory Worts Produced by the Method of Cereal Adjuncts-5 (1) with Boiling (B) or without Boiling (NB)

	Wort pH		Wort Haze[a]		Wort Viscosity[b]	Fermentable Extract (% of Total)	
	NB	B	NB	B	NB	NB	B
Klages control malt[c]	5.75	5.72	1	4	1.120	62.7	62.0
Larker malt	5.77	5.75	0	0	1.060	65.1	63.3
Piroline malt	5.80	5.77	0	0	1.120	55.1	56.6
Traill barley	5.65	5.57	4	2	1.270	64.7	65.7
Compana barley	5.62	5.55	4	2	1.540	65.3	65.3
Waxy Compana barley	5.72	5.73	2	2	1.520	62.2	63.8
Glacier barley	5.79	5.76	4	4	1.600	63.9	65.8
High Amylose barley	5.75	5.76	3	4	1.480	58.8	62.1
Wocus barley	5.84	5.82	4	1	1.670	55.1	55.4
Montezuma oats	5.89	5.90	3	2	1.770	55.9	54.1
Curt oats	5.82	5.82	3	5	1.500	60.4	58.2
Merced rye	6.00	5.97	5	5	1.740	56.8	56.7
Cinnamon triticale	6.02	6.04	2	2	1.130	63.4	64.6
UC 8825 triticale	6.01	6.01	1	2	1.220	65.6	65.8
Yecora wheat	6.00	6.01	2	1	1.100	64.6	65.4
Leeds wheat	5.94	5.93	4	2	1.160	60.6	62.7
Anza wheat	5.93	5.89	3	1	1.120	60.1	62.9
ND 6655 wheat	5.96	5.91	3	2	1.140	61.5	62.6
Brewer's rice	5.96	5.92	3	1	1.030	68.3	65.7
Rough rice	5.97	5.94	3	2	1.070	64.6	65.3
Refined corn grits	5.85	5.89	3	0	1.020	62.6	66.1

[a]0 = No haze, 1 = very slight haze, 2 = slight haze, 3 = moderate haze, 4 = hazy, and 5 = very hazy.
[b]Centipoise.
[c]The materials listed were used as the 'adjunct' in the method Cereal Adjuncts-5 (1).

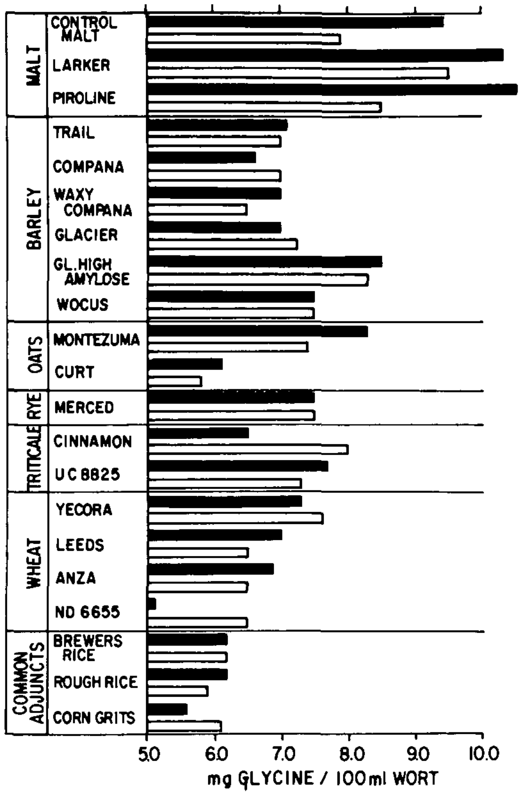

Fig. 2. As for Fig. 1, but the bars represent the amount of amino nitrogen in the wort, reported as mg glycine/100 ml.

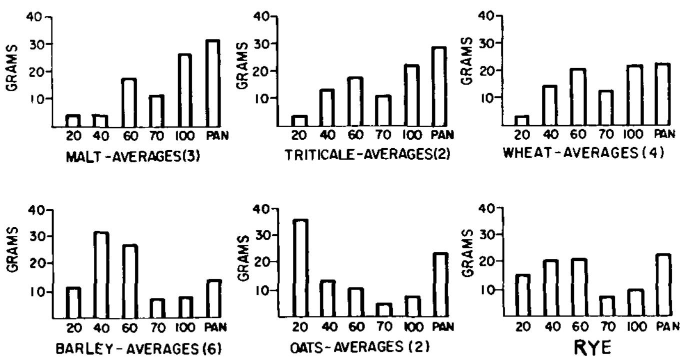

Fig. 3. The grains shown were milled and sifted under fixed conditions (see **Experimental**). The weight of grain particles remaining on each U.S. standard sieve was determined.

TABLE IV
Brewing Analyses for Ten Unmalted, Unboiled Cereals Brewed at 40%

	Beer No.											
	1[a] Corn grits	2 Traill barley	3 Compana barley	4 Waxy Compana barley	5 Glacier barley	6 Glacier High Amylose	7 Merced rye	8 Cinnamon triticale	9 UC 8825 Triticale	10 ND 6655 Durum wheat	11 Yecora wheat	12[a] Corn grits
pH	4.53	4.77	4.81	4.65	4.53	4.83	4.85	4.67	4.71	4.74	4.76	4.54
Color (°SRM)	1.89	3.47	2.69	3.72	3.02	2.67	12.06	2.96	3.67	2.44	3.02	2.56
Bitterness units	19.5	18.0	19.5	19.5	20.7	20.0	21.0	20.5	18.5	18.0	18.0	19.0
Apparent extract, °P	2.62	4.38	4.29	4.67	3.27	3.41	4.03	3.81	4.47	3.61	3.77	3.68
Alcohol, % by wt	2.86	2.22	2.57	2.12	2.30	2.07	2.07	2.46	2.42	2.23	2.92	2.58
Real extract, °P	3.93	5.26	5.16	5.73	4.44	4.31	5.02	4.96	5.66	4.67	5.15	4.86
Original gravity, °P	8.46	8.90	9.50	8.98	7.95	7.60	8.23	8.82	9.38	8.15	9.22	8.94
Real ° ferm., %	68.9	50.4	54.8	47.8	58.7	55.0	50.8	56.6	52.2	55.5	58.9	58.7
Apparent ° ferm., %	69.1	50.8	54.9	48.0	58.9	55.2	51.0	56.8	52.4	55.7	59.1	58.6
Brewhouse yield, %	64.1	56.4	53.2	56.2	53.5	47.6	54.6	57.4	61.3	58.9	62.0	65
Lauter time, min	45	55	45	60	45	...	100	60	65	65	65	50
Chill haze, FTU	500	450	450	400	700	500	...	420	450	370	300	480

[a]40% Corn grits controls.

TABLE V
Taste Panel Evaluation of Pilot Plant Beers Produced with 60% Standard Malt and 40% of the Material Listed (Extract Basis)

Beer	Mean	Similarity at 99% Confidence[a]		
Set No. 1				
Corn grits	49.833	I		
Compana barley	44.667	I	I	
Glacier barley	43.589	I	I	I
Traill barley	42.778		I	I
High Amylose barley	42.422		I	I
Waxy Compana barley	37.444			I
Set No. 2				
Yecora wheat	56.344	I		
Cinnamon triticale	54.400	I		
Corn grits	52.100	I		
UC 8825 triticale	51.256	I	I	
ND 6655 wheat	40.722		I	I
Merced rye	30.778			I

[a]The vertical line in each case joins those beers that are equally liked by the flavor panel. A score of over 50 implies the beer is better liked than the identified control (corn grits) beer.

The vertical line drawn in Table V joins those beers that were equally well liked by the flavor panel; the data represent approximately 1100 tastings. The control beers were accurately scored in each test set. Two barley beers, two triticale beers, and one wheat beer were as well liked as the control beers.

DISCUSSION

The mechanics of the U.S. mashing process are essentially unaffected by inclusion of 40% unmalted grain. Shorter lautering times could be expected if the grain/malt mixtures were diluted with a traditional adjunct (as malt usually is). Of the ten grains tested in pilot brewing, one-half produced beers with flavors as well liked as control beer, which suggests that potential beer flavor must be considered when selecting unmalted grain for use in brewing. Unmalted grains cannot be regarded as inert sources of extract; the DP of some wheats, triticales, and barleys was surprisingly high. Because β-amylase is heat-labile, it is likely to be in short supply in mashing (7), and an added source of this enzyme may be desirable. Unmalted grains also contributed amino nitrogen to wort but, since the malting process is primarily responsible for the amino nitrogen of wort (2), it is unlikely that unmalted grains could match malt despite high native protease activity.

Some unmalted grains are similar to malt in kernel size and character, physical and chemical characteristics, and brewing analyses, and may have similar milling properties. Therefore, unmalted grain could be purchased as a specific portion of the brewer's malt blend. This grain/malt blend could be used as malt is used now. In this context, unmalted grain is a malt adjuvant, not a malt diluent, and practical advantages can be expected to accrue by the exploration and use of such grains by the maltster. Wheat and triticale have many desirable properties for use as an adjuvant grain, while barley is less desirable and, of the three grains, barley benefits most from the malting process.

SUMMARY

Unmalted grains in a mash provided as much as or more DP and protease activity than malt, almost as much extract, roughly half as much amino nitrogen, and a variable low level of amino acids. Milled wheat and triticale yielded a distribution of particle size remarkably similar to malt, but barley, rye, and oats were different. Pilot plant operations and beer analyses were minimally affected by unmalted grains incorporated in the mash. Beers made with some unmalted grains were liked as much as corn grits beer, while other unmalted grains, especially rye, gave less liked beers.

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