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Rapid Performance Assessment of Barley and Malt in the Malting and Brewing Process by Near Infrared Diffuse Reflectance Spectroscopy

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Introduction

In malting and brewing, it is essential to estimate the quality and performance potential of barley and malt in process control and in achieving optimal quality of malts and beers.

In this study, the rapid assessment of malting and brewing performance using NIR diffuse reflectance spectroscopy of un-malted barley and malt were examined. Typically, this kind of evaluation can only be carried out through actual malting and brewing trials that is costly and time consuming, taking up to several weeks.

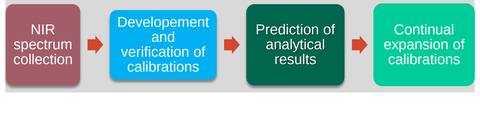
Experimental

1. Barley, malting and brewing trials

Barley samples of AC Metcalfe and CDC Copeland included in this study were collected throughout several crop years and from Alberta, Saskatchewan and Manitoba, Canada. The barley samples with selectable malting quality were malted using a 100kg pilot malting system, and the brewing trials with the malts generated from the pilot malting trials were conducted with a 3 hL brewing system at the Canadian Malting Barley Technical Centre. All the reference analyses for barley, malt and beer were conducted according to ASBC official methods.

2. NIR instrument and calibration development

The SpectraStar 2500XL (Unity Scientific) instrument was used in this study, it is equipped with a dry sample holder and a liquid sample holder. The NIR spectra (600 -2500nm) were collected on the whole kernels of barley and malt, as well beer samples that has been de-gassed.



Calibrations were developed follow the steps above using the software from the instrument manufacture. Various combinations in wavelength selection and treatments, and mathematical models were used to achieve better accuracy and repeatability.

Results

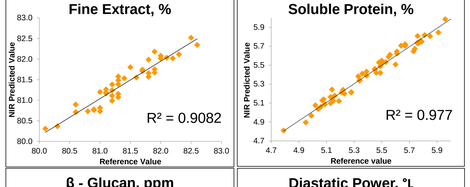
Using the NIR spectra (600-2500nm) collected from barley, malt, and beer samples, several sets of useful calibrations with high R^2 values and satisfactory SECs were developed.

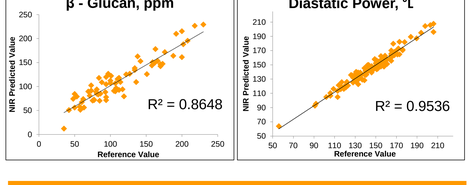
1. Scanning barley to predict its malt quality

Calibrations for assessing barley's malting quality potential were developed. A barley sample's malting quality potential could be assessed by these calibrations with satisfactory accuracy without going through the malting process. The assessed parameters include malt friability, β-glucan content, extract yield, soluble protein, total protein, β-glucan content, α-amylase and diastatic power (Table 1, Figures. 1-4).

Table 1. NIR regression values used to predict potential malt quality of raw barley samples

Parameters	R^2	SEC	SECV	NIR Predicted Results	Reference Method Results
Friability, %	0.941	1.3	2.3	79.7	78.8
Fine Extract, %	0.908	0.17	0.21	81.7	81.6
Soluble Protein, %	0.977	0.04	0.16	5.43	5.62
Beta-Glucan, ppm	0.865	17	37	126	112
Diastatic Power, °L	0.954	5.1	13.0	148	156
Alpha-amylase, D.U.	0.948	1.9	2.5	60.8	75.4



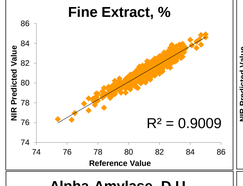


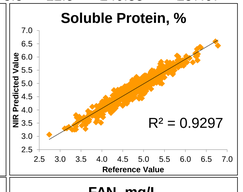
2. Scanning malt to predict malt quality

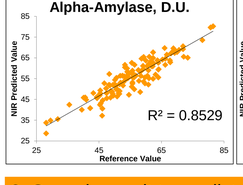
Calibrations for malt quality assessment were developed. Without going through the mashing and wet chemistry procedures, malt analysis could be predicted by using these developed calibrations with satisfactory accuracy. The quantified parameters include friability, extract yield, soluble protein, total malt protein, β-glucan content, α-amylase and diastatic power, FAN levels (Table 2. Figures 5-8).

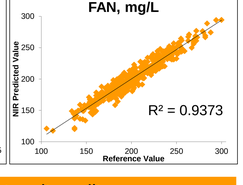
Table 2. NIR regression values used to predict quality of finished malt samples

Parameters	R^2	SEC	SEC V	NIR Predicted Results	Reference Method Results
Friability, %	0.911	3.3	4.09	79.24	78.83
Fine Extract, %	0.901	0.44	0.60	81.17	81.60
Soluble Protein, %	0.930	0.17	0.25	5.83	5.62
Beta-Glucan, ppm	0.951	41	59	94.26	111.67
Diastatic Power, °L	0.991	9.1	7.27	154.33	156.33
Alpha-amylase, D.U.	0.853	3.8	7.60	77.77	75.37
FAN, mg/L	0.937	8.5	12.5	240.33	257.67







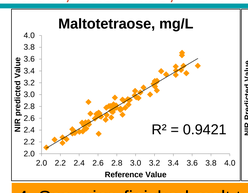


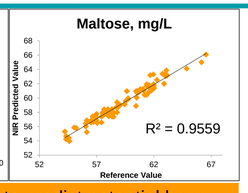
3. Scanning malt to predict malt quality

Calibrations for quantifying malt sugar profile were developed. These calibrations were able to predict the fermentable and non-fermentable sugars in malt samples, and the results were very promising (Table 3; Figures 9-10)

Table 3. NIR regression values used to predict potential wort sugar profiles of finished malt samples

Sugar Profile	R^2	SEC	SECV	NIR Predicted Results	Reference Method Results
Maltotetraose, mg/L	0.942	0.09	0.28	2.99	2.54
Maltotriose, mg/L	0.971	0.24	0.97	13.04	13.43
Maltose, mg/L	0.956	0.57	2.11	57.29	50.96
Glucose, mg/L	0.981	0.24	0.96	12.17	13.44
Fructose, mg/L	0.978	0.15	0.47	2.72	3.26



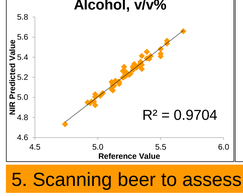


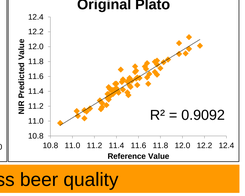
4. Scanning finished malt to predict potential beer quality

Satisfactory results were also obtained for assessing malt's brewing potential by using NIR scans of malt samples. The predicted parameters by the developed calibrations include beer alcohol content, original Plato, apparent extract and real extract (Table 4; Figures 11-12)

Table 4. NIR regression values used to predict potential beer quality of finished malt samples.

Parameters	R^2	SEC	SECV	NIR Predicted Results	Reference Method Results
Alcohol, v/v%	0.970	0.032	0.109	5.30	5.42
Original Plato, °P	0.909	0.077	0.108	11.81	11.76
Apparent Extract, °P	0.983	0.025	0.123	1.63	1.28
Real Extract, °P	0.954	0.044	0.136	3.59	3.25



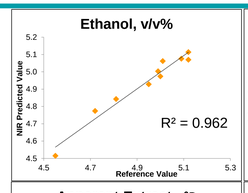


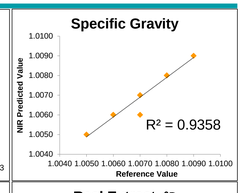
5. Scanning beer to assess beer quality

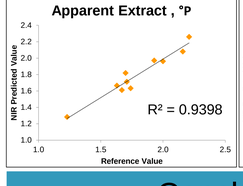
Attempts were made to conduct beer analysis by using the NIR instrument, however, a liquid apparatus for presenting beer samples is needed. Calibrations with high R^2 values and satisfactory SECs for assessing alcohol content, original gravity, apparent extract and real extract were developed (Table 5; Figures 13-16).

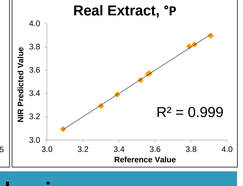
Table 5. NIR regression values used to predict potential quality of beer samples

Parameters	R^2	SEC	SECV	NIR predicted results	Reference method results
Alcohol, v/v%	0.962	0.037	0.202	4.88	5.08
Original Gravity	0.936	0.000	0.001	1.005	1.003
Apparent Extract, °P	0.940	0.071	0.280	1.88	1.38
Real Extract, °P	0.999	0.009	0.224	3.72	3.24









Conclusion

The test results suggest the NIR technique could offer a unique tool for assessing performance potential for a given barley or malt sample without having to conduct conventional small scale malting and brewing trials as well as the related analytical procedures in barley and malt quality assessment. This technique will allow maltsters and brewers to examine quality and performance in a rapid and very cost efficient manner.

References

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