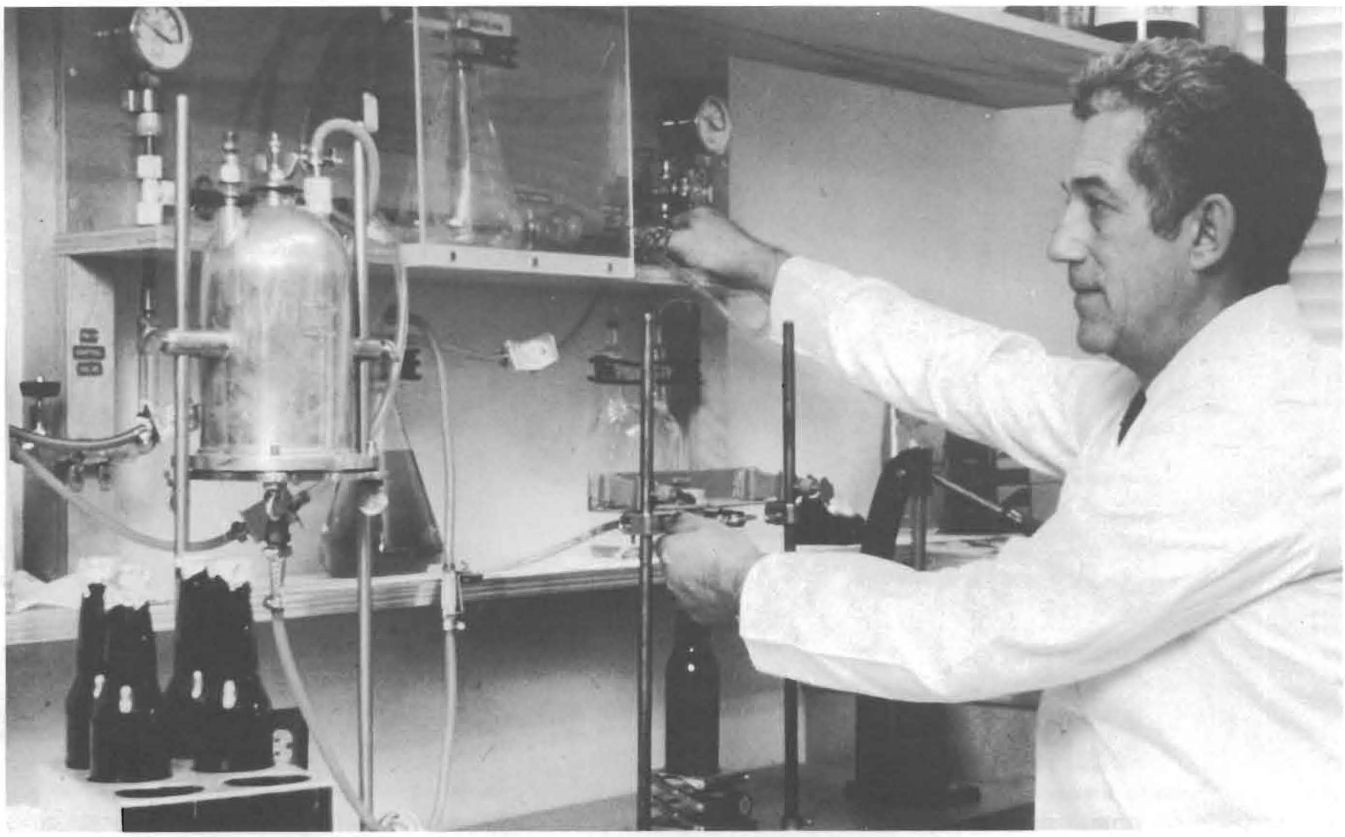

Fig. 1. O. J. Banasik demonstrates the beer filtering and bottling operation of the micro-brewing process.

MICRO-BREWING AND ITS USE IN MALTING BARLEY DEVELOPMENT

Orville J. Banasik

INTRODUCTION

In any malting barley improvement program, quality data are essential for guidance in selecting the best potential malting types. Limited, but valuable, quality information can be obtained by physical and chemical analysis of barley samples. Kernel size, protein, potential extract and potential diastatic power are the usual determinations that are measured.

Small-scale or micro-malting of 60-100 grams of barley followed by analysis of the malt gives additional quality information, and will improve the efficiency of selecting acceptable malting types. Pilot malting of 250-gram samples gives sufficient material for a standard malt analysis. However, even a complete malt analysis does not give all the desired information on suitability of the barley for beer production. This can be obtained only by actually brewing beer from the malt.

Thirty years ago, the only brewing tests considered valid were commercial scale tests requiring several thousand bushels of barley. By 1950, pilot brewing had become an accepted testing procedure and, since then, its use has spread rapidly in the malting and brewing industries. However, the quantity of malt required, 5 to 20 pounds, still prohibited its use for early-generation testing.

One of the first small-scale breweries was reported by Day in 1956 (2). His experimental brewing required 250 grams of malt to produce about one quart of finished beer. This experimental pro-

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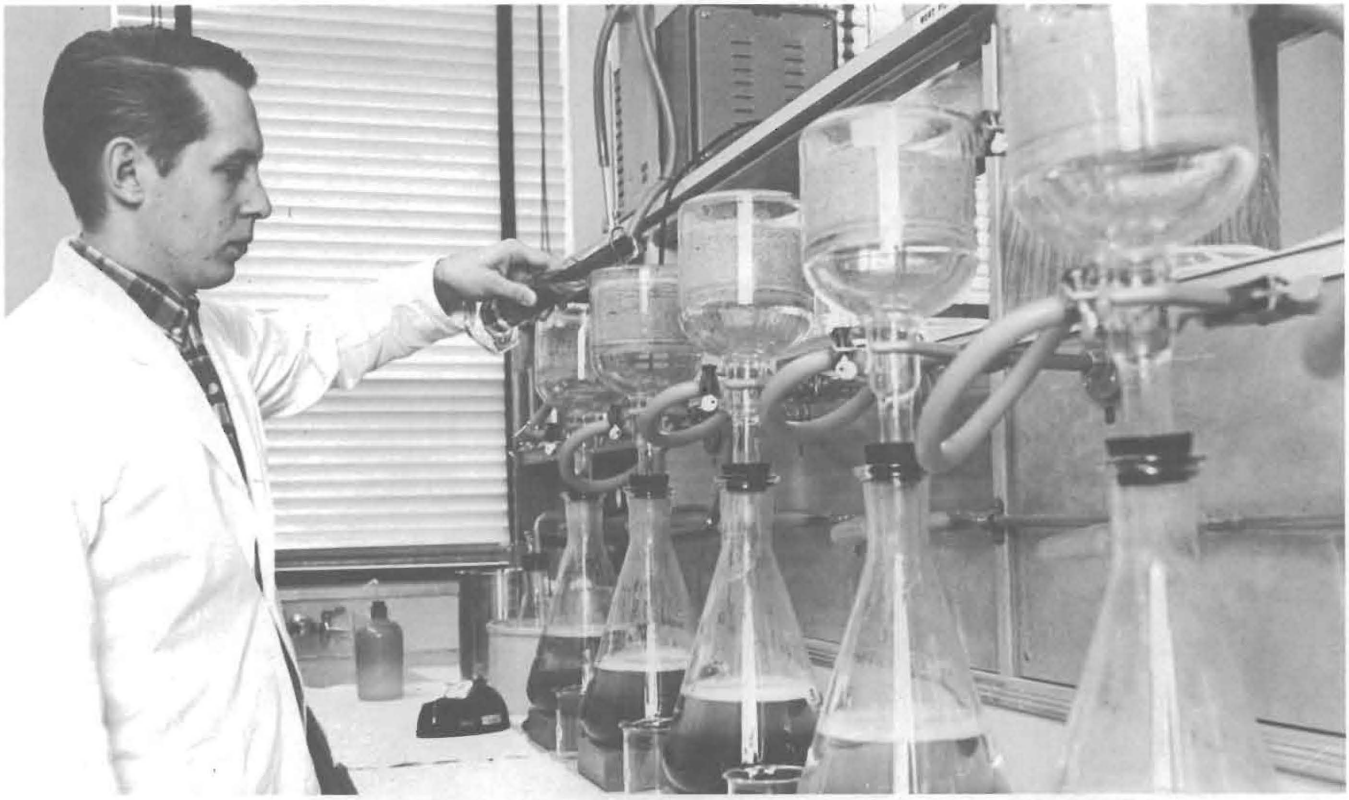

Fig. 2. The mash filteration is an important step in brewing. Larry Nelson rinses the spent grains with water to obtain maximum brewhouse yield.

cedure used such conventional laboratory equipment as Buchner funnels and thermos bottles. The developer stated that it was relatively easy to match commercial beer analysis, but it was difficult to match flavor. The procedure developed proposed that small-scale brewing would give as much information as the larger pilot plants at far less cost.

Kneen (4) reported the use of a micro-brewery to study the relationship of a variety of malt and procedural variables on wort attenuation. He found that while the analyses of micro and pilot brews were not always the same, the malts generally were ranked in the same order.

Burkhart et al. in 1960 (1) and Dietel in 1965 (3) reported the use of micro breweries of about three-liter capacity to study new barley varieties. Both of these breweries were constructed of conventional laboratory equipment such as stainless steel beakers and glassware. Each produced one brew per day.

The value of any procedure for quality evaluation depends upon its ability to distinguish between samples. Based on data presented by Burkhart, Otis and Dickson (1), their micro-brewing procedure appeared to be capable of distinguishing between samples for beer extract, degree of fermentation and wort soluble nitrogen. For alcohol and brewhouse yield, the variation between samples was at times too small and the error between duplicate brews so large that a significant distinction could not be made.

MICRO-BREWING AT NDSU

During the last decade, the quality specifications for new malting barley have become more exacting. These specifications are established by the industry and, consequently, have to be met by a barley breeding and quality development program. Although, there has been no real problem in developing good malting types, several new selections had to be discarded because of faulty brewing performance. Therefore, there appeared to be a need for adding a small brewing method to our testing sequence. Consequently, a procedure was developed in our laboratory that utilized some of the techniques proposed by Burkhart and co-workers (1).

One of the major changes was developing a six-place brewing unit capable of producing six brews a day instead of the usual one. Also, the capacity of each brewing unit was scaled down to brew 120 grams of malt instead of 250 to 260 grams as others had used.

Fig. 3. During the bettle boil, Evan Cummings adds hop extract which is the main flavor component of beer.

Since the details of the brewing procedure have been published previously (6), there would be no useful purpose in describing the entire process. However, Figures 1 to 3 give an idea of the micro-brewery.

RESULTS AND DISCUSSION

Comparison with Pilot Brewing

Before a high degree of confidence could be placed on the micro-brew determination of brewing quality, it was necessary to compare beers made from the same malts which had been previously brewed in a larger, pilot scale facility. With the assistance of several people in the industry, it was possible to make some direct comparisons. Some typical results are illustrated in Table 1.

Table 1. Beer analysis of micro and pilot brewed beers.

Property Measured	Pilot Beer	Micro Beer
Color, °SRM	3.5	3.2
Protein, %	0.32	0.41
pH	4.32	4.48
Total acidity, Ml.	1.67	1.91
Alcohol (by wt.), %	3.62	3.37
Original extract, °P	11.4	11.4
Degree of fermentation, %	60.5	57.5

While there were some differences, as shown by this one set of data, the important aspect was the ability of the micro-procedure to rank the various malts in the same approximate order for the various properties. In general, micro-beers will be higher in beer protein, lower in fermentability which results in a lower production of alcohol, and higher in beer extract.

Replication

A series of 20 duplicate brews were prepared from 20 malt samples to determine the experimental error between duplicate samples. The error terms for processing and beer analysis are shown in Table 2. In most cases, the errors are relatively small and show that the micro-brewing procedure is a reasonably precise determination.

Table 2. Standard errors between replicate determinations.

Property Measured	Error	Property Measured	Error
Brew house yield	0.30%	Alcohol, by volume	0.15%
Conversion time	1.7 Min.	Protein	0.02%
Color	0.18 °SRM	Real extract	0.21%
pH	0.02 Units	Degree of fermentation	1.6%
Alcohol, by weight	0.13%	Haze	16 FTU

Establishing Varietal Characteristics

A relatively large experiment was set up to determine what brewing or beer properties were varietal characteristics or were affected more by environmental conditions. Varieties experimentally malted included Larker, Conquest, B-130, Yukon and Keystone. The varieties chosen represented a wide range of malting quality and were grown at eight experiment station locations in North Dakota to provide differences in environmental growing conditions. The malts were brewed and the resulting beers were analyzed for all beer properties. The resulting data were subjected to an analysis of variance, and the results are summarized in Table 3.

Table 3. Analysis of variance of beer processing and beer properties "F" test.

Property	Station	Variety
Conversion time	2.17	7.83[2]
Brewhouse yield	3.56	15.85[2]
Beer pH	9.22[2]	2.00
Degree of fermentation	6.83[1]	0.49
Chill haze	11.73[2]	4.65[1]
Beer protein	17.64[2]	14.87[2]
Alcohol % (wt.)	8.76[2]	0.80
Beer extract	4.49[1]	0.32
Color	1.55	3.72
Beer extract	4.49[1]	0.32

[1]5% and [2]1% level of significance.

The data show that the majority of significant effects were due to environmental conditions rather than variety. However, important variety effects were found, especially brewhouse yield and beer protein.

The average values of the analytical data obtained for the five varieties are shown in Table 4.

In brewhouse yield, Conquest tops the list with 82.4 per cent, which is nearly 5 per cent more than the poorest malting variety, Keystone. Conquest also displays the shortest conversion time, which is a reflection upon its higher enzyme activity. In alcohol production and beer extract, the varieties are very similar. For the degree of fermentation, color and beer pH are all similar for the five varieties except for the tendency of Conquest to be somewhat higher in color. This is probably due to its higher beer protein content. In haze formation, Conquest had the lowest value, while the poorer malting types, B-130, Yukon and Keystone, gave the highest values.

At this point, an interesting observation might be made concerning the North Dakota selection, B-130. According to the malt analytical data, B-130 appeared to be a promising new variety. However, when the selection was pilot-brewed, it consistently gave low brewhouse yields when compared to a Larker check. This fact was not noted in the laboratory malt extract determination and indicates the value of a micro-brewing test.

Relationship of Malt Quality to Micro-Brewing Analytical Properties

In an attempt to relate malt quality to micro-brewing processing and beer analysis, all possible combinations of correlations were determined between these two groups of data and are shown in Tables 5 and 6.

Mash conversion time as shown in Table 5 is negatively correlated with wort protein, soluble/total protein, diastatic power and alpha amylase activity, and correlates positively with F-C extract difference. All of these malt properties are associated with enzyme activity. The higher enzyme content malts will reduce conversion time.

Brewhouse yield is the most important measure made during processing and represents the economics of brewing. From the data, a larger kernel size, high soluble protein, a high laboratory extract and alpha amylase activity all contribute to a higher brewhouse yield. Also, high protein malts with a high F-C difference will reduce brewhouse yield.

High beer protein content results from malts with high total protein, enzyme activity and wort protein. Larger kerneled malts with poor modifi-

Table 4. Processing and beer analysis.

Variety	Brewhouse Yield	Con. Time	Alcohol (wt.)	Alcohol Vol.	Beer Extract	Deg. of Ferm.	Beer Color	Beer pH	Haze	Beer Protein
	%	Min.	%	%	%	%	°SRM		FTU	%
Conquest	82.4	16	3.18	4.09	5.61	52.4	2.78	4.66	78	0.52
Larker	81.7	20	3.29	4.24	5.51	53.7	2.52	4.67	87	0.46
B-130	80.5	20	3.27	4.21	5.55	53.3	2.44	4.64	105	0.44
Yukon	78.7	23	3.19	4.11	5.68	52.2	2.29	4.63	102	0.42
Keystone	77.5	24	3.22	4.14	5.52	53.1	2.36	4.63	104	0.44

Table 5. Correlation of malt quality factors with brew processing or beer analysis

Malt Quality Factor	Correlation with Processing or Beer Analysis				
	Conv. Time	Brewhouse Yield	Beer Alcohol Content (wt.)	Beer Protein Content	Beer Color
Kernel size		.483		-.493	
Protein		-.415	.380[1]	.489	
Wort protein	-.651	.313[1]	.360[1]	.781	.387[1]
Sol/total protein	-.441	.622		.324[1]	.453
Extract		.807			.314[1]
Diastatic power	-.574		.388[1]	.734	
Alpha amylase	-.676	.440		.648	.468
F-C difference	.539	-.682		-.491	-.404

[1]5% level of significance, all others 1% level of significance.

cation (large F-C difference) will tend to reduce beer protein content.

Beer color is positively correlated with soluble/total protein, malt extract, and alpha amylase activity, but negatively correlates with malt F-C extract difference.

The extent or degree of fermentation appears to be highly correlated with wort protein and diastatic activity of the malt.

As indicated in Table 6, wort and beer pH are positively correlated with malt protein, wort protein, diastatic power and alpha amylase activity.

A review of the literature shows a limited amount of information available regarding the exact nature of the relations between ordinary analytical determinations for malt and various brewing factors. Since large variations are inherent in barley and additional variations are introduced during malting and brewing, Martin and Sfat (5) examined data from two extensive pilot malting and brewing experiments. Correlations were determined between a number of malt and brewing factors. It was interesting to note the relatively good agreement between pilot and micro-scale testing. They found a high positive correlation between malt fine or coarse grind laboratory extract and brewhouse yield. For the two experiments, the coefficients ranged from 0.84 to 0.96 and compared well with the 0.807 correlation shown in Table 5.

Table 6. Correlation of malt quality factors with beer analysis.

Malt Quality Factor	Correlation with Beer Analysis			
	Deg. of Ferm.	Wort pH	Beer pH	Beer Extract (Real)
Kernel size	-.315[1]			
Protein	.419	.478	.406	-.415
Wort protein	.401	.435	.459	.313[1]
Diastatic power	.412	.496	.509	.400
Alpha amylase		.357[1]	.329[1]	
F-C difference			-.370[1]	

[1]5% level of significance, all others 1% level of significance.

Wort and beer protein contents were predictable from malt soluble protein. For pilot-scale brews, the coefficient was 0.42 and for the micro-scale test the value was 0.46. Finally, significant relationships were obtained for both the pilot and micro-scale tests between malt diastatic power and real degree of fermentation. The coefficients were 0.71 and 0.41, respectively, for the pilot and micro-tests.

Summary

Although the precision of these small-scale tests is relatively good, the usefulness of the test in selecting potentially good brewing barleys is somewhat limited. From the data, only mash conversion time, brewhouse yield, chill haze and beer protein appear to be attributed to a varietal characteristic. However, one cannot disregard the importance of brewhouse yield and its economic value to the brewer.

A number of tests are important to the brewer that cannot be determined by small-scale testing; e.g., flavor, run-off rate and yeast flocculation. Also, a number of tests cannot be defined by chemical or physical means. This decision must be left to the artistry of brewing under the watchful supervision of the brewmaster. The small-scale brewing test has considered value in the whole scheme of barley variety development. However, the final decision still will have to depend upon larger tests such as pilot or plant-scale tests.

References

1. Burkhart, B. A., O. J. Ottis and A. D. Dickson. 1960. *A Micro Brewery for the Early Quality Evaluation of Hybrid Barley Selections.* Proc. Am. Soc. Brew. Chem. 123.
2. Day, F. E. 1956. *Small Scale Brewing in the Laboratory.* J. Inst. Brew. 62:107.
3. Dietel, H. W. 1965. *Kleinmalzungs und Kleinbrauversuche mit neuen Gerstensorten.* Brauwissenschaft, 18:48.
4. Kneen, E. 1955. *Brewery Wort Attenuation.* Brewers Digest, 30:53.
5. Martin, E. G. and M. R. Sfat. 1959. *Correlations between Malt Analytical Data and Brewing Factors.* Proc. Am. Brew. Soc. Chem. 10.
6. Urquidi, Rafael L. and O. J. Banasik. 1971. *The Water-Soluble Proteins of Barley. I. Electrophoretic Patterns and Amino Acid Composition.* Brewers Digest 46:68.